NAVSARI AGRICULTURAL UNIVERSITY

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# Water Management Research in Gujarat

Soil and Water Management Research Unit,
Navsari Agricultural University
Navsari – 396 450

2013

SWMP Pub. 29

# Water Management Research in Gujarat

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## Foreword

Gujarat state has emerged as front runner in the country in taking up innovative projects in the field of agriculture and more so in rain water harvesting and efficient utilization of available water resources. As a result of which Gujarat is the only state where ground water level has considerably increased in the last 8 years as per the information generated by Central Ground Water Board. Simultaneously, for efficient utilization of irrigation water, Gujarat has made special efforts in bringing more area under micro-irrigation methods. At present, in Gujarat about 7.5 lakh ha area is under micro-irrigation methods. This has also contributed in achieving two digits decadal agricultural growth rate.

However, major challenges lies in reclaiming the water logged and secondary salinized soils in South and middle Gujarat and recharging the receding ground water table in the North and Saurashtra regions. Further, poor quality of ground water is another problem in rest of the Gujarat, especially in coastal and industrial areas. In this context, Soil and Water Management Research Unit, Navsari Agricultural University, Navsari has done commendable works to address all these aforesaid problems during the last 40 years. All these technologies have been recommended and transferred to the farmers through government departments and extension agencies. Intensive efforts are also being made through training of farmers trainers, cooperatives and government officials for popularizing the technologies among the farmers.

The publication, "Water Management Research in Gujarat" has come out at right time. The information given in various chapters is in concise manner highlighting the augmentation, availability and efficient utilization of water resources in Gujarat. I congratulate the team of scientists who have contributed whole heartedly in bringing out this publication. I am confident that this publication will be a base document for the researchers, planners and policy makers.

Navsari
July 29, 2013

**A. R. Pathak**
Vice Chancellor,
Navsari Agricultural University,
Navsari (Gujarat)

## Preface

Gujarat is an unique state with respect to diversity in natural resources and longest coastline of 1600 km among the states. Because of this diversity, the soil and water management related problems are multiplexed. This demands generation of location specific soil and water management technologies in Gujarat. In this direction, concerted joint efforts by the Govt. of Gujarat and State Agricultural Universities are being done to generate location specific technologies for the farmers. Not only this, but these technologies are also popularized among the farmers through training, demonstration, *krishi mahotsav*, *etc*. The information with special reference to water generated by different organization is compiled in present publication. This publication envisages different aspects of water *viz*., augmentation, availability, efficient utilization through modern methods of irrigation, pollution, effect of climate change and brackish water aquaculture. I congratulate the scientists who are involved in bringing out this publication at appropriate time. I hope the information furnished in this publication will be immensely useful to researchers, students and policy makers.

Navsari
29 July, 2013

**A. N. Sabalpara**
Director of Research & Dean PGS
Navsari Agricultural University
Navsari (Gujarat)

## Contents

Dr. Swaminathan Raman, was born on the 26th of September, 1942 at Thanjavur in Tamil Nadu. After completing his graduation in Agriculture from the Madras College of Agriculture, Coimbatore, under Madras University, Dr. Raman obtained his M.Sc.(Agri.) in the field of Soil Science from Institute of Agriculture, Anand. Subsequently, he was deputed for his Ph.D. programme and he obtained his doctorate in the field of Soil Science, from the Indian Agricultural Research Institute, New Delhi, during 1981.

Dr. Raman has served the Gujarat Agricultural University in various capacities from 1969 to 2002 and retired as the Chief Scientist, Soil and Water Management Research Unit, Navsari Campus, Navsari. He has got more than 34 years of experience in the fields of teaching and research and 25 years of experience in the field of administration.
His major areas of specialization and major contributions are in the areas of:

- Water resources and its management
- Development of technologies in all aspects of water management including modern irrigation methods
- Use of plastics in agriculture
- Management of coastal salt affected soils with special reference to agro forestry and bio reclamation
- Drainage in agricultural lands with special reference to use of corrugated PVC pipes for closed sub surface drain

**Recognizing the contribution of Dr. Raman made to the scientific and farming community, he has been awarded with many distinctions, some of which are**

- Outstanding Scientist of Gujarat Award instituted by The GSFC Science Foundation, Vadodara, for the year 2000-2001.
- Honoured by The Navsari Nagar Palika with a plaque in recognition of outstanding contribution in the field of science for the year 2001.
- Krushi Seva Award - 1999 by Western Agro Seeds Pvt. Ltd., Ahmedabad in recognition of his contribution made in the field of soil and water management in South Gujarat.
- Admitted as fellow of the Indian Society of Coastal Agricultural Research 1998 in recognition of his contribution to the management of coastal salt affected field in South Gujarat.
- Sardar Patel Award for the work on bio -reclamation of coastal salt affected soils, sponsored by the Govt. of Gujarat for the year 1998.
- Hari Om Ashram Sponsored J.P.Trivedi Award from the Gujarat Association of Agricultural Sciences for the year 1997.
- Sardar Patel Award for best Scientist in the field of Agronomy, Soil Science and Agril. Engineering for the year 1995, Sponsored by the Govt. of Gujarat in recognition of the water management research in Gujarat.
- Honoured by "Phoolchap" with a plaque for the outstanding significant contribution in the field of drip irrigation in the Gujarat state 1994.
- Recipient of Hari Om Ashram, Sponsored Chambraj Sheroff Award for Chemistry Research, 1975.
- Dr. Raman, has visited Egypt, Israel and the Netherlands as member of different delegations of the government of India/ State.

**After retirement Dr. Raman has been consultant to different national and International Organizations , Presently, he is helping the Government of Gujarat as Advisor to Gujarat Green Revolution Company and Government of India as** part time Chief Consultant ( Micro Irrigation) NCPAH, Ministry of Agriculture and Cooperation, Government of India, New Delhi Agricultural Finance Corporation, Mumbai *etc*.

- Dr. Raman has got more than 200 publications to his credit in addition to around 30 technical bulletins.
- He has recently co authored a book entitled "MICRO IRRIGATION Economics and Outreach" Pub. by MACMILLAN publishers.

At the age of 71 also, he is still active and providing guidance and encouragement to the young scientists working in the field of water management at state and national levels.

# 1

## Differential Impacts of Climate Change on Water Resources: An Overview of Gujarat

*[1]Dr A. M. Shekh and Dr. [2]M. L. Gaur*
*AAU, Anand- 388 110*

No country in the world is as vulnerable, on so many dimensions, to climate change as India. Whether it is our long coastline of 7000 kms, our Himalayas with their vast glaciers, our almost 70 million hectares of forests (which incidentally house almost all of our key mineral reserves) – we are exposed to climate change on multiple fronts. Rigorous science based assessments are therefore always critical in designing our adaptation strategies. Gosain *et al*. (2006) revealed certain important finding, when simulation over 12 river basins of the country were made using 40 years (20 years belonging to control or present and 20 years for GHG *i.e.*, Green House Gas or future climate scenario) of simulated weather data. The initial analysis has revealed that under the GHG scenario, severity of droughts and intensity of floods in various parts of the country is going to get deteriorated. Moreover, a general reduction in the quantity of the available runoff was predicted under the GHG scenario. India faces a turbulent water future. The country has a highly seasonal pattern of rainfall, with 50 per cent of precipitation falling in just 15 days and over 90 per cent of river flows occurring in just four months. The Indian mainland is drained by 15 major (drainage basin area >20,000 $km^2$), 45 medium (2,000 to 20,000 $km^2$) and over 120 minor (<2,000 $km^2$) rivers, besides numerous ephemeral streams in the western arid region. The Himalayan glaciers feed India's most important rivers. But rising temperatures means that many of the Himalayan glaciers are melting fast, and could diminish significantly over the coming decades with catastrophic results. In the long run, the water flow in the Ganges could drop by two-thirds, affecting more than 400 million people who depend on it for drinking water. In the short term, the rapid melting of ice high up in the Himalayas might cause river swelling and floods. The formation of glacial lakes of melt-water creates the threat of outburst floods leading to devastation in lowland valleys. Floods, droughts, and climate change are the three most important influences of climate on India's water resources. The problem is more serious in states like Gujarat where the water resources are vulnerable to both climate variability and change; for example, runoff into major reservoirs has declined by significant quantities since long delivering series of floods and droughts. Climate change has played a part in recent reductions in rainfall and water resources, however its specific contribution remains difficult to quantify. It is expected that climate

[1] *Hon'ble Vice Chancellor, Anand Agricultural University, Anand (Gujarat)*
[2] *Dean & Principal , College of Agricultural Engineering & Technology (AAU), Godhra (Gujarat)*

change by 2030 is likely to reduce average river flows by 10 to 25 per cent in some regions of State. The relationships between climate and water are now being considered one of the sensitive and important issues looking into the overall demands keeping in view the prevailing status of vital and most relevant natural resources of the country (Table1). Need is being felt for better predictions on seasonal forecasts of water resources as useful for researchers, irrigators, dam operators, and environmental managers.

**Table 1:** Land and water resources of India

| Particulars | Quantity |
|---|---|
| Geographical Area | 329 million ha |
| Flood Prone Area | 40 million ha |
| Ultimate Irrigation Potential | 140 million ha |
| Total Cultivable Land Area | 184 million ha |
| Net Irrigated Area | 50 million ha |
| Natural Runoff (Surface Water and Ground Water) | 1869 Cubic km |
| Estimated Utilisable Surface Water Potential | 690 Cubic km |
| Groundwater Resource | 432 Cubic km |
| Available Groundwater resource for Irrigation | 361 Cubic km |
| Net Utilisable Groundwater esource for irrigation | 325 Cubic km |

*Source: National Institute of Hydrology; Water Resource India, Website: www.nih.ernet.in*

**Water resources at national and regional scale**

Water resources of any nation or region play a governing role to deal and effectively tackle the undesired scenarios in such areas, as water scarcity remains a well-established context for development in arid and semi-arid countries. For many parts of the arid regions there is an expected precipitation decrease over the next century of 20 per cent or more. It is expected that overall water stress will increase. Projected temperature increase will imply higher evaporation and drier conditions. Rain is also expected to reduce in frequency but increase in intensity. All these will result in frequent droughts and floods. A pictorial view of such categorised variations across different states of the nation is illustrated in below given fig.1, which depicts an abstract view of water availability across different parts of India. The surface water and groundwater resources in India play a major role in agriculture, hydropower generation, livestock production, industrial activities, forestry, fisheries, navigation, recreational activities, *etc*. Potential impact of global climate change on water resources include enhanced evaporation due to warming, geographical changes in precipitation intensity, duration and frequency, together affecting the hydrological parameters such as, runoff, soil moisture, *etc*. It is well documented by researchers like Arora (2001).

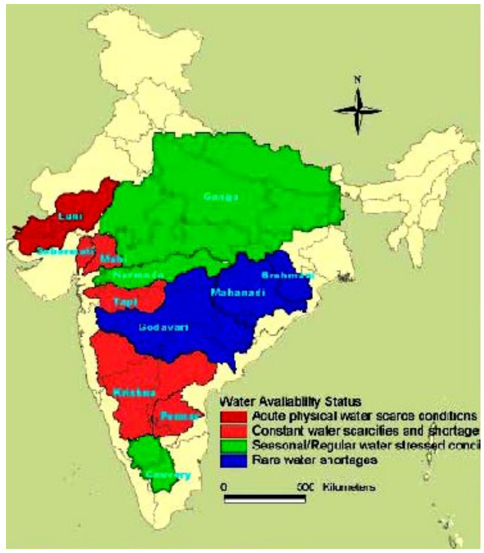


**Fig. 1:** Variations in water availability across different regions of India

## Surface water resources

Proper assessment of the availability of water resources is the cornerstone for proper planning, development and management. Different commissions, agencies, researchers have estimated water resources of the country using different approaches (CWC, 1999). The geographical area of the country is 329 million hectare (Mha), and the mean annual rainfall, taking the country as a whole is 1170 mm. This gives an annual precipitation of about 4,000 BCM. Significant part of the water from surface flows may enter ground water and add to the ground water resources and part of the ground water again returns to streams and rivers. Thus the surface and the ground water sources are inter-linked, continuously inter-active and therefore very much part of a single entity. The data in table 2 show the water resources, establishing the fact that this country is gifted with many rivers.. As many as 12 of them are classified as major rivers, whose total catchment area is 252.8 mha and average annual potential in rivers is 1570.98 b.cu.m. (85% of the total natural run-off). Another 48 rivers are classified as medium rivers, whose total catchment area is 24.9 mha. Total annual discharge in the rivers that flow in various parts of the country, amounts to 1869 $km^3$. Many of these rivers are perennial, though few are seasonal. This is because precipitation over a large part of India is strongly concentrated in the summer monsoon season during June to September/October and the tropical storm season from May to October. It is only a spell of heavy rains, which may last for a period of several hours to few days, that generates large run-off in the catchments.

***Scope of Rainwater Harvesting:*** India being a monsoon dependent country, any slight variation in the periods of rainfall might lead to dire consequences in the economy and thus the life in the country. It is recognised that the country has low water efficiency having mere 1197 mm rains every year i.e. 4000 billion cubic meters. However, 3000 billion cubic meters are lost as runoff and only 1000 billion cubic meters is available. At country level there exists 200 cubic meters storage capacity per capita. Further there is increased demand of water due to increasing population, urbanization, industrialization, economic growth, insufficient water use, high pollution, heavy use of groundwater leading to depletion. If we see the scenarios of Gujarat, water scarcity still remains a leading characteristic in that context over the time, people have developed, techniques to meet their water requirements. Rainwater harvesting is one of them. Per capita availability of water has fallen by 70 per cent since 1950. Water supply per capita in 2002 was 1902 cubic meters and is now expected to decline to 1401 cubic meter by 2025. The average per capita availability of water estimated to be 1600 $m^3$/yr is expected to decline by 1000 $m^3$ by 2050 as per current population projections.

**Table 2:** Major river basins of the country

| River | Origin | Catchment area ($km^2$) | Average annual potential in river (b.cu.m./yr) |
|---|---|---|---|
| Indus | Mansarovar (Tibet) | 321289 | + 73.31 |
| Ganga | Gangotri (Uttar Kashi) | 861452 | + 525.02 |
| Brahmaputra | Kailash Range (Tibet) | 194413 | + 585.60 |
| Barak and other rivers | flowing into Meghna like Gomti, Muhari,Fenny, *etc.* | 41723 | +10 |
| Sabarmati | Aravalli Hills (Rajasthan) | 21674 | 3.81 |
| Mahi | Dhar (Madhya Pradesh; MP) | 34842 | 11.02 |
| Narmada | Amarkantak (MP) | 98796 | 45.64 |
| Tapi | Betul (MP) | 65145 | 14.88 |
| Brahmani | Ranchi (Bihar) | 39033 | 28.48 |
| Mahanadi | Nazri Town (MP) | 141589 | 66.88 |
| Godavari | Nasik (Maharashtra) | 312812 | 110.54 |
| Krishna | Mahabaleshwar (Maharashtra) | 258948 | 78.12 |
| Pennar | Kolar (Karnataka) | 55213 | 6.32 |
| Cauvery | Coorg (Karnataka) | 81155 | 21.36 |
| Total | | 2528084 | 1570.98 |
| Other river basins of the country | - | 248505 | 298.02 |
| Total | | 2776589 | 1869.00 |

*Source: Central Water Commission, 1999*

**Climatic characteristics of Gujarat**

As there are variations in the geographical conditions of Gujarat, characteristics of the climate also vary. In Gujarat the winter season is moderately cold and dry. The humidity is almost absent. The coastal region is experience less cold. The coastal regions experience moderate climate. Whereas central regions *i.e.,* central Gujarat and North Gujarat experience more cold during winter season. The climate of Rann of Kutch experience continental or temperate climate. Generally, in winter temperature is between 4° C to 29°C. In Gujarat summer season is mostly hot and dry. During the summer season the coastal region is less hot. The temperature is more in regions which are away from coastal area. Rann of Kutch experiences extreme heat. In the summer season North Gujarat experience more heat. Generally in summer temperature is between 27° C to 44°C. The overall variability of climatic situations across various regions of Gujarat could be categorized as given below,

***1. Inequitable water availability and erratic rainfall:*** The rainfall depends on the local winds which change their directions accordingly to the seasons. Towards the end of the summer season the winds blowing over Arabian Sea bring rain. Every year the amount of rainfall is different in different areas of Gujarat. The trend of rainfall in Gujarat is given in table 3. Gujarat has total 185 river basins. Out of 185, Saurashtra region have 71 river basins, while Kutch region have 97 river basins. As per one preliminary estimate the total available water resources of the state are estimated to the tune of 50000 MCM, but distribution of water resources in different regions is inequitable.

