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Editors: Dr. Reza Ardakanian
Dr. Dirk Jaeger

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THE ROLE OF WATER TECHNOLOGY IN DEVELOPMENT: A CASE STUDY IN GUJARAT, INDIA

RAJIV K GUPTA[1]

THIS ARTICLE TRACES THE HISTORICAL WATER PROBLEM IN GUJARAT BOTH FOR DRINKING AND IRRIGATION WATER THAT AFFECTED THE DEVELOPMENT OF THE STATE, CAUSED REGIONAL IMBALANCES, AND INCREASED INCIDENCES OF RURAL POVERTY. TECHNOLOGICAL INITIATIVES LIKE STATE-WIDE WATER GRID, MICRO WATER HARVESTING, INTER-BASIN TRANSFER OF WATER, AND POWER SECTOR REFORMS HAVE CHANGED THE ENTIRE WATER SCENARIO IN THE STATE. THERE HAS BEEN A GREAT DEAL OF EMPHASIS ON PEOPLE'S PARTICIPATION IN WATER GOVERNANCE AS WELL.

Background of the Water Problem in Gujarat

Gujarat has just 2.3 % of India's water resources and covers 6.4 % of the country's geographical area. This is further 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 the southern part. Around 80 % of the state's surface water resources are concentrated in central and southern Gujarat, whereas the remaining three-quarters of the state have only 20 %. On average, three years in a cycle of 10 years have been drought years. Since Indian independence in 1947, the draught 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.[2]

1 Rajiv K gupta, Government of Gujarat, India [2] (Gupta, 2004)

Until 2001, drinking water scarcity posed a serious threat to human and cattle population in Gujarat. Successively, governments had to spend billions of Rupees (Rs) on temporary measures to supply drinking water by road tankers and sometimes even through special water trains. The state, which generally had a track record of peace and harmonious social ethos, even witnessed "water riots" due to severe water scarcity caused by poor water resource management.

Overdrafting of ground water (as compared to annual recharge) caused serious water quality problems due to excessive fluoride, nitrate and salinity levels. The number of fluoride-affected settlements increased from 2,826 in the year 1992 to 4,187 by 2003. The fluoride concentration in these villages ranged from 1.5 mg/liter to as high as 18.90 mg/liter. Fluoride has been the cause of extensive health damages in many parts of Gujarat. Dental fluorosis causes permanent pigmentation of teeth in children and bone deformities result from skeletal fluorosis even in adults. Other serious problems experienced due to high concentration of fluoride have been anemia, loss of appetite, nausea, and thyroid malfunction. This sometimes results in brain impairment in children, may have adverse impacts on fetuses and cause abortion or stillbirth in expectant mothers. The water problem also led to intra-state migration from drought-prone regions like Saurashtra and Kutch (western & southwestern Gujarat) to the central & southern regions of the state. Many times, this migration included a relocation of livestock and caused a shift of the prime workforce of hundreds of thousands of people, dislocating them economically, socially and culturally. Therefore, regional imbalances in Gujarat got accentuated because of increasing water scarcity.[1]

In the past, most of the drinking water supply was based on ground water. Deep tubewells with high-capacity pumping machinery were being utilized in the state, leading to tremendous electricity consumption and high carbon footprints of water supply.

Technological Initiative for Drought Proofing

During the last 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 settlements. 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 liters and 10,683 storage sumps and high ground level reservoirs with a capacity of 2,504.80 million liters have also been constructed in the state. Along with this 151 water filtration and treatment plants with a total capacity of 2,750 million liters per day (MLD) have been constructed. Thanks to the water supply grid, about 2,250 MLD of treated water are delivered to more than 10,501 villages and 127 towns in the state, ensuring safe and secure water supply to about 65 % of the state's population in draught-prone and water-quality-affected areas.

Impacts

This major technological initiative has not only largely solved the drinking water problem but has also made a significant impact on water quality issues faced in the past.

