WATER CONSERVATION AND SAVING IN AGRICULTURE

Initiatives, Achievements and Challenges in Maharashtra

Government of Maharashtra

Water Resources Department
Government of Maharashtra, India
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Traditionally, the thrust of the Government has been on construction of big dams to increase water storages. However, owing to their long gestation period and unequal spread of irrigation benefits, a large part of the State’s cultivated area remained deprived of minimum water availability for growing crops. On this backdrop, the Government of Maharashtra launched its flagship programme ‘Jalyukt Shivar Abhiyan’ (Water Secure Farms) in 2014. Of the 22,593 villages selected for Jalyukta Shivar Abhiyan, 16,151 villages have become water secured thereby achieving freedom from drought. Till now, 5,57,216 soil and water conservation works have been completed under the scheme creating a storage capacity of 2436 million cubic meter to provide one protective irrigation to 3.4 million hectares of farmland. In the second phase of the programme, the desilting of reservoirs and depositing it over the farmlands so as to improve their fertility as also to control soil erosion was undertaken. In just a short span of 18 months, the Galmukt Dharan-Galyukt Shivar (Silt-free Dams and Silt-filled Fields) scheme has resulted in the removal of 2.3 million cubic meters of silt from 5,270 dams, rejuvenating their water storage capacity equivalent to 3.2 million water tankers. For effective implementation of this programme, the Government has established a separate Soil and Water Conservation Commissionerate at Aurangabad. These
programmes have succeeded in reducing the drinking water supply through tankers by more than 75 percent, increase in crop productivity of rainfed areas by 30 to 50 percent and rise in the groundwater level by 1.5 to 2 meter. All these initiatives of the Government of Maharashtra taken up during the last four years have been proved as the way forward towards making drought-free Maharashtra.

Maharashtra in the year 2012, received 90 percent of the annual average rainfall and yet it was one of the worst years in the history of Maharashtra. As a consequence, the drought was declared in the State. In Maharashtra, despite the construction of about eighty-five thousand big and small storage structures with a huge amount of money, a large part of the State still has to depend on rainfall every year. In such a situation, only 10 percent of the farmland was under irrigation and this did not come as a surprise. The worst sufferers of the perpetual water scarcity were the farmers who produce food for the State’s population. Water shortage also adversely impacts on other spheres of life like health, hygiene and nutrition.

In the year 2014, when the present Government came into power, the first priority was to tackle the water scarcity issue that too on a perpetual basis. In the past, the water scarcity issue has been addressed in a traditional way by focusing on construction of huge irrigation projects which has been proved as failure. So, we decided to adopt an innovative approach which will be cost effective, cheaper, encourages community participation and completed within a short time period. The Government launched the ‘Jalyukt Shivar Campaign’ with an ambition of making twenty-five thousand villages of Maharashtra drought-free by 2019 with the participation of the people and it has already become a movement of the people.

Maharashtra’s geography and geology are such that almost 80 percent of the total rainwater flows away along with the soil. This issue was effectively addressed through Jalyukt Shivar Campaign. The works carried out under in the programme consists of deepening and widening of water sources and streams, construction of small bandharas/check dams and farm ponds thereby preventing rapid runoff and accelerating percolation of rainwater in the soil. The prime objective of the programme is recharging of groundwater.

After experiencing the success of the scheme and realizing its importance, people from hundreds of villages across the State voluntarily came forward to participate in this campaign and in its true spirit and it has became the people’s movement. In the last three years, water storage capacity of about 2436 million cubic meters has been created which is adequate to provide one protective irrigation to 3.4 million ha of agricultural land in kharif season. A total of seven thousand crore rupees were spent on this scheme including Rs. 638 crores which were collected through public participation. As a result, 16,151 villages have become drought-resilient in the State. Such a far-reaching positive impact could be achieved only through the works carried out under

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The Government launched the ‘Jalyukt Shivar Campaign’ with an ambition of making twenty-five thousand villages of Maharashtra drought-free by 2019 with the participation of the people and it has already become a movement of the people.
Jalyukta Shivar Campaign and not through construction of big water resources projects where benefits do not commensurate with the investment made.

It is well known that most reservoirs are getting silted due to soil erosion taking place in their catchment area. As a result, not only the storage capacity of the reservoir reduces but also the infiltration rate of water, affecting its in-situ percolation rate. Thanks to the initiative of ‘Gal Mukta Dharan Gal Yukt Shivar’ (Silt-Free Dams Silt-Filled Fields) which means desilting of the reservoirs and using the silt to spread over the farmland. The programme was launched in May 2017 with the twin objectives of enhancing the storage capacity of the reservoirs and to improve the fertility of farmlands, thereby reducing the expenditure on fertilizers while increasing the crop yields. The desilting programme, in a way is in harmony with Jalyukta Shivar Campaign as it is complementary in making villages permanently drought free.

I am happy to let you know that the programme was a huge success in bringing together various government departments, non-government organizations, experts and people from various villages and implementing it effectively. During the last two years, 2.3 million cubic meters of silt was removed from 5,270 dams and percolation tanks.

According to the study carried out by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), there has been two to four-fold increase in the crop yields due to improved fertility of the farmland. All these achievements, although look amazing, became possible due to the adoption of unique approach in its implementation, voluntary and whole-hearted people’s participation and effective public-private-people partnership. It has become evident from both these campaigns that when everyone takes up a task as his/her own work, then miracles do happen. I consider myself lucky to be a part of this huge and noble mission of providing water security to the State. I am confident that, in coming years, as a cumulative impact of these twin programmes, all the villages in Maharashtra will become ‘Water Prosper’ and no village will be adversely impacted due to vagaries of the rainfall. I am sure that the typical image of a farmer looking to the sky and praying for the rain will surely henceforth be transformed into the picture of a farmer who is smiling by looking to his/her rain enriched fields and expressing gratitude in the collective participation of people.
Since the last four years, the Maharashtra Government’s emphasis has been on completion of irrigation projects that have been delayed for a long time. Many irrigation projects have gained momentum and the Government is endeavouring to complete those on time. Upon completion, additional area will be brought under assured irrigation facility benefiting and further boosting the rural economy of the State. The Water Resources Department is committed to supply water to its millions of stakeholders including farmers. Revised administrative approvals were provided to 249 delayed projects. More than 25,000 hectares of land was acquired for completion of irrigation projects. Of this, 7,675 hectare land was purchased directly from farmers and they were compensated to the tune of Rs 7,000 crore. Maharashtra has a major share of funds in Prime Minister Krishi Sinchayee Yojana (PMKSY). Out of 99 projects under the PMKSY, 26 are from Maharashtra. On completion of these projects, additional irrigation potential of 0.576 million ha will be created. Till June 2018, four projects were completed creating an irrigation potential of 0.125 million ha. The Govt of India has approved a special package, with special 25 percent Central assistance for completion of 91 ongoing irrigation projects from suicide prone districts in Vidarbha and Marathwada region and chronically drought prone districts in the rest of Maharashtra. On completion of these 91 irrigation projects, 0.376 million ha additional irrigation potential will be created. Funds worth Rs. 59,162 crores were made available.
through Central and State Government for early completion of projects for availing speedy benefits.

A historic inter-state agreement was signed between Maharashtra and Telangana States towards the use of Godavari water. An agreement among Maharashtra, Gujarat and Central Government regarding inter-state river linking schemes is under consideration. Policy reforms like, framing of the State Water Policy, enactment of Maharashtra Management of Irrigation System by Farmers (MMISF) Act, 2005 and Maharashtra Water Resources Regulatory Authority (MWRRA) Act, 2005 for efficient, equitable and sustainable use of the State’s water resources were carried out. Preparation of Integrated State Water Plan comprising all the six river basins of the States viz Godavari, Krishna, Tapi, West Flowing rivers, Narmada and Mahanadi basin was taken up in 2015 and is now completed. This will enable planned and integrated use of available surface and groundwater resources equitably to fulfill the needs of various sectors like agriculture, domestic, industry, energy, water conservation etc. up to year 2030. The Integrated State Plan also includes diversion of water from surplus basin/sub basins to the water short basin/sub basins. Maharashtra has become the first State in the country to prepare such an integrated plan.

The work carried out in the irrigation water management by the State has been recognized by the Central Government. A Central Board of Irrigation and Power (CBIP) Award towards ‘Best Effective Participatory Irrigation Management’ was received on 3rd January 2018 by the Water Resource Department at New Delhi. Similarly, CBIP Award 2019 for the ‘Best Maintained Project for Koyna Hydro-Electric Project’ was also awarded to the Water Resource Department. In order to further bolster the reform process many innovative measures and modern practices are being implemented by the Water Resources Department. In the last 4 years, concepts such as irrigation through pipeline distribution system, recovering operation, maintenance and repair expenses from the water charges levied to agriculture, domestic and industrial users, expansion of micro irrigation, especially for perennial crops, land acquisition through direct purchase, recycle and reuse of treated sewage water, e-governance and use of information technology are being implemented. Due to adoption of a transparent tendering system, 90 percent of the tenders were received either at the estimated or below estimated cost resulting into saving to the tune of Rs. 2 billion.

A Needle Fabrication Mission was started under which 50,000 Kolhapur type bandhara needles are manufactured and used in various K.T bandharas. As a result, an additional area of 50,000 hectare is brought under irrigation and drinking water facilities have been provided for a population of 3.5 million in a very short period of last 3 years.

In the 167 km reach of Girna River, a series of 7 barrages using innovative type pneumatically operated obermayer type rubber gates are approved to create an additional storage of 21.49 million cubic meters. This will provide irrigation to 4,432 hectare of land and drinking water facilities in the drought prone area. Similarly, the Government has also come up with the Tapi River Mega Recharge Project wherein surplus surface water during monsoon will be used to recharge the river. This will arrest fast depletion of ground water in the area of Tapi basin.

All the afore narrated reforms and development aims in achieving better, sustainable and efficient water resource development and management system. The Water Resources Department is endeavoring to create an additional irrigation potential 1.4 million ha of during the period 2014-2022. Out of which, 0.257 million ha additional irrigation potential was already created till June 2018. In the last four years, 118 irrigation projects have been completed, while gorge filling of 88 irrigation projects has been done, which has resulted in creation of additional storage capacity of 1615 million cubic meter (57 TMC). In the year 2017-18, a record actual irrigation of 4 million ha was achieved.
Maharashtra State has a cultivable area of 22.5 million ha (Mha). According to the Maharashtra Water & Irrigation Commission Report (1999), the ultimate irrigation potential of the State is 12.6 million ha, comprising 8.5 million ha from surface water and 4.1 million ha through groundwater. As of June 2017, an irrigation potential of 6.832 million ha, both by the State sector (5.037 Mha) and the local sector (1.795 Mha) projects was created.

In view of the hilly topography of the State, large-scale lift irrigation schemes (LIS) to supply water to lands located at higher altitude, especially to drought prone areas were constructed. The Government is also focusing on improving water use efficiency by promoting micro-irrigation in the canal commands. As per the Integrated State Water Plan, the basin-wise area proposed to be brought under micro-irrigation by 2030 is- Godavari Basin - 2.857 million ha, Krishna Basin-1.404 million ha, Tapi Basin-0.345 million ha and in West Flowing River basin 0.014 million ha.

The State has established the Water Resources Regulatory Authority (MWRRA) in Aug 2005. This is the first functional regulatory authority in water sector in the country. The mandate of MWRRA is to regulate, facilitate and ensure judicious, equitable as also sustainable management, allocation and utilization of water resources in the State. The State is the pioneer in introducing participatory irrigation management (PIM) in the command areas and has been bestowed with national award for “Effective
Participatory Irrigation Management” in 2018.

With growing population, increasing urbanization and industrialization, water demand is rising exponentially so also the competition and conflicts among various water use sectors. With an aim of sustainable development and judicious use of State’s scarce water resources, both surface and groundwater, an Integrated State Water Plan for all the major river basins has been prepared. The water resources of the State are to be planned, developed and managed with river basin and sub-basin as the unit.

The Water Resources Department (WRD) has also launched a few important initiatives like preparation of irrigation status report, benchmarking report and water audit report of irrigation projects. A comprehensive water accounting framework is also being devised.

The State, has recently taken a policy decision to introduce pipe distribution system for supply of irrigation water from dam to fields in view of prohibitive cost of the land acquisition as also to reduce high conveyance losses through earthen canals.

Irrigation acts as an engine for assured and increased food production and for boosting the rural economy. The State is focusing on devising ways/means and framing policies in order to bring maximum area under irrigation, encourage use of micro-irrigation and eventually improving water use efficiency. The State has planned to complete all ongoing water resources projects in a phased manner and also to maintain already created irrigation infrastructure.

This compendium of articles is being published on the occasion of the 9th International Micro irrigation Conference (9 IMIC) to be held from 16 to 18 January 2019 at Aurangabad. This global event is jointly organized by the International Commission on Irrigation and Drainage (ICID), Central Water Commission, and WAPCOS Ltd, New Delhi. The Water Resources Department (WRD) under the aegis of the Government of Maharashtra (GoM) has the honour to host this important international event. It is a unique opportunity for policy makers, professionals from water and agriculture sectors, farmers, students to interact with the renowned international experts, see and learn latest advances in micro irrigation technology and networking with professionals from overseas in the field of drip and sprinkler irrigation.

Maharashtra has been at the forefront in adoption of micro irrigation technology and other water savings and conservation measures and practices. In order to showcase various initiatives and achievements of the State at the national and international level, it was decided to bring out a compendium of articles in a Special Publication. I am pleased to note that there has been an overwhelming response from various Government Departments, State Agricultural Universities, Regulatory Authorities and Agencies, Research and Financing Institutions, Private Sector, NGOs, Civil Society Associations in contributing their valuable knowledge in the subject matter. I sincerely thank all those Authors and Heads of the Department for their rich contribution. I would like to extend my special thanks to Dr. Suresh Kulkarni, Secretary, Maharashtra Water Resources Regulatory Authority, Mumbai for volunteering to shoulder the responsibility of preparation of this publication. His dedicated efforts in bringing out this book in a short time is praise worthy. Thanks are also due to Dr. Sanjay Belsare, Deputy Secretary for contributing to this document and facilitating its timely publication. I hope that the information provided in various articles will be of use to the policy makers, water professionals, researchers, students and all those interested in sustainable development and management of water resources.
1. Overview of the State:
Maharashtra occupies the western & central part of the country and has got 720 km long coastline along the Arabian Sea and is also fortified naturally by Sahyadri and Satpuda mountain ranges. The State is surrounded by Gujarat to the northwest, Madhya Pradesh to the north, Chhattisgarh to the east, Telangana to the southeast, Karnataka to the south and Goa to the southwest. The elevation map of the state is presented below-

The elevation map of Maharashtra
For the administrative convenience, State has been divided into 36 districts and 6 revenue divisions (viz. Konkan, Pune, Nashik, Aurangabad, Amravati and Nagpur). With a population of 11.24 crore, as per Population Census-2011 and with geographical area of about 3.08 lakh sq. km, Maharashtra is ranked 2nd by population and 3rd in terms of area. The State is highly urbanised with 45.2 per cent population living in towns.

Maharashtra is one of the highly industrialized states. It is pioneer in Small Scale Industries and continues to attract industrial investments from both, domestic as well as foreign institutions. It is a major IT growth centre. The State has given importance to primary education, which has resulted in consistent improvement in literacy rate. The literacy rate of the State is 82.3 per cent against 73 per cent at national level as per Census 2011.

The state capital Mumbai is not only home for leading corporate houses and firms but also has Asia’s oldest Stock Exchange, the Bombay Stock Exchange.

2. Rainfall:
The average rainfall of the State is approximately 1360 mm. Nearly 98% of the total average rainfall occurs between June to September, while nearly 8% occurs between October to December. July is the month of maximum rainfall in all but Ahmednagar, Beed, Aurangabad and Solapur Districts of Maharashtra, September is the month of maximum rainfall in these four districts. The rainfall during the months of January to May is on an average about 4%. The rainfall over Konkan and the ghat area is more intense during June to September. The winds from the Bay of Bengal entering the hinterland crossing the coastline bring cyclonic rains over the region on east of Central Maharashtra. The proportion of the north-east monsoon rains is higher in East Maharashtra due to this reason. There is a considerable variation in the amount of reliability of the rains in different parts of the
State. The annual rainfall in Konkan is between 2000 to 3500 mm. At Mahabaleshwar it is 6208 mm, while at Panchgani, just 15 km to its east, it is merely 1923 mm.

Temperature, Evaporation and Isohyet Map is shown as below-
There is wide variation in regard to this aspect when different regions of the State are considered. The number of average annual rainy days is maximum 95 days in Konkan, 55 days in Vidarbha, 51 days in Western Maharashtra and the minimum 46 days in Marathwada.

3. River Basins:
Maharashtra State is mainly covered by the six river basins, namely Krishna, Godavari, Tapi, Narmada, west-flowing rivers of Konkan strip and Mahanadi Basin.
The river basin map is shown on next page-

3.1. Godavari Basin:
Godavari River Basin spreads across the states of Maharashtra, Madhya Pradesh, Karnataka, Chhattisgarh, Odisha, Telangana, Andhra Pradesh and Union Territory of Puducherry, draining an area of 3,12,811 sq. km. It is largest river basin in the Peninsular India. Within Maharashtra state, Godavari River Basin drains an area of 1,52,598 sq.km. (i.e. 48.78% of the total Godavari Basin Area).Godavari River originates in the Western Ghats at Trimbakeshwar (at an altitude of 1067 m in the Brahmagiri ranges), flows eastwards through the Deccan plateau and cuts across the
Eastern Ghats to meet the Bay of Bengal, after travelling a distance of 1465 km and carrying an annual average runoff of 1,18,000 mm³ of water. Godavari River, also known as Vriddha Ganga or Dakshin Ganga flows for little more than half its initial distance of 764 km through Maharashtra State, while the rest 701 km through Andhra Pradesh State. It meets the Ganga Sagar or Bay of Bengal at Rajamundri in Andhra Pradesh. Godavari River has 68 major tributaries. Godavari river basin in Maharashtra covers some districts of Northern and Western Maharashtra regions and almost entire area of Marathwada and Vidarbha regions.