***2. Salinity ingress in coastal areas:*** Problem of salinity ingress is being faced by Gujarat along Saurashtra and Kutch coast for coastline of approximately 1125 kms. The problem is severe along Una-Madhavpur stretch of Saurashtra and Maliya – Lakhpat stretch of Kutch region. In these stretches in selected tracts intensive agricultural development and exploitation of ground water and poor recharge from upland areas has resulted into sea water ingress even up to 5 to 6 km inland causing salinity. This phenomenon of salinity ingress has adversely affected the lives of people, both on agricultural and drinking water front. Approximately 10.80 lakh of people of 534 villages are badly affected by salinity. In all 700120 ha of cultivable land has become useless and about 32750 wells have gone dry. Major factors responsible for this problem may be categorized as under,

- Irregular and very low precipitation
- Highly porous geological formations
- Low natural charge
- Poor land management
- Excessive withdrawal of water for irrigation

***3. Ground water depletion in North Gujarat:*** Even in past the state of Gujarat had total replenishable ground water resources of 15811 MCM /yr, whereas utilizable ground water resources for irrigation were to the tune of 15020 MCM/yr. The draft from ground water structures was estimated to be 11486 MCM/yr, offering the level of development of ground water resources as 76.47 per cent, leaving a balance of 3051 MCM / yr for future development of ground water resources. Unfortunately, the same could not be achieved and beside it the situation of ground water resources is further deteriorated. Ground water scarcity areas are mostly located in North Gujarat, Saurashtra and Kutch regions of the state. In North Gujarat, the ground water scarcity areas cover parts of Patan, Banaskantha, Mehsana, Gandhinagar and Ahemdabad districts of Gujarat. The scarcity in these areas is faced on account of erratic and scanty rainfall, high level of irrigation development and partly due to inherently saline formations. Major part of Saurashtra covering parts of Surendranagar, Jamnagar, Junagadh, Amreli and Bhavnagar district experience acute scarcity of water resources on account of fissured hydrogeological formation which have limited storage and low transmission capacity, scanty and erratic rainfall and partly due to inherent saline nature of formations and salinity ingress along the coastal aquifers. The Kutch district also faces acute shortage of water due to frequent failure of monsoon creating drought like situation, limited aerial extent of productive aquifers, high level of ground water development and also partly due to inherently salinity in the coastal aquifers. The status of ground water development in the state is depicted in fig. 2.

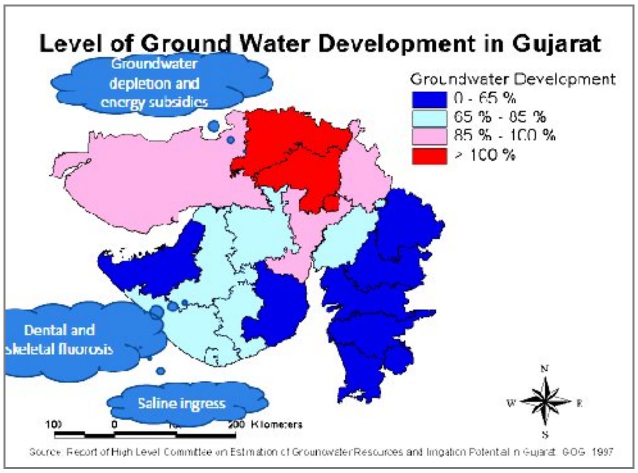


**Fig. 2:** Groundwater development scenario of Gujarat

**Table 3:** Spatial distribution of rainfall and estimated available water resources in Gujarat

| ***Region*** | ***Average Annual rainfall*** | | | ***Rainy days*** |
|---|---|---|---|---|
| South Gujarat | > 1100 mm | | | 120 |
| Central Gujarat | 800 – 1000 mm | | | 30 – 70 |
| Saurashtra | 400 – 800 mm | | | 20 – 30 |
| Kutchh | < 400 mm | | | 10 – 20 |
| ***Region*** | ***Estimated Avail. Water Resources, MCM*** | | | ***%*** |
| | ***Total*** | ***Surface Water*** | ***Ground Water*** | |
| South Gujarat Region (South of Sabarmati River) | 35700 | 31750 | 3950 | 71.40 |
| North Gujarat (North of Sabarmati river) | 5300 | 2000 | 3300 | 10.60 |
| Saurashtra | 7900 | 3600 | 4300 | 15.80 |
| Kutch | 1100 | 650 | 450 | 2.20 |
| Total | 50000 | 38000 | 12000 | 100 |

## Water challenges in Gujarat

Stream flow constitutes the principal source of fresh water in Gujarat. River flows are concentrated in the relatively short monsoon season. There are 17 rivers in Gujarat mainland, 71 in Saurashtra and 97 in Kutch region. Gujarat has just 2.28 per cent of India's water resources and 6.39 per cent of country's geographical area. This is again constrained by imbalances in intra-state distribution. The state has an average annual rainfall of 80 cm with a high coefficient of variance over time and space and as a result droughts have been frequent. Out of 185 rivers, the state has only eight perennial rivers and all of them are located in southern part. Around 80 per cent of the state's surface water resources are concentrated in central and southern Gujarat, whereas the remaining three-quarters of the state has only 20 per cent. On an average, three years in a cycle of 10 years have been drought years. Since Indian independence in 1947, the drought years of Gujarat have been as follows: 1951, 1952, 1955, 1956, 1957, 1962, 1963, 1965, 1968, 1969, 1972, 1974, 1980, 1985, 1986, 1987, 1991, 1999, 2000 and 2003 (Gupta, 2004).

***Inter-basin water transfer through Sardar Sarovar Project:*** The Sardar Sarovar Project on river Narmada is a multi-state, multi-purpose river valley Project, borne out of deliberations of a constitutional body, following the principles of 'Equality of Right' and 'Equitable Utilisation' of the whole course of an Inter-State River. This unique project will irrigate 1.905 M ha of land, increase the agricultural production by 8.7 million tons per annum (worth US $ 430 million), generate environment friendly hydropower with installed capacity of 1,450 MW, supply drinking water to 8,215 villages and 135 urban centres of Gujarat (around 20 million population), generate 1 million jobs (mostly in rural areas), and prevent rapid processes of desertification, salinity ingress and rural to urban migration being experienced in many parts of Gujarat. The command area and drinking water supply areas of the project are exactly the worst water scarcity-hit areas of the state (Gupta, 2004, Table 4).

**Table 4:** Sardar Sarovar dam height and storage increase in the Sardar Sarovar Project

| **Stage** | **2003** | **2004** | **2006** | **Ultimate** |
|---|---|---|---|---|
| Height | 100 m | 110.64 m | 121.92 m | 138.68 m |
| Gross storage | 2,602.6 MCM (3.00MAF) | 3,700 MCM (3.00 MAF) | 5,265.8 MCM (4.27 MAF) | 9,460 MCM (7.7 MAF) |
| Live (usable) Storage | _ _ | _ _ | 1,565.8 MCM (1.27 MAF) | 5,800 MCM (4.77 MAF) |

*Source: Sardar Sarovar Narmada Nigam Limited, 2009*

It is also observed that the climate change often delayed the monsoon cycle even by about a month. Gujarat is having the longest sea line, making fishing as one of the important interventions. Owing to above described scenarios of climate change most of the fishers do not go for fishing in peak monsoon to avoid wrath of nature. However, they follow their local traditional calendar to observe the fishing holidays where as these dates does not match under prevailing changing climate. That is why recently enhanced number of incidences of fishers caught in offshore cyclonic storms are becoming common. This changing climate is affecting all section of society demanding large awareness and management drive. If we analysis the broader domain where the climate change is going to put it's ever influences, it is expected to affect agriculture, following food security and farmers' livelihood. For all these categories of effects, water remains the most vital entity, which remains the crucial driver for quantitative magnitudes of climate change effects. Keeping this in view and the facts described there exists a dearth of systematic literature with reference to climate change at micro scale.

***Technological initiative for drought proofing:*** During last one decade the state drew up an ambitious strategy for creating a 'State Wide Drinking Water Grid' for bulk water transmission from sustainable surface water resources to water scarce and poor water quality habitations. Large scale infrastructure has been created which includes 1,987 km of bulk pipelines and more than 115,058 km of distribution pipelines, 10,781 hydraulic structures like elevated storage reservoirs with a total capacity of 1,164 million litres and 10,683 storage sumps and high ground level reservoirs with a capacity of 2,504.80 million litres have also been constructed in the state. Along with this, 151 water filtration and treatment plants with a total capacity of 2,750 million litres per day (MLD) have been constructed. About 2,250 MLD of treated water is delivered to more than 10501 villages and 127 towns in the state, ensuring safe and assured water supply to about 65 per cent of state's population in drought prone and water quality affected areas through the water supply grid (Table 5).

**Table 5:** Energy Saving Estimates as applicable to Gujarat

| Sr.No. | Particulars | Energy Saving MWh per annum |
|---|---|---|
| 1 | Piped water supply to villages and towns | 65905.00 |
| 2 | Savings due to energy audit | 5184.78 |
| 3 | Solar based pumping systems | 611.16 |
| 4 | Rooftop rain water harvesting | 386.74 |
| | Total | 72087.68 |

*Source: Gujarat Water Supply and Sewerage Board, 2009*

**Climate change and its expected impacts at different levels**

Researchers have reported different kind of impacts of climate changes on water resources at different scales of time as well as locations. The impacts of climate change on small and marginal farmers, and on agricultural labour, brings out one of its ironies - that those most affected most by global warming are those who have, and are contributing to it the least. Adaptation measures should not only be developed for individual sectors but a more integrated approach is necessary. Most recently a comprehensive report from ministry of Environment and Forests Government of India is released giving a sectoral and regional analysis for 2030's. This report (INCCA, 2010) has been prepared by the Indian Network for Climate Change Assessment, a network-based programme that brings together over 120 institutions and over 220 scientists from across the India to undertake scientific assessments of different aspects of climate change.

It brings together a review of what is known about the impacts of climate variability in the four major climate sensitive regions in India, namely, the Himalayan region, the North-Eastern region, the Western Ghats and the Coastal regions. Further, it presents an assessment of the impacts of climate change in the 2030s on four key sectors of the economy that are climate dependent, namely, Agriculture, Water, Natural Ecosystems and Biodiversity and Human Health. The crisped information on various sectors of futuristic climate change and its spread over different regions of the country (including Gujarat) is described below,

***Temperature***

- The annual mean surface air temperature is projected to rise by 1.7°C and 2.0°C in 2030s. Seasons may be warmer by around 2.0$^o$C towards the 2030s. The variability of seasonal mean temperature may be more in winter months

***Precipitation***

- The annual rainfall in the Himalayan region is likely to vary between 1268±225.2 and 1604±175.2 mm in 2030s. The projected precipitation is likely to increase by 5 to 13 per cent in 2030s with respect to 1970s.
- In North Eastern region, the mean annual rainfall is projected to vary from a minimum of 940± 149 mm to a maximum of 1330±174.5mm. The increase in the 2030s, with respect to the 1970s, is of the order of 0.3 to 3 per cent.
- In the western Ghats in the 2030s, the mean annual rainfall is likely to vary from 935±185.33mm to 1794±247mm, which is an increase of 6–8 per cent with respect to the 1970s.
- In eastern coast, the rainfall is likely to range between 858±85.8mm to 1280± 204.8mm in 2030s. The increase in the 2030s with respect to the 1970s is estimated to range between 0.2 to 4.4 per cent. Projections for the western coast indicate a variation from 935±185.33mm to 1794±247mm, which is an increase of 6–8 per cent with respect to the1970s.

***Extreme precipitation:*** Extreme precipitation can be defined in terms of number of rainy days if it exceeds the currently observed average number of rainy days in a year (exceeding 2.5mm) as well as the volume of rainfall in a day if it exceeds a particular threshold. Currently, the frequency of rainy days is more in East and North-East India and less over western India. Projections for the 2030s, however, indicate that the frequency of rainy days is likely to decrease in most parts of the country.

- The number of rainy days in the Himalayan region may increase by 5–10 days on an average in the 2030s. They will increase by more than 15 days in the eastern part of the Jammu and Kashmir. The intensity of rainfall is likely to increase by 1–2 mm/day.
- In the North-eastern region, the number of rainy days are likely to decrease by 1–10 days. The intensity of rainfall in the region is likely to increase by 1–6 mm/day.

- The number of rainy days is likely to decrease along the entire western coast, including in the Western Ghats. However, there may be an increase in rainfall in the range of 1-5 days in the Karnataka region of the western Ghats. The intensity of rainfall is likely to increase by 1–2 mm/day.
- In the eastern coast, the number of rainy days is likely to decrease by 1–5 days, with a slight increase along the Orissa coast. The intensity of rainfall is likely to increase between 1 mm/day and 4 mm/day. The projections of extreme precipitation events for the western coast are same as projected for western Ghats

***Cyclones:*** Projected number of cyclonic disturbances along both the coasts in 2030s is estimated to decrease with respect to 1970s, with more intense cyclonic systems in future.

***Storm surges:*** Storm surge1 return periods could only be estimated at a 100 year time scale. It is found that all locations along the eastern coast of India, that are North of Visakhapatnam, except Sagar and Kolkata, show an increase in 100 year return periods of storm surges by 15 to 20 per cent with respect to the 1970s.

***Sea-level rise*:** Global sea-level change results mainly from 2 processes, mostly related to recent climate change, that alter the volume of water in global ocean through a) thermal expansion and b) the exchange of water between oceans and other reservoirs (glaciers, ice caps, ice sheets, other land water reservoirs *etc*). Observations based on tide gauge measurements along the Indian coast, for a period of 20 years and more for which significantly consistent data is available indicate that the sea level along Indian coast is rising @ about 1.3 mm/year on an average.

**Impacts on agriculture**

*Western Ghats*

- *Rice:* The productivity of irrigated rice is likely to reduce by 4 per cent in most of the areas in this region.
- *Maize and sorghum***:** Climate change is likely to reduce yields of maize and sorghum by up to 50 per cent depending upon area in this region
- *Coconut* ***:*** Coconut yields are projected to increase as much as 30 per cent in the majority of the region by the 2030s
- *Livestock productivity:* The *Temperature Humidity Index (THI),* an index used to define losses due to thermal stress is highest in the months of September–April and is likely to remain under highly stressful conditions in the 2030s. The heat-stress days per annum are likely to increase with THI above 80 in the 2030s in the western Ghats, leading to severe thermal discomfort of the livestock and hence, negative impact on livestock productivity is expected.

*Coastal region*

- *Rice: Y*ields of irrigated rice are projected to decrease by about 10 to 20 per cent in this region.