Reduction in Fluoride

All these efforts have resulted in considerable relief from the problem of excessive fluoride contamination. According to a recent survey, only 987 settlements have been found to still be affected and the range of fluoride content has also shrunk considerably.

1 Gupta, 2003

TABLE (1): STATUS OF FLUORIDE-AFFECTED SETTLEMENTS

DISTRICT	NO. OF TOTAL SETTLEMENTS	AS PER 2003 SURVEY	AS PER RECENT SURVEY	MAXIMUM FLUORIDE LEVEL (PPM)
Ahmedabad	727	120	20	7.20
Gandhinagar	424	132	2	6.27
Patan	651	246	43	13.25
Mehsana	851	176	2	4.40
Sabarkantha	2,438	531	9	6.93
Banaskantha	1,736	521	20	5.75
Surendranagar	696	205	72	8.72
Rajkot	871	126	120	5.40
Jamnagar	756	52	5	2.00
Junagadh	925	76	48	2.80
Porbandar	184	46	0	3.70
Bhavnagar	804	108	66	6.40
Amreli	650	49	146	3.20
Kutch	1,126	34	6	3.20
Vadodara	2,187	438	189	5.81
Narmada	722	49	0	2.60
Kheda	2,101	406	52	10.03
Anand	920	96	17	5.89
Panchmahals	2,531	401	86	6.40
Dahod	3,168	286	0	12.50
Surat	3,258	44	29	2.20
Bharuch	790	21	30	4.00
Valsad	3,923	2	25	1.79
Navsari	2,080	22	0	–
Dangs	326	0	0	–
Total	34,845	4,187	987	

Source: Gujarat Water Supply and Sewerage Board, 2009

TABLE (2): ANNUAL EXPENDITURE ON TANKER SUPPLY FROM 1990 TO 2009

YEAR	VILLAGE	COST (RS. IN MILLION)*
1990-91	896	23.40
1991-92	1,943	92.90
1992-93	700	14.00
1993-94	1,803	83.00
1994-95	724	24.96
1995-96	1,619	96.30
1996-97	1,642	123.95
1997-98	1,447	62.19
1998-99	1,215	41.02
1999-2000	2,987	346.20
2000-2001	4,054	436.94
2001-2002	2,959	348.11
2002-2003	3,961	475.36
Sub-total		2,168.06
2003-2004	600	47.38
2004-2005	869	92.32
2005-2006	398	77.06
2006-2007	207	17.08
2007-2008	188	14.17
2008-2009	326	13.94
Sub-total		261.95
Total		2,430.01

Source: Gujarat Water Supply and Sewerage Board, 2009 * 1 US$ = Rs.46

Less Expenditure

The improved water infrastructure has also resulted in a sharp decline in expenditure on tanker water supply in the state from 2003-04 onwards. This is another indicator of the creation of water security in the state.

Reduction of Carbon Footprints

In several villages, bore wells are now utilized as a secondary source and operational hours have been reduced. Based on a random survey, significant savings have been achieved in electricity consumption. These are now available for alternative uses, which is an eco-friendly achievement. Solar pumps have also been commissioned in 260 villages in the state and about 200 more solar-based pumping systems will be installed in the near future. In various parts of the state, including coastal and also tribal areas, roof top rain water harvesting structures have also been constructed for public buildings, schools and individual households. These measures, as well as energy audits for various group water supply schemes, have resulted in substantial electricity savings.

Paradigm Shift

Many fluoride-affected settlements have been connected to piped water supply. This is a paradigm shift from dependence on drinking water supply by tankers, trains, and deep bore wells to the availability of safe surface water. Technological interventions like defluoridation through reverse osmosis have also been taken up in some villages. In the remaining villages safe water sources have been identified or created and are being used for drinking water purpose. Thus, a "vicious circle" has been transformed into a "virtuous cycle" with a win-win situation for water, energy, environment, and health sectors and considerable economic benefits. In short, this is Gujarat's technology-oriented response to the existing and future water stress and insecurity due to Climate Change.