3.2. Krishna Basin
Krishna River Basin spreads across the states of Maharashtra, Karnataka, Telangana & Andhra Pradesh, draining an area of 2,58,948 sq. km. within Maharashtra state, Krishna River Basin drains an area of 69,425 sq. km. (i.e. 26.81% of the total Krishna Basin Area). The Krishna is the second largest river in Peninsular India. It rises in the Mahadev range of the Western Ghats near Mahabaleshwar at an altitude of 1337 m. above sea level. Rising in the Ghats near the Arabian sea, the Krishna flows through Maharashtra, Karnataka, Telangana and Andhra Pradesh gathering water on its way from innumerable rivers, streams or tributaries and drops into the Bay of Bengal. The Krishna basin lies between latitudes 13° 7’/N to 19° 20’/N and longitudes 73° 22’/E to 81° 10’/E. It is roughly triangular in shape with its base along the Western Ghats, and apex at Vijayawada. The basin extends over an area of 258748 square km. which is nearly 8 per cent of the total geographical area of India

3.3. Tapi Basin
Tapi River Basin spreads over the states of Maharashtra, Madhya Pradesh and Gujarat having an area of 65,145 sq. km. with a maximum length and width of 724 km and 196 km respectively. The drainage area of Maharashtra, Madhya Pradesh and Gujarat is 51504 sq. km, 9804 sq. km. and 3837 sq.
km. respectively. It lies between 72°38’ to 78°17’ East longitudes and 20°5’ to 22°03’ North latitudes. It is bound in the north by the Satpura range, in the east by the Mahadeo hills, in the south by the Ajanta range and Satmala hills and in the west by the Arabian Sea. The river is bound on the three sides by the hill ranges. Tapi River originates near Multai reserve forest in the Betul district of Madhya Pradesh (at an altitude of 752 m in the Satpura ranges), flows through the central part of India, flows in Westward direction and merges into Arabian sea at a distance of 724 km. Tapi River, also known as Tapti flows for little more than half its initial distance through Maharashtra State, while the rest through Madhya Pradesh and Gujarat State. Its important tributaries are the Suki, Gomai, Arunavati and the Aner which joins it from right and those joining from left are the Waghur, the Amravati, the Burai, the Panjhra, the Bori, the Girma, the Purna, the Morna and the Sipna.

3.4. West Flowing River Basin (WFRB)
West Flowing Rivers Basin consists of 27 major independent rivers originating in Western Ghats or parts their off and flowing in westward direction for an average distance of 50 km. to meet the Arabian Sea at various places along the west coast. It drains an area of 31780 sq. km. which is approximately 10 percent of area of Maharashtra state.

3.5. Narmada Basin
Common border of Narmada river along Madhya Pradesh and Maharashtra is approx. 35.42Km. long. Also, along Gujrat and Maharashtra Appro. 35.42 Km Long. In this area, very small pockets of land are available for irrigation. Among the River Devganga (36 Km) is main river with flows along Gujrat and Maharashtra. Also, Udai river (90Km Long), Devnand and Katri combines from 70 km. Ghat river which originate from Tal. Akkalkuawa and ends at Tal. Dhadgaon in Narmada River. Zalkhel river which flow along border of Maharashtra and MP end in Narmada river. Rain gauge Station are established at taluka place itself at Akkalkuwa and Dhadgaon. Also, in Dhagaon Taluka new Raingauge station is Started at 1) Asali 2) Bijari 3) Kakaripati from 1984.

3.6. Mahanadi Basin
The river Mahanadi originates from a pool, 6 km from Farsiya village of Dhamtari district of Chhattisgarh state, at an elevation of 442 m above mean sea level. It then flows east and drains into the Bay of Bengal. The Mahanadi basin extends over an area of 141672.38 km² in the country which is nearly 4.3% of the total geographical area of the country. It is bounded on the north by the Central India hills, on the south and east by the Eastern Ghats and on the west by the Maikala range. The upper basin is a saucer shaped and mostly lies in Chhattisgarh state. The basin is circular in shape with a diameter of about 400 km and an exit passage of about 160 km length and 60 km breadth. Mahanadi Basin has a very limited presence in Maharashtra state spread in far eastern part of Vidarbha region i.e. in Deori tahsil and Korchi tahsil of Gondia and Gadchiroli district respectively. Total area of Mahanadi Basin is 322.38 Sq.km. in MH State.

4. Surface and Groundwater Resources
In Maharashtra, there are 380 small or big rivers having total length of about 20000 km. Based
on the monthly/monsoon/annual linear R-R models developed for every group of watersheds, subbasin-wise runoff series are developed along with post monsoon yields and subbasin-wise gross yields at various dependable have been worked out. Further, basin-wise gross yield has been calculated on the basis of subbasin-wise yields. Present estimated yield is given in following table-

<table>
<thead>
<tr>
<th>Basin</th>
<th>Catchment area Sq.Km.</th>
<th>Derived Dependable yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Godavari</td>
<td>151122 #</td>
<td>54670</td>
</tr>
<tr>
<td>Krishna</td>
<td>69425</td>
<td>39218</td>
</tr>
<tr>
<td>Tapi</td>
<td>52058**</td>
<td>10185</td>
</tr>
<tr>
<td>WFR (Konkan)</td>
<td>31507</td>
<td>77342</td>
</tr>
<tr>
<td>Narmada</td>
<td>1048</td>
<td>NA</td>
</tr>
<tr>
<td>Mahanadi</td>
<td>322</td>
<td>159</td>
</tr>
<tr>
<td>Total</td>
<td>305479</td>
<td>181574 (Mcum)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6412.20 (TMC)</td>
</tr>
</tbody>
</table>

Out of six river basins, except West Flowing Rivers, all other rivers are inter-stake in nature. Hence there is limitation on permissible water use, considering water dispute tribunal awards. The total surface water availability & its permissible use in the five major river basin is given below-

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Name of the River Basin</th>
<th>Geographical Area (Mha)</th>
<th>Culturable Area (Mha)</th>
<th>Average Annual availability</th>
<th>75% dependable Yield (MCM)</th>
<th>% w.r.t. State</th>
<th>Permissible use as per Tribunals (Mcum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Godavari</td>
<td>15.43</td>
<td>11.25</td>
<td>50880</td>
<td>37300</td>
<td>28.35</td>
<td>34185</td>
</tr>
<tr>
<td>2</td>
<td>Tapi</td>
<td>5.12</td>
<td>3.73</td>
<td>9118</td>
<td>6977</td>
<td>5.3</td>
<td>5415</td>
</tr>
<tr>
<td>3</td>
<td>Narmada</td>
<td>0.16</td>
<td>0.03</td>
<td>580</td>
<td>315</td>
<td>0.24</td>
<td>308</td>
</tr>
<tr>
<td>4</td>
<td>Krishna</td>
<td>7.01</td>
<td>5.63</td>
<td>34032</td>
<td>29371</td>
<td>21.56</td>
<td>16818</td>
</tr>
<tr>
<td>5</td>
<td>West Flowing Rivers</td>
<td>3.16</td>
<td>1.86</td>
<td>69210</td>
<td>58599</td>
<td>44.55</td>
<td>69210</td>
</tr>
<tr>
<td></td>
<td>Maharashtra</td>
<td>30.88</td>
<td>22.5</td>
<td>163820</td>
<td>131562</td>
<td>100</td>
<td>125936</td>
</tr>
</tbody>
</table>

Groundwater Surveys & Development Agency (GSDA) and CGWB have carried out the Groundwater Assessment, in the Year 2011-12, watershed-wise recharge, and annual gross groundwater draft and groundwater availability. As per this assessment, total annual groundwater recharge is 32292 Mcum. However, in view of ‘safe’ groundwater withdrawal only 70% of net groundwater should be utilized so as to avoid any undesired effect on groundwater potential. Thus, utilizable Net Annual Groundwater available is 22612 Mcum. Annual gross groundwater draft is 17175 Mcum. The remaining quantum of 5437 Mcum is available for future use. Basin wise Groundwater availability is given in following table-
### 5. Status of Agriculture in the State:
Agriculture & allied activities sector plays an important role in the economic development of the State. The share of agriculture & allied activities sector in the total Gross State Value Added (GSVA) is about 12.2 per cent during 2016-17 as against 15.3 per cent during 2001-02 which shows declining trend over the period, whereas major portion of the population is still dependent on this sector. Reduction in average size of agricultural holdings, increasing number of marginal & small farmers, dependency on monsoon & weather, low productivity are the major concerns of the agriculture sector in the State. Though, the share of the allied activities in the Agriculture & allied activities sector is comparatively less, its contribution with reference to livelihood is of immense importance. The increasing consumption of fruits & vegetables, milk & milk products, poultry, meat, fish and flowers due to changing lifestyle indicates substantial growth potential. This potential needs to be tapped to the greater extent for enhancing farmers income.

Sustainable Development Goals envisages promotion of sustainable agriculture and ensuring availability & sustainable management of water. Accordingly, the major initiatives like, enhancement of crop productivity, improving yield and quality of horticulture & floriculture, reducing cost of cultivation, integrated farming system approach, promotion of group farming, soil & water conservation for moisture security, creation of quality infrastructure for storage and processing to control wastage, post-harvest technology for value addition, promotion of value addition chain, promoting export of agriculture produce, agriculture credit and risk mitigation are incorporated in the Vision2030 document of the State.

The State has 231 lakh ha of land under cultivation and area under forest is 52.1 lakh ha. Many irrigation projects are being implemented to improve irrigation. A watershed development programme is being implemented to ensure that soil and water conservation measures are implemented speedily in the unirrigated area. Animal husbandry is an important agriculture related activity. The State’s share in livestock and poultry population in India is about 6.3 per cent and 11 per cent respectively.

### 6. Irrigation Development during Pre-independence Period:
During the period 1858 to 1867, the British Government entrusted the responsibility of executing irrigation projects to the East India Irrigation Company and Madras Irrigation company by assuring them 5% profit on the capital investment. However, both the Companies proved unsuccessful in accomplishing the works which led the Government to withdraw from them the works in a partly carried out state. After 1867, the Government established

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Sub basin</th>
<th>No. of Watersheds</th>
<th>Catchment area (Sq. Km)</th>
<th>Net Recharge (Mcum)</th>
<th>70% of Net GW Recharge (Mcum) (col. 5) x 70%</th>
<th>Draft Mcum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Godavari</td>
<td>807</td>
<td>152598</td>
<td>17498</td>
<td>12249</td>
<td>8496</td>
</tr>
<tr>
<td>2</td>
<td>Krishna</td>
<td>315</td>
<td>69425</td>
<td>7817</td>
<td>5479</td>
<td>5385</td>
</tr>
<tr>
<td>2</td>
<td>Tapi</td>
<td>299</td>
<td>52058</td>
<td>4651</td>
<td>3256</td>
<td>2956</td>
</tr>
<tr>
<td>3</td>
<td>WFR (Konkan)</td>
<td>91</td>
<td>24633</td>
<td>2264</td>
<td>1584</td>
<td>322</td>
</tr>
<tr>
<td>4</td>
<td>Narmada</td>
<td>8</td>
<td>1048</td>
<td>35</td>
<td>25</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>Mahanadi</td>
<td>4</td>
<td>354</td>
<td>27</td>
<td>19</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1524</strong></td>
<td><strong>300116</strong></td>
<td><strong>32292</strong></td>
<td><strong>22612</strong></td>
<td><strong>17175</strong></td>
<td></td>
</tr>
</tbody>
</table>
an independent department for irrigation and formed one construction organization. In 1869, comprehensive irrigation development plan of 10 years had been evolved. A scheme involving $150 million expenditure was contemplated. The next 10 years subsequent to the year 1867 saw expending $52.85 million on this scheme. As the project works undertaken by the Government and the capital investment made therein in this new system proved satisfactory and worthy of use, a policy of undertaking further irrigation projects at the Government expense and through governmental organization was implemented. It can be said that the presently practiced Government system and methodology find their roots in this very step.

The concluding years of the nineteenth century saw a horrible famine. This has forced the British Government to undertake at least protective irrigation schemes, though out of reluctance. The first such major irrigation work could be cited as the Krishna Canal which started in 1870. The water of Krishna River has been used through a canal by constructing across it a weir at ‘Khodshi’. The area to be irrigated on downstream used to be in proportion to the water available in the river course. Seeing that area being irrigated on canals was got affected after diminution inflow that occurred in post-monsoon period, it became clear that unless there had been a sizeable storage in Maharashtra, no systematic irrigation could be possible. Inception of canals off-taking from water storages came in the form of ‘Khadakwasla’ Dam constructed across the Mutha River and canals taking off therefrom. This work had been completed in 1875. Vihar (1860), Powai & Tulshi (1876) and Tansa (1883) Projects (drinking and industrial water supply for Mumbai) were completed in that order. Thereafter, the Neera Left Bank Canal was commissioned by completing the Bhatghar Dam in 1885. The Union Irrigation Department had conducted one survey in 1902 to assess the water availability. This survey was the sequel of the Hydrographic and Hydrological Survey Report of H. F. Beale which saw the light of day in 1901. The following schemes had been envisaged therein: Neera (Left Bank), Mutha Extension Canal, Girna, Mula Canal, Bhima, Kukadi, Ghod, Meena, Koyna, Mukane, Tapi (Hatnoor) and so on.

Canals from Godavari were drawn by accomplishing completion of Darna Reservoir in 1916. By constructing Chanakapur Dam across the Girna River in 1918 canals were commissioned. The reservoir at Bhandardara provided in 1920 the canal network off-taking from Pravara River and the year 1930 saw the commissioning of Neera Right Bank Canal as an extension of the already existing Bhatghar Dam. Irrigation commenced at Ramtek, Ghorazari, Asolamendha and Naleshwar in Vidarbha in the years 1909, 1910, 1911 and 1919 respectively.

During this period, lack of flawless engineering techniques prevented from going in for high earth dams. Therefore, masonry dams had been constructed. The engineering of masonry dams, too, had also not been sufficiently developed. As such, the pre-independence period could boast of creation of (1) Godavari (Nandur-Madhameshwar) (2) Pravara (Ozar) (3) Neera (Veer) (4) Mutha (Khadakwasa) (5) Krishna (Khadshi) and (6) Girna – all major projects and 15 medium projects – in all 21 reservoirs.

In 1869, comprehensive irrigation development plan of 10 years had been evolved. A scheme involving $150 million expenditure was contemplated. The next 10 years subsequent to the year 1867 saw expending $52.85 million on this scheme.
Irrigation potential of 2.74 lakh hectare has been created.

Photographs of some of the projects

7. Irrigation Development during Post-independence Period

In order to accelerate the completion of irrigation projects in Maharashtra State, the Government has established five Irrigation Development Corporations in the state. Viz Maharashtra Krishna Valley Development Corporation, Vidarbha Irrigation Development Corporation, Tapi Irrigation Development Corporation, Godavari Irrigation Development Corporation, Marathwada Irrigation Development Corporation, Konkan Irrigation Development Corporation. All the Corporations are headed by the officers of the rank of Secretary to Govt. and designated as Executive Directors. These corporations were allowed to raise funds through open market in the initial period. Now a
centralized procedure is followed for funding the construction activities of the corporations through Maharashtra Irrigation Finance Corporation (MIFC). The projects not covered by corporation jurisdiction are rest with Water Resources Department. Now, one of the key institutional reform initiatives of the state is reconstructing of the existing Irrigation Development Corporation’s into River Basin Agency’s with a view to strengthen the states capacity in multi sector planning and management of water resources at river basin level.

7.1. Flow irrigation:
The irrigation projects are classified as major, medium and minor projects depending on area irrigated. The state has undertaken about 3900 projects and about 36 percent of large dams in India belongs to Maharashtra state and details of same is given below-

The total geographical area of Maharashtra state is 307.42 Lakh Ha. Out of this area the cultural command area (CCA) is 209 Lakh Ha. and Net sown area is 175 Lakh Ha. The Ultimate irrigation potential of completed and ongoing projects is 74.53 Lakh Ha. Till June 2018, about 50.37 lakh ha area was brought under irrigation facilities. Following photo shows the details of projected irrigation area, irrigation potential created and actual area irrigated for last 10 years-
Photos of some of the projects are shown below:

↑Photo of Ujani Dam

↑Photo of Jayakwadi Dam

↓Photo of Ghatghar Roller Compacted Dam
7.2. Lift Irrigation:
The water is lifted by means of pumps from the source and conveyed through the rising mains to the main delivery chamber that is situated at the topmost location in the command area. This water is further conveyed and distributed amongst the beneficiary farmers by means of suitable secondary and tertiary systems. The present scenario for the various lift irrigation schemes in different 6 basins is given in the following table:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Basin</th>
<th>No. of Lift Schemes</th>
<th>Status</th>
<th>Potential Lakh Ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Godavari</td>
<td>98</td>
<td>Completed-73, Ongoing-25</td>
<td>3.97</td>
</tr>
<tr>
<td>2</td>
<td>Krishna</td>
<td>22</td>
<td>Under construction</td>
<td>Completed-73</td>
</tr>
<tr>
<td>3</td>
<td>Tapi</td>
<td>08</td>
<td>Under construction</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Narmada</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>WFRB (Konkan)</td>
<td>03</td>
<td>Completed</td>
<td>0.009</td>
</tr>
<tr>
<td>6</td>
<td>Mahanadi</td>
<td>03</td>
<td>Completed-1, Ongoing-1, Future-1</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>134</td>
<td></td>
<td>11.26</td>
</tr>
</tbody>
</table>

Following are photos of some of the major lift irrigation schemes undertaken in the state.