- *Maize and sorghum:* Impacts of climate change on irrigated maize in coastal districts are projected to be much higher with projected yield loss between 15 and 50 per cent, whereas in the case of rain-fed maize, the projected yield loss is up to 35 per cent.
- *Coconut:* Yields of coconut are projected to increase in the west coast of India by up to 30 per cent (provided current level of water is made available in the future as well), while in the east coast, yields may increase by about 10 per cent in the North coastal districts of Andhra Pradesh. All other coastal districts in eastern coast and those in the Gujarat coast are projected to lose coconut yields up to 40 per cent.
- *Livestock productivity:* The livestock in the Coastal regions are likely to be highly vulnerable with consequent adverse impacts on its productivity throughout the year in the 2030 scenario with THI above 80.

*North-Eastern region*

- Rice: Here irrigated rice yields may range between -10 and 5 per cent, with respect to the 1970s, while rain-fed rice yield may vary between -35 to 5 per cent with respect to 1970s
- *Maize:* Maize crop yields are projected to reduce by about 40 per cent.
- *Livestock productivity:* In this region, the THI is likely to increase during April–October months with THI > 80.

*Himalayan region*

- Apples: Apple production in Himachal Pradesh region has decreased between 1982 and 2005 as the increase in maximum temperature has led to a reduction in total chilling hours in the region- a decline of > 9.1 units per year in last 23 years has taken place
- *Livestock productivity:* THI is projected to rise in many parts of Himalayan region during March–Sept, maximum rise during April–July in 2030s with respect to 1970s

**Natural ecosystems and biodiversity**

- *Western Ghats:* The entire western Ghats region is covered by 54 forest grids, out of which 18 per cent are projected to undergo change in the 2030s
- *Himalayan region:* The Himalayan region considered in the study includes the states of Jammu and Kashmir, Uttrakhand and Himachal Pradesh. Of the 98 IBIS grids covering this region, 56 per cent of the grids are projected to undergo change in the 2030s. The Net Primary Productivity (NPP) is projected to increase in the region by about 57 per cent on an average by the 2030s.
- *Coastal region:* The coastal region is defined by all districts that lie on the Indian coast. The entire coastal region is covered by 96 grids, excluding the grids in the western Ghats. Of this, 30 per cent are projected to undergo change. The NPP in this region is predicted to rise by 31 per cent on an average.

- *North-eastern region:* Much of the dense forests of Assam, Nagaland and Arunachal Pradesh are part of the Himalayan biodiversity hotspot. In the North-eastern region, only about 8 per cent of the 73 forested grids are projected to undergo change in the 2030s. The region is projected to see an increase of 23 per cent in NPP on an average

**Impact on human health:** There is a likelihood that the windows of transmission of malaria may increasingly remain open for at least 7–9 months and may even remain open for a larger number of months (10–12 months) in a year

**Water:** The water resources in this study have been assessed in terms of water yield in the various river basins that are part of these regions. The water yield is the total surface runoff, which is usually a function of the precipitation, its distribution, evapotranspiration (ET) and soil characteristics.

- *Himalayan region:* The water yield in the Himalayan region, mainly covered by river Indus, is likely to increase by 5 to 20 per cent in most of the areas, with some areas of Jammu and Kashmir and Uttrakhand showing an increase of up to 50 per cent with respect to the 1970s
- *North-Eastern region:* The trend in precipitation in the North-eastern region exhibits considerable spatial variability in water yield in the 2030s but is in line with the projected patterns of precipitation and evapotranspiration.
- *Western Ghats:* The western Ghats region exhibit wide variability in water yield in the 2030s. The northern portion of the Western Ghats shows a decrease in the water yield, ranging from 10 to 50 per cent in the 2030s with respect to the 1970s. The central portion, however, indicates an increase in the water yield between 5 and 20 per cent. The southern portions of Karnataka and Kerala show a decrease in the yields up to 10 per cent.
- *Coastal region:* There is a general reduction in water yield in the eastern coastal region of West Bengal, Orissa and the northern coastal regions of Andhra Pradesh. The reduction in water yield in the 2030s in this region is as less as 40 per cent. However, in the southern parts of Andhra Pradesh and northern parts of Tamil Nadu, the water yield is projected to rise by 10 to 40 per cent. The western coastal region also shows an overall reduction in water yield (ranging from 1%–50%) except for the coast along Karnataka, which shows an increase in water yield in the 2030s by 10 to 20 per cent with respect to the 1970s. No change in water yield is projected for the 2030s in the southern tip of the coastal region.

**Impact of climate change on frequency of droughts:** The percentage change in the spatial distribution of Soil Moisture Deficit Index (SMDI) between the 1970s and 2030s has been used for defining the drought index. The weeks when the soil moisture deficit may start drought development (drought index value between 0 and -1) as well as the areas which may fall under moderate to extreme drought conditions (drought index value between -1 and -4) have been assessed. There is an increase in the drought development for those areas of various regions that have either projected decrease in precipitation or have enhanced level of evapotranspiration in the 2030s.

**Impacts of climate change on floods:** Possible floods have been projected using the daily outflow discharge in each sub-basin as generated by the SWAT model, ascertaining the change in magnitude of flood peaks above 99th percentile flow in 1970s and in 2030s. Change in peak discharge equal to or exceeding at 1per cent frequency in the 1970s and 2030s for various regions indicates that the flooding varies from 10 to over 30 per cent of the existing magnitudes in most of the regions. This has a very severe implication for existing infrastructure such as dams, bridges, roads, *etc.*, in the areas.

**Climate change – the Gujarat model**

Most recently the Chief Minister of Gujarat state has published a comprehensive information in the shape of a book (Modi, 2009) which depicts the overall scenario of Gujarat and in true sense the real strategic Gujarat Model on Climate Change. According to it, the groundwater levels are falling in other States, in Gujarat the levels are increasing. Data from the Central Ground Water Board (CGWB) shows Gujarat has increased groundwater levels over the last eight years. Over four hundred thousand water- harvesting structures have been constructed: check dams, *bori-bandh* and *khet-talavadi* (farm ponds). Analysis, results and implications for policy and/or research Gujarat's agriculture has come to depend heavily on groundwater resources. It is estimated that over 80 per cent of its irrigated area is served by groundwater; and less than 20 per cent is served by small and large surface storages and irrigation systems. Besides, groundwater meets 82 per cent of Gujarat's domestic water demand, 65 per cent of industrial water demand and 50 per cent of urban water demand. A large proportion of the food production in Gujarat is based on un-sustainable exploitation of groundwater that at the same time is threatened by increasing problems of depletion and quality deterioration. In addition, climate change is increasing the unpredictability of rainfall, the rate of evapo-transpiration and the occurrence of extreme events. In a situation where the competition for water is getting stiffer, these changes are making food production more uncertain. Managed Aquifer Recharge (MAR) assumes critical importance, as it would significantly improve groundwater availability and quality, massively reduce energy consumption in groundwater irrigation and in general pave the way for its sustainable use. The first results of these calculations revealed that the availability of non-committed surplus run-off is the key constraint in shaping the MAR strategy for the four water-stressed basins of the state. It is estimated that 1650 MCM/yr of non-committed surplus run-off available in the six basins can be recharged by constructing 15,678 percolation tanks, 22,607 check dams, 14,712 injection wells and modification of 42,000 dug wells for recharge Social Forestry in Gujarat sets a benchmark of 14 Trees per Hectare. More than 30,000 hectares of mangroves planted. Around 20,000 ha of land were undertaken for plantation outside forest area. 'Per drop-more crop' is kept as a Mantra for Water Conservation, where more than 4 lakh Micro Water Harvesting Structures constructed. Drip Irrigation is initiated, inter-linking 21 rivers of the State for Conservation of water and thus offering extremely positive results in terms of ground water recovery and overall agricultural income hike even to the tune of by 4 times.

Gujarat is having, total 185 rivers, out of which only 8 are perennial. All such perennial rivers are located in southern part. It all together gives very challenging scenarios in respect of climate change influences on meagre water resources therein. If we compare the Gujarat state with India, it reflects below given prime relative indicators, which are self speaking the fact having close and more intense importance in regards to climate change scenarios and their influences towards water resources across its principle river basins (Table 7; Fig. 3).

- Geographical Area 5.96%
- Population (Census 2001) 4.93%
- Surface water Resources 2.28%
- Annual population growth rate 2.27% (Country's average 2.154%)
- Urban population 37.36% (Country's average 27.82%)
- Per capita income Rs. 37532 (Country's average Rs. 29642)
- Contribution to the Nation: 16% in industrial production, 22% in exports, 30% in stock market capitalization

Suitable concrete mitigation measures are inevitable to control the possible high magnitude impacts of climate change on river basins of Gujarat, for example,

1. Narmada river basin is likely to experience seasonal or regular water shortage condition
2. Estimated almost 2/3rd decline in run off for Sabarmati and Luni
3. Luni which occupies 1/4th of Gujarat and 60 per cent of Rajasthan likely to have acute water stress conditions
4. Low annual per capita water availability:
   - Sabarmati river basin: 360 $m^3$
   - Mahi and Tapi basins: 1000 $m^3$

**Table 7:** Salient features of principal river basins of Gujarat

| Sr. No. | Basin Name | Average Annual Runoff, (MCM) | Major Irrigation Projects | | |
|---|---|---|---|---|---|
| | | | Name | Gross Storage, (MCM) | Live Storage, (MCM) |
| 1 | Tapi (South Gujarat) | 6694 | Ukai dam<br>Kale dam | 8510<br>96 | 7092<br>86 |
| 2 | Narmada (South Gujarat) | 34273 | Karjan dam<br>Tawa dam<br>Bama dam | 630<br>2310<br>639 | -<br>2050<br>455 |
| 3 | Mahi (North Gujarat) | 4359 | Mahi sagar<br>Kadana | 2180<br>1542 | 1712<br>1203 |
| 4 | Sabarmati (North Gujarat) | 1559 | Dharoi<br>Batrak | 908<br>177 | 732<br>164 |
| 5 | Banas (North Gujarat) | 450 | Sipu<br>Dantiwada | 178<br>464 | 156<br>444 |
| 6 | Shatrunji (Saurashtra) | 182 | Shatranji | 350 | 309 |
| 7 | Bhadar (Saurashtra) | 474 | Bhadar | 238 | 221 |

*Source: Gupta, 2004*

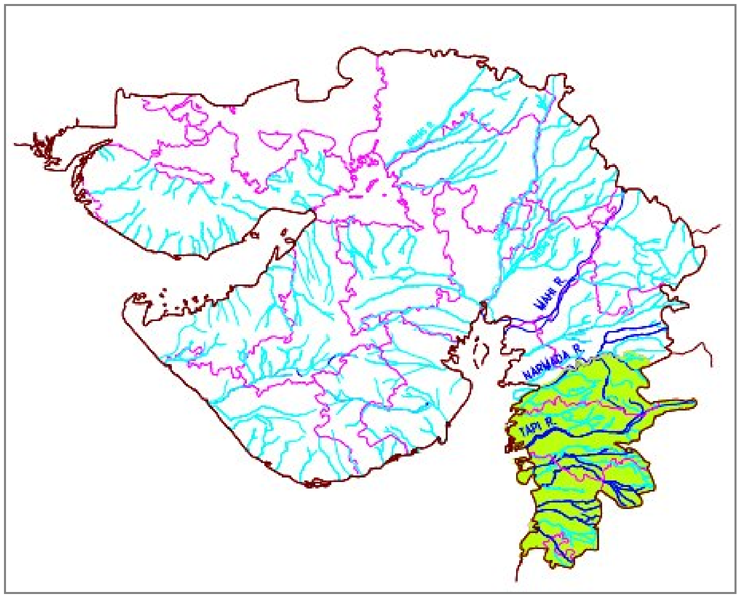


**Fig. 3:** River basins of Gujarat likely to face pronounced climate change effects

Beside river basins the coast lines (about 1,600 km) being longest amongst Indian states, is also expected to have very high and unpredictable adverse consequences owing to climate change, as envisaged below,

- Maximum damage is predicted at a rise of 1m
- Coast is characterized by creeks and inland waters-- classified as submergence type - which is more prone to the effects of sea level rise.
- Maximum area (0.181 million hectares) likely to be inundated by sea level rise will be experienced in Gujarat

| Sea Level Rise/Surge | Area Affected in Sq. Km |
|---|---|
| • 1 m | 14,149 |
| • 2 m | 16,463 |
| • 3 m | 18,438 |
| • 4 m | 20,218 |
| • 5 m | 21,949 |

*(Sea level rise along the Gulf of Kutch will be the highest)*

To overcome the above cited issues in Gujarat certain peculiar efforts are already planned and effectively executed at grass root level, to set an example, which is now-a-days being termed as Gujarat Model to deal with so called Climate Change. The water resources projects like that of Panam and Kalpsar have given a new direction for conceiving and successfully implementing the environmental friendly irrigation and water resources projects at mega and micro scales. Creation of state wide drinking water grid is also another innovative effort to cope up with the problem of climate change influences on water resources. (Fig. 4)

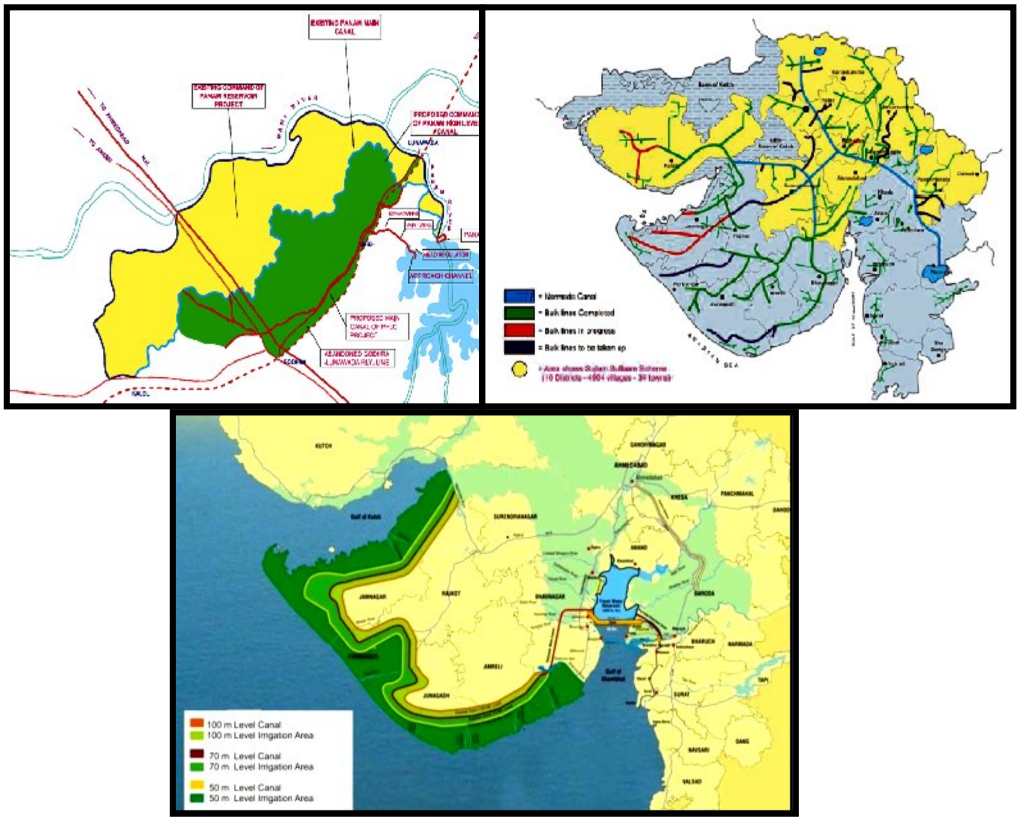


**Fig. 4:** Environmental Friendly Innovative Projects
(Panam, Kalpasar, and State water Grid)

## Approaches and future prospects

As climate change mostly affects water and food security, the strategies to be adopted by the policy makers to face the challenges are : Rights of water, Water markets, Virtual water imports, Water metering and pricing, Reduce tariffs on efficient technologies, Local watershed management, Providing information, Seasonal forecasts, and Education. The impacts of climate change on small and marginal farmers, and on agricultural labour, brings out one of its ironies — that those most affected most by global warming are those who have, and are contributing to it the least. Adaptation measures should not only be developed for individual sectors but a more integrated approach is necessary.