TABLE (3): EMISSION SAVINGS IN DRINKING WATER SUPPLY

SR. NO.	PARTICULARS	ENERGY SAVINGS MWH PER ANNUM	EQUIVALENT CARBON DIOXIDE EMISSION PER ANNUM IN TONS
1.	Piped water supply to villages and towns	65,905.00	14,696.82
2.	Savings due to energy audit	5,184.78	1,156.21
3	Solar based pumping systems	611.16	136.29
4	Rooftop rain water harvesting	386.74	86.24
	TOTAL	72,087.68	16,076.14

Source: Gujarat Water Supply and Sewerage Board, 2009

New Water Governance Model

The creation of Water and Sanitation Management Organization (WASMO) was a significant shift in the role of governance from provider to facilitator, empowering village-level institutions through extensive capacity building and pro-active facilitation. Since its inception, WASMO has been able to bring in effective citizen engagement through its innovative governance model for facilitating successful community-led water supply programme throughout the state of Gujarat. Now more than 16,740 Village Water and Sanitation Committees have been established in the state that are ready to take on the responsibility of management of service delivery and water resource management at the decentralized level. More than 6,500 villages have already commissioned infrastructure and water conservation projects in a demand-driven mode. Another 4,547 villages are presently implementing the decentralized community-managed rural water supply programme in their villages with a strong feeling of ownership.

WASMO's strength lies in its organizational professionalism, innovations in governance, and strong partnerships with about 48 civil society organizations. The rural community is the central focus of WASMO's decentralized approach. Its innovation has led to the scaling up of reform processes to cover the entire state. Its professionals have created an enabling environment which has resulted in communities being fully empowered to take ownership of their water service delivery wherein operation and maintenance are secured through tariff mechanisms devised by consensus in the village assembly. WASMO has also been able to institutionalize the rural water quality monitoring and surveillance programme. The majority of villages are now able to monitor their duly-trained water quality teams. WASMO's innovative approach in Gujarat has emerged as a model for learning and exchange, influencing policy initiatives in the water sector at the national level. WASMO received the United Nations Public Service Award in the category of fostering participation in policy-making decisions through innovative mechanisms.[1]

Inter-basin Water Transfer through Sardar Sarovar Project

The Sardar Sarovar Project on river Narmada is a multi-state, multi-purpose river valley project born out of deliberations of a constitutional body and following the principles of "Equality of Right" and "Equitable Utilization" of the whole course of an inter-state river. This unique project is planned to irrigate 1.905 million ha of land, increase the agricultural production by 8.7 million tons per annum (worth US$ 430 million), generate environmentally friendly hydropower with installed capacity of 1,450 MW, and supply drinking water to 8,215 villages and 135 urban centers of Gujarat (with a population of around 20 million). In addition, it is supposed to generate 1 million jobs, mostly in rural areas, prevent rapid processes of desertification, salinity ingress, and

[1](Modi, 2010), [2](Gupta, 2003)

TABLE (4): SARDAR SAROVAR DAM HEIGHT AND STORAGE INCREASE IN SARDAR SAROVAR PROJECT

STAGE	2003	2004	2006	ULTIMATE
Height	100 m	110.64 m	121.92 m	183.68 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

rural to urban migration being experienced in many parts of Gujarat. The catchment and drinking water supply areas of the project are precisely the zones with the highest water scarcity rates in the whole state.[2]

Increased Dam Height & Storage

With a concerted strategy and satisfactory compliance of the project obligations in terms of rehabilitation of project-affected persons and environmental measures, the dam height was raised to 100 m in 2003, 110.64 m in 2004 and 121.92 m in 2006. This facilitated a much higher increase in storage of Narmada waters. Raising the dam height and the corresponding increase in the storage capacity have significantly improved the water supply. The real benefits of the project, awaited for almost 15 years, have now started to show. The diversion of Narmada water to the main canal of the project, the world's largest lined irrigation canal, was just 705 million cubic meters (MCM) in the year 2001 but spectacularly increased to 5,195 MCM in 2003 and to 6,194 MCM in 2004. Although the water flow was decreased in subsequent years due to consecutively rain-laden monsoons, it remained to the extent of 4,201 MCM in 2005, 4,292 MCM in 2008, 5,870 MCM in 2008 and 5,870 MCM in 2009. The construction of the main canal was also completed in the year 2008 and water supplies started to be provided to the neighboring state Rajasthan in March 2008, fulfilling the real objective of this project as inter-state river project.