Mhaisal Lift Irrigation Scheme
7.3. Groundwater-based irrigation:

All 6 basins are dotted with a substantial large number of dug wells/borewells in command area of irrigation projects as well as in the un-command area. The wells in the command area facilitate conjunctive use of water whereas the wells outside provide an independent facility for drawing upon the groundwater. The statistics covering the numbers of wells, area irrigated on wells, connections and energy are monitored by Agriculture Department, Government of Maharashtra and is presented in following table:

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Basin</th>
<th>IP (Lakh Ha.)</th>
<th>Area Under Wells (Lakh ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Command</td>
</tr>
<tr>
<td>1</td>
<td>Godavari</td>
<td>37.00</td>
<td>12.69</td>
</tr>
<tr>
<td>2</td>
<td>Krishna</td>
<td>24.16</td>
<td>3.27</td>
</tr>
<tr>
<td>3</td>
<td>Tapi</td>
<td>9.69</td>
<td>0.89</td>
</tr>
<tr>
<td>4</td>
<td>Narmada</td>
<td>0.001</td>
<td>0.007</td>
</tr>
<tr>
<td>5</td>
<td>WFRB (Konkan)</td>
<td>3.42</td>
<td>0.13</td>
</tr>
<tr>
<td>6</td>
<td>Mahanadi</td>
<td>0.02</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>Maharashtra</td>
<td>73.37</td>
<td>25.68</td>
</tr>
</tbody>
</table>
8. Micro-irrigation:
It can be defined as the application of water at low volume and frequent interval under low pressure to plant root zone. Since water is the limiting factor today, it must be utilized properly and maximum benefit shall be taken to the possible extent. Micro-irrigation means application of optimum water according to plant requirement. Introduction of advanced and sophisticated methods viz. drip irrigation, sprinkler etc. makes it possible.
As per Irrigation Status Report of 2017-18, about 22.68 lakh ha are is brought under micro-irrigation, which includes 16.26 lakh ha under drip irrigation and 6.42 lakh ha under sprinkler irrigation. The micro-irrigation area is proposed up to 2030 for Godavari Basin-28.57 Lakh Ha., Krishna Basin-14.04 Lakh Ha, Tapi Basin-3.45 Lakh Ha, Narmada Basin-Nil, WFRB-0.14 Lakh Ha.

9. Hydropower Development:
Hydropower has Modern history associated with it in Maharashtra. Hydropower was used firstly for running in areas a flour mill at Aurangabad way back in 17th Century. In Maharashtra in West flowing river basin Tata Power commissioned India’s first power plant- at Khopoli in 1915. The second and third HEP station were erected at Bhivpuri in 1919 and Bhira in 1922. In Maharashtra state large project imply capacity above 25 MW while Mini Hydel schemes have 2MW or less capacity. Hydel project in between is small. In Maharashtra state the total installed capacity of Hydropower generation is 4298MW including all large and small plant. Its basin wise breakup is as given below.

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Description</th>
<th>Total No</th>
<th>Completed</th>
<th>Ongoing</th>
<th>Future</th>
<th>Total Mw</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No</td>
<td>MW</td>
<td>No</td>
<td>MW</td>
<td>No</td>
</tr>
<tr>
<td>1</td>
<td>Krishna</td>
<td>23</td>
<td>22</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Godavari</td>
<td>434</td>
<td>14</td>
<td>916</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>WFRB</td>
<td>67</td>
<td>21</td>
<td>1261</td>
<td>17</td>
<td>65</td>
</tr>
<tr>
<td>4</td>
<td>Tapi</td>
<td>31</td>
<td>8</td>
<td>7</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Narmada</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>Mahanadi</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>555</td>
<td>65</td>
<td>4298</td>
<td>23</td>
<td>478</td>
</tr>
</tbody>
</table>

Following table gives summary of Pump Storage Scheme in the state of Maharashtra:

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Description</th>
<th>Total No</th>
<th>Completed</th>
<th>Ongoing</th>
<th>Future</th>
<th>Total Mw</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No</td>
<td>MW</td>
<td>No</td>
<td>MW</td>
<td>No</td>
</tr>
<tr>
<td>1</td>
<td>Krishna</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Godavari</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>WFRB (Konkan)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Tapi</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Narmada</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>Mahanadi</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>80</td>
</tr>
</tbody>
</table>
Compared with the total power generation of 14400 MW the component of hydel power waves out to be 25% which is satisfactory from operational point of view.

Koyna Hydroelectric Project is one of the largest completed hydroelectric power plants in India. The total installed capacity of the project is 1,960 MW. The project consists of four stages of power generation. All the generators are located in underground powerhouses excavated deep inside the mountains of the Western Ghats. Due to the project's electricity generating potential this project is considered as the lifeline of Maharashtra.

In 2019, this project was awarded as “Best Maintained functional Project for more than 50 years” by Central Board of Irrigation and Power
10. Interstate Water Transfer:
Interstate Water Transfer is in the form of interstate projects, interlinking of rivers for either inter basin or intra basin water transfer and also barter method in a few cases of water transfer between the two states. Status of various projects and schemes existing and proposed for interstate water transfer related to Maharashtra is given in following paragraphs.

10.1. Interlinking of Rivers (ILR) Projects - National Interlinking Projects
The National Water Development Agency (NWDA), GoI has identified a total of 30 inter-basin water transfer links which include 14 under peninsular component and 16 under Himalayan component. Following 9 links in peninsular component are related to Godavari, Krishna, Tapi and West Flowing Rivers basins of Maharashtra State.

1. Mahanadi (Manibhadra) - Godavari (Dolaiswaram) Link Project
2. Godavari (Ichampalli) - Krishna (Nagarjuna Sagar) Link Project
3. Godavari (Ichampalli) - Krishna (Pulichintala) Link Project
4. Godavari (Polavaram) - Krishna (Vijaywada) Link Project
5. Krishna (Nagarjuna Sagar) - Pennar (Somasila) Link Project
6. Krishna (Srisailam) - Pennar (Proddatur) Link Project
7. Krishna (Almatti) - Pennar Link Project
8. Par - Tapi - Narmada Link Project
9. Damanganga - Pinjal Link Project

Out of these 9 ILR Projects two links viz. Par - Tapi - Narmada Link Project and Damanganga - Pinjal Link Project are more important for Maharashtra State.

10.2. Interlinking of Rivers within State of Maharashtra (ILR)
After identification of 30 ILR projects by NWDA spread all over the country, Govt. of Maharashtra has proposed 20 schemes for interlinking of Rivers within the state and requested to NWDA for pre-feasibility report study (PFR) of the same. Status of pre-feasibility reports (PFR) of 20 schemes is available on NWDA website and is as given in following table-

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Name of Intra-State Link</th>
<th>River</th>
<th>Quantum of Water MCM</th>
<th>Present Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Inter Basin Links</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Wainganga (Gosikhurd) – Nalganga (Purna Tapi)</td>
<td>Wainganga &amp; Nalganga</td>
<td>2721</td>
<td>Dropped by State Government</td>
</tr>
<tr>
<td>2</td>
<td>Upper Ghat – Godavari Valley (Damanganga (Ekdare) - Godavari Valley)</td>
<td>Damanganga &amp; Godavari</td>
<td>143</td>
<td>PFR Completed</td>
</tr>
<tr>
<td>3</td>
<td>Upper Vaitarna – Godavari Valley</td>
<td>Vaitarna &amp; Godavari</td>
<td>136</td>
<td>PFR Completed</td>
</tr>
<tr>
<td>4</td>
<td>North Konkan – Godavari Valley</td>
<td>Patalganga &amp; Godavari</td>
<td>269</td>
<td>PFR Completed</td>
</tr>
<tr>
<td>5</td>
<td>Koyna – Mumbai city</td>
<td>Koyna</td>
<td>1912</td>
<td>PFR Completed</td>
</tr>
</tbody>
</table>
11. Plans for Future Development:
The future planning is forecasted for the year 2030 and is based on Water potential, Available water in light of Various Award Provision and Interstate Agreements, Equitable distribution of water through appropriate cropping pattern and Eight Monthly irrigation to the maximum possible extent, Optimal utilization of available water resources through modern techniques such as drip and sprinkler irrigation, Efficient water resources management through beneficiaries’ participation, measured volume of supplied water and irrigation water supply rates, and Integrated optimal operation schedule for reservoirs, canal system and distribution network. Following table summarised the water availability in perspective of present and future planning.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Basin</th>
<th>Average Water Availability</th>
<th>Water Use Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>50/65% 75% 2016 2030</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Godavari</td>
<td>51757 (1827.84) 49800 (1758.72) 38607 (1363.43) 31296 (1105.24) 36430 (1286.55)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Krishna</td>
<td>33710* (1190.48) 31633** (1117.14) 29301 (1034.77) 18215 (643.28) 18215 (643.28)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Tapi</td>
<td>9656 (341) 9221 (325.65) 7027 (248.16) 5525 (195.12) 7461 (263.50)</td>
<td></td>
</tr>
</tbody>
</table>
Water Conservation & Saving in a Culture

<table>
<thead>
<tr>
<th></th>
<th>Narmada</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>308 (10.89)</td>
<td>292 (10.32)</td>
<td>179 (6.32)</td>
<td>308 (10.89)</td>
<td>308 (10.89)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>WFRB (Konkan)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>74739 (2639.46)</td>
<td>74317 (2624.56)</td>
<td>64219 (2267.94)</td>
<td>57563 (2032.88)</td>
<td>51977 (1835.61)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Mahanadi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>165 (5.83)</td>
<td>120 (4.24)</td>
<td>102 (3.60)</td>
<td>12 (0.42)</td>
<td>110 (3.88)</td>
<td></td>
</tr>
<tr>
<td>Total Maharashtra</td>
<td>170335 (6015.50)</td>
<td>165383 (5840.62)</td>
<td>139435 (4924.25)</td>
<td>112919 (3987.82)</td>
<td>114501 (4043.70)</td>
<td></td>
</tr>
</tbody>
</table>

12. Participatory Irrigation Management
Participation of water users’ organization is being evoked in irrigation management pursuant to the current Government policy. To empower the users and provide justice to tail enders and weaker section of society, Government of Maharashtra had enacted standalone act for WUA called as the MMISF-Act 2005. With the formation of WUA’s and transfer of irrigation management to users, the job of Water Resources Department would remain as facilitator. This is a major breakthrough in water resources management where users are adequately empowered and centre of reforms.

13. Maharashtra Water Resources Regulatory Authority:
With growing population and water scarcity, there is growing competition among various sectors of water users. This leads to conflict among them & to overcome it, state had enacted Maharashtra Water Resources Regulatory Authority (MWRRA) Act 2005 & established a Regulatory Authority in Aug 2005. It is the first such regulatory Authority in water sector in the country. Mandate of MWRRA is to monitor and regulate acts resources within the state, which will facilitate and ensure judicious, equitable, and sustainable management, allocation and utilization of water resources.

14. State Water Policy:
The Maharashtra state among few states to have its own water policy. The state has adopted state water policy in 2003. The policy advocates river basin management. The policy underlines the important principle such as “polluter to pay and first re-habitation then dam construction. The state water policy is good example of visionary and down to earth approach.

15. Integrated State Water Plan:
Maharashtra is one of the states who had prepared Integrated State Water Plan for all river basins in the state. Objectives of the Maharashtra State Water Policy is to adopt an integrated and multi sectoral approach to water resources planning, development and management on a sustainable basis taking river basin / sub-basin as a unit. The water resources
of the State shall be planned, developed, managed with a river basin and sub-basin as the unit, adopting multi-sectoral approach and treating surface and sub-surface water with unitary approach. It is also mentioned in the state policy that State shall prepare a State Water Resources Plan to promote a balanced development and by proper coordination among diverse water uses, which shall include structural, operational, watershed management, demand management, water pollution control and monitoring measures that will assure comprehensive sustainable management of the water resources and equity in water distribution for the benefit of the State and its people.

16. Best Practices:
The state has also initiated and institutionalized important reform like preparation of irrigation status report, benchmarking report and water auditing report of irrigation projects. The state has been publishing status report of irrigation projects (schemes) annually since 1999. Maharashtra is the first state after Australia who is publishing report on benchmarking regularly. A comprehensive water accounting method is devised, with water accounting at project level as well as at last manageable units i.e. section office level. The state has been publishing report on benchmarking and water auditing of irrigation projects which is a unique example in the country as well as on international forum. Bencing and water auditing of irrigation projects resulted in transparency, accountability among the management staff & improvements in performance of irrigation projects. The successful implementations of reforms have resulted in improvement in performance of irrigation projects. The reforms have also improved financial performance of irrigation project, with operation and maintenance expenses being recovered through water charges. With all around reforms in water resources management and its successful implementation, Maharashtra state has emerged as one of the best performing state in India.

The office of Directorate of Irrigation Research and Development is established in the state for conducting research and development relating to irrigation management. It also looks after the construction and maintenance of land reclamation works in the canal command areas. The state has recently decided to introduce pipe distribution system on irrigation projects, for supply of water to the field from dam. The traditional canal distribution system will be converted to pipe distribution system and policy in this respect is formulated and its implementation is under carried out. Gunjawani is one of the projects designed to irrigate about 21,000 ha area through PIN and which is expected to work on gravitational head, saving water and energy. The MWRRA has also made it compulsory to use water by micro-irrigation for all perennial crops (12 monthly crops).
Department had decided to use submergence area of the reservoir for floating solar panel for generating electricity. In future, some projects will be undertaken in this sector.

17. Challenges:
The water sector in Maharashtra is faced with critical challenges. First, competition among different sectors has increased dramatically, giving rise to disputes and conflicts. Of the total water used in the state, about 80% goes to irrigation, 12% for domestic water supplies, 4% for industrial use, and the remainder for other uses such as livestock, and hydro and thermal power. With an urban population of about 41 million (42%), and rapidly growing urban centres and industries, the long term efficient and equitable intra and inter-sectoral management of the state’s scarce water resources will become more critical. Second, poor quality irrigation service delivery is undermining the performance of irrigated agriculture. Third, limited cost recovery in the irrigation sector contributed to inefficient on-farm use of irrigation water and added to the fiscal burden of the state. Fourth, planning and management of water resources in the state are fragmented and uncoordinated and is not being done holistically, treating surface & groundwater as one resource.

18. Conclusion:
Irrigation is a key element for agricultural sector. The state has achieved a landmark in irrigation potential creation, but performance is utilisation of potential remains comparatively low. It was high time to work upon minimising gap between the two, and conserve irrigation water to make best use of available water resources. State has 36% dams of the country, and area under irrigation is more than 50 lakh ha, still there is need to emphasis in water resources sector. Attention is given and policies are framed in order to bring maximum area under irrigation, encourage use of micro-irrigation and improving water use efficiency and maximum crop yield. State had planned to complete all ongoing projects in phased manner and maintain the irrigation infrastructure considering the forthcoming challenges. Department had formulated Vision document and objective was decided as “Optimally conserve allocated water resources of the state in sustainable, equitable and efficient manner to fulfil drinking, irrigation, industrial and environmental needs at reasonable cost by efficient utilisation of water using advanced technology, best practices and empowered competent human resources, so as to make MWRD as a leader in Water Resources Management.” Further, Integrated State Water Plan will help phase-wise development of various activities envisaged in the plan. Department is committed to ensure that the challenges envisaged will be taken care and more crop, per drop will be achieved.

References:
- Annual Reports published by Maharashtra Irrigation Development Corporations
- Benchmarking Reports published on website of WRD
- Economic Survey Report of State of Maharashtra
- Integrated State Water Plan
- Irrigation Status Reports published on website of WRD
- Maharashtra Irrigation Development Corporation Acts (5 No’s)
- Maharashtra State Water Policy
- MMISF Act, 2005
- MWRRA Act, 2005
- National Register of Large Dams
- Piped Distribution Network Policy of WRD
- Report of Irrigation Related Special Inquiry Committee, 2014
- Report of Maharashtra Water and Irrigation Commission, 1999
- Vision Document of WRD
- Water Audit Reports published on website of WRD
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POLICY, REFORMS AND MEASURES TOWARDS ENHANCING WATER USE EFFICIENCY IN IRRIGATION

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Abstract
Maharashtra is the third largest state in India. The availability of water in the state is highly uneven, both spatially & temporally. Presently, the irrigation constitutes about 80% of the total water use, which would further reduce because of rapid urbanization & industrialization. Enhancing the water use efficiency is one of the several measures to alleviate water stress in the State.

The state has already taken steps like water auditing & benchmarking of irrigation projects. Promotion of micro-irrigation in the canal command area would help in greater extent as most of the water-intensive crops are grown in the command area of irrigation projects. MWRRA has already notified that cultivators of perennial crops must adopt water saving technologies. The Government of Maharashtra (GoM) has adopted a policy of creation of decentralized storages to support the micro-irrigation. The policy to adopt pipe distribution network (PDN) will help saving of water substantially. The pilot projects like Dehani lift irrigation schemes (LIS) & Arvi LIS will lead by the example. command area development and water management (CADWM) programme is also promoting lining of water courses & micro-irrigation. It is hoped that the goal of increasing water use efficiency by 20% will be achieved through all these measures & consistent efforts.