### *Hard measures*

- Adopting operation of existing resources in the context of climate change
- Protecting key existing resources (local water systems, wetlands, lakes, tanks, forests)
- Soil and water conservation, increasing soil carbon content

- Prioritising the developmental options keeping in mind the needs of those who do not have access and who are vulnerable.

***Soft measures***

- Monitoring, forecasting, measuring, analysing and providing data about rainfall, snowfall, stream flows, groundwater levels, water quality, soil moisture, floods, droughts, storms, cloud bursts, glacial floods.

The futuristic approaches and prospects become most important under these situations, which needs to be devised categorically. Past and recent studies have made number of recommendation to deal with climate change induced vulnerability to enhance adaptive capacity of communities thereby ensuring food security, livelihood security and water security. Moreover the three basic points or line of actions required may be pinpointed as follows,

1. Water Harvesting for Drinking Water
2. Water Harvesting for Agriculture
3. Enhancing Water Productivity in Drylands

***Adaptation***

- To enhance adaptive capacity by strengthening disaster management capability, artificially lowering waters, and installing an early warning system with good communication system.
- Proper information systems with sound techniques need to be developed and therefore research work must be taken up to identify the critical regions, which are at risks
- Identifying/using appropriate sectoral tools and an integrated assessment approach with adequate data inputs can lead to improved assessments with reduced uncertainties.
- Planners have to consider sea-level rise in the design of infrastructure in the coastal zone areas in prediction of future climate change, Information and means of improving adaptive capacity should provide to vulnerable communities i.e., improved conservation and management of water resources (supply-side and demand-side)
- Adaptation programmes should integrate climate component into water management practices to reduce impacts of extreme weather events on society/ecosystems helping communities to assess risks/options to adapt to drought/coastal flooding/ health risks.
- Involvement and participation of community at various levels of planning
- Early flood and drought warning with good communication system

***Mitigation***

- Preventing and limiting the cause of climate change, by cutting back on production of greenhouse gases and planting more forests.
- Afforestation programme can help in controlling the phenomena.
- Improvements are needed in both GCMs and scenario development techniques.
- Climate change scenarios and models should be selected so that the results will be directly comparable with historical observations.

- More accurate forecasting methodology is required to forecast the changes in land use
- Hydrological models should incorporate better physical based understanding of processes/their interaction.
- International and national funding agencies should focus on areas with scarce data.
- Budget planning should permit sufficient flexibility to accommodate departments to deal with extreme climatic events.
- Better communication and interaction between planners, researchers, and policy makers
- Involvement of community is important at all decision-making levels.
- Monitoring and evaluation programs should be implemented as an ongoing activity

**Conclusions**

The information or results described in present manuscript is carefully reviewed from different sources , moreover this write up do not envision an easy future for users and managers of the water resources, but it is our contention that better information about this future will prepare us to do a better job in facing its challenges. However, the stuff presented in this write up cannot be viewed as the final word on the problem. It is because the climate change is an ever changing concept and phenomenon as well. How and why Does Climate Change Matter to Water Resource Managers? It remains the big question or challenge for we water resource managers as such unpredictable climate change is expected to have dramatic effects on water resources in the country and thus on the relevant developmental works. In addition, steps taken to reduce the release of greenhouse gases could have consequences, positive as well as negative—for water resources and programs, looking into the depth of another important question i.e. . What are the water-related effects of climate change in India? Often, warmer air temperature is anticipated to have the following water-related effects,

- Increases in water temperature
- Changes in the location, timing, form and amount of precipitation
- Increases in tropical storm intensity
- Rising sea levels and Changes in oceans and coastal regions— chemical and physical

The increase in the air temperature will cause water temperatures to increase as well. As water temperatures increase, water pollution problems will increase, and many aquatic habitats will be negatively affected. Water availability too is supposed to be greatly influenced and the net impact on water availability will depend on changes in precipitation (including changes in the total amount, form and seasonal timing of precipitation). In areas where precipitation increases sufficiently, net water supplies might not be affected or they might even increase. If the precipitation remains the same or decreases though, net water supplies would decrease. Where water supplies decrease, there is also likely to be an increase in demand as a result of higher temperatures, which could be particularly significant for agriculture and energy production (the largest consumers of water) and also for municipal, industrial and other uses. There is a need to put equal emphasis on probable adverse influence on water quality too, as changes in the timing, intensity and duration of precipitation can negatively affect water quality. Flooding, a result of increased precipitation and intense rain storms, transports large volumes of water and contaminants into water bodies. Flooding also can overload storm, combined sewer and wastewater systems, resulting in untreated pollutants directly entering waterways. In regions with increased rainfall frequency and intensity, more pollution and sedimentation might be produced because of runoff.

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# 2

**Water Resources of Gujarat- Availability, Demand and Problems**

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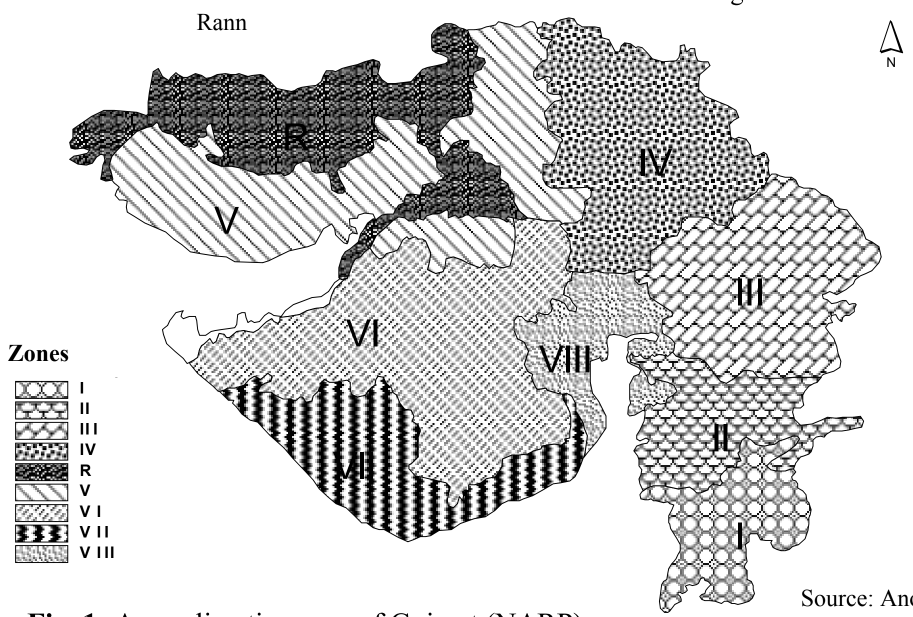
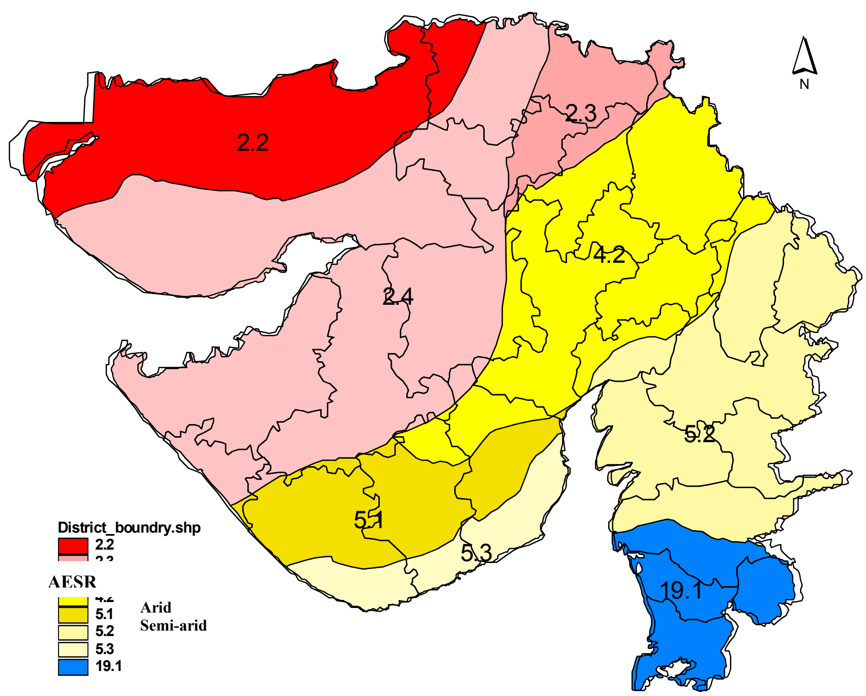
The state of Gujarat is western most part of the country, and lies between 20° 10' and 24° 7' N latitude and 68° 40' and 74° 4' E longitude covering an area about 196 thousand $km^2$ and furnishes a mosaic of geologic, physiographic, soil and climatic variation. These diversities are further accentuated as the state possess longest sea coast of 1600 km. The heterogeneity in rainfall is evident from less than 500 mm in Kutch to as high as 2000 mm in the Dangs with annual average of 828 mm in the state (Raman *et al.,* 2000). Based on these diversities, the state has been divided in to eight agro-climatic zones *viz*., I) South Gujarat heavy rainfall, II) South Gujarat, III) Middle Gujarat, IV) North Gujarat, V) North – West Gujarat, VI) North Saurashtra, VII) South Saurashtra and VIII) *Bhal* and Coastal (Fig. 1). Thus availability of water resources and its related constraints vary considerably from one location to another in the state. The agro-climatic zone-wise soil related water management constraints are enumerated in table 1. Subsequently, based on agro-climatic conditions including length of growing period, the National Bureau of Soil Survey and Land Use Planning, Nagpure has identified 20 agro ecological regions in India. Of these, in Gujarat 8 Agro ecological sub regions have been identified falling under 3 ecosystems *viz;* arid, semi arid and coastal (Fig. 2).




Source: Anon. (1988 – 89)

**Fig. 1:** Agro climatic zones of Gujarat (NARP)




Source: Velayutham *et al.* (1999)

**Fig. 2:** Agro ecological sub regions of Gujarat (NBSS and LUP, Nagpur)

**Table 1:** Agrocliamtic zonewise soil related water management constraints

| Agro-climatic zone | Physiographic location | Predominant sub-order association | Constraints |
|---|---|---|---|
| **I. South Gujarat heavy rainfall** | -Piedmont slope and valley plains<br>-Mid alluvial plains<br>-Coastal alluvial plains | Ochrepts<br>Ochrepts-Usterts<br>Aquepts-Ochrepts | - Shallow depth, highly erosive, low to moderate MHC, highly permeable<br>- High MHC, severe cracking, low to very low permeability, poor internal drainage, secondary salinization and water logging in parts<br>- Salt affected, highly dispersive, poor drainage, low permeability, mild cracking |
| **II. South Gujarat** | - Piedmont slope and valley plains<br>- Alluvial plains<br>-Coastal alluvial plains | Ochrepts<br>Usterts-Ustochrepts<br>Aquepts, Ochrepts | - Highly errosive, low to medium MHC, highly permeable<br>- Prone to erosion, moderate to poor drainage, medium to low permeability, secondary salinization and water logging in parts<br>- Same as those of coastal alluvial plains of zone I |
| **III. Middle Gujarat** | - Eastern hilly belt<br>-Mid alluvial plains<br>- Coastal plains | Orthents-Ochrepts<br>Fluvents-Usterts<br>Orthids, Argids, Aquents | - Prone to erosion, low MHC, shallow depth<br>- Erosion adjoining river beds, secondary salinization and water logging in canal command areas.<br>- Salt affected poor to medium drainage |

**Table 1:** Continue…

| **Agro-climatic zone** | **Physiographic location** | **Predominant sub-order association** | **Constraints** |
|---|---|---|---|
| **IV. North Gujarat** | - Border high lands<br><br>- Mid plains<br><br>- Western plains | Orthents, Ochrepts<br><br>Fluvents, Psamments, Ochrepts, Orthids<br>Argids, Aquents, Psamments, Usterts<br>(in pockets) | - Highly erodible, deep with low MHC, excessively drained.<br>- Low MHC, salinity, excessive permeability, very low AMC<br>- Salt affected, low permeability, poor drainage in some pockets |
| **V. North- West** | - Eastern plain<br><br>- Western plains | Orthents, Aquepts, Psamments, Ochrepts<br><br>Orthids, Argids, Psamments | -Excessive permeability, poorly drained and salt affected in pockets, low MHC and AMC<br><br>-Poorly drained and hydromorphic in pockets, salt affected, low to medium MHC |
| **VI. North Saurashtra** | - Southern plains<br><br>- Northern plains (Including hilly areas)<br>- Coastal belt | Orthents, Ochrepts, Orthids, Psamments (in pockets)<br><br>Orthents, Ochrepts<br>Orthids, Orthents,<br><br>Ochrepts | - Highly calcareous, salt affected soil in patches, erodible in hilly areas<br><br>- Low to medium MHC, Calcareous<br><br>- Salt affected |
| **VII. South Saurashtra** | - Inland areas (Including hilly areas)<br>- Coastal areas Including Ghed) | Orthents, Ochrepts,<br><br>Usterts | - Highly calcareous, poor permeability poor MHC in hilly areas<br>- Salt affected highly dispersive and water logged in Ghed |
| **VIII. *Bhal* and Coastal area** | - Whole zone | Usterts, Ochrepts Aquepts, Argids | - Salt affected, poor drainage, water logging in monsoon |

*Source: Anon. (1988-89)*

**Surface and ground water potentials in the state**

Gujarat is endowed with many rivers, some of which are perennial while many of them are seasonal. The perennial large rivers like Narmada, Tapi, Mahi and small ones like Daman Ganga are flowing in the South and Central Gujarat. On the other hand, in North Gujarat the rivers are not only few but also seasonal in flow. Sabarmati, Banas, Rupen and Saraswati are the important ones (Fig.3)

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 2), while only 2 thousand MCM comes from North Gujarat. The ground water potential is only 16 thousands MCM. Though, the combined contribution of South and Central Gujarat is the maximum but unlike the surface water potential wherein the contribution from this region is 84 per cent, in case of the 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, respectively.