What's more, with the command area being covered to the extent of around 500,000 ha, significant interlinking has been achieved for many rivers through the interbasin transfer of Narmada waters using the Sardar Sarovar Canal Network.

Hydro Power

Another long-pending issue was that of operationalizing the 250 megawatt (MW) Canal Head Power House, which was built to fulfill the required water head in the reservoir. We started running this power house in August 2004. Thereafter, a river bed power house with 1,200 MW capacity was also put into operation in several phases between February 2005 and June 2006. Between August 2004 and March 2010 hydropower generated from the Sardar Saroval Project was 15,070 million kWh of electricity.

Micro Water Harvesting

The miseries of millions of small and marginal farmers due to vagaries of nature and difficult terrain conditions have been reduced through rainwater harvesting with micro irrigation structures. The local population participated in the implementation.

Sardar Patel Participatory Conservation Project (SPPWCP)

This scheme stipulated that check dams and village tanks/ponds could be taken up for construction by a beneficiary group or any non-governmental organization (NGO) with technical and financial assistance from the local representative body of the District Panchayat. Initially, a contribution of 40 % of the estimated costs was required; this was later reduced to 10 %. The rest was to be funded by the government depending upon the progress of the work. Since 2007, groups benefitting from the project have been given the option of contributing their 10 % by way of physical labor which increased their identification with the project by "the gospel of dirty hands". Six prototype designs were circulated with a maximum cost of Rs 1,000,000.

However, the beneficiary groups were also given the latitude to take up the work as per their own design if necessary and feasible. The technical scrutiny and work supervision was to be conducted by the engineers of the local body. The entire responsibility of the quality of construction of work, however, was to rest with the beneficiary group/NGO under continuous guidance and technical inputs from the government technical staff. Maintenance works for these micro water harvesting structures were to be carried out by the beneficiary group at their own expense. The result: A total of 353,937 check dams and village ponds/tanks have been created in the last eight years, providing direct benefit to over 13 million people in rural Gujarat.

Drip Irrigation: Gujarat Green Revolution Company Ltd.

Gujarat has created the Gujarat Green Revolution Company Ltd. (GGRC), a special-purpose vehicle to popularize the adoption of drip irrigation among farmers. GGRC offers attractive subsidy loans to adopters, but more importantly, it has fast-tracked and simplified the administrative procedures for accessing these. Farmers contribute only 5 % of the cost initially; GGRC provides a 50 % subsidy and helps arrange a loan for the remaining 45 %. Around 100,000 ha are covered by drip irrigation and most of these have been moved to high-value crops (Gulati, 2009). It has been estimated that around 74.1 million kWh of energy are saved in just one year due to the adoption of drip irrigation by GGRC, a body specially created for this purpose.

Jyotigram Scheme (Technological Initiative in Power Sector for Irrigation Needs)

Like elsewhere in India, unreliable farm power supply in Gujarat had been anathema to farmers as well as to rural society as a whole. Uncontrolled farm power subsidies had led to an unsustainable increase in ground water withdrawals and left the Gujarat Electricity Board nearly bankrupt. To control farm power subsidies, the government began to reduce the hours of three phase power supply used by tubewell owners while providing 24 hours single/two phase supply sufficient for domestic users. In response, farmers in many parts began using capacitors to run heavy motor pumps on two-phase or even single-phase power. This resulted in a poor power supply environment in rural areas.