1.0 Introduction
About 58% of the state’s population is in rural area, 80% of whom are dependent on agriculture for their livelihood. The availability of water in the state is highly uneven, both spatially and temporally, most of the rainfall occurs in just 40 to 100 days. The available utilizable water resources would be inadequate to meet the future water demand of all the sectors. The water used for irrigation is about 80% which would further reduce because of
rapid urbanization & industrialization. Hence the panacea is to enhance water use efficiency.

2.0 Water Use Efficiency in Irrigation

Water use efficiency relates to the efficiency of delivering water from the intake of the irrigation system to the crop root zone for the purpose of beneficial crop evapo-transpiration, taking account of any use or reuse of seepage or other conveyance, distribution or application losses that might subsequently be used by farmers within the boundaries of the irrigation scheme. The prevailing water use efficiency in surface water resources schemes are typically low which can be substantially improved.

<table>
<thead>
<tr>
<th>Irrigation Methods</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conveyance</td>
<td></td>
</tr>
<tr>
<td>• through unlined canal for surface water</td>
<td>55 – 60</td>
</tr>
<tr>
<td>• through lined canal for surface water</td>
<td>70 – 75</td>
</tr>
<tr>
<td>Field Application for both surface and groundwater</td>
<td></td>
</tr>
<tr>
<td>• Flood irrigation</td>
<td>65</td>
</tr>
<tr>
<td>• Furrow irrigation</td>
<td>80</td>
</tr>
<tr>
<td>• Sprinkler</td>
<td>85</td>
</tr>
<tr>
<td>• Drip</td>
<td>90</td>
</tr>
<tr>
<td>Overall efficiency for surface water system</td>
<td>30 – 65</td>
</tr>
<tr>
<td>Overall efficiency for groundwater system</td>
<td>65 – 75</td>
</tr>
</tbody>
</table>

Source :- CWC Guidelines for Improving water use Efficiency

The overall efficiency of conventional irrigation project is around 30 to 40%. The capital investment of any irrigation project varies from 6 lakhs to 15 lakhs. Hence investment for enhancing water use efficiency will be fruitful considering tremendous scope for the same.

3.0 Water Use Efficiency & National water Policy

The National Water Policy of India was issued in year 2012. One of the objectives of the policy is as follow.

“Given the limits on enhancing the availability of utilizable water resources and increased variability in supplies due to climate change, meeting the future needs will depend more on demand management, and hence, this needs to be given priority, especially through (a) evolving an agricultural system which economizes on water use and maximizes value from water, and (b) bringing in maximum efficiency in use of water and avoiding wastages.”

4.0 National Water Mission

The National Water Action plan on Climate Change (NAPCC) was prepared by government of India, Which has been released by the Hon’ble Prime Minister on 30th June 2008. National water Mission was part of NAPCC.

The main objective of the National Water Mission is “conservation of water, minimizing wastage and ensuring its more equitable distribution both across and within States through integrated water resources development and management”. The five identified goals of the Mission are: (a) comprehensive water database in public domain and assessment of impact of climate change on water resource; (b) promotion of citizen and state action for water conservation, augmentation and preservation;
(c) focused attention to vulnerable areas including over-exploited areas; (d) increasing water use efficiency by 20%, and (e) promotion of basin level integrated water resources management.

4.1 Increasing water use efficiency by 20 percent
One of the most important goals of the National Water mission is to improve the efficiency of water use at least by 20% by year 2017. The objective can be achieved by ensuring improved efficiency both on the demand-side as well as the supply-side. Research in the area of increasing the water use efficiency in agriculture, industry and domestic water is very important strategy. Similarly, full utilization of the created facilities and better design and proper operation and maintenance would considerably help in improving the efficiency on supply-side. Use of micro-irrigation, promotion of water neutral and water positive technologies, recycling of water etc. are also very important measures for increasing the efficiency. At the same time adoption of better management practices are also very important.

An analysis shows that modernization and renovation of existing old projects, command area development including selective lining of water courses etc. may increase the overall irrigation efficiency by about 20-21%. The main strategies included under the goal “Increasing water use efficiency by 20%” are (a) promotion of water-efficient techniques and technologies; (b) Undertake Pilot projects for improvement in water use efficiency in collaboration with State; (c) Promote Water Regulatory Authorities for ensuring equitable water distribution and rational charges for water facilities; (d) Promote mandatory water audit including those for drinking water purposes; (e) Adequate provision for operation & maintenance of water resources projects; (f) Incentive through award for water conservation & efficient use of water; and (g) Incentivize use of efficient irrigation practices and fully utilize the created facilities.

5.0 Policies adopted by State of Maharashtra
Govt. of Maharashtra (GoM) adopted various strategies for enhancing water use efficiency. The predominant strategies are as follows:

5.1 Adoption of Micro-irrigation (MI) Systems
Maharashtra is the water-scarce state. The per capita water available is 300 m³ which is much below universal norm of 1000 m³. Hence adoption of micro-irrigation system is evitable. The horticulture crops, sugarcane & cotton can be covered under drip & most of the other crops under sprinkler irrigation. Maharashtra is the leading state having about 23 lakh ha under MI. Maharashtra has adopted various policies to promote MI-

a) MI for perennial crops in canal command area
In Maharashtra, sugarcane is cultivated on around 10 lakh ha of which 6.14 lakh ha are cultivated under the canal command. A major share of irrigation water goes to sugarcane & the farmers have the tendency to apply excessive water to sugarcane. But only @ 30% of the total sugarcane area is irrigated by the drip system. There is a growing conflict between sugarcane farmers & non-sugarcane farmers.
In order to ensure that the aforesaid issue do not assume serious proportions in the future, the Government of Maharashtra in its ‘State Regulatory Authority Act 2005’ have emphasized the judicious use of water resources in the State. In Para 10.4 of the Maharashtra State Water Policy (2003), the optimal development and use of the State’s water resources is advocated through the promotion of research & development as well as the state-of-the-art technology in
the water sector. The Maharashtra Water Resources Regulatory Authority (MWRRA) Act 2005, in Section 14(4), states as follows:
“Water shall not be made available from the canal for perennial crops in such area and from such date as may be notified by the Authority, unless the cultivator adopts drip irrigation or sprinkler irrigation or such other water saving technology, approved by the Authority. The quantity of water so saved, after satisfying the future increased demand of drinking water, shall be distributed equitably in the command area and the adjoining area” MWRRA has issued notification in this regard on 25th June 2015 & It’s proposed to implement above stipulation on eight projects in priority & it would be made applicable to the entire state from June 2019

b) Decentralized storages in command area for Micro-irrigation
The open canals have rotation period of 12 days which practically extends even upto 30 to 40 days due to various unavoidable reasons. But micro-irrigation needs daily supply of water. Localised storage in the reach of every farmer is the prerequisite to promote MI. Hence GoM issued resolution dated 2nd May 2017 to create decentralized storages in the command area considering blocks of approximately 100 ha. Even the storages already created in the command area can be used for this purpose. The Irrigable Command Area (ICA) of Tembhlu LIS is 80,472 ha distributed in 217 villages of three districts viz, Satara, Sangli & Solapur. The entire command area is drought-prone but the farmers are well versed with MI. The cropping pattern as per the project report is: 20% perennial (grapes); 19% two seasonal, 32 % rabi, and 10% hot weather (groundnut). There is no provision for sugarcane in the project cropping pattern. In view of increasing farmers’ inclination towards cultivation of grapes and sugarcane, the cropping pattern has been revised comprising 20% sugarcane, 30% orchards, 10% vegetables and 40% other crops. As per the proposed cropping pattern, area under sugarcane will be 26,624 ha. In the year 2016-17 the total area under sugarcane was 11,782 ha; of which 4308 ha were equipped by drip system. According to the proposal, there will be saving of Rs. 633 Crores as compared to the earlier planning without decentralized storages.

c) Projects having entire command Area under MI -
In conventional irrigation project, water distribution system is not linked with method of Irrigation. But need of the hour, is to think & act in totality. Hence few projects have been taken up having MI from the inception & integral part of the project.
i) Dehani LIS in Yavatmal district having 6068 ha command area is planned. The scheme is functional for 2000 ha.

ii) Arvi LIS in Wardha district and Waghur project in Jalgaon district having command area 8400 ha and 9969 ha respectively is being executed. Thus in all MI on 24,437 ha area is already being executed.

d) Micro-irrigation through CADWM Programme-
The Command Area Development & Water Management (CADWM) programme of Govt of India insisted for minimum 10% command area under micro-irrigation. The scheme facilitates for supporting system required for MI like pumps, sump etc.

5.2 Pipe Distribution Network (PDN) in Command Area
The conveyance efficiency of open canal varies from 55 to 75 % which is major factor for reduction of water use efficiency. The conveyance efficiency achieved through pipe distribution network is up to 95%.

When the New Land Acquisition Act came into force from 1st January 2014, the land cost increased substantially. In many instances the cost of open canal plus land acquisition is more than PDN. Considering all these facts & circumstances GoM has issued detailed guidelines in year 2017 to promote PDN. The proposed area through PDN in the state is about 6.15 lakh ha. The Irrigation Development Corporation (IDC) wise status is as below.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Name of IDC</th>
<th>Total Area proposed under PDN</th>
<th>Area on which works are completed</th>
<th>Area on which tendering is completed / in progress</th>
<th>Area under Survey &amp; planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Vidarbha Irrigation Development Corporation (VIDC)</td>
<td>179272</td>
<td>620</td>
<td>79728</td>
<td>98914</td>
</tr>
<tr>
<td>2.</td>
<td>Maharashtra Krishna Valley Development Corporation (MKVDC)</td>
<td>241956</td>
<td>25584</td>
<td>136816</td>
<td>79556</td>
</tr>
<tr>
<td>3.</td>
<td>Tapi Irrigation Development Corporation (TIDC)</td>
<td>129580</td>
<td>7034</td>
<td>43939</td>
<td>78607</td>
</tr>
<tr>
<td>4.</td>
<td>Godavari Marathwada Irrigation Development Corporation (GMIDC)</td>
<td>33902</td>
<td>10757</td>
<td>9339</td>
<td>13806</td>
</tr>
<tr>
<td>5.</td>
<td>Konkan Irrigation Development Corporation (KIDC)</td>
<td>30240</td>
<td>0</td>
<td>1169</td>
<td>29071</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>614950</strong></td>
<td><strong>43995</strong></td>
<td><strong>271001</strong></td>
<td><strong>299954</strong></td>
</tr>
</tbody>
</table>
6.0 Reforms & measures for enhancing water use efficiency
GoM has undertaken various reforms in irrigation management which directly or indirectly increase in water use efficiency.

6.1 Water Auditing of Irrigation Projects
Water audit is the scientific approach to analyze water accounts of the project. It determines sectoral water use & also amount of water lost from distribution system. The system performance can be judged & action can be initiated for reduction in losses. Conveyance efficiency, water use pattern, Irrigation system performance are few indicator used for water auditing. WRD, GoM is carrying out the water audit since 2003-2004.

6.2 Benchmarking of Irrigation Projects
Benchmarking is the tool for analyzing & improving the performance of Water Resources projects. Each project can be compared based on performance indicators and hence it is very useful for continual improvement. There are eleven indicators for system performance, agricultural output, financial analysis & social aspects. Benchmarking is being done from year 2001 – 02.

7.0 Reuse of Urban Wastewater –
GoM issued policy to reuse the treated wastewater for thermal power plants, industries & other non-potable purposes. It is the prime responsibility of the municipalities to reuse the treated wastewater. Action plan is to be prepared within one year & commissioned within the next three years. Dam water supplies for all such industrial areas & power plants located within 50 Km of the municipality would be withdrawn for non-potable use, once the treated wastewater is available.
Treatment plan of 40 MLD is being set up by the Navi Mumbai Municipal Corporation to supply the treated water to nearby industrial area

8.0 Conclusion
Enhancing water use efficiency is one of the alternatives to face the growing crisis of water scarcity. Irrigation is the major user of water and therefore has the high potential for improvement in its efficient use.

The state has already taken steps like water auditing & benchmarking of irrigation projects. Promotion of micro-irrigation in the canal command area would help reduce the water demand for irrigation as most of the water-intensive crops are grown in the command area of irrigation projects. MWRRA already notified that cultivators of perennial crops must adopt water saving technologies. GoM decided to adopt policy of creation of decentralized storages to support the micro-irrigation. The PDN policy will help saving of water substantially. The pilot projects like Dehani LIS & Arvi LIS are the beginning of adoption of large-scale of drip irrigation in the command area. CADWM Programme is also promoting lining of water courses & MI. The goal of increasing water use efficiency by 20% will be achieved through all these measures & consistent efforts.

References:
- Central Water Commission – Guidelines for Improving Water Use efficiency in Irrigation, Domestic & Industrial Sectors, November 2014
- Maharashtra Water Resources Regulatory Authority Act 2005
- Ministry of Water Resources, GoI – Operation guidelines of PMKSY.
- National Water Policy, 2012
- Notification issued by MWRRA on dated 27/1/2015
- Patil E.B. & Dr. Belsare Sanjay- Policy & Institutional Reforms in Water Resources Sector in Maharashtra State, India.
1. Background

Maharashtra occupies the western and central part of the country and has got 720 km long coastline along the Arabian Sea and is fortified naturally by Sahyadri and Satpuda mountain ranges. The Maharashtra state has geographical area 307.58 Lakh ha., gross cropped area of 231.75 lakh ha. which includes net sown area of 174.06 lakh ha. and area sown more than once about 57.69 lakh ha. Total area under irrigation is 17.9 %. The state is surrounded by Gujarat to the North West, Madhya Pradesh to the North, Chhattisgarh to the East, Telangana to the south east, Karnataka to the South and Goa to the South West. For the administrative convenience, State has been divided into 36 districts and 6 revenue division (Konkan, Pune, Nashik, Aurangabad, Amravati and Nagpur). Maharashtra has typical monsoon climate with tropical conditions with three distinct seasons. The state has nine agro-climatic zones based on rainfall, soil type and the vegetation.

Maharashtra is one of the water stressed states. State Government has been endeavoring to up-scale area under micro-irrigation system through various schemes. National Mission on Micro-Irrigation Scheme (NMMI), Vidarbha Intensive Irrigation Development Programme (VIIDP), Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) and Jalyukta Shivar Yojana play important role in the promotion of Micro-irrigation system in the State.

In Maharashtra, agriculture is the largest user of water which consumes more than 80 % of the State’s exploitable water resources. Due to this, the groundwater is depleting fast. Under these circumstances, the State has consistently stressed the need of water and steps should be taken to use available water and land resources more effectively and efficiently.

Micro-irrigation especially drip irrigation plays an important role in ensuring efficient...
use of water by improving quality of produce and reducing cost of cultivation. In view of these advantages, Drip Irrigation has become very popular amongst orchard growers, especially in the areas where water availability is limited. Government of Maharashtra has been providing subsidy since 1986 through various schemes to encourage farmers to adopt drip irrigation system.

2. Development of Micro-irrigation in the State

Maharashtra State has always been at the forefront in adopting modern agricultural practices/technologies. State Govt. has implemented Micro-irrigation on large scale as a campaign during last three decades. Micro-irrigation systems help to save water up to 35 to 40%, increasing the production, helps to produce better quality of fruits, vegetables and other crops, reduces pests and disease incidence, saves labour, electricity and fertilizer cost. By keeping in view these objectives, the state has implemented its own scheme for Micro-irrigation from 1986-87. From 1991, Centrally Sponsored Micro-irrigation Scheme has been implemented within the state with the state share. The National Mission on Micro-irrigation has been implemented during 2010-11 to 2014-15. During 2014-15 Government of India converted “National Mission on Micro-irrigation” into” On Farm Water Management” as a submission of “National Mission for Sustainable Agriculture”. From 2014, Govt. of India (GoI), has decided to implement this scheme as a Centrally Sponsored, Micro-irrigation Scheme under PMKSY. The GoI has changed the funding pattern of centrally sponsored schemes under PMKSY to 60:40 (Centre: state) from 2015-16. The financial assistance for Micro-irrigation from 2015-16 is being made available under the Centrally Sponsored Scheme called Pradhan Mantri Krishi Sinchayee Yojana (PMKSY). The results of the study conducted by A Narayanamoorthy show that water saving and water use efficiency of different crops cultivated under drip method of irrigation is significantly higher when compared with those under flood method of irrigation. Productivity as well as profit of different crops is also found to be higher with the crops cultivated under drip method of irrigation. This new irrigation technology also helps to save considerable amount of electrical energy used for lifting water from wells. Benefit-cost ratios with different discount rates indicate that drip investment in sugarcane, banana and grapes cultivation remains economically viable even without subsidy. In Maharashtra the total area under Micro-irrigation up to March, 2018 under subsidy programme is about 23.10 lakh ha., out of which 16.60 lakh ha are covered under drip irrigation and 6.50 lakh ha. under sprinkler irrigation. Table 1 shows the year-wise area covered under drip and sprinkler irrigation from 1986-87 to 2017-18. Table 2 shows the district wise coverage of Micro-irrigation. At present, almost all horticulture growers use Micro-irrigation systems particularly for grape, pomegranate, banana and the area of other cash crop like sugarcane, cotton and turmeric is also increasing rapidly.
### Table 1. Year-wise coverage of Micro-irrigation from 1986 up to March 2018 (Hectare)

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Year</th>
<th>Drip Irrigation</th>
<th>Sprinkler Irrigation</th>
<th>Total Area</th>
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<td>1990-91</td>
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Table 2. District-wise coverage of Micro-irrigation from 1986 up to March 2018 (Hectare)

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<tr>
<th>Sr.</th>
<th>District</th>
<th>1986-87 to 2017-18 (Area in Hectare)</th>
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</table>
Revenue Division-wise drip and sprinkler irrigated area is shown in Figure 1, while Figure 2 shows crop-wise area covered under micro-irrigation system since 1986 up to March 2018.