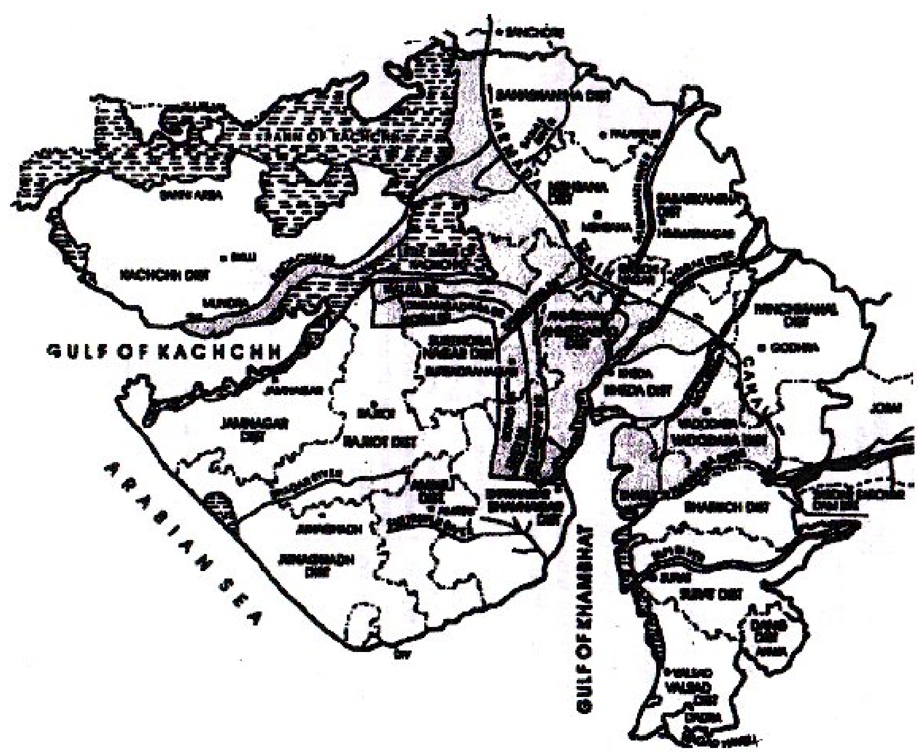



**Fig. 3:** River basins of Gujarat

**Table 2:** Surface and ground water potentials of Gujarat ('000 MCM)

| Region | Surface Water | Ground Water | Total |
|---|---|---|---|
| **South and Central** | 32.3 | 5.7 | 38.0 |
| **North Gujarat** | 2.0 | 4.1 | 6.1 |
| **Saurashtra** | 3.6 | 5.6 | 9.2 |
| **Kutch** | 0.6 | 0.6 | 1.2 |
| **Total** | **38.5** | **16.0** | **54.5** |

*Source : Anon.( 2000)*

Out of the 54.5 thousand MCM /yr of available water 19.1 thousand MCM is being utilized (Table 3). Among the different regions, the utilization was lowest in South and Central Gujarat (18%) though the actual usage is highest (7.0 thousand MCM/yr). On the other hand, in North Gujarat, where the availability is 6.1 thousands MCM/yr, the utilization is 6.0 thousand MCM (98 %). In other words, all the available waters are almost utilized in this region. The utilization in Saurashtra and Kutch are 59 and 58 per cent, respectively.

**Table 3:** Water utilization in Gujarat ('000 MCM)

| Region | Utilization | % of the state | % of total availability |
|---|---|---|---|
| **South and Central Gujarat** | 7.0 | 36 | 18 |
| **North Gujarat** | 6.0 | 31 | 98 |
| **Saurashtra** | 5.4 | 29 | 59 |
| **Kutch** | 0.7 | 4 | 58 |
| **Total** | **19.1** | | **50** |

*Source: Srinivas Mudrakartha (2004)*

Irrespective of the sectors during the year 2000, the total water requirement of the state was estimated to be around 29.43 thousand MCM which is estimated to rise to 36.5 thousand MCM during 2010, 46.86 thousand MCM during 2020 and 53.1 thousand MCM during 2025 registering an increase of 80 per cent (Table 4). At the state level, the maximum contribution for the per cent increase is from industry, which is estimated to draw 736 per cent more water than existing water utilization in 2000. This is followed by the demand for domestic use with a percentage increase of 165.

The water requirement for agriculture, which was 93 per cent during 1997, will be going down steadily and it will contribute to 82 per cent of the total water requirement by 2025. This reduction is mainly due to increased demand from other sectors and not due to reduction in the quantity of water required in agricultural sector. In fact by 2025, the state needs 16 thousand MCM more water for agriculture use.

**Table 4:** Water requirements for different sectors

| **Sector** | **Water requirement(MCM)** | | | | |
|---|---|---|---|---|---|
| | **1997** | **2000** | **2010** | **2020** | **2025** |
| **Domestic** | 1374 | 1545 | 2288 | 3618 | 4103 (165) |
| **Industrial** | 448 | 644 | 1505 | 3522 | 5386 (736) |
| **Livestock** | 224 | 230 | 239 | 263 | 284 (23) |
| **Agriculture** | 25672 | 27013 | 325151 | 39352 | 43306 (60) |
| **Total** | **27616** | **29431** | **36558** | **46769** | **53088 (80)** |
| **%Agriculture** | 93 | 93 | 90 | 84 | 82 |
| **%Domestic** | 5 | 5 | 6 | 8 | 8 |
| **%Industry** | 2 | 2 | 4 | 8 | 10 |

Figures in parenthesis shows per cent variation over 2000 *Source: Anon. (2000)*

**Ground water development**

During 1997, out of the 16 thousand MCM of ground water recharge at the state level, it was estimated that about 13 thousand MCM was estimated to be utilizable recharge. About 9.7 thousand MCM was estimated to be the draft leaving around 3.1 thousand 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 (Table 5).

Out of the 5 North Gujarat districts, three, namely Mehsana, Gandhinagar and Banaskantha were falling under over exploited category while Ahemedabad and Sabarkantha were 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. 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. During 1984, out of the 184 talukas, 163 talukas were falling under 'white' category while the numbers reduced to 96 talukas during 1997. Simultaneously, the talukas under 'over exploited' category were only 5 during 1984 which increased to 31 during 1997 (Table 6).

**Table 5:** Status of ground water exploitation in Gujarat (1997)

| District | Ground water balance (MCM) | Ground water development (%) | Category |
|---|---|---|---|
| **Ahemedabad** | 55.85 | 92.63 | Dark |
| **Amreli** | 196.92 | 71.03 | Grey |
| **Banaskantha** | -91.45 | 111.49 | OE |
| **Baroda** | 278.99 | 63.90 | White |
| **Bhavnaagar** | 277.93 | 62.98 | White |
| **Bharuch** | 161.33 | 59.61 | White |
| **Bulsar** | 392.71 | 45.45 | White |
| **Dangs** | 71.33 | 1.03 | White |
| **Gandhinagar** | -41.09 | 146.04 | OE |
| **Jamnagar** | 277.80 | 57.44 | White |
| **Junagadh** | 217.38 | 77.59 | Grey |
| **Kheda** | 252.48 | 72.80 | Grey |
| **Kutch** | 70.41 | 85.96 | Grey |
| **Panchmahal** | 286.64 | 45.85 | White |
| **Rajkot** | 299.46 | 69.57 | White |
| **Sabarkantha** | 86.54 | 88.75 | Grey |
| **Surat** | 755.69 | 32.00 | White |
| **Surendranagar** | 147.91 | 70.54 | Grey |
| **Mehsana** | -557.42 | 164.65 | OE |

<70% White; 71-90 Grey; 91-100 Dark :> 100 over exploited (OE)

*Source: Raman et al. (2000)*

**Table 6:** Ground water development trend in Gujarat

| Category | Districts | | | Talukas | | |
|---|---|---|---|---|---|---|
| | **1984** | **1991** | **1997** | **1984** | **1991** | **1997** |
| **White** | 19 | 14 | 9 | 163 | 123 | 96 |
| **Grey** | Nil | 2 | 6 | 13 | 26 | 43 |
| **Dark** | Nil | 3 | 1 | 1 | 10 | 7 |
| **OE** | Nil | Nil | 3 | 5 | 24 | 31 |
| **Saline** | - | - | | 2 | 31 | 7 |
| **Total** | **19** | **19** | **19** | **184** | **184** | **184** |

*Source: Raman and Patil (2005)*

**Ground water quality**

The ground water quality in the state is subjected to three major constituents. These are mainly salt concentration, nitrate and fluoride. With respect to salt concentration, waters of the eastern belt districts from the 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 contributes to the maximum of fluoride problem (Fig. 4).

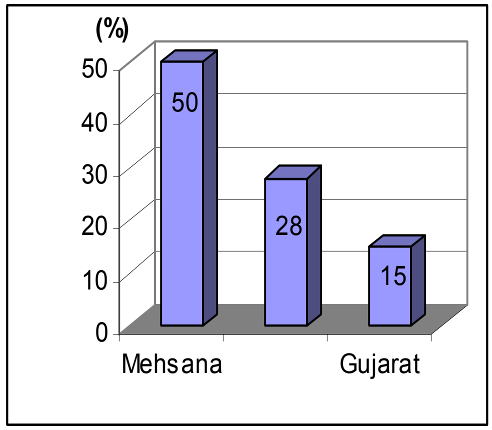



**Fig. 4:** Fluoride affected villages
*(Source: Anon., 2004)*

**Per capita availability**

The per capita availability of water at the state level as per the 2001 census has been reported to be 938 $m^3$ per year (Table 7). Falkenmark, suggested 1700 $m^3$ per person as the critical level for assessing the sufficiency of per capita availability. As per this standard, the state is definitely facing the acute shortage of water. Further, it striking to note that in North Gujarat, the per cent utilization is more than 100. So there is need to take appropriate steps to minimize the per cent utilization of water.

**Table 7:** Per capita availability and utilization of water in Gujarat

| **Particulars** | **South and Central Gujarat** | **North Gujarat** | **Saurashtra** | **Kutch** | **Gujarat** |
|---|---|---|---|---|---|
| **Water availability (MCM/Yr)** | 37926 | 6105 | 9287 | 1275 | **54593** |
| **Population (million)** | 23.73 | 19.27 | 13.09 | 2.09 | 58.17 |
| **Per capita availability($m^3$/yr)** | 1599 | 317 | 709 | 610 | 938 |
| **Per capita ($m^3$/yr) utilization** | 634 | 407 | 406 | 413 | 390 |
| **%utilization** | 40 | 128 | 57 | 68 | 42 |

*Source: Raman and Patil (2010)*

**Irrigation**

Out of the 196 thousand $km^2$ of total geographical area of the state, 124 thousand $km^2$ are cultivable. With all the available water resources, it is estimated that the state has an ultimate irrigation potential of 64.88 lakh ha (Table 8).

**Table 8:** Irrigation potential (lakh ha) in Gujarat (June, 2003)

| Source | Ultimate | Potential created | Maximum utilization |
|---|---|---|---|
| **A)Surface water** | | | |
| **Major and medium schemes** | 18.00 | 14.09 | 12.93 |
| **Sardar Sarovar( including conjunctive use)** | 17.92 | 0.25 | 0.25 |
| **Minor irrigation** | 3.48 | 2.65 | 1.62 |
| **Total** | **39.40** | **16.99** | **14.80** |
| **B)Ground water ( including pvt. resources)** | **25.48** | **20.35** | **20.33** |
| **Total(A+B)** | **64.88** | **37.34** | **35.13** |
| C) Rain fed Areas* | 59.12 | 2.5 | 2.5 |
| **Grand Total** | **124.0** | **39.84** | **37.63** |

* Protective irrigation during *Kharif* with the help of water harvesting structures *etc.*

*Source: Anon. ( 2002)*

Out of the 124 lakh ha of cultivable area, the gross irrigated area in the state during 1998-99 was 38.4 lakh ha working out to a percentage of 31. The corresponding net irrigated area was 30.8 lakh hectares with a percentage of 24.8 (Fig. 5). The area under gross canal irrigated area was 7 lakhs contributing 18 per cent of the gross irrigated area in the state. The tank command in the state is less than 1 per cent.

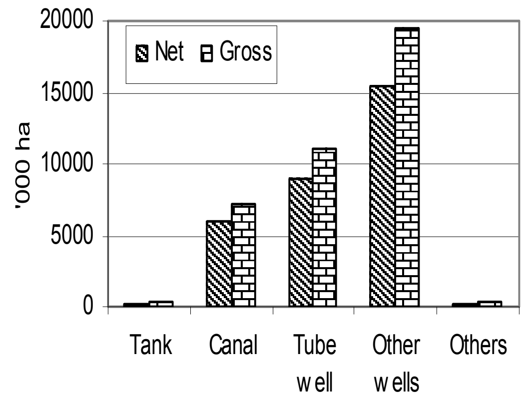



**Fig. 5**: Sources wise gross and net irrigated area in Gujarat ('000 ha)

*Source : web site: Irrig .Dept.*

As per the 1998-99 statistics, the state had approximately 50,000 tube wells and 8 lakh open wells. The respective intensities, as measured by the number of wells per unit area were 0.25 and 4.0. Thus, the intensity of open well in the state was 16 times more than the tube well intensity. While, the tube wells are concentrated only in North Gujarat and in parts of central Gujarat, the open wells are distributed through out the state. However, the concentrations were more in Saurashtra, followed by Central Gujarat (Table 9).

The highest intensity of tube well was observed in Gandhinagar with a value of 2.4 tube wells per $km^2$ followed by Surendranagar (1.64) and Mehsana (1.26).The tube wells are scanty in Saurashtra. The ill effect of high intensity of tube well in the

North Gujarat, particularly in Mehsana, is reflected in the receding water table conditions and the over exploitation of ground water in Mehsana, Gandhinagar and Banaskantha districts.

**Table 9:** Tube well and open well intensities (No./km$^2$)

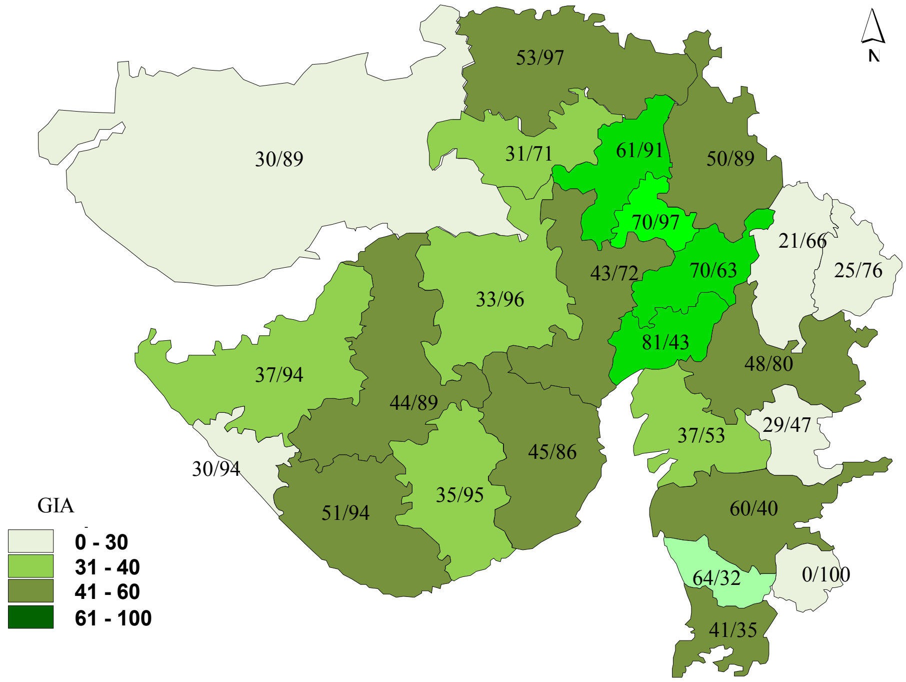
| **Taluka** | **Tube well intensity** | **Open well intensity** | **Taluka** | **Tube well intensity** | **Open well intensity** |
|---|---|---|---|---|---|
| Ahemedabad | 0.37 | 2.3 | Kheda | 0.28 | 3.6 |
| Amreli | - | 8.3 | Kutch | - | 0.6 |
| Banaskantha | 0.78 | 4.3 | Mehsana | 1.26 | 1.5 |
| Bharuch | - | 0.8 | Panchmahals | - | 7.3 |
| Bhavanagar | - | 6.7 | Rajkot | - | 8.0 |
| Dangs | - | 0.5 | Sabarkantha | 0.20 | 11.4 |
| Gandhinagar | 2.4 | - | Surendranagar | 1.64 | 2.8 |
| Jamnagar | - | 5.2 | Vadodara | 0.26 | 2.3 |
| Junagadh | - | 10.7 | Valsad | - | 3.4 |
| | | | **State** | **0.25** | **4.0** |

*Source: Raman and Patil (2005)*

Out of the 112 lakh ha GCA in the state, 36 lakh ha is irrigated (32%). Gandhinagar is having the highest irrigated area (73%), while Kutch and Bharuch districts have the lowest (17-19%). In North Gujarat and Saurashtra, ground water is the major source of irrigation water, while in middle and South Gujarat, surface water is predominant source. At state level, the contribution of surface and ground water is 21 and 79 per cent, respectively (Fig. 6).