International donors and power sector professionals advocated the metering of tubewells and consumption-linked charging for farm power. However, for a variety of reasons, farmers strongly resisted metering. Researchers had advocated a second-best policy of intelligent rationing of farm power supply by separating feeders supplying power to tubewells. In 2003, the Gujarat government implemented the Jyotigram Scheme (JGS, the "lighted village scheme"), which incorporated the core ideas of the second-best strategy of intelligent rationing. JGS's aim was to provide three-phase power supply to Gujarat's 18,000 odd villages; but this could be done only if effective rationing was imposed on farmers. During 2002-06, around US$ 260 million were spent on the project to ensure 24 hour, three-phase power supply for domestic and commercial uses in schools, hospitals, etc, and eight hours a day, three-phase full voltage power supply for agriculture, i.e., continuous and full voltage power especially for agriculture at predictable timings for villages across Gujarat. By 2007-08 all 18,066 villages were covered by JGS. With this, Gujarat has become the first state in the country where villages get three-phase power with 24 hour supply per day and farmers get three-phase, uninterrupted power supply at 430-440 voltage for eight hours according to a strict, pre-announced schedule.

Jyotigram pioneered a real-time co-management of electricity and groundwater for agriculture found nowhere else in the world. Farmers were satisfied because they were spared the very high repair and maintenance cost that poor power supply imposed on them. Moreover, most farmers welcomed Jyotigram for limiting competitive pumping of water and addressing the common property externality inherent in groundwater irrigation. Ground water and power rationing through the Jyotigram scheme not only increased efficiency of water and power utilization for agriculture, but also freed these resources for the rural non-farm economy to grow. Higher access to water not only had a land-augmenting effect, but also allowed for multi-cropping and cultivation of high-value fruits and vegetables like mango and banana that require much water. More water has also been available for livestock, animal husbandry and fisheries, which are significant sectors of Gujarat's economy.

Impacts

There have been wide-ranging impacts of both large-scale water management and micro water harvesting in improving ecology of other rivers, reversing the trend of depleting water tables and tremendous growth in agricultural production.

Greening of other Rivers

Narmada water has been released into the dry beds of Heran, Orsang, Karad, Dhadhar, Mahi, Saidak, Mohar, Shedhi, Watrak, Meshwo, Khari, Sabarmati and Saraswati rivers. The ecology and water quality of these rivers have drastically improved over the last couple of years.

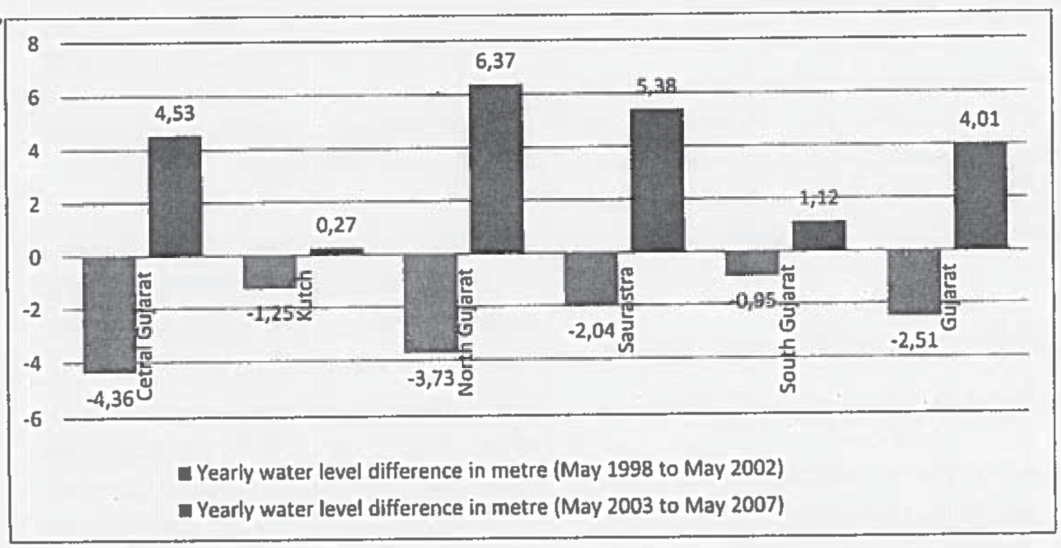

Figure (1): Ground water level fall/rise (in meters) Source: Narmada, Water Resources, Water Supply and Kalpsar Department, 2009