Figure 1. Area Covered under Micro-Irrigation System in the State since 1986 upto March 2018 (in Hectare)

Coverage of Micro-Irrigation System since 1986 to March 2018 (in Hectare)

Figure 2. Crop-wise area covered under micro-irrigation system since 1986 up to March 2018

Cropwise Area covered under Micro-irrigation System (in %)
Crop wise area covered under mi from 1986 up to march 2015 (Table 3)

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Crop</th>
<th>Area in Lakh Hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cotton</td>
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<tr>
<td>2</td>
<td>Sugarcane</td>
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<td>3</td>
<td>Other Crop</td>
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<td>4</td>
<td>Vegetables</td>
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<td>Banana</td>
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<td>6</td>
<td>Pomegranate</td>
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<td>7</td>
<td>Citrus group Crops</td>
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<td>Grape</td>
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<td></td>
<td><strong>Total</strong></td>
<td><strong>23.10</strong></td>
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</tbody>
</table>

3. Per Drop More Crop (Micro-irrigation) Component of PMKSY

Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) launched on 1st July 2015, with the objective to achieve convergence of investment in irrigation sector at field level. The scheme aims at providing end-to-end solutions in irrigation supply chain, viz. water sources, and distribution network and farm level applications. PMKSY not only focuses on creating water sources for assured irrigation, but it is also creating protective irrigation by harnessing rain water at micro level through ‘Jal Sanchay’ and ‘Jal Sinchan’. Micro-irrigation is an integral component of the scheme to maximize water use efficiency at farm level.

4. Objectives of Per Drop More Crop (Micro-irrigation)

The main objectives of the Per Drop More Crop (Micro-irrigation) programme are as under:

1. Increase the area under Micro-irrigation technologies to enhance water use efficiency.
2. Increase productivity of crops and income of farmers through precision water management.
3. Promote Micro-irrigation technologies in water intensive/consuming crops like sugarcane, banana, cotton etc and give adequate focus to extend coverage of field crops under Micro-irrigation technologies.
5. Promote Micro-irrigation technologies in water scarce, water stressed and critical ground water area.
6. Link tube-well / river-lift irrigation projects with Micro-irrigation technologies for best use of energy both for lifting and pressurized irrigation as far as possible.
7. Establish convergence and synergy with activities of on-going programmes and schemes.
8. Promote, develop and disseminate Micro-irrigation technology for agriculture and horticulture development with modern scientific knowledge.
9. Create employment opportunities for skilled and unskilled persons, especially unemployed youth for installation and maintenance of Micro-irrigation systems.

5. Pattern of Assistance and Procedure to Release Subsidy

The pattern of assistance payable to the beneficiary under the Micro-irrigation scheme is 55 % for small and marginal farmers and 45 % for other farmers. The subsidy payable to the beneficiary will be limited to an overall ceiling of 5 hectare per beneficiary.

a. Mandatory criteria for the selection of Farmers

1. Own Land on farmers name,
2. Irrigation source; If there is no irrigation source mentioned in the 7/12 then self-declaration should be mandatory about well. Self-declaration is also essential if irrigation available from the respective (water conservation/water resources department) like canal,
3. Irrigation facility (pump set, Diesel engine, Solar engine),
4. Permanent electricity connection,
5. Caste Certificate,
6. If the group of farmers apply for the micro-irrigation set then the group members shall submit bond certificate,
7. After receiving pre-sanction approval, farmers should purchase drip/sprinkler set from the authorized dealer/distributor within 30 days.

b. Documents Required to release Subsidy
1. Online Application Form
2. Aadhar card
3. 7/12 Certificate
4. 8 A Certificate
5. Land Marking Graph
6. Bank Passbook copy linked with Aadhar Card
7. Self-declaration form
8. Spot Verification Form
9. Bill proof
10. Pre-sanction letter
11. Design or map of the micro-irrigation installation in field prepare by company representative
12. Photograph with latitude/longitude of the plot
13. Pre-sanction letter
Farmer receives all the information through SMS and email

A flow chart showing step by step for application and disbursement of subsidy is shown in Figure 3.

Implementation Time line for Micro-irrigation under subsidy scheme is shown below

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<th>Sr. No</th>
<th>Implementing Stage</th>
<th>Time Line</th>
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<td>I.</td>
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<td></td>
<td></td>
<td>Division to District office 2 Days</td>
</tr>
<tr>
<td></td>
<td></td>
<td>District to Taluka office 2 Days</td>
</tr>
<tr>
<td>II</td>
<td>Auto Pre-sanction</td>
<td>Immediate (As per Availability of Funds)</td>
</tr>
<tr>
<td>III</td>
<td>Installation of MI Set</td>
<td>30 Days</td>
</tr>
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</table>

Figure 3. Flow chart showing step by step for application and disbursement of subsidy
### Implementing Stage Time Line

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<tr>
<th>Sr. No</th>
<th>Implementing Stage</th>
<th>Time Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV</td>
<td>Online Scrutiny of proposal</td>
<td>7 Days</td>
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<tr>
<td>V</td>
<td>Spot Verification</td>
<td>10 Days</td>
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<tr>
<td>VI</td>
<td>Subsidy calculation &amp; payment</td>
<td>5 Days</td>
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(Note: Average 60 days of time required to disburse subsidy amount to beneficiary from the date of Installation)

### c. Indicative cost of Drip Irrigation System for calculation of subsidy (Table 4)

**(Cost in Rs.)**

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<th>Spacing (m x m)</th>
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<th>2 ha</th>
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<td>64084</td>
<td>99665</td>
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<td>72759</td>
<td>112065</td>
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<td>116042</td>
<td>177345</td>
<td>246276</td>
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<td>80599</td>
<td>152551</td>
<td>229637</td>
<td>312784</td>
<td>389511</td>
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<tr>
<td>1.2x0.6 (or lower spacing)</td>
<td>50388</td>
<td>112237</td>
<td>213400</td>
<td>323019</td>
<td>435788</td>
<td>545181</td>
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</table>

### d. Indicative Cost of Sprinkler Irrigation System (Table 5)

#### i. Portable Sprinkler Irrigation System

**(Cost in Rs)**

<table>
<thead>
<tr>
<th>Area</th>
<th>Pipe Dia. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>63</td>
</tr>
<tr>
<td>Upto 1 ha</td>
<td>19542</td>
</tr>
<tr>
<td>Upto 2 ha</td>
<td>28213</td>
</tr>
<tr>
<td>Upto 3 ha</td>
<td>NA</td>
</tr>
<tr>
<td>Upto 4 ha</td>
<td>NA</td>
</tr>
<tr>
<td>Upto 5 ha</td>
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</table>

#### ii. Micro Sprinkler Irrigation System (Table 6)

<table>
<thead>
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<th>Area (ha)</th>
<th>Spacing (m x m)</th>
</tr>
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<tbody>
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<td>1 x 1</td>
</tr>
<tr>
<td>0.4</td>
<td>29613</td>
</tr>
<tr>
<td>1</td>
<td>58932</td>
</tr>
<tr>
<td>2</td>
<td>103581</td>
</tr>
<tr>
<td>3</td>
<td>149305</td>
</tr>
<tr>
<td>4</td>
<td>201612</td>
</tr>
<tr>
<td>5</td>
<td>254872</td>
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</table>
iii. Mini Sprinkler Irrigation System (Table 7)

<table>
<thead>
<tr>
<th>Area (ha)</th>
<th>Spacing (mxm)</th>
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<tbody>
<tr>
<td></td>
<td>10 x 10 8 x 8</td>
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<tr>
<td>0.4</td>
<td>41363 43023</td>
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<tr>
<td>1</td>
<td>85212 94028</td>
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<tr>
<td>2</td>
<td>160013 170118</td>
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<tr>
<td>3</td>
<td>242982 263361</td>
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<tr>
<td>4</td>
<td>312752 344013</td>
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<td>5</td>
<td>383123 425355</td>
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iv. Semi-Permanent Sprinkler System (Table 8)

<table>
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<th>Cost (in Rs)</th>
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<tr>
<td>0.4</td>
<td>22557</td>
</tr>
<tr>
<td>1</td>
<td>36607</td>
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<td>2</td>
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<tr>
<td>3</td>
<td>94218</td>
</tr>
<tr>
<td>4</td>
<td>120392</td>
</tr>
<tr>
<td>5</td>
<td>146053</td>
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v. Large Volume Sprinklers (Rain-gun) (Table 9)

<table>
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<tr>
<th>Area (Ha)</th>
<th>Pipe Dia. (mm)</th>
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<tr>
<td>63</td>
<td>75 90</td>
</tr>
<tr>
<td>1</td>
<td>28681 34513</td>
</tr>
<tr>
<td>2</td>
<td>NA 43786</td>
</tr>
<tr>
<td>3</td>
<td>NA NA 56818</td>
</tr>
<tr>
<td>4</td>
<td>NA NA 65856</td>
</tr>
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<td>5</td>
<td>NA NA 72322</td>
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vi. Physical & Financial progress under per drop more crop scheme under PMKSY (Table 10)

<table>
<thead>
<tr>
<th>Year</th>
<th>Area covered under Micro-irrigation (Hectare)</th>
<th>Beneficiary covered</th>
<th>Expenditure (Rs. Crore)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015-16</td>
<td>135939</td>
<td>146142</td>
<td>445.98</td>
</tr>
<tr>
<td>2016-17</td>
<td>134429</td>
<td>162481</td>
<td>414.92</td>
</tr>
<tr>
<td>2017-18</td>
<td>207000</td>
<td>262000</td>
<td>690.04</td>
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### vii. Expenses under Drip Irrigation Scheme since 2010-11 to 2017-18 (Rs. In Crore), Table 11

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Year</th>
<th>Source of Fund</th>
<th>Approved Funds</th>
<th>Expenses</th>
<th>Covered Area (Rs. In Lakh)</th>
<th>No. of beneficiaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2010-11</td>
<td>1) National Micro-irrigation Scheme 2011-12 (Central share)</td>
<td>248.03</td>
<td>248.03</td>
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<td>2.15</td>
</tr>
<tr>
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<td></td>
<td>2) Rashtriya Krishi Vikas Yojana 2011-12 (Central share)</td>
<td>156.04</td>
<td>156.04</td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3) State Share (DPC)</td>
<td>100.99</td>
<td>100.99</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>TOTAL</td>
<td>505.06</td>
<td>505.06</td>
<td>2.15</td>
<td>227556</td>
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<tr>
<td>2</td>
<td>2011-12</td>
<td>1) National Micro-irrigation Scheme 2012-13 (Central share)</td>
<td>131.04</td>
<td>131.04</td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) Rashtriya Krishi Vikas Yojana 2012-13 (Central share)</td>
<td>200</td>
<td>200</td>
<td>2.86</td>
<td>295018</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3) State Scheme 2012-13 (Central Share)</td>
<td>40</td>
<td>40</td>
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<tr>
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<td></td>
<td>4) Rashtriya Krishi Vikas Yojana 2013-14 (Central share)</td>
<td>196.89</td>
<td>196.89</td>
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<td></td>
</tr>
<tr>
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<td></td>
<td>5) State Share (DPC)</td>
<td>137.41</td>
<td>137.41</td>
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</tr>
<tr>
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<td>TOTAL</td>
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<td>705.34</td>
<td>2.86</td>
<td>295018</td>
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<td>1) National Micro-irrigation Scheme 2013-14 (Central share)</td>
<td>122.77</td>
<td>122.77</td>
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<td>2) State Scheme 2014-15 (Central Share)</td>
<td>212.43</td>
<td>185.36</td>
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<tr>
<td></td>
<td></td>
<td>3) Rural Foundation Development Fund 2014-15 (Central Share)</td>
<td>120</td>
<td>101.95</td>
<td>1.42</td>
<td>165866</td>
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<td>4) State Scheme 2016-17 (Central Share)</td>
<td>4.8</td>
<td>3.88</td>
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<td></td>
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<td></td>
<td></td>
<td>5) State Share (DPC)</td>
<td>113.81</td>
<td>102.52</td>
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<td>516.48</td>
<td>1.42</td>
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<tr>
<td>Sr.</td>
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<td>Source of Fund</td>
<td>Approved Funds</td>
<td>Expenses</td>
<td>Covered Area (Rs. In Lakh)</td>
<td>No. of beneficiaries</td>
</tr>
<tr>
<td>-----</td>
<td>---------</td>
<td>--------------------------------------------------------------------------------</td>
<td>----------------</td>
<td>----------</td>
<td>---------------------------</td>
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</tr>
<tr>
<td>4</td>
<td>2013-14</td>
<td>1) Rural Foundation Development Fund 2015-16 (Central Share)</td>
<td>231</td>
<td>225.98</td>
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<tr>
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<td></td>
<td>2) Remaining funds from those released for delayed proposal for the year 2012-13</td>
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<td>42.62</td>
<td>1.27</td>
<td>147691</td>
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<td>3) State Scheme 2016-17 (Central Share)</td>
<td>121.73</td>
<td>120.51</td>
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<td>66.91</td>
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<td><strong>TOTAL</strong></td>
<td><strong>466.88</strong></td>
<td><strong>456.02</strong></td>
<td><strong>1.27</strong></td>
<td><strong>147691</strong></td>
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<tr>
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<td>1) Sub-Scheme of Farm Water Management (Central Share)</td>
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<td>4) State Share (DPC)</td>
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<td>59.16</td>
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<td><strong>122469</strong></td>
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<td></td>
<td>3) State Share (DPC)</td>
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<td>46.66</td>
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<td><strong>149.14</strong></td>
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<td><strong>0.35</strong></td>
<td><strong>47106</strong></td>
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<td>1.02</td>
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<td>36.07</td>
<td>0.15</td>
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<tr>
<td>Sr. No.</td>
<td>Year</td>
<td>Source of Fund</td>
<td>Approved Funds</td>
<td>Expenses</td>
<td>Covered Area (Rs. In Lakh)</td>
<td>No. of beneficiaries</td>
</tr>
<tr>
<td>---------</td>
<td>------</td>
<td>--------------------------------------------------------------------------------</td>
<td>----------------</td>
<td>----------</td>
<td>--------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>3)</td>
<td></td>
<td>Rashtriya Krishi Vikas Yojana 2016-17 for Marathwada (Central share)</td>
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<td>42.05</td>
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<td></td>
<td>Marathwada Micro-irrigation Scheme (100 % State share)</td>
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<td>13.94</td>
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<td><strong>424.55</strong></td>
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<td><strong>162402</strong></td>
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<td>2017-18</td>
<td>Pradhan Mantri Krishi Sinchayee Yojana 2017-18 (Central and State Share)</td>
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<td>92.59</td>
<td>84.62</td>
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<td>21.26</td>
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<td>4)</td>
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<td>Rashtriya Krishi Vikas Yojana 2016-17 remaining fund for Marathwada (Central share)</td>
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<td>23.59</td>
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<tr>
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<td></td>
<td>Marathwada Micro-irrigation Scheme 2017-18 (100 % State share)</td>
<td>93.71</td>
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<td></td>
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<td>28.17</td>
<td>23.59</td>
<td>0.07</td>
<td>9611</td>
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<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>714.39</strong></td>
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<td><strong>2.08</strong></td>
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**Irrigation Development Programme— (Yearwise Financial Progress)**

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<th>Programme</th>
<th>Physical</th>
<th>Financial</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Area (Ha.)</td>
<td>Benefici. (No.)</td>
<td>Total</td>
<td>Central</td>
</tr>
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<td>2012-13</td>
<td>Vidarbha Irrigation Development Programme (Central Share)</td>
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<td>105</td>
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<td>2013-13</td>
<td></td>
<td>81.95</td>
<td>81.95</td>
<td>0.33</td>
<td>68041</td>
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<td>2014-15</td>
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<td>85.64</td>
<td>83.24</td>
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<tr>
<td>2015-16</td>
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<td>50</td>
<td>50</td>
<td>0.2</td>
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<td><strong>320.19</strong></td>
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<td><strong>GRAND TOTAL</strong></td>
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<td><strong>162467</strong></td>
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</table>

**Viii. Annual Action Plan for the year 2018-19 (Table 12)**

<table>
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<th>Component</th>
<th>Physical</th>
<th>Financial (Rs. Crores)</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>Area (Ha.)</td>
<td>Benefici. (No.)</td>
</tr>
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<td>Sprinkler IrrigationSys.</td>
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</tr>
<tr>
<td></td>
<td>a. Horticulture Crop</td>
<td>42556</td>
<td>63833</td>
</tr>
<tr>
<td></td>
<td>b. Agriculture Crop</td>
<td>63833</td>
<td>95750</td>
</tr>
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<td>2</td>
<td>Drip Irrigation Sys.</td>
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</tr>
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<td></td>
<td>a. Horticulture Crop</td>
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<td>22342</td>
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<td>b. Agriculture Crop</td>
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<td>89367</td>
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<td>group Projects under Irrigation Projects</td>
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<td>14365</td>
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<td>Contingencies</td>
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<td><strong>Total</strong></td>
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<td>285657</td>
</tr>
</tbody>
</table>

**ix. Role of manufacturing companies & their Registration under MI scheme**

The companies willing to participate in the scheme ensure supply of quality product as per BIS standards and can provide prompt after sales services. Registration of Micro-irrigation system manufacturers shall be done with the approval of SLSC for a period of five years. Micro-irrigation Manufacturers registered during 2016-17 is shown in Table 13.