With such spatial and temporal variability in availability and quality of water in the state, the problems are bound to vary region wise. However, the major ill effects of faulty water management practice are rise in water table in canal command and receding water table in lift command.

***Rise in water table:*** Irrigation projects play pivotal role in enhancing the crop productivity and bringing prosperity to the area. However, if the created irrigation facility is not properly utilized, then the natural resources *viz.,* soils and crops/vegetation are deteriorated to such an extent that they become unproductive. This is the case in most of the major and medium irrigation projects in different states of India and Gujarat is not an exception. In Gujarat, the ill effects like water logging, salinity and sodicity *etc.,* are apparent in both the major projects *i.e.* Ukai-Kakrapar (UKC) on river Tapi in South Gujarat and Mahi-Kadana (MKC) on river Mahi in Central Gujarat. The severity of these problems is more in South Gujarat due to higher rainfall and heavy texture of the soil than Central Gujarat (Table 10).




*Source: Anon. (1994-95)*

**Fig. 6:** District wise irrigated area in Gujarat

**Table 10:** Command wise water logged areas in Gujarat ('000 ha)

| **Command** | **Water table depth (m)** | |
|---|---|---|
| | **< 1.5** | **1.5 to 3.0** |
| Kakrapar | 11.46 | 66.00 |
| Ukai Right Bank | 2.15 | 21.00 |
| Ukai Left Bank | 2.04 | 13.08 |
| Mahi Right Bank | 3.94 | 28.80 |
| Kadan Left Bank | 0.80 | 5.05 |
| Shetrunj Left Bank | 0.02 | 5.54 |
| Ghed | 69.00 | - |
| Total | 89.41 | 139.56 |
| **Per cent of command** | **15.00** | **39.60** |

*Source: Anon. (1996)*

Further, the rate at which water table is rising in Surat branch of UKC suggest that about 40 per cent of the command area will become water logged with in a period of 10 years (Patel *et al*., 2000). The salinity and sodicity are the associated problems of the water logging situation. The major causes of water logging and its associated problems are due to adoption of faulty irrigation methods (flooding, field to field *etc*.) by ignoring the land irrigability classification, inclination towards high water consuming crops like paddy, sugarcane, banana *etc*., by neglecting suggested cropping pattern and heavy rainfall (1400 mm). This is also true for MKC, but with relatively less severity owing to loamy soils and relatively lower rainfall (Raman *et al*., 1999). Based on these experiences, adequate care has been taken in partly commissioned Narmada project, wherein limited quantity of water will be supplied for low water consuming crops during r*abi* season only. Not only this, farmers are being encouraged for conjunctive use of surface and ground water.

***Receding water table:*** Contrary to South and central Gujarat, receding water table is a matter of serious concern in North Gujarat which has arisen due to unscientific way of irrigation, higher evaporative demand and inappropriate choice of crops. As a result of this, as on today all the districts of North Gujarat (Banaskatha, Sabarkantha, Mehsana, Gandhinagar and Ahmedabad) including Kutch are in 'dark' or 'over exploited' zone. Not only this, but along with receding water table @ 0.3 m/yr, ground water quality is also deteriorating at an alarming rate. Consequently, most of the ground waters are becoming unfit for irrigation and drinking as well. Though, fluoride content in ground water is above permissible limit, people are drinking such waters in absence of other options (Anon., 2004). In fact, human intervention is the cause of both rising and receding water table situations.

In order to counteract the multiplexed problems of water management in the state, the erstwhile Gujarat Agricultural University has developed crop and location specific water management technologies with the financial help from ICAR, other agencies, state government and foreign agencies and this work is being continued in all the recently formed four agricultural universities. The information generated in this context is presented un subsequent chapters.

# 3

## Water Resources Augmentation in Gujarat

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Population pressure calls for a quantum jump in production from the almost stagnant net sown area of 142.22 M ha of our country. The per capita availability of land has already decreased from 0.5 ha in 1950 - 51 to 0.15 ha in 1999 - 2000 and will reduce to 0.08 ha in 2020. The four fold increase in production of food grain from 50.8 Mt in 1950-51 to 202.53 Mt in 1998-99 is due to all round agriculture developments in India during and after Green revolution. The Gujarat State has an area of 1.96 lakh km$^2$, which is 6.96 % of the area of the whole country. Total 47.31 lakh ha area of the state, has been treated under various schemes up to march-2007. External evaluation agencies observed that watershed development project schemes increased 10 to 30 % agriculture production, 25 to 30 % agriculture income, 3 to 15 m ground water depth, 20% additional irrigation and 20 to 30 % milk production. The projects also generated employments and indirect benefits also have been observed with reduction in migration. State still has about 70 lakhs ha area (52 lakh ha area for land development and 18 lakh ha area under problem soils) to be treated. Suggestions like strengthening the data base on soil and water resources, inter basin water transfer to minimize water scarcity and regional imbalance in supply and demand, more efficient approach promoting soil and water conservation and demand management, higher entitlement for those using water more efficiently, economical biomass production, policy measures to arrest soil erosion, proper water management practices, effective utilization of water resources, judicious use of water for irrigation *etc*,. are envisaged in this paper.

### Physiographic and demography

The Gujarat state has been an area of 1,96,024 km$^2$ and is divided into 26 districts. It is the seventh largest state in India. It is situated on the west coast of country between 20-6' to 24-42' north latitude and 68-10' to 74-28' east longitude. Gujarat is bounded by the Arabin sea in the West, by the State of Rajsthan in the North and North–East, by Madhya Pradesh in the East and by Maharashtra in South and South-East. The total population of the State it is 5,05,96,992 with a population density of 258 persons per sq km. The rural population of the state is 63 % (31,69,7,615) of total population of the state. The literacy rate of the state is about 70 % with 50 % literacy rate in the rural area.

### Rain fall

The average rainfall in Gujarat varies from 340 to 1900 mm. The Southern region of the state has an average rainfall ranging from 750 to 1500 mm. The Dangs district has the highest average rainfall of 1900 mm. The northern districts have a

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rainfall varying from 500 to 1000 mm. The rainfall in the Southern highland of Saurashtra and the Gulf of Cambay is approximately 630 mm, while other parts of the Saurashtra receive rainfall less then 630 mm. The desert area of Kutch has very low average rainfall.

**Soils**

The soils of Gujarat are classified in to seven broad groups, namely (a) black Soils, (b) alluvial Soils, (c) saline – alkali soils, (d) forest soils, (e) desert Soils (f) hilly soils (g) laterite soils. Black Soils are divided in to two sub groups, *viz*., medium black and deep black. Medium black soils have been derived from the basaltic trap and are found in whole of the saurashtra region except coastal belt, South-West of Ahmedabad, part of Baroda and Bhuj taluka of Kutch district. Shallow black soils are derived from granite and gneiss parent material and are generally found in parts of Sabarkantha and Panchmahals districts. Medium black soils are calcareous in nature as the parents materials are impregnated with native lime stone. The typical black cotton soils cover major part of Bharuch, Surat, Balsar and southern part of Baroda districts.

Allivial soils cover a major area in the state. These soils have been formed due to silting by the Indus river system in the state. They are very deep and uniform throughout the profile with undifferentiated horizon formation, showing thereby that they are of recent origin. Sandy alluvial soils are found in Surendranagar, Jamnagar, Kutch and Sabarkantha districts where they are either formed in situ or due to wind - blown sand brought from upper sandy area. Sandy loam alluvial soils are found in Kaira, eastern part of Ahmedabad, southern part of Mehsana and western part of Baroda districts. These soils are good in natural fertility, water holding capacity, drainage and base exchange capacity, hence ideal for irrigated farming. Coastal alluvial soils are situated in narrow strips of 7-15 km along the sea shore of about 1600 km. These soils are formed from a mixture of black clay material and old marine silt deposits. Saline soils occur in a narrow strip along the coast line. The Rann of Kutch constitutes a vast marshy area in the arid coastal region. Saline / alkali areas in Kaira and part of Ahmedabad are formed due to poor drainage conditions. Forest soils are immature, shallow to moderately deep and residual in nature. They consist of thin skeleton solum and generally occur on hill plateau. These soils are found in the North-East and South-East parts of the state, Poshitra area of Himmatnagar, The Dangs and Junagadh districts with sharp division of hills having 25-30% slope.

Desert soils are found mostly in Rann of Kutch, where the rainfall ranges from <300 to 500 mm with a high potential evapo-transpiration of 1620 to 2060 mm. Rann soils are fine textured and part of the region consists of sand dunes and undulating sandy plane. Hilly soils are very shallow skeleton soils mostly found in isolated patches in eastern Panchmahals, Baroda, Bharuch, Surat, Valsar, Dangs, Surendranagar, Amreli and Junagad districts. The Soils are highly undulating, nutritionally shallow and poor. However, in the Dangs district and eastern part of Valsar, Surat and Bharuch districts where the forest in abundant and annual rainfall is about 2500 mm, these typical soils have developed. These are neutral to acidic in reaction with yellowish red colour in upper horizon and highly susceptible to erosion hazards.

**Land Use**

The reporting area of Gujarat state is 19.01 million hectares for which land use statistic is available. Per capita land availability in Gujarat is about 43% higher than the all India figure. The detailed land use statistics of the state is given in table 1.

**Table 1 :** Land use pattern of Gujarat state

| SN | Land Use | Area* ('000 ha) | % of total reporting |
|---|---|---|---|
| 1 | Forests | 1854 | 9.75 |
| 2 | Not available for cultivation | 3753 | 19.75 |
| 3 | Permanent pastures and other grazing | 850 | 4.47 |
| 4 | Land under misc. tree crops and groves | 4 | 0.02 |
| 5 | Culturable waste land | 1985 | 10.44 |
| 6 | Fallow land other than current fallows | 11 | 0.06 |
| 7 | Current fallows | 930 | 4.89 |
| 8 | Net area sown | 9622 | 50.62 |
| **Total Reporting area** | | **19009** | **100.00** |

* Estimated

**Major crops**

The major crops in the state are rice, wheat, sorghum, peal millet, maize, pigeon pea, gram, groundnut, cotton and tobacco. Of the total cropped area, food crops like cereals and pulses account for about 50 per cent, while the remaining area is under oilseed, fiber and fodder crops. The dominant crops in different districts of the state are given in table 2.

**Table 2:** Prevalent crops in different districts of Gujarat state

| SN | Crop | Major district |
|---|---|---|
| 1. | Groundnut | Rajkot, Junagadh |
| 2. | Pearl millet | Banaskantha, Bhavanagar |
| 3. | Cotton | Surendranagar, Ahmedabad |
| 4. | Pulses | Bharuch, Kutchchh |
| 5. | Sorghum | Mehsana, Banaskantha |
| 6. | Wheat | Kheda, Ahmedabad |
| 7. | Paddy | Panchmahal, Valsad |
| 8. | Narcotics | Kheda, Vadodara |

**Problems of soil erosion and constraints**

An area of 81.33 lakh ha. has been reported as degraded in Gujarat state due to various problems (41.5 % of TGA) in which water erosion contributes to the maximum extent *i.e.,* 64 %.

The state of Gujarat, within its relatively limited geographical extent of 1.9 lakh km$^2$, exhibits a wide variation of geo-climatic environments. A wide range of physiographic features are displayed within relief variations from sea level to 1000 m elevation. The state astride the Tropic of Cancer in its North-western part and forms a sub-tropical high pressure region.

As a result, the atmospheric conditions are influenced dominantly by the monsoon and to some extent by physiography insularity and the Thar Desert. Thus climatically, the state experience extremes of arid to humid conditions. Gujarat holds a unique bio-climatic gradation ranging from dry desert conditions to humid sub-evergreens, as well as dry hilly scrub lands to dry thorny plains and forests. Due to water scarcity during critical periods, most of the districts possess the drought area characteristics giving relatively poor crop yields. The vast stretch of wastelands under different categories is another constraint. The recent status of wastelands in the state encompassing various districts and different categories of wastelands is given in table 3.

**Table 3:** District-wise status of wastelands in Gujarat

| District | Categorized wastelands area (km$^2$) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **GR** | **S** | **WLM** | **SA** | **DNF** | **DPG** | **DPC** | **SIC** | **MIW** | **BR** | **SS** | **TW** | **% to TGA** |
| Ahmedabad | 65 | 107 | 0 | 865 | 1 | 53 | 0 | 5 | 0 | 3 | 0 | 1100 | 13 |
| Amreli | 3 | 372 | 6 | 12 | 73 | 0 | 0 | 0 | 0 | 33 | 0 | 500 | 7 |
| Banaskantha | 80 | 1237 | 54 | 552 | 547 | 9 | 1 | 47 | 4 | 53 | 160 | 2743 | 22 |
| Bharuch | 76 | 144 | 292 | 109 | 110 | 0 | 2 | 0 | 7 | 3 | 0 | 742 | 8 |
| Bhavanagar | 26 | 1265 | 0 | 574 | 34 | 8 | 0 | 7 | 0 | 47 | 0 | 1962 | 18 |
| Dangs | 0 | 0 | 0 | 0 | 113 | 0 | 0 | 0 | 0 | 0 | 0 | 113 | 6 |
| Gandhinagar | 24 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 27 | 4 |
| Jamnagar | 0 | 2536 | 0 | 1 | 35 | 0 | 0 | 0 | 0 | 311 | 0 | 2884 | 20 |
| Junagadh | 0 | 2329 | 0 | 0 | 487 | 0 | 0 | 0 | 0 | 325 | 0 | 3141 | 30 |
| Kheda | 153 | 73 | 0 | 147 | 27 | 19 | 4 | 9 | 2 | 93 | 0 | 527 | 7 |
| Kutchchh | 108 | 8860 | 1619 | 4462 | 1765 | 161 | 1 | 107 | 14 | 1876 | 148 | 19120 | 42 |
| Mehsana | 80 | 330 | 0 | 116 | 0 | 90 | 0 | 4 | 0 | 0 | 0 | 619 | 7 |
| Panchamahal | 33 | 272 | 0 | 0 | 985 | 0 | 0 | 0 | 3 | 63 | 0 | 1356 | 15 |
| Rajkot | 57 | 1592 | 23 | 49 | 100 | 24 | 24 | 0 | 1 | 125 | 1 | 1996 | 18 |
| Sabarkantha | 181 | 600 | 0 | 3 | 432 | 2 | 2 | 4 | 0 | 135 | 163 | 1522 | 21 |
| Surat | 20 | 133 | 250 | 30 | 251 | 17 | 16 | 0 | 8 | 1 | 0 | 724 | 9 |
| Surendranagar | 35 | 1514 | 82 | 710 | 56 | 2 | 0 | 0 | 0 | 214 | 0 | 2614 | 25 |
| Vadodara | 61 | 218 | 8 | 0 | 304 | 0 | 2 | 0 | 0 | 10 | 3 | 605 | 8 |
| Valsad | 12 | 205 | 324 | 8 | 123 | 0 | 26 | 6 | 10 | 2 | 12 | 728 | 14 |
| **Total** | **1013** | **21787** | **2656** | **7637** | **5443** | **388** | **78** | **188** | **50** | **3293** | **487** | **43021** | **22** |

**Notes : GR** : Gullied / Ravine land, **S** : Land with / without scrub, **WLM** : Waterlogged / Marshy land, **SA** : Saline/Alkaline land, **DNF** : Degraded Notified Forest land, **DPG** : Degraded Pasture/Grazing land, **DPC** : Degraded land under plantation crops, **SIC** : Sands-Inland/Costal, MIW: Mining / Industrial Wastelands, **BR** : Barren Rocky Area, **SS**: Steep Sloping land, **TW**: Total Wastelands, **TGA**: Total Geographical Area

**Status of natural resources management in Gujarat**

The entire area of the state has been demarcated in region, basin catchment, sub catchments, watershed and sub, mini and micro watershed by the Bhaskaracharya Institute of Space Application and Geo-Informatics (BISAIG), Gandhinagar (Table 4). Total micro watershed (MWS) in Gujarat are 13587 covering 196.024 lakh ha area, untreatable micro watersheds are 1005 which cover 27.24 lakh ha area having reserved forest, barren rocky, assured irrigation etc. Total treatable MWS in the state are 12582, covering an area of 168.79 lakh ha. At present 6047 MWS are treated covering an area of 51.93 lakh ha. Total 6535 MWS are remained will be treated during 12 to 14th plan covering an area of 116.86 lakh ha.