In addition to minor rivers, around 700 village tanks have also been filled with Narmada water as part of drought management measures. This has substantially improved water availability for irrigation purposes in these villages.

Increasing Water Tables

The average depletion of water levels in northern Gujarat before the launch of this massive programme was around 3 m per year, which by now would have cumulatively declined almost 20-26 m, leading to a sharp rise in electric consumption for withdrawal of ground water. But there has been a reported average water level rise of about 4 m during recent years as shown in figure (1).

Boost for Rural Economy

Myriads of micro water harvesting structures dotting the landscape of Gujarat have led to the reduction of soil moisture evaporation in the surrounding agricultural fields and have facilitated the creation of orchards in places that barely used to produce single rain-fed crops. Employment opportunities have been created for local residents and agricultural production has been enhanced, leading to a rise in household incomes. The living standard and the average productivity of milk cattle has also gone up due to the now year-around availability of fodder. The average annual growth rate of milk production in the state during the last decade has been recorded at 6.8 % whereas the same for the entire country has been at 4.4 %. See also figure (2).

This in turn has bolstered the rural economy of Gujarat and has particularly supported the 4.2 million families of the state who rear animals for their livelihood.

Outstanding Performance in Agriculture

The cumulative effect of all these innovative technological and participative water management initiatives has been an increase in productivity of the major crops of the state, despite 0.1 C to 0.9 C average increase in

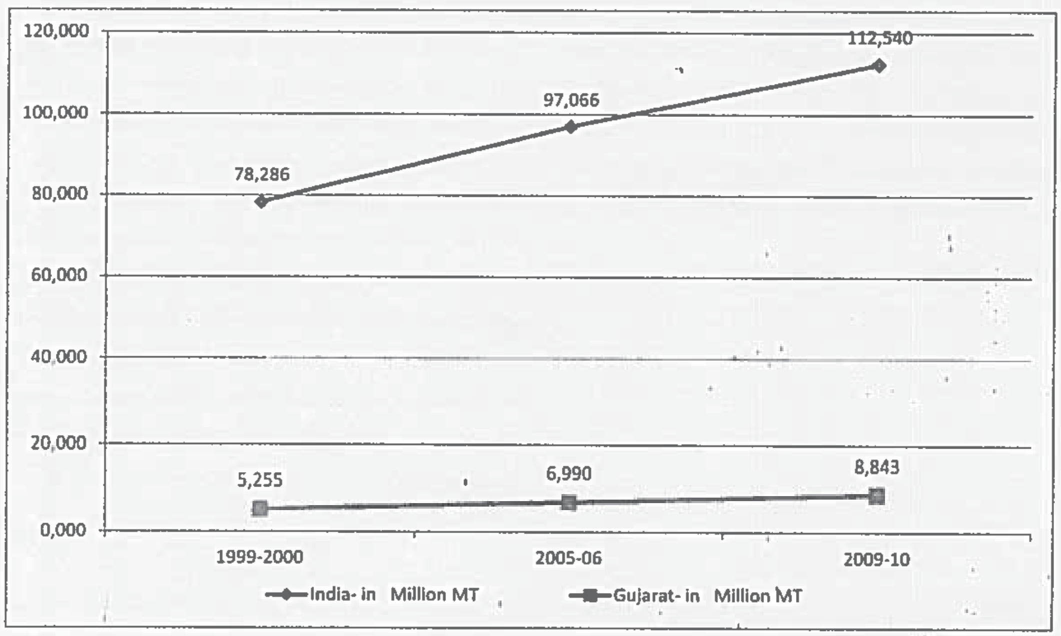

Figure (2): Comparative Growth of Milk Production in Last Ten Years, Source: Directorate of Animal Husbandry, 2010