**Table 13**

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Micro-irrigation System</th>
<th>No of Manufacturers registered</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Drip Irrigation</td>
<td>26</td>
</tr>
<tr>
<td>2</td>
<td>Sprinkler Irrigation</td>
<td>24</td>
</tr>
<tr>
<td>3</td>
<td>Both Drip &amp; Sprinkler Irrigation</td>
<td>55</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>105</strong></td>
</tr>
</tbody>
</table>
6. **E-Thibak software for Micro-irrigation**

E-Thibak has been developed by Agriculture Department with the help of NIC, Pune since 2012-13. This software enables farmers to apply online for Micro-irrigation (MI) systems. All stages of scheme implementation viz. beneficiary application, dealer's quotation, pre-sanction, bill invoicing, spot verification, subsidy fixation and payment, real time reporting are covered in the software. The entire process is online and transparent thereby increasing efficiency and reducing chances of corruption. Dealers have access to online customer data and can schedule after sales services. Manufacturers get to see dealer wise, crop wise customer data and get dealer performance reports. The software is developed covering all aspects and performing End to End process.

7. **Initiatives taken by State for upgrading micro-irrigation scheme in the state**

- Farmers application entry will be open for whole year.
- Online manufacturer registration software is developed.
- Manufacturers registration/renewal open throughout the year.
- Application with Minimum Documents
- Farmers registration is done with the help of AADHAR number.
- Subsidy is being transferred in Beneficiary’s AADHAR linked bank account.
- Auto generated Pre-sanction letter
- For increasing transparency & farmers awareness, SMS to farmers registered mobile number will be sent at various implementing stages through e-thibak.

8. **Micro-irrigation-potential in the State**

Maharashtra has enormous potential for Micro-irrigation (Table 14). Potential area for MI is also expected to increase faster due to fast decline of irrigation potential. Various crops that are suitable for drip and sprinkler method of irrigation are extensively cultivated in different parts of the State. Prevailing trend shows that, both narrow and wide spaced crops can be grown under drip and sprinkler method of irrigation. Due to various measures taken by the Central and State governments along with the support of Drip manufactures, the area under has been increasing rapidly.

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Crop</th>
<th>Total Area (Lakh Ha)</th>
<th>Area so far (Lakh Ha) covered</th>
<th>Available potential (Lakh ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DRIP IRRIGATION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Fruits</td>
<td>15.65</td>
<td>5.51</td>
<td>10.14</td>
</tr>
<tr>
<td>2</td>
<td>Vegetable</td>
<td>7.26</td>
<td>1</td>
<td>6.26</td>
</tr>
<tr>
<td>3</td>
<td>Spices</td>
<td>1.09</td>
<td>0.1</td>
<td>0.99</td>
</tr>
<tr>
<td>4</td>
<td>Plantations</td>
<td>2.14</td>
<td>0.01</td>
<td>2.13</td>
</tr>
<tr>
<td>5</td>
<td>Flowers</td>
<td>0.23</td>
<td>0.1</td>
<td>0.13</td>
</tr>
<tr>
<td>6</td>
<td>Sugarcane</td>
<td>9.65</td>
<td>2.89</td>
<td>6.76</td>
</tr>
<tr>
<td>7</td>
<td>Cotton</td>
<td>39.42</td>
<td>5.41</td>
<td>34.01</td>
</tr>
<tr>
<td>7</td>
<td>Others</td>
<td>4</td>
<td>1.58</td>
<td>2.42</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>79.44</strong></td>
<td><strong>16.60</strong></td>
<td><strong>62.84</strong></td>
</tr>
<tr>
<td><strong>SPRINKLER IRRIGATION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Groundnut, Soybean, Tur, Gram &amp; vegetables</td>
<td>89.08</td>
<td>6.50</td>
<td>82.58</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>89.08</strong></td>
<td><strong>6.50</strong></td>
<td><strong>82.58</strong></td>
</tr>
<tr>
<td><strong>GRAND TOTAL</strong></td>
<td></td>
<td><strong>168.52</strong></td>
<td><strong>23.10</strong></td>
<td><strong>145.42</strong></td>
</tr>
</tbody>
</table>

9. **Challenges in further up-scaling of Micro-irrigation**

- Use of Mi in paddy Crop is negligible
- Limitation of MI in Konkan region due to Hilly Area
- Cannal Irrigation not converted in to MI Completely
- Use of non-ISI material
- Motivation to all potential farmers
- Proper designs through professionals
(Company Engineers).
• Development of service providers
• Development of skills among farmers
• Operational research studies
• More testing centers for "Quality Control"
• Bank loans at lower interest rates

10. Policy decisions needs to be taken
Micro-irrigation reduces cost of cultivation, weed problems, soil erosion and increases water use efficiency as well as power use efficiency, besides performing as an useful devise in reducing the over-exploitation of groundwater. However, despite providing substantial amount of subsidy, the spread and coverage of drip irrigation is not very encouraging as of today due to various reasons. Some policy recommendations are given below, which may be useful for expanding the adoption of Micro-irrigation in this area.

1. The capital cost required to install Micro-irrigation is relatively high. Because of this reason, considerable percentage of farmers are unable to adopt this technology for low value crops. If Micro-irrigation system is made available with low cost, area under Micro-irrigation can be increased at a faster rate. Therefore, measures can primarily be taken to reduce the fixed cost of Micro-irrigation by promoting research and development activities as well as reducing some taxes of manufacturing industries.

2. The rate of subsidy provided through government schemes is fixed uniformly for both water intensive as well as less water intensive crops. This needs to be restructured. Special subsidy programme may be introduced for water-intensive crops like sugarcane, banana, vegetables, etc. Differential subsidy rates can be fixed based on the types of crops and the rate of consumption of water. Uniform level of subsidy schemes currently followed for water-scarce and water-abundant areas need to be changed and higher subsidy should be provided for those regions where the scarcity of water is acute and exploitation of groundwater is very high as well.

3. Inadequate information about the operation, maintenance and usefulness of Micro-irrigation is one of the main reasons for its uneven spread across the state. Farmers still do not have full knowledge regarding the usefulness of Micro-irrigation. In fact, many farmers do not know the fact that Micro-irrigation can also be used efficiently and economically for crops like sugarcane, banana, vegetables, etc. The implementation network currently operated mainly by agriculture department does not seem to be making significant impact on the adoption of this technology due to lack of full time separate field staff. Therefore, there is a need to revamp the whole implementation network by providing separate/dedicated field functionary to increase the area and quality service.

4. Groundwater is the only source of water being used for Micro-irrigation. Water from surface sources (dams, reservoirs, etc) is not used for Micro-irrigation. Since water use efficiency under surface sources is very low owing to heavy losses through conveyance and distribution, farmers should be encouraged to use water from surface sources for Micro-irrigation. This can be done by allocating certain proportion of water from each irrigation projects only for the use of Micro-irrigation.

5. All irrigation projects are designed for surface irrigation and water is made available through canals by Rotation Systems. The cropping pattern in command area is also became stable accordingly. Micro-irrigation is pressurized system and needs to operate continuously. The present Rotation Systems as such, is not suitable for Micro-irrigation and because of this water
from surface sources (dams, reservoirs, etc) is not used for Micro-irrigation. For the continuous supply of water, storage structures (farm ponds/wells/community tanks) needs to be constructed in the command area. But the availability of land for such structures will not be easy. So, for the availability of land to construct the storage structures in command area, some Special policies to framed.

6. Both drip and sprinkler irrigation will be driven through state and central governments sponsored subsidy schemes. To earn quick profit from the subsidy programmes, many companies are marketing various sub-standard components in the market. Often the sub-standard components affect the working condition of the system which creates enormous doubt about the functioning of the system among the farmers’ mind. It is to be ensured that only good quality components having certification of Bureau of Indian Standards (BIS/ISO) are supplied to the farmers. For this there is a need to establish a Quality Testing Laboratory to deal comprehensively with the design, development and testing of all equipments, devices, machines used in sprinkler and micro systems.

7. Automation of drip/Micro-irrigation system refers to operation of the system with no or minimum manual interventions. Irrigation automation is well justified where a large area to be irrigated is divided into small segments called irrigation blocks and segments are irrigated in sequence to match the flow or water available from the water source. Automatic arrangement is to run the machinery of the farm without fully manpower. The purpose of this system is to save water, labor, energy, increase crop production and improve soil health, adopt grouping. In the state, the use of Micro-irrigation has increased in large numbers and to increase the efficiency of Micro-irrigation system, it is necessary to put a modern system in the Micro-irrigation system. hence Govt needs to frame separate programme for automation.

8. Considering the all above facts and to implement Micro-irrigation programme effectively, there is a need to introduce some regulatory mechanism in the form of Act towards its enforcement. The following aspects needs to be regulated through the Act.

- Production of MI material / components
- Supply of the components
- Quality standards of the components
- Movement and Prices
- Testing of material
- After sale Services
1. Introduction
In Maharashtra State, it is observed that due to the erratic nature of rainfall during the monsoon season there occurs a recurrent scarcity condition and dry spells during the crop growth stages adversely affecting the crop yields. Moreover, various factors namely limitations of the available irrigation infrastructure, very large tracts of the drought-prone area, shallow and degraded lands have further aggravated the challenges of agriculture development. As a result, the crop production in rainfed areas during the last four decades has been fluctuating. Unavailability of adequate moisture in the root zone depth of the soil during the crop growing period is the main reason for this situation. As per the Maharashtra Water and Irrigation Commission Report (1999), even after utilizing the full irrigation potential, about 44 percent cultivable area will still remain rainfed. Water conservation works implemented in an integrated and planned manner with coordination of all agencies can overcome the issue of water scarcity by making available drinking water to human and cattle population and protective irrigation to crops. In the year 2014, about 184 blocks (talukas) received 20 percent less than average rainfall, while groundwater level fell below three meters in 72 blocks, two to three meters in 116 blocks and one to two meters in 190 blocks. This means
188 blocks (2234 villages) had more than two meters of groundwater depletion. During the year 2011-12, there was a severe scarcity in Western Maharashtra and Marathwada. Further, it is also observed that every two years there is water scarcity in some part of the State. Over the last few years, the State has implemented ‘Series of Cement Nalla Bunds’ and ‘Mahatma Phule Jal Bhumi Sandharan Abhiyan’. Water harvesting efforts like desilting in Latur district and recharging of wells in Nanded district had also been implemented successfully. During 2012-13 Jalyukta Gaon Abhiyan was implemented in five districts of Pune region as a permanent solution to overcome droughts. An action plan was prepared jointly to harvest rainwater and increase groundwater through the coordination of all departments. In this campaign watershed works, series of cement nalla bunds, repair & renovation of old cement nalla bunds, KT weir, de-silting of water storage structures, water source strengthening, well recharge, effective use of available water and linking of streams were undertaken for water conservation. Decentralised water bodies were created through these works. Consequently, the groundwater level increased by 1 to 3 meters thereby providing adequate drinking water and protective irrigation for crops.

Taking into consideration outcome of all the aforesaid programmes, the State Government launched an ambitious ‘Jalyukta Shivar Campaign’ (Water Secured Fields) through a well-coordinated Action Plan in an integrated manner to achieve the objective of “Water for All – Scarcity-Free Maharashtra 2019” and to permanently tackle scarcity situation.

2. The objectives of the Campaign are
1. Harvesting maximum rainwater within the village area,
2. Increasing groundwater levels,
3. Increasing irrigated areas in the State – by providing protective irrigation and by increasing water-use efficiency,
4. Assuring water availability for all - Increasing water supply through rejuvenation of defunct Rural Water Supply Schemes (RWSS),
5. Implementing the Groundwater (Development and Management ) Act 2009,
6. Creating decentralized water storages,
7. Undertaking new works to increase water storage capacity,
8. Restoring/ increasing the storage capacity of all existing and defunct water bodies (bunds/ village tanks/ percolation tanks/ cement bunds),
9. Increasing the water storage capacity of existing water bodies by desilting through people’s participation,
10. Encouraging and implementing tree plantation,
11. Creating community awareness for Water Budgeting,
12. Encouraging and creating awareness for efficient water use in agriculture, and
13. Sensitizing people and increasing people’s participation in harvesting rainwater and recharging groundwater.

3. Works to be implemented under JSA
Following works will be implemented under Jalyukta Shivar Abhiyan
1. Watershed development works,
2. Construction of a series of cement nalla bunds along with nala deepening/widening,
3. Rejuvenation of old water bodies,
4. Repairing of existing minor irrigation structures (KT Weirs/storage tanks),
5. Repairs-Renovation-Restoration (RRR) of percolation tanks and minor irrigation tanks,
6. Desilting of percolation tanks/ village tanks/ storage tanks/ tanks of Chattarpati Shivaji Maharaj’s regime/ tanks of British period/ tanks of Nizam regime/ earthen nalla bunds,
7. Measures to ensure utilization to the capacity of major and medium irrigation projects,
8. Linking of small streams/ nallas,
9. Recharging of wells/ borewells,
10. Efficient use of available water,
11. Strengthening of drinking water sources,
12. Strengthening the Water User Associations, and
13. Canal repairs and maintenance.

4. Village selection criteria:
The criteria for selection of villages under Jalyukta Shivar Abhiyan as mentioned in the circular of Department of Rural Development and Water Conservation dated 02 January 2015 are as follows;
1. Village included in watershed (IWMP 1,2,3/ RIDF/ VIIDP/ Accelerated watershed/ Dryland Campaign/ Other) where more than 50% works are completed + Scarcity affected village in current year (less than 50 paisewari) + Tanker-fed village + part of Over Exploited watershed.
2. Village included in watershed (as above) where more than 50% works are completed + Scarcity affected village in current year (less than 50 paisewari) + Tanker fed village.
3. Village included in watershed (as above) where more than 50% works are completed + Scarcity affected village (less than 50 paisewari).
4. Village included in watershed (as above) where more than 50% works are completed + Scarcity affected village in last 05 years (less than 50 paisewari) + Tanker fed village + part of Over Exploited watershed.
5. Village included in watershed (as above) where more than 50% works are completed + Tanker fed village at least for one year in last 05 years.
6. Village included in a sanctioned watershed project + Scarcity affected village at least once in last 05 years.

Two additional village selection criteria mentioned in the circular of Department of Rural Development and Water Conservation dated 14 August 2015 are as follows:
i) In Yavatmal and Osmanabad district villages under criteria 1 above (over exploited) priority will be given to villages where farmer’s suicides found to be more based on the survey to be carried out.
ii) Priority will be given to the villages where the people have proactively come forward and collected contribution or have practically initiated the process for collecting contribution as per the need.

5. Convergence of Schemes:
Efforts will also have to be taken to ensure that the remaining parts of the State do not face water
scarcity in the future. For this purpose, Jalyukta Shivar Abhiyan is being implemented in all districts of the State through the convergence of funds through sanctioned schemes of different departments, MREGS, MLA/MP Funds/ District Funds/ NGOs/ CSR and people’s participation. This campaign is implemented in a mission mode through available funds of government departments, NGOs, people’s contribution and corporates (CSR) in scarcity affected talukas and rest of the State so that scarcity is not faced in future.

Funds available under different schemes should be utilised for implementation of Jalyukta Shivar Abhiyan. Planned activities should be completed by converging funds available for different schemes under respective account heads. Similarly, people’s participation should be initiated in order to complete tasks undertaken in the campaign.

6. Village Plans:
It is possible to conserve soil and water in the select villages using well-developed technologies. Potential Treatment Maps are very useful to undertake water conservation works in watershed areas in a scientific manner through a study of satellite images.

Based on the study of scientific parameters like geomorphology, land capability, soil depth, soil erosion, and land slope undertook using the GIS system, specific zones for area treatment and gully control are decided.

Action Plan maps used in Jalyukta Shivar Abhiyan are prepared using state-of-art technology in Remote Sensing & GIS. High-end technologies developed by Maharashtra Remote Sensing Application Centre (MRSAC), Nagpur, Groundwater Survey & Development Agency (GSDA), Pune, National Bureau of Soil Survey & Land Use (NBSSLUP), Nagpur are used and these maps are prepared by Vasundhara Watershed Development Agency (VWDA), Pune. Soil and water conservation work to be undertaken in watershed areas is determined by the land capability class, land slope, soil erosion, contours, geomorphology, lineaments, etc. All these parameters are studied in the software programme developed to prepare village-wise action plans.

Funds available in different government schemes, NGO contribution, CSR, Cooperative Societies and people’s contribution are considered while preparing these action plans. While preparing the work plan at district level targets and fund requirement are finalised for 1) completion of existing water conservation works on priority, 2) new works, 3) repair and de-silting of existing works and water bodies. In order to prepare a village action plan, various government officials such as Gramsevak,
Talathi, Agriculture Supervisor, Agriculture Assistant, Section Engineer, Junior Engineer are required to participate in shivar pheri (village transect). The District Collector will appoint Extension Officer (Agriculture)/ Circle Agriculture Officer/ Circle Officer (Revenue); and will participate in the shivar pheri along with Sarpanch, gram panchayat members, and progressive farmers. Action plans are prepared considering the village needs and these plans are approved in Gram Sabha. These village plans are consolidated at taluka and then at the district level to prepare taluka and district work plans. All concerned departments participate in preparing the work plan of Jalyukta Shivar Abhiyan.