**Table 4:** The details regarding micro watersheds in Gujarat

| SN | **Item** | | | **Details** | |
|---|---|---|---|---|---|
| | | | | **Number** | **Area (lakh ha)** |
| 1 | Total micro watersheds (MWS) in the state | | | 13587 | 196.024 |
| 2 | Total untreatable MWS (Reserved Forest, Barren Rocky, assured irrigation, *etc,*.) | | | 1005 | 27.2386 |
| 3 | Total treatable MWS in the state | | | 12582 | 168.7854 |
| a | Total MWS covered under pre-IWMP schemes of DoLR | | | 3895 | 31.6302 |
| b | Total MWS covered under schemes of other Ministries | | | 645 | 6.07954 |
| c | Total MWS covered under IWMP 2009-10 and 2010-11 of DoLR | | | 1507 | 14.218 |
| | **Total** of 4 a to d | | | **6047** | **51.9277** |
| 5 | Balance micro-watersheds not covered till date | | | 6535 | 116.858 |
| 6 | Plan for covering balance micro-watershed | 11th Plan | 2011-12 | 835 | 7.11 |
| | | 12th Plan | | 1842 | 39.7477 |
| | | 13th Plan | | 1940 | 37 |
| | | 14th Plan | | 1745 | 33 |
| | | **Total** | | **6535** | **116.858** |

**Rainfall budget of Gujarat**

(1) Water requirement of the state:
For drinking and domestic purpose: 2,000 MCM
For irrigation purpose: 22,400 MCM
For industrial and other purpose: 5,600 MCM
Total: 30,000 MCM water / annum is required for the state.

(2) Total available rainfall water in Gujarat : 1,30,000 MCM in a normal year.

(3) The average available rainfall in the state in about 90,000 MCM. About 70% runoff water goes in to the Sea.

So, about 27,000 to 30,000 MCM water can be used. The capacity of the reservoir is about 32,000 MCM. Out of this, about 20000 to 22,000 MCM water remains in the reservoir, 18,000 to 19,000 MCM water is available from the reservoir in the place of 30,000 MCM requirement per annum. So the gap of 11,000 to 12,000 MCM water is to be satisfied from the ground water. The quntity of ground water in the state is about 12,800 MCM and we have to draw about 11,000 MCM water from ground source (85%). As per the International standard those states which draw more than 75% of ground water storage then states may be considered as a severe water scarcity state.

**Major programme implementing agencies**

Gujarat State Land Development Corporation Limited (GSLDC) is one of the leading implementing agency for watershed development works in the state. It was established in March 1978, with the main objective of executing land reclamation and soil conservation schemes in the state. It acts as a wholly Government and Watershed Development Programme in the state, such as (1) Soil conservation schemes in normal areas (2) Soil conservation schemes in tribal area (3) Farm pond and village ponds scheme (4) Macro management schemes (5) Flood relief scheme (6) Water harvesting structure scheme and other such schemes. Rural Development Department is also carrying watershed development work through District Rural Development Agency (DRDA). GSLDC is implicating numbers of soil and moisture conservation schemes (37) sponsored by state and central govrenment.

**LAST TEN YEARS (2002-03 TO 2011-12) WORK DONE BY GSLDC**

| | | | | |
|---|---|---|---|---|
| 1. | Area covered under watershed | : | 15.26 | lakh ha. |
| 2. | Desilting work of village ponds | : | 8135 | Nos. |
| 3. | Water harvesting structure constructed | : | 145089 | Nos. |
| 4. | Farm ponds | : | 60826 | Nos. |
| 5. | *Sim talavadi* | : | 9766 | Nos. |
| 6. | Beneficiaries covered | : | 7.67 | Nos. |
| 7. | Estimated water harvesting | : | 200 | lakh cmt |
| 8. | Estimated increased irrigated area (per year) | : | 133000 | ha |

**Impact of water harvesting activities in the state in rainfed area**

Gujarat state has achieved 10.4% GDP during the 10$^{th}$ five year plan which was higher than allocated target to the state (10.2%). This was only due to runoff water harvesting in rain fed areas. Due to intensive water harvesting work in last 10 years number of village ponds, farm ponds and water harvesting structure have been constructed and the visible benefits realized are:

- Increase in ground water table, well irrigated area in the state increased from 19,30,100 to 27,36,400 ha.
- Cultivation of cash crops /value added crops has been increased compared to cereals crops.
- Due to runoff water harvesting works cultivation of summer and winter crops has been increased.
- Quality of ground water has been improved
- More employment has been generated.
- Production of fruits, vegetable, medicinal, and spices crops has been increased.

Expenditures on water harvesting may be recovered within one year, if the rainfall is normal and more than 100 per cent profit is possible every year after completion of work. In the state during the year 1990-91, total irrigated area was 29,10,500 ha., which has been increased up to 41,11,200 ha during the year 2003-04 which shows, increase to the extent of about 35 per cent. The share of state in the production of groundnut is, 42.37 per cent, for cotton 22.17 per cent and total oil seed production, 18.22 per cent of the country. Gujarat is ranking first in the country with respect to production of cotton, tobacco and spices food crops. Similarly, state ranks second in groundnut, onion, sapota, papaya, *guvar* and turmeric production in the country.

Information regarding water harvesting structures constructed, water storage by GSLDC is given in table 4 indicated that total 177901 water storage structures are constructed which stored about 9319 lakh $m^3$ water which irrigate 913702 ha areas including supplementary irrigation.

The work carried out by Gujarat State Land Development Corporation Ltd. (GSLDC) has been evaluated by number of evaluation agencies : *viz.,*

1. Agriculture Finance Corporation
2. Gujarat Institute of Development Research
3. Director Evaluation, Govt. of Gujarat Gandhinagar
4. The Energy and Resource Institute (TERI) Bangalore
5. Sadguru Foundation, Dahod
6. Sardar Patel Agro Economics Research Center, Vallabh Vidhyanagar

They reported that 10 per cent to 30 per cent agriculture production, 25 to 30 per cent agriculture income, 3 to 15 mt. ground water table, and 20 per cent additional irrigation potential and 20 to 30 per cent milk production has been increased due to implementation of watershed management schemes in the state.

The Energy Resource Institute, New Delhi in his Mid Term Evaluation of 10$^{th}$ Plan watersheds of NWDPRA Gujarat state revealed that there is a tangible increase in agriculture income of the project beneficiaries, which varies from Rs. 14,000 to Rs. 25,880. Along with these, the project has yielding 2200 to 18000 person days of employment opportunities. Family income per year varies from Rs. 3500 to 25880. Decrease in migration of rural labour from 25 to 65 per cent.

Ground water level increased between 6 and 8 m. Crop productivity has definitely and substantially enhanced during project implementation. The increase has been in the range of 25 to 200 per cent in these watersheds, depending on the crop. There was an increase in green cover / biomass by 40 to 45 per cent in these watersheds.

Financial analysis of the watershed at 10 per cent discount rate gives Cost-Benefit Ratio (CBR) ranging from 0.05-0.2 and Internal Rate of Return (IRR) for the project varies from 45-132.2 per cent.

Evaluation study on state government scheme for water harvesting which was implemented by GSLDC was conducted by Directorate of Evaluation Government of Gujarat, Gandhinagar and reported that:

Out of 400 sample beneficiaries, 371 had got more than one benefits *viz*., increase in production of crops as well as irrigation, increase in ground water table i.e. increase in water level in their wells, increase in fertility of land etc.

- After the implementation the scheme the area under *kharif* crops had increased from 851.57 ha to 924.98 ha and the area under *rabi* crops had increased from 35.70 ha to 92.25 ha which shows increase of 8.62 per cent and 158.40 per cent, respectively in *kharif* and *rabi* seasons.
- The increase in irrigated area under *kharif* crop was 37.45 per cent and in *rabi* crops was 275.45 per cent.

**Table 4:** Statement showing information on rain water storage

| SN | Year | Village Pond | | Farm Ponds/ Sim Talavdi | | Water harvesting structures | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Nos** | **Water storage (lakh $m^3$)** | **Nos** | **Water storage (lakh $m^3$)** | **Nos** | **Water storage (lakh $m^3$)** | **Nos** | **Water storage (lakh $m^3$)** | **Estimated Increase in Irrigated area** (ha) |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1 | 1996-1997 | 0 | 0 | 6910 | 391 | 0 | 0 | 6910 | 391 | 78264 |
| 2 | 1997-1998 | 0 | 0 | 5853 | 46 | 62 | 4 | 5915 | 50 | 10064 |
| 3 | 1998-1999 | 20 | 5 | 6425 | 59 | 380 | 27 | 6825 | 91 | 17644 |
| 4 | 1999-2000 | 616 | 154 | 1536 | 13 | 575 | 40 | 2727 | 207 | 29140 |
| 5 | 2000-2001 | 1156 | 289 | 4682 | 37 | 1295 | 91 | 7133 | 417 | 60118 |
| 6 | 2001-2002 | 755 | 189 | 5055 | 41 | 672 | 47 | 6482 | 277 | 40218 |
| 7 | 2002-2003 | 66 | 17 | 546 | 4 | 139 | 10 | 751 | 31 | 4790 |
| 8 | 2003-2004 | 319 | 80 | 1824 | 14 | 375 | 26 | 2518 | 119 | 17530 |
| 9 | 2004-2005 | 165 | 41 | 29 | 0 | 1499 | 118 | 1693 | 160 | 28630 |
| 10 | 2005-2006 | 302 | 76 | 0 | 0 | 1592 | 121 | 1894 | 197 | 33416 |
| 11 | 2006-2007 | 412 | 103 | 2342 | 95 | 2305 | 168 | 5059 | 366 | 64946 |
| 12 | 2007-2008 | 1081 | 270 | 5497 | 271 | 1764 | 123 | 8342 | 664 | 111440 |
| 13 | 2008-2009 | 2118 | 508 | 13269 | 1327 | 2825 | 141 | 18212 | 1976 | 132918 |
| 14 | 2009-2010 | 1580 | 379 | 12186 | 192 | 25819 | 1291 | 39585 | 1862 | 120618 |
| 15 | 2010-2011 | 858 | 206 | 15163 | 230 | 19115 | 956 | 35136 | 1392 | 90803 |
| 16 | 2011-2012 | 618 | 148 | 12804 | 206 | 15297 | 765 | 28719 | 1119 | 73163 |
| | **TOTAL** | **10066** | **2465** | **94121** | **2926** | **73714** | **3928** | **177901** | **9319** | **913702** |



42

- In *kharif* and *rabi* season agriculture production of different crops had increased by 29.14 per cent and 269.31 per cent, respectively after the implementation of the scheme. The overall agriculture production had increased to 34.06 per cent after the implementation of the scheme.

- Amongst 400 sample beneficiaries 371, (92.75%) were using improved seeds, 347 (86.75%) were using chemical fertilizers, 314 (78.50%) were using pesticides and 214 (53.50%) beneficiaries were using improved agriculture implements.

- Out of 400 sample beneficiaries, 310 (77.50%) had made change in the cropping pattern after the implementation of the scheme (within 1999 - 2000 to 2001 - 02).
- Out of 400 sample beneficiaries, 201 (50.25%) had well in their farm and ground water table increased in their well. The remaining 199 (49.75%) beneficiaries had no well in their farm.
- Out of 400 samples beneficiaries, 308 (77.00%) were taking responsibility of repairing and maintenance work of structure regularly and remaining 92 (23.00%) beneficiaries were not doing maintenance.
- The average annual income of 400 selected beneficiaries from all sources was Rs. 63914 prior to scheme which has increased to Rs. 86966 after the implementation of the scheme which shows 36.07 per cent increase in the average annual income of sample beneficiaries.
- Out of 400samples beneficiaries, 378 (94.50%) beneficiaries felt that after the implementation of the scheme, their agriculture production of crops had increased, hence their economic condition had improved.
- Out of 400 sample beneficiaries 324 (81.00%) beneficiaries opined that their social condition had improved after the implementation of the scheme.
- Out of 400 samples beneficiaries, 373 (93.25%) samples beneficiaries opined that their living standard of life had improved.
- Four hundred selected beneficiaries possessed 2076 different livestock *viz.*, cows, buffaloes, bullocks, sheep and goats *etc.*, before the implementation of the scheme. After the implementation of the scheme the number of livestock had increased from 2076 to 2195 which shows 5.73 per cent increase in total live stocks.
- Total bullocks had reduced to 18.50 per cent after implementation of the scheme. This may be due to adoption of new technology for farming like tractor *etc*.

**Future Planning**

During the 12$^{th}$ Five Year Plan 775532 ha area will be treated through GSLDC at the estimated cost of Rs. 270886 lakh moreover 4615 village pond, 28847 farm pond, 66809 WHS will be constructed and 387766 beneficiaries will be benefited. Scheme wise 12$^{th}$ Five Year Plan details are given in table 5.