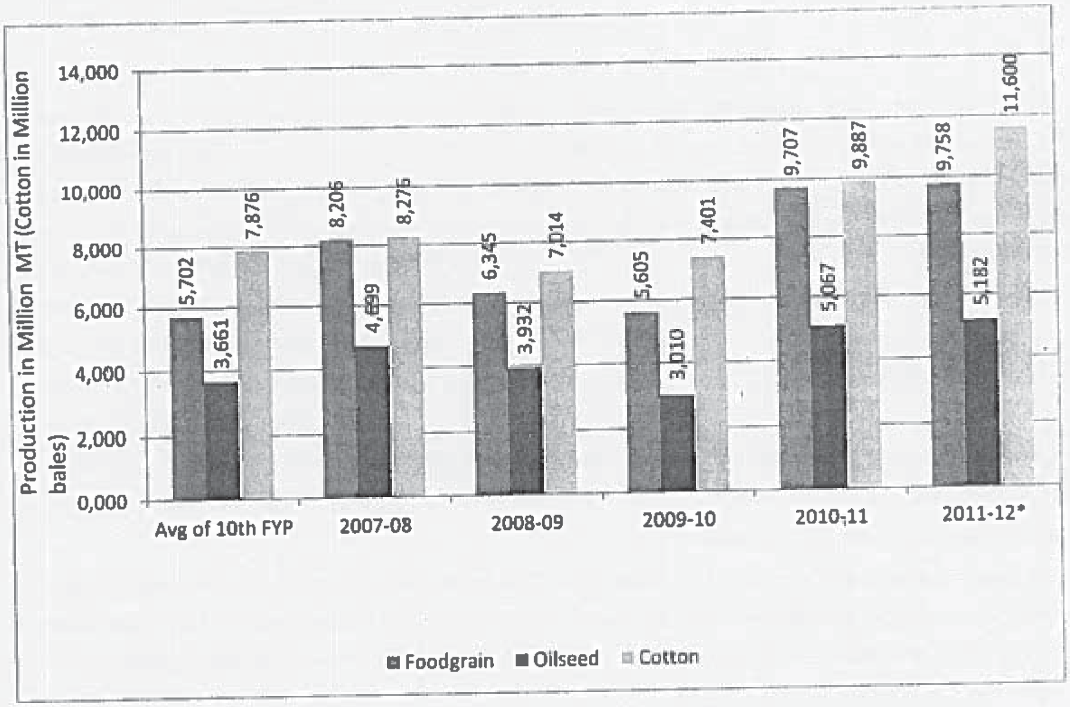

Figure (3): Agriculture Production Scenario Data for 2011-12 provisional, Source: Agriculture and Cooperation Department, 2011

temperatures recorded at various locations during the last couple of years as. Please see figures (3) to (5). As compared to other states in India, Gujarat is an outstanding performer in agriculture, growing at the rate of 9.6 % per annum. Though there is high volatility in the agricultural growth rate for almost all states in India, the performance of Gujarat's agriculture is more than thrice that of India as a whole. The International Food Policy Research Institute, in a document from 2009, specifically commended Gujarat's recent growth in cotton, fruit, vegetable and wheat production.

Conclusion

The most important lesson that emerges from the foregoing discussion is that technological initiatives to improve drinking and irrigation water supply have to be duly complimented by grassroot people's participation in the management of water distribution. The decentralized community-managed water supply programme in Gujarat has proven to be a suitable model for the entire country. Another very significant aspect is the necessity to balance the importance given to both micro-water harvesting and large water resources development projects. This has led to unprecedented agricultural growth in the state. The increased availability of water and the reduction in consumption of conventional power have also led to a reduction of carbon footprints in water supply and have promoted further development of a low-carbon economy in the state.