However, since 2017-18 all field agencies were instructed to consider Village Watershed as planning unit instead of Village Area. The village area is generally distributed in one or two micro-watersheds. Instructions are issued to include the area of a village micro watershed falling outside the village boundary while preparing the plan. Watershed boundaries are clearly indicated in the proposed action plan and field agencies have been instructed to follow the ridge-to-valley principle. In case any area of a village falls beyond the ridge such an area should be fully included in the action plan. Works included in the action plan are categorised as: 1) Completing on-going and incomplete soil conservation/ water conservation works, 2) Repair and rejuvenation works of existing works necessary to restore its planned irrigation potential, 3) Area treatment works like Deep CCT, CCT, compartment bunding, graded bunding, gabion bunds, well recharge, farm ponds, etc. 4) De-silting of tanks, nala deepening, widening and de-silting of nalla; all such works will have minimum budget allocation of 70 percent in the village action plan while 30 percent will be allocated for new cement nalla bund and KT weir. Clear instructions are given through government circular dated 23 May 2017 that drainage line works should not be started before completing at least 70 percent of the area treatment works.

7. Preparing Village-level Water Budget: - Village Water Budget is necessary for the scientific implementation of Jalyukta Shivar Abhiyan. Important parameters considered while preparing the water budget of the village are given below:

- Actual Rainfall in the watershed area,
- Net Runoff,
- Gross Water Availability in Watershed,
- Actual Needs of village a) for drinking and b) for irrigation,
- Calculate run-off harvested and balance run-off, also run-off harvested through different
works and need for additional run-off harvesting, and

- Priority of new works/ activities to fulfill the
  water needs of the village 1) CCT / Deep
  CCT, 2) Farm Pond, 3) Gabian Bunds, 4)
  Cement Nala Bunds, 5) New K.T. Weir/
  Percolation Tank / Minor Irrigation Tank /
  Village Tank, 6) Interlinking of small rivers/
  streams/ nalas, 7) Forestry/ pasture land
  development, and 8) Well Recharge.

Instructions are issued to prepare action plans
for villages selected in Jalyukta Shivar Abhiyan
considering water budget. Accordingly, action
plans were prepared considering water budget in
villages selected during 2015-16 and 2016-17.
Indian Institute of Technology, (IIT) Mumbai
was requested to prepare revised guidelines
for water budget. Accordingly, IIT Mumbai
has prepared a draft of the revised guidelines.
It considers parameters like soil moisture,
evaporation. The draft prepared by IIT Mumbai
is attached.

8. Net Planning of Village:
Net Planning of Village will include basic
information of the village, water budget of the
village watershed, a summary of Annexure C
of government resolution dated 05 December
2014, potential work plan maps and abstract of
estimates, as per the instructions. These village
plans are then sanctioned.

9. Implementation and monitoring:

A) District Level Committee
- District Collector will be the nodal officer
  for implementation of the Scarcity-free
  Maharashtra Campaign. A committee is
  constituted under the District Collector
  all information, statistics related to
  implementation is compiled in the prescribed
  format.
- Regular review of the implementation of
  works at the district level.
- Regular reporting to Divisional
  Commissioner about implementation status
  and measures undertaken at the district
  level. Sub-campaign of reports related to
  problems, challenges in implementation to
  the Divisional Committee.
- Creating awareness at the district level, ensuring increased people’s participation,
  encouraging best performers with awards
  and implementing the plan as per schedule
  and taking administrative actions against
  those failing in implementation.
- Monitoring the Jalyukta Shivar Abhiyan
  at every stage. District Collector and Chief
  Executive Officer will jointly review works
  undertaken by various agencies.

B) Divisional Committee
- Divisional Commissioner will be the
  nodal officer at the division level for
  implementation of Scarcity-free Maharashtra
  Campaign. This committee will compile
  all reports related to implementation of this
  campaign received from district committees
  and review the same.
- The committee will submit these reports,
along with its recommendations and
  comments about problems, challenges in
  implementation, wherever required, to a
  special cell in the Department of Water
  Conservation.

C) Coordination/ Monitoring Cell
- An interactive website is developed by the
  department to ensure Online Monitoring
  of this Abhiyan in the next five years.
  Coordination and monitoring cell is
  established in the department of Water
  Conservation, which obtains reports from
  Divisional Commissioners to send them
  to respective departments/officers for their
  comments and a compiled report is submitted
to the cell set in the Hon. Chief Minister’s
  Office.
- Jalyukta Shivar Abhiyan is an ambitious
  programme of the State Government
  and therefore, Hon. Chief Minister, Hon.
  Minister (Soil & Water Conservation),
  Hon. Chief Secretary and Secretary (Soil &
  Water Conservation) review this programme
A ‘High Power Committee’ is constituted under Hon. Chief Secretary for effective implementation of Jaluyakta Shivar Abhiyan as per the GR dated 7 January 2015 and its members are Additional Chief Secretary/ Principal Secretary/ Secretary of Agriculture, Finance, Planning, Water Resources, Command Area, Energy, Rural Development, Water Supply & Sanitation, Relief & Rehabilitation, while Secretary, Water Conservation is the Member Secretary of this committee. The committee will be responsible to make adequate financial provisions for the schemes included in Jaluyakta Shivar Abhiyan, providing additional funds, policy revision of these schemes, re-allocation of funds, promote convergence of people’s contribution, CSR, NGO contribution, etc. It will also make fundamental changes in any of the resolutions to achieve physical and financial targets. Periodic meetings of this committee will be organized.

- Computer software is developed by MRSAC for effective implementation of Jaluyakta Shivar Abhiyan that includes all types of updated information ranging from village action plan to completion certificate. One data entry operator for each taluka, district and division is appointed. Project Management Unit (PMU) is formed in Mantralaya and monitoring is done through the PMU. Information of the software developed by MRSAC is attached.

- Concurrent monitoring is done in Jaluyakta Shivar Abhiyan and third-party evaluation is conducted after completion of works.

11. Outcomes of the campaign:
GIS-based photographs (latitude & longitude) and other information is compiled and uploaded to determine the outcomes of Jaluyakta Shivaar Abhiyan. Jaluyakta Shivar Abhiyan (JPA) was launched from 2015-16 and 6202 villages were selected during 2015-16, 5288 villages during 2016-17, 5028 villages during 2017-18 totaling 16,518 villages out of which 15037 villages were made water neutral. In these villages till 26th November, 2018 it is reported that 5,44,706 works were completed and 8,810 works are in progress. This Abhiyan is being implemented as people’s movement and works of about Rs. 637.47 crores through people’s contribution. Water harvesting potential of 2.435 million thousand cubic meter (TCM) is created through the works completed. Of the total 16,518 villages, 100 percent works were completed in 15037 villages, 80 percent and above in 1091 villages and more than 50 percent works in 304 villages. The following tables (1 to 4) show the impact of Jaluyakta Shivar Abhiyan in Maharashtra:

Kharif season in JSA villages included in 2015-16

<table>
<thead>
<tr>
<th>Name of Crop</th>
<th>Productivity increase in percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearl millet</td>
<td>10.16</td>
</tr>
<tr>
<td>Pigeon Pea</td>
<td>61.90</td>
</tr>
<tr>
<td>Green Gram</td>
<td>9.78</td>
</tr>
<tr>
<td>Black Gram</td>
<td>19.6</td>
</tr>
<tr>
<td>Cotton</td>
<td>58.5</td>
</tr>
</tbody>
</table>

The data reveals that there is a marginal increase in the productivity (yield) of about 10% of pearl millet and green gram, moderate increase in black gram (about 20%) and marked increase of about 60% in pigeon pea and cotton.
Division-wise analysis shows that increase in the Rabi area in the state is about 2.08 lakh hectares (19% over 2014-15); Nashik, Pune & Nagpur are lower than the state average; whereas Kokan, Aurangabad and Amravati are above the state average. Predominantly, the kharif crop in Kokan and drought-affected Aurangabad division have shown the highest change.

Table 2. Division-wise Rabi area in hectares in 2014-15 and 2016-17

<table>
<thead>
<tr>
<th>Division</th>
<th>2014-15</th>
<th>2016-17</th>
<th>Increment in percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kokan</td>
<td>9662</td>
<td>12433</td>
<td>28.7</td>
</tr>
<tr>
<td>Nashik</td>
<td>190969</td>
<td>223884</td>
<td>17.2</td>
</tr>
<tr>
<td>Pune</td>
<td>259107</td>
<td>284776</td>
<td>9.90</td>
</tr>
<tr>
<td>Aurangabad</td>
<td>368257</td>
<td>464988</td>
<td>26.30</td>
</tr>
<tr>
<td>Amravati</td>
<td>187891</td>
<td>226434</td>
<td>20.50</td>
</tr>
<tr>
<td>Nagpur</td>
<td>66832</td>
<td>77915</td>
<td>16.60</td>
</tr>
<tr>
<td>State (JSA Villages)</td>
<td>1082719</td>
<td>1290431</td>
<td>19.20</td>
</tr>
</tbody>
</table>

Table 3. Water Tanker Supply Situation

<table>
<thead>
<tr>
<th>Date</th>
<th>Tankers in number</th>
<th>Number of Villages being supplied by Tanker</th>
<th>Number of Hamlets being supplied by Tanker</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.5.2016</td>
<td>5423</td>
<td>4600</td>
<td>7418</td>
</tr>
<tr>
<td>22.5.2017</td>
<td>1343</td>
<td>1424</td>
<td>3437</td>
</tr>
<tr>
<td>21.5.2018</td>
<td>1470</td>
<td>1405</td>
<td>1047</td>
</tr>
</tbody>
</table>

Table 4. Change in Groundwater level (JSA Villages)

<table>
<thead>
<tr>
<th>Period</th>
<th>Percentage Where GWL increases</th>
<th>Percentage Where GWL is maintained</th>
<th>Percentage change in rainfall in comparison with 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 2016</td>
<td>81</td>
<td>13</td>
<td>-8</td>
</tr>
<tr>
<td>January 2017</td>
<td>69</td>
<td>21</td>
<td>-8</td>
</tr>
<tr>
<td>October 2017</td>
<td>52</td>
<td>21</td>
<td>-19</td>
</tr>
<tr>
<td>January 2018</td>
<td>54</td>
<td>20</td>
<td>-19</td>
</tr>
</tbody>
</table>

The groundwater levels of October 2016, January 2017, October 2017 and January 2018 show that the water levels in the wells have increased as compared to the 5-year average of the baseline years for the respective months. It may be noted that this gain in groundwater levels is in spite of deficit rainfall. During 2016 and 2017 there was a deficit rainfall in the state ranging between 8% and 19%.

12. Conclusion:
The government’s ambitious program has now become a people’s movement, since increased groundwater levels and protective irrigation capacity have helped to increase crop productivity, thus benefitting the farmers.
1. Introduction:

The rainfall in Maharashtra has seen a steadily decline over the past few years. This has adversely affected the agriculture yield in the arid areas. In view of the water scarcity in the state with irregular rainfall, government has launched ‘Magel Tyala Shettale’ (Farm Pond on Demand). The GR regarding this was issued on February 17, 2016. The scheme was formulated after thorough analysis of watershed and irrigation in arid areas based on the rainfall percentage in the state. Aim of this scheme is to provide sustainable and protected irrigation facility to the farmers.

The funds for this scheme are provided by the relief and rehabilitation department under Draught Mitigation Measures. The said scheme is controlled by the Department of Employment Guarantee Scheme under the planning department, while implementation in the field by Agriculture Department. All the farmers who own agricultural land can avail the benefits of the scheme. The target is set at 1,12,311 farm ponds under the scheme.

2. Objectives of the Campaign:

Farm Pond On Demand Scheme is being undertaken under “Water for All – Scarcity Free Maharashtra” considering the recurring scarcity
conditions in the State.

1. Harvesting maximum rainwater within the village area
2. Recharge and Increasing groundwater levels
3. Increasing protective irrigation facility
4. Creation of decentralized water storages
5. Creating community awareness for Water Budgeting
6. Encouraging and creating awareness for efficient water use in agriculture
7. Sensitize people and increase peoples’ contribution to harvest rainwater and recharge groundwater

3. Eligibility criteria under the ‘Farm Pond on Demand’ scheme:
   • Farmer should own at least 0.60 Hectare agriculture land. There is no maximum limit for land ownership.
   • Site should be technically fit for the farm pond.
   • Already benefited applicant in the scheme like farm pond, common farm pond or well, should not eligible.
   • Farmers of BPL category and Survivors of suicide family are given priority in this scheme.
   • According to the GR dated 11.09.2016, farmers in East Vidarbha can avail the benefits of either farm pond or Bodi.
   • Considering the geographical circumstances and land holding capacity of the Konkan region, the condition of minimum land holding is relaxed to 0.20 hectare from 0.60 hectare, while the maximum depth for a farm pond without inlet and outlet in the salt pans along the coast has been relaxed to 2 meter from 3 meter.
   • The condition for 0.60 hectare minimum land ownership has been relaxed in Tribal Sub Plan (TSP), vide GR dated 02/08/2017 to 0.40 hectare.
   • In Murmad region it has approved as a ‘Recharge Measure’ vide GR dated 26.11.2018.

4. Implementation and monitoring:
   To maintain transparency and hassle-free procedure regarding selection of the beneficiaries, online applications are invited from the farmers. The applications are accepted on ‘Aaple Sarkar’, the portal created with the help of MahaOnline. The applications received are scrutinised as per the criteria in GR. The technical verification of the survey number of the land, is done by the department for site selection. The taluka level committee under the chairmanship of Sub Divisional Officer (Revenue) selects the beneficiaries having technically suitable site. The taluka agriculture officer issues work (commencement) order to the selected beneficiary. Once the work (commencement) order has been issued, the beneficiary has to start digging at the selected spot as per the design and layout. After completion beneficiary has to upload completion certificate as per the work completion on the website. Then Regional Officer of Agriculture Department visit to the site and conduct physical verification of the dimensions, also geotagged photograph of the farm pond is uploaded to the website via a Farm Pond Mobile App developed by MRSAC. The subsidy due for the complete farm pond is directly transferred in the bank account of the beneficiary.

5. Types of Farm Ponds:
   The farm ponds are created to store the runoff water and facilitate it to recharge in the ground. The water stored in the pond or recharged can be used during the scarcity or in dry spell as protective irrigation. Inlet is provided to collect the runoff water and outlet for flow out excess water. In some cases, where there are natural streams near the land of beneficiaries, farm ponds without inlet and outlet are preferred and filled by lifting the
flowing water from natural streams with the help of pump. Thus, there are two types of farm pond 1) with inlet and outlet and 2) without inlet and outlet.
Farm ponds with seven different dimensions are available under the scheme. Farmers can demand the dimensions depending upon the available land. The dimension of the farm pond is finalised according to the technical criteria of available watershed area to collect runoff water.

Dimensions of the Farm Pond and Payable Subsidy:

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Dimension (Mtr)</th>
<th>Payable Subsidy in Rs (Side Slope 1:1)</th>
<th>Payable Subsidy in Rs (Side Slope 1:1.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Farm Pond with inlet and outlet</td>
<td>Farm Pond without inlet and outlet</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Farm Pond with inlet and outlet</td>
<td>Farm Pond without inlet and outlet</td>
</tr>
<tr>
<td>1</td>
<td>15x15x3</td>
<td>22110</td>
<td>18312</td>
</tr>
<tr>
<td>2</td>
<td>20x15x3</td>
<td>29706</td>
<td>24980</td>
</tr>
<tr>
<td>3</td>
<td>20x20x3</td>
<td>40467</td>
<td>34770</td>
</tr>
<tr>
<td>4</td>
<td>25x20x3</td>
<td>50000</td>
<td>44603</td>
</tr>
<tr>
<td>5</td>
<td>25x25x3</td>
<td>50000</td>
<td>50000</td>
</tr>
<tr>
<td>6</td>
<td>30x25x3</td>
<td>50000</td>
<td>50000</td>
</tr>
<tr>
<td>7</td>
<td>30x30x3</td>
<td>50000</td>
<td>50000</td>
</tr>
</tbody>
</table>

6. Subsidy:
The subsidy is directly transferred to the bank account of the beneficiary after completion and verification by field officer. The subsidy of Rs 50,000 or the actual cost of digging the farm pond, (as per the guidelines dated 22.02.2016, whichever is less) is deposited in the bank account of the beneficiary. The 100% subsidy is benefited for the farm pond with dimensions less than 25x20x3 meter while the cost of the bigger farm ponds is high, the same is capped at Rs 50,000. This means small sizes farm ponds get 100% subsidy.

7. Evaluation of the Scheme:
As per the GR, Rambhau Mhalgi Prabodhini, Pune is entrusted for evaluation of the ‘Farm Pond on Demand’ scheme. The 5% of the 44,279 farm ponds completed by the end of September 2017, which is 2214 farm ponds, were evaluated during April to June 2018. The major inferences of the evaluation carried out on regional level are as under –
1. The Farm Ponds have resulted in water level increase in the well of 29% beneficiaries.
2. During the Kharif season, 37% beneficiaries have used stored water to protective irrigation during dry spell of monsoon. On an average 1.70 hectare land was irrigated and crop was saved.
3. According to 29% beneficiaries, the Farm Ponds have resulted in increasing irrigation area during Rabbi Season. The average increase during Rabbi Season was 0.76 hectare.
4. The 15% beneficiaries have taken the benefits of allied activities such as dairy, livestock, poultry, vegetable, horticulture and fisheries.
5. With the help of farm ponds, 33% beneficiaries diverted to vegetable, horticulture and fodder, thereby changing the crop pattern.