**Table 5:** Statement sowing proposed physical target and financial outlays for the XII FYP

| Program | Unit | 2012-13 | | 2013-14 | | 2014-15 | | 2015-16 | | 2016-17 | | Grand Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | P | F | P | F | P | F | P | F | P | F | P | F |
| SLC-1 | ha | 9300 | 1860 | 10230 | 2046 | 11253 | 2251 | 12378 | 2476 | 13616 | 2724 | 56777 | 11357 |
| SLC-2 | ha | 6900 | 1380 | 7590 | 1518 | 8349 | 1670 | 9184 | 1837 | 10102 | 2021 | 42125 | 8426 |
| SLC-3 | ha | 10800 | 2160 | 11880 | 2376 | 13068 | 2614 | 14375 | 2875 | 15813 | 3163 | 65936 | 13188 |
| SLC-4 | ha | 11200 | 2240 | 12320 | 2464 | 13552 | 2710 | 14907 | 2981 | 16398 | 3279 | 68377 | 13674 |
| SLC-5 | ha | 125 | 25 | 138 | 28 | 152 | 31 | 167 | 34 | 184 | 37 | 766 | 155 |
| SLC-8 | ha | | 910 | 0 | 1001 | 0 | 1101 | 0 | 1211 | 0 | 1332 | 0 | 5555 |
| SLC-28 | FP | 4725 | 8190 | 5198 | 9009 | 5717 | 9910 | 6289 | 10901 | 6918 | 11991 | 28847 | 50000 |
| | ST | 1356 | | 1492 | | 1641 | | 1805 | | 1985 | | 8279 | |
| SLC-9 | | | 322 | | 354 | | 389 | | 428 | | 471 | | 1964 |
| SLC-29 | WHS | 2898 | 2898 | 3188 | 3188 | 3507 | 3507 | 3857 | 3857 | 4243 | 4243 | 17693 | 17693 |
| SLC-10 | | | 420 | | 462 | | 508 | | 559 | | 615 | | 2564 |
| SLC-30 | VP | 756 | 3780 | 832 | 4158 | 915 | 4574 | 1006 | 5031 | 1107 | 5534 | 4615 | 23077 |
| AER - 4 | | | 66 | | 73 | | 80 | | 88 | | 97 | | 404 |
| SLC - 17 | ha | | 982 | | 1080 | | 1188 | | 1307 | | 1438 | | 5995 |
| SLC - 31 | ha | 44194 | 8838 | 48613 | 9722 | 53474 | 10694 | 58821 | 11763 | 64703 | 12939 | 269805 | 53956 |
| SLC-18 | ha | | 186 | | 205 | | 226 | | 249 | | 274 | | 1140 |
| SLC- 32 | ha | 8350 | 1670 | 9185 | 1837 | 10104 | 2021 | 11114 | 2223 | 12225 | 2445 | 50978 | 10196 |
| SLC - 19 | ha | 1400 | 280 | 1540 | 308 | 1694 | 339 | 1863 | 373 | 2049 | 410 | 8546 | 1710 |
| SLC - 20 | ha | 600 | 120 | 660 | 132 | 726 | 145 | 799 | 160 | 879 | 176 | 3664 | 733 |
| SLC - 21 | WHS | 1243 | 373 | 1367 | 410 | 1504 | 451 | 1655 | 496 | 1820 | 546 | 7590 | 2276 |
| SLC - 22 | ha | 458 | 55 | 504 | 61 | 554 | 67 | 609 | 74 | 670 | 81 | 2795 | 338 |
| SLC- 25. | ha | 8533 | 1706 | 9386 | 1877 | 10325 | 2065 | 11358 | 2272 | 12494 | 2499 | 52096 | 10419 |
| SLC - 26 | ha | 220 | 147 | 242 | 162 | 266 | 178 | 293 | 196 | 322 | 216 | 1343 | 899 |
| SLC-27 | ha | 548 | 274 | 603 | 301 | 663 | 331 | 729 | 364 | 802 | 400 | 3345 | 1670 |



44

Table 5: continue………

| Program | Unit | 2012-13 | | 2013-14 | | 2014-15 | | 2015-16 | | 2016-17 | | Grand Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | P | F | P | F | P | F | P | F | P | F | P | F |
| **FP** | | **4725** | | **5198** | | **5717** | | **6289** | | **6918** | | **28847** | |
| **ST** | | **1356** | | **1492** | | **1641** | | **1805** | | **1985** | | **8279** | |
| **VP** | | **756** | | **832** | | **915** | | **1006** | | **1107** | | **4615** | |
| **WHS** | | **4141** | | **4555** | | **5011** | | **5512** | | **6063** | | **25282** | |
| **NWDP(R)** | **ha** | 9660 | 1932 | 10626 | 2125 | 11689 | 2338 | 12858 | 2572 | 14144 | 2829 | 58977 | 11796 |
| **RVP** | **ha** | 9660 | 1932 | 10626 | 2125 | 11689 | 2338 | 12858 | 2572 | 14144 | 2829 | 58977 | 11796 |
| | **WHS** | 6440 | | 7084 | | 7792 | | 8572 | | 9429 | | 39317 | |
| **RAS** | **ha** | 5082 | 1016 | 5590 | 1118 | 6149 | 1230 | 6764 | 1353 | 7440 | 1488 | 31025 | 6205 |
| **DWB** | **ST** | 250 | 600 | 280 | 700 | 292 | 730 | 320 | 800 | 348 | 870 | 1490 | 3700 |
| | **WHS** | 350 | | 420 | | 438 | | 480 | | 522 | | 2210 | |
| **Total of New Item** | **Ha** | 24402 | 4880 | 26842 | 5368 | 29527 | 5906 | 32480 | 6497 | 35728 | 7146 | 148979 | 33497 |
| | **WHS** | 6790 | 0 | 7504 | 0 | 8230 | 0 | 9052 | 0 | 9951 | 0 | 41527 | |
| | **ST** | 250 | 600 | 280 | 700 | 292 | 730 | 320 | 800 | 348 | 870 | 1490 | |
| **Total of State Plan + New Items** | **ha** | **127030** | **43762** | **139733** | **48140** | **153707** | **52956** | **169077** | **58252** | **185985** | **64077** | **775532** | **270886** |
| | **WHS** | **10931** | **0** | **12059** | **0** | **13241** | **0** | **14564** | **0** | **16014** | **0** | **66809** | |
| | **ST** | **1606** | **600** | **1772** | **700** | **1933** | **730** | **2125** | **800** | **2333** | **870** | **9769** | |
| | **FP** | **4725** | **0** | **5198** | **0** | **5717** | **0** | **6289** | **0** | **6918** | **0** | **28847** | |
| | **VP** | **756** | **0** | **832** | **0** | **915** | **0** | **1006** | **0** | **1107** | **0** | **4615** | |

P: physical (ha), F: Financial (Rs. in lakh), VP: Village pond, ST: *Sim talvadi*, FP: Farm pond, WHS: Water harvesting structure

**Strategies:**

Suggestions are for promoting conservations of natural resource for sustainable development and environment protection.

1. Strengthening the data base, on soil and water resource - use of modern techniques in data collection, processing, documentation and transfer for resource planning.
2. Inter - basin water transfer to minimize water scarcity and regional imbalances in the supply and demand.
3. Shift in emphasis from an expensive supply management approach to a more efficient approach promoting soil water conservation and demand management.
4. Legislative measure to promote removal of water from areas affected by degradation, higher entitlement for those using water more efficiently.
5. Watershed approach, a forestation, policy measures to arrest soil erosion.
6. Proper water management practices, efficient utilization of water resource.
7. Judicious use of water for irrigation
8. Gypsum application in alkali land.
9. Application of Bio-mass, afforstation, balanced fertilization, proper cropping practices.
10. Appropriate tillage, irrigation, manure and fertilization practices.

# 4

**Watershed Management in Gujarat**

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Gujarat is one of the most industrialized states of India. The share of agriculture in the Net State Domestic Product (NSDP) is lower than in most other Indian states. Still, 66 per cent of the population lives in rural areas, most of them dependent on agriculture to make a living. Phyography and agro-climatic conditions vary from the mountainous areas in the East to the plain lowlands mainly in central and northern Gujarat. Livestock husbandry, mainly on degraded areas, suffers from a lack of adequate fodder resources for the large number of animals. Few efforts are made by the villages to improve and regulate the use of common grazing lands. However, Gujarat has a very well developed cooperative milk industry, which is reflected in an increasing overall milk production. In answer to the problem of natural resource degradation, more than 1200 watershed development projects have been implemented under different programmes by the Rural Development Department in Gujarat since 1995. More than 70 percent of these are operated by NGOs.

No matter which overall watershed development approach is adopted for Gujarat, there are a number of policy issues, which require attention. A large part of the problem, which now calls for watershed development, is caused by subsidizing the extraction of groundwater. The same organizations, which manage watershed development programmes can at least partly, also be held responsible for the current water problems. Instead of subsidizing water use, sustainable and efficient use could be better achieved by putting a price on this scarce resource. All developmental activities, and in particular the water related ones, which take place in watershed development, should be embedded in an overall land-use planning system. Water problems are state-wide phenomena in Gujarat. Efforts to preserve water and to make best use of it should be planned and coordinated at the state.

**Importance of Watershed Approach**

Gujarat is predominantly the state for dryland agriculture. Out of the total area of Gujarat state, 88% falls under arid and semi-arid climatic zones. At present, about 23 per cent of cultivated area in the state is irrigated while 77 per cent is rainfed. Even harnessing all the irrigation potential, the irrigated area would be around 45 per cent. Thus, about 55 per cent would be under the rain fed agriculture. To overcome such arid and semi-arid situation, watershed management - a holistic approach for the development of rain fed farming is considered important for efficient utilization of land and water resources for optimization of productivity in a sustainable manner.

**Planning steps:**

Institutional, social and economic factors operating within the watershed need to be taken in to account while finalizing the management programme. Typically, the management process include six different planning steps *viz*.,

(1) Diagnosis characteristics
(2) Management objectives
(3) Design plan
(4) Operation/ implementation
(5) Research backup
(6) Monitoring and evaluation

Brief overview on the watershed development activities of the Government of **Gujarat**

The experience of the Government of Gujarat in the field of undertaking watershed development projects dates back to 1995. Since then, the Rural Development Department, the Department for Agriculture and the Forestry Department implemented a number of watershed development projects under different programmes. Between 1995 and 2000, the Rural Development Department, for example, completed more than 1260 watershed projects. These projects were launched under the Drought Prone Area Programme, the Desert Development Programme, the Integrated Wasteland Development Programme and the Employment Assurance Scheme, and cover an area of 633,000 ha. Around 70 per cent of these projects were implemented by NGOs. In order to decentralize the programme, the District Rural Development Agency (DRDA) serves as a nodal agency at district level. It has to supervise the programme and is responsible for the selection of PIAs, the approval of watershed plans and the distribution of the funds to the Watershed Committees. Furthermore, the DRDA organises regular meetings of the District Watershed Committee 12. Watershed development activities are also undertaken by the Department for Agriculture within the National Watershed Development Programme for Rainfed Areas, and by the Forest Department within the Joint Forest Management Programme. The Gujarat State Land Development Corporation (GSLDC), a semi governmental agency, is involved in implementing projects for the Department of Agriculture. Gujarat is one of the first states to introduce a state scheme in 1999/2000 under the auspices of the Rural Development Department to speed up the work in the field of watershed development (Table 1).

**Table 1:** Watershed development programme in Gujarat state 1995-96 to 2005-06

| Name of Programme | Total No. of Projects | Area covered (ha) | Project completed | Project ongoing |
|---|---|---|---|---|
| DPAP | 2149 | 1074500 | 449 | 1700 |
| DDP | 2642 | 1321000 | 445 | 2197 |
| IWDP | 911 | 455500 | 24 | 887 |
| EAS (W.S) | 546 | 273000 | 546 | 0 |
| State WS | 198 | 99000 | 198 | 0 |
| **Total** | **6446** | **3223000** | **1662** | **4784** |

Considering various adverse edapho-meteorological conditions of the state, to utilize the land, water and plant resources for optimization of the productivity and to meet the basic demand of the people in sustained manner, a project on adaptive research was initiated with the assistance from World Bank in collaboration with Gujarat Land Development Corporation under Integrated Watershed Development Project (Plains) at four locations viz., (1) Bhadar Sakario 1-R (2) Machchhu Asoi 1-L (3) Vatrak-47-R and (4) Narmada Direct 1-R in Gujarat (Figs.1 and 2). The Gujarat Agricultural University was assigned to undertake the location specific adaptive research in these watershed areas. The project covers nine talukas in four districts *viz*., Sabarkantha, Rajkot, Vadodara and Bharuch. The total project area is 80,911.82 ha out of which 13,772 .98 ha was in micro and pilot phase and 67,138.84 ha is expansion area. The watershed wise salient findings are enumerated here (DR, GAU, 1998).

**Bhadar Sakario-1-R watershed**

- Contour farming helped in increasing soil moisture conservation thereby increasing productivity of groundnut as compared to set-row system of planting. Set row system is the traditional practice followed by the farmers.
- Intercropping system (groundnut + pigeon pea/castor) gave higher returns as compared to sole groundnut during years of low and average rainfall.
- The performance of tree species such as *neem, khijdo, pilu, deshi baval, gliricidia, asitro* and *kher* from survival point of view was better. Based on survival as well as growth, *neem* should be preferred for planting on non-arable lands as compared to other tree species.
- Israel *baval* should be should be preferred for planting in watershed area while *gunda* showed very poor performance.
- V-ditch as well as staggered trench planting system conserved more moisture as compared to crescent bund and pit method. V-ditch system also helped in reducing soil loss and conserving more moisture in the soil profile.
- For getting maximum biomass production *Jinjavo* should be preferred as fodder species in the watershed area.
- *Aval* should be preferred as shrub due to its fast growth, better establishment and more canopy cover.

**Machhuasoi-1-L Watershed**

- Contour farming helped in increasing soil moisture conservation thereby increasing productivity of groundnut as compared to set-row system of planting.
- Intercropping system with groundnut should be adopted for higher returns. This system also covers risk under condition of low and early withdrawal of monsoon.
- The survival of tree species such as *gorad, neem, and khijdo* species was better as compared to other tree species. The *pipal* and *gunda* failed to survive due to their slow initial growth.
- Higher moisture conservation was observed in V-ditch as well as staggered trench planting system

- Less runoff and soil loss was observed in V-ditch system of planting as compared to other methods of planting.
- To develop canopy cover in the watershed area, *aval* is an important shrub species due to its faster initial growth and better establishment and higher canopy cover.

**Vatrak 47-R Watershed**

- Deep ploughing (30 cm depth) is recommended over shallow ploughing (10 cm depth) for higher castor yield and better *in-situ* moisture conservation.
- Both *munja* and *vetiver* as vegetative barriers appreciably increased the yields of arable crops (bajra, sole groundnut. groundnut + castor) in sole as well as intercropping systems though conserving more moisture.
- Under rainfed agri-horti system, survival and growth of guava and custard apple was better. The yield of *guar* was higher as compared to moth bean in *ber* based agroforestry system.
- Contour farming along with *munja* as vegetative barrier resulted in higher groundnut yield (20%) as compared to traditional method of planting.
- For proper establishment of *munja*, V-ditch method of planting at a spacing of 10 cm with 2 clumps/hill is recommended.
- Munja as vegetative barrier should be preferred as compared to *vetiver*. For obtains its proper tillering and growth, it should be planted using 4 clumps/hill at a distance of 10 or 15 cm.
- Forest tree species such as *neem, desi baval* and *sisoo* and arid fruit species such as *gunda, goras amli and khati amli* should be preferred for plantation on non-arable lands.
- Bio engineering measures *viz.,* earthen *nala* plug, *masonary* waste weir alongwith *munja*, *vetiver* and ipomeas as vegetative barriers resulted in arresting more rain water increasing water table in the well located in the treated area.
- *Neem* as top feed species could be utilizated along with *stylo* and *dhaman* in silvi-pastrol system of agroforestry.
- V-trench planting is recommended for ber plantation of non-arable lands.

**NARMADA DIRECT-1-R WATERSHED**

- In agri-silvipastoral system of agroforestry, deshi baval + pigeonpea is recommended.
- Vetiver as vegetative barrier alongwith arable crops should be used for *in-situ* moisture conservation and high yields of arable crops.
- For multiplication of *veltiver* growing three slips/ hill with application of 100-40-0 NPK kg/ha is advocated.
- For getting higher stand of *veltiver*, slips with 1-3 shoot-root ratio should be planted at the depth of 7-5 cm.
- Deep ploughing with tractor is recommended for higher moisture conservation and higher yield of arable crops.

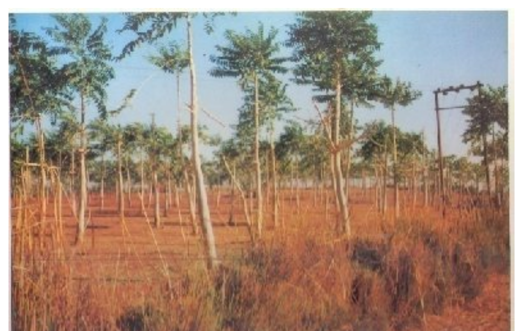
- For obtaining higher production of rainfed maize, recommended dose of fertilizer (60-30-0 NPK kg/ha) application should be used.
- Maize should be intercropped with short duration pulses (green gram- black grams soybean) for obtaining higher yields as well as higher monetary returns.
- For obtaining higher seed cotton yield of Hy. G. Cot.-6, interculturing at each *vapsa* condition is recommended.

**Fig. 1:** Water storage structures

Plate 3.5 b : Loose rock structure

Plate 3.5 c : Ipomea-a vegetative barrier

Deshi baval plantation in watershed area



ARDUSO PLANTATION IN VATRAK WATERSHED AREA

**Fig. 2:** Soil conservation activities