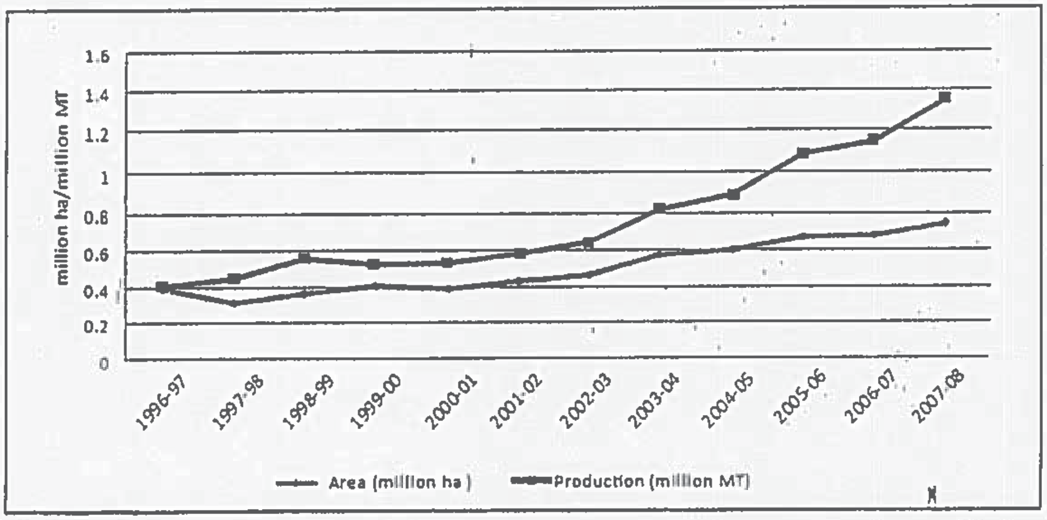

Figure (4): Area and Production under Total Fruits and Vegetables in Gujarat (area in million ha, production in million MT)

Source: Directorate of Horticulture, 2011

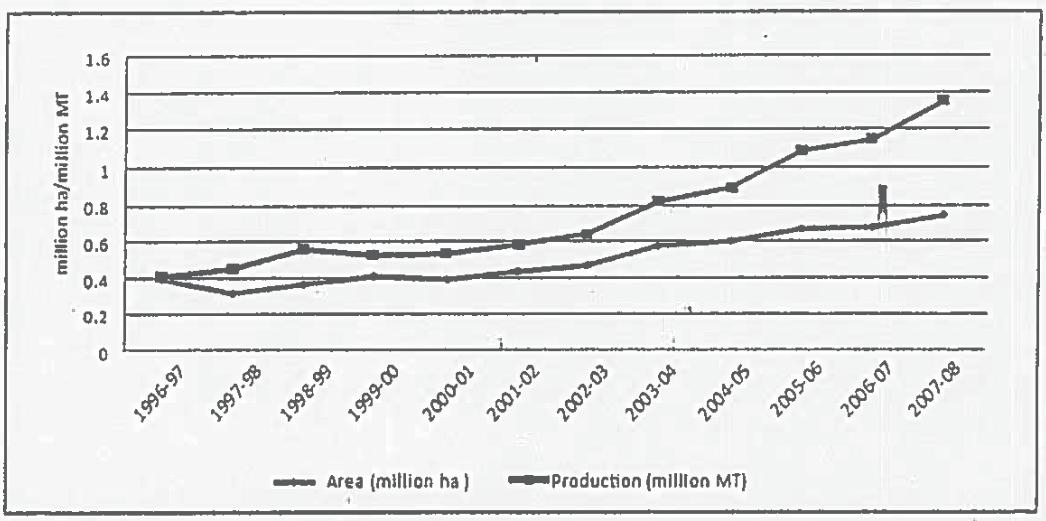

Figure (5): Growth in Agriculture Income (Rs in million), Source: Agriculture and Cooperation Department

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