8. Achievement:
The target for farm ponds is set at 1,12,311. Out of these, 30208 farm ponds were completed in 2016-17. The subsidy of Rs 115.43 Cr was paid against 25,246 farm ponds.
Similarly, in the year 2017-18, Rs 218.15 have been spent on 46,364 farm ponds. The funds of Rs 130.00 Cr have been received in the year 2018-19, which is being distributed at regional level.

9. Present Condition:
The progress report as on 01/12/2018 (2016-17 and 2017-18)
- Funds received till today Rs: 466.70 Cr
- Number of application received: 371382
- Eligible applications after scrutiny: 293372
- Technically suitable site: 249609
- Work (commencement) order issued: 207784
- Work in progress: 3027
- Farm Ponds completed: 102068
- Subsidy paid Farm Ponds: 90504
- The amount of subsidy paid: 419.60 Cr
10. Conclusions:
The government’s ambitious program now converted into a people’s movement, resulted in increase groundwater level and protective irrigation capacity which help in increasing the productivity of farmers. Figure 1a and 1 b., shows the Division-wise completed Farm ponds and their share in percentage. The regional distribution of the completed projects Nagpur 10,174, (10%), Konkan, 1032 (1%), Nashik 21166 (21%), Pune 14787 (14%), Aurangabad, 35,508 (35%) and Amravati 19401 (19%).
PRESENT SCENARIO OF WATER CONSERVATION AND SMALL-SCALE IRRIGATION SCHEMES IN MAHARASHTRA

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Small Scale Irrigation (Water Conservation), Pune.
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Introduction

As per the Census 2011, the total population of Maharashtra is about 11.24 crores, which is 9.29% of the total population of India. The total geographical area of Maharashtra is 308 lakh Ha and comprises 36 districts and 255 talukas. Geographically, Maharashtra is the third largest state in India, while based on population, it is second largest. The state is largely agrarian, with a cultivable area around 75% (234 lakh hectares) to the total area. Majority of the population in the state is dependent on agriculture and agricultural allied activities, and hence agriculture is the backbone of economic development of Maharashtra. In this context systematic planning and development of irrigation and sustainable management of the created resource will definitely increase the employment generation and improve the standard of living of the populace. Multipurpose use of the irrigation infrastructure – drinking and industrial use – also addresses water demand for domestic and industrial use.

In 1999, the Maharashtra Irrigation Water Commission enumerated that with the use of surface water and groundwater, around 85 lakh Ha area could be brought under irrigation. Hence a combination of major, medium and minor irrigation projects is vitally important for agricultural development. However, the scope for major and medium irrigation projects is considerably reduced due to issues pertaining to land acquisition, rehabilitation, need for huge capital investments and also long gestation period. On the other hand, small-scale irrigation schemes, minor irrigation schemes, can be completed within a short period of 3 years and can expedite the benefits provided to the farmers. These schemes are also suitable to cover remote and hilly areas where conventional gravity fed dam-canal network might not suffice.

Considering the above the Government of Maharashtra has formed Water Conservation Department (WCD) through a Government Resolution dated 30.09.1992.

Water Conservation Department (WCD)

The WCD is expected to work on construction and maintenance of minor irrigation projects having capacity up to 250 Ha. Further too expedite the maintenance, development and regulation of minor irrigation schemes and to undertake watershed and soil conservation, Water Conservation Corporation was formed in August 2000. The office is currently headed by Managing Director stationed at Aurangabad. For effective implementation of Soil and Water conservation schemes, and construction of irrigation projects up to 600 Ha command area, the Government has also
formed Commissionerate for Soil and Water Conservation at Aurangabad vide the GR Dated 31.05.2017.

The Water Conservation Department is entrusted to do following types of works:

A. Minor Irrigation / Small Scale Irrigation works having irrigation potential unto 600 Ha.
B. Jalyukta Shivar Abhiyan and River Rejuvenation Works.
C. Galmukta Dhara and Galyukta Shivar.
D. Repairs of Maji Malgujari Talav
E. Area Treatment works.

Activities of the Water Conservation Department

A. The Minor Irrigation / Small Scale Irrigation works:
These works are undertaken as per the Minor Irrigation Manual (MI Manual) 1983 which takes into consideration:


II. Topography: (i) Coastal strip of Konkan and (ii) Deccan Plateau; the dividing range commonly called Sahyadri runs almost parallel to the Arabian Sea Coast at a distance varying from 25 to 40 Kms, from one end of the state to the other. The coastal plain is interspersed with numerous low spurs of the main Sahyadri range, which makes it a very hilly and undulated region and serves as a river basin for a large number of west flowing rivers.

III. River Basins: The main river basins formed in the Deccan plateau include: (a) Krishna Basin – extending from the Mahadeo range starting from the Mahabaleshwar hills up to the southern border of State, an area of 20.53 lakh Ha. Of which 15.78 lakhs Ha. (39 lakh acres) of culturable land; (b) Bhima Sub Basin - This basin lies between the Balaghat range, is narrow and hilly in the west and broader and flatter in the east, an area of 48.90 lakh Ha. and 41.28 lakh Ha. of culturable land. (c) Godavari Basin (Proper)

The Water Conservation Department undertake different type of MI works. These include:

a) Tanks (M.I. / S.S.I. Projects) / Storage Tanks
b) Bandharas K.T. Weirs / C.N.B’s
c) Repairs and Renovation of Tanks and Bandharas, Mama Talav.
d) Land Drainage Schemes
e) Tube Wells
f) Lift Irrigation Schemes
g) Construction of new wells, installation of pumping sets, boring and blasting of wells etc.

B. Jalyukta Shivar Abhiyan

In Maharashtra nearly 82% area is rainfed and about 52% area is drought-prone. Overextraction of groundwater has resulted in depletion of the water table in many parts of Maharashtra. In order to eliminate water scarcity, recharge groundwater, reduced number of water tankers used for water supply and to provide facility for protective irrigation through insitu water harvesting projects the Government of Maharashtra has taken a mission programme termed as Jalyukta Shivar Abhiyan. The works under Jalyukta Shivar include:

• Construction of Cement Nalla Bandh (CNB) in chain across the Nalla or River
- Regradation, Strengthening and Deepening of Nallas
- Repairs of existing old Small Scale Irrigation Schemes
- Area treatment works by Soil Conservation Department

Over a period of time the river bed would get silted and hence it became shallow and narrow, resulting in reduction in the water carrying capacity. The groundwater recharge also got reduced. In monsoon such shallow rivers sometimes would result in flooding of the adjoining areas. To address these problem one important activity undertaken through the Jalyukta Shivar Abhiyan is the River Rejuvenation Program. A committee has been established in 2016 under the chairmanship of the Water Conservation minister and co-chairmanship of state minister for approval of river rejuvenation program. Works related to construction of cement Nalla Bandh are being taken under this programme where widening and deepening has been done. The programme also include construction of K.T. Weirs across the rivers, rejuvenation of old bodies, desilting of river, nalla and stream.

The river, nalla, stream rejuvenation works takes into account the following:
River rejuvenation works are to be taken in the drought-prone area or water scarcity area on first priority.

- Public participation is mandatory in the river, nalla and stream rejuvenation works.
- Existing structure on river, nalla, streams are to be repaired with priority.
- The catchment area treatment works adjoining to the river, nalla and stream are to be executed as a part of a project.
- The existing soil nalla bandh / cement nalla bandh in the catchment area are to be widened and deepened.
- In order to develop the entire catchment area, small bandharas are to be taken on the secondary streams / nallas.

Due to these Jalyukta Abhiyan Shivar works, following goals are achieved:
- The completion of construction of CNB in chains helped to reduce the flood and erosion of lands.
- Construction of CNB in chains created the water storages, which helps to increase the cattle feed and irrigated area (refer Table 1).
- The production capacity of farms has been approximately increased by 15% to 20%.
- These completed series of CNB store the water thereby increasing the groundwater table and water table of dug wells around the structures by 10% to 15%.
- Due to rejuvenation of dead and defunct water bodies the water flow in the rivers have improved as compared to previous flows.

### Table 1: Achievements under River Rejuvenation Program

<table>
<thead>
<tr>
<th>Sl. no</th>
<th>Name of Region</th>
<th>No of CNB Completed</th>
<th>Irrigation Potential created Ha</th>
<th>Storage created in TCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Thane</td>
<td>469</td>
<td>940</td>
<td>4690</td>
</tr>
<tr>
<td>2</td>
<td>Pune</td>
<td>4837</td>
<td>9675</td>
<td>48370</td>
</tr>
<tr>
<td>3</td>
<td>Nasik</td>
<td>7116</td>
<td>14230</td>
<td>71160</td>
</tr>
<tr>
<td>4</td>
<td>Aurangabad</td>
<td>8975</td>
<td>17950</td>
<td>89750</td>
</tr>
<tr>
<td>5</td>
<td>Amravati</td>
<td>1774</td>
<td>3550</td>
<td>17750</td>
</tr>
<tr>
<td>6</td>
<td>Nagpur</td>
<td>1411</td>
<td>2820</td>
<td>14110</td>
</tr>
<tr>
<td>Total</td>
<td>25582</td>
<td>49164</td>
<td>245830</td>
<td></td>
</tr>
</tbody>
</table>
C. Galmukta Dharan and Galyukta Shivar

There are large number of Major, Medium and Minor Irrigation Projects in Maharashtra. It is observed that every year the capacities of these dams are reducing due to accumulation of silt in the dams. But if and when those silt is deposited on agriculture land it increases the fertility of the soil. Taking this into consideration the Government of Maharashtra, through a G.R. dated 6th May 2017, has decided to remove accumulated silt and provide it to be spread over individual farms, free of cost through the Department of Rural Development and Water Conservation Department, Government of Maharashtra.

The principal feature of this programme is as below.

• Participation of local farmers
• Private and Public Participation and Partnership
• Use of updated technology
• Monitoring and Evaluation by 3rd party.

D. Repairs and Rejuvenation of Maji Malgujari Tanks

The Government of Maharashtra has planned the repair and rejuvenation of Maji Malgujari Tanks from the Nagpur, Bhandara, Gondia, Chandrapur and Gadchiroli districts from Vidarbha region. During 2016-17 to 2018-19 a total 4032 Maji Malgujari Tanks are proposed to be repaired and rejuvenated under a special programme. The works considered under this programme are repairs of Maji Malgujari Tanks by way of earthwork, head regulators etc.

Organisation Set Up and Reforms

The Water Conservation Department is formed in 1992. The staff and the engineers were the employees of Water Resources Department. The work and activity was mostly carried out as per the Government Resolutions (G.R.), Circulars and Directives received by the Water Resources Department.
The water conservation and small-scale Irrigation Works are executed from multiple sources of funds. These include: Maharashtra Water Conservation Corporation, State Pool Funds, funds from the District Planning Committee, Zilla Parishad Funds and Tribal Development Funds.

Completed, Ongoing and future plans of the Water Conservation Department
One activity of the WCD is the M.I / S.S.I. works. The details of the work are mentioned in Table 2. Under the Jalyukta Shivar Abhiyan and River Rejuvenation Works the Water Conservation Department executed near about 30747 CNBs all over Maharashtra impounding about 307470 TMC of water (Refer Table 3). The Galmukta Dharan and Galyukta Shivar programme is mostly implemented through the Revenue Department and the requisite technical guidance and services are provided by the Water Conservation Department. The details of the progress in this program is mentioned in Table 5. The details of the repair work undertaken on the Maji Malgujari tanks are mentioned in Table 4. The ongoing works on Jalyukta Shivar Abhiyan and River Rejuvenation Works, Galmukta Dharan and Galyukta Shivar programme and Maji Malgujari tanks program are listed in Table 6, Table 7 and Table 8 respectively. The future plan for the three flagship activities are also listed in Table 9, Table 10 and Table 11.

<table>
<thead>
<tr>
<th>Table 2: Position schemes of Water Conservation as on June 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title</td>
</tr>
<tr>
<td>No.of various types of Completed M.I. Schemes</td>
</tr>
</tbody>
</table>

Direct and Indirect Irrigation potential created through completed status.

<table>
<thead>
<tr>
<th>Schemes</th>
<th>Nos</th>
<th>Irrigation potential in Lakh ha</th>
<th>Utilization in Lakh ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Irrigation (Minor Irrigation Tank, Storage Tank, Kolhapur Type weirs, Lift Irrigation Schemes)</td>
<td>18413</td>
<td>6.35</td>
<td>2.37</td>
</tr>
<tr>
<td>Indirect Irrigation (Diversion Weirs, Maji Malgujari Talav, Percolation Tank, Village Tank, Cement Nalla Bandh)</td>
<td>80933</td>
<td>12.23</td>
<td>6.12</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>99346</strong></td>
<td><strong>18.56</strong></td>
<td><strong>8.49</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3: Progress in the River rejuvenation works, CNB and Jalyuka Shivar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sl. No.</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>
### Table 4: Progress in the Galmukta Dharan and Galyukta Shivvar programme

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Region</th>
<th>No: of Completed Schemes</th>
<th>Expenditure in Rs. Lakhs</th>
<th>Slit Removed Cum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Konkan</td>
<td>5</td>
<td>6</td>
<td>620</td>
</tr>
<tr>
<td>2</td>
<td>Western Maharashtra</td>
<td>51</td>
<td>52</td>
<td>163000</td>
</tr>
<tr>
<td>3</td>
<td>North Maharashtra</td>
<td>1140</td>
<td>1236</td>
<td>5767461</td>
</tr>
<tr>
<td>4</td>
<td>Marathwada</td>
<td>928</td>
<td>948</td>
<td>8186</td>
</tr>
<tr>
<td>5</td>
<td>Vidharbh Nagpur</td>
<td>192</td>
<td>138</td>
<td>1789460</td>
</tr>
<tr>
<td>6</td>
<td>Vidharbh Amravati</td>
<td>219</td>
<td>212</td>
<td>2334051</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>2535</strong></td>
<td><strong>2592</strong></td>
<td><strong>10062778</strong></td>
</tr>
</tbody>
</table>

### Table 5: List of completed repairs of Maji Malgujari Tank

Progress Report of Maji Malgujari Repairs Programme 2016-17 & 2017-18

Office - Regional Water Conservation Officer, Soil & Water Conservation Division Nagpur

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Name of Division</th>
<th>No. of Schemes included in Programme</th>
<th>No. of A. Approved Schemes</th>
<th>No. of Schemes Issued (Work Orders issued)</th>
<th>No. of Schemes (work Started)</th>
<th>Completed Schemes</th>
<th>Fund Available in Rs. Lakhs</th>
<th>Expenditure in Rs. Lakhs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M.I. Z.P. Nagpur</td>
<td>83</td>
<td>83</td>
<td>79</td>
<td>71</td>
<td>56</td>
<td>544.67</td>
<td>521.13</td>
</tr>
<tr>
<td>2</td>
<td>M.I. Z.P., Bhandara</td>
<td>493</td>
<td>482</td>
<td>482</td>
<td>466</td>
<td>466</td>
<td>3838</td>
<td>3177.44</td>
</tr>
<tr>
<td>3</td>
<td>M.I. Z.P., Gondia</td>
<td>541</td>
<td>541</td>
<td>541</td>
<td>528</td>
<td>480</td>
<td>3746.09</td>
<td>2565.94</td>
</tr>
<tr>
<td>4</td>
<td>M.I. Z.P., Chandrapur</td>
<td>520</td>
<td>520</td>
<td>520</td>
<td>494</td>
<td>350</td>
<td>3446</td>
<td>2237.09</td>
</tr>
<tr>
<td>5</td>
<td>M.I. Z.P. Gadchiroli</td>
<td>163</td>
<td>158</td>
<td>158</td>
<td>158</td>
<td>144</td>
<td>1816</td>
<td>1082.64</td>
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<tr>
<td><strong>Total Z.P. Dn.</strong></td>
<td></td>
<td><strong>1800</strong></td>
<td><strong>1784</strong></td>
<td><strong>1780</strong></td>
<td><strong>1714</strong></td>
<td><strong>1497</strong></td>
<td><strong>13390.76</strong></td>
<td><strong>9584.24</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>W.C. Division, Nagpur</th>
<th>12</th>
<th>12</th>
<th>12</th>
<th>12</th>
<th>8</th>
<th>143.75</th>
<th>143.75</th>
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<tr>
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<td>50</td>
<td>50</td>
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<td>49</td>
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<td>670.46</td>
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<tr>
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<td>W.C. Division, Chandrapur</td>
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<td>51</td>
<td>51</td>
<td>50</td>
<td>35</td>
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<td>1069.31</td>
</tr>
<tr>
<td>4</td>
<td>W.C. Division, Gadchiroli</td>
<td>36</td>
<td>36</td>
<td>35</td>
<td>35</td>
<td>25</td>
<td>714.56</td>
<td>814.56</td>
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</table>
### Table 6: Jalyukta Shivar ongoing Schemes

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Region</th>
<th>No. of On-Going Schemes</th>
<th>Estimated Cost Rs. Lakhs</th>
<th>Proposed Irrigation Ha.</th>
<th>Proposed Storage TMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Konkan</td>
<td>9</td>
<td>36</td>
<td>19</td>
<td>91</td>
</tr>
<tr>
<td>2</td>
<td>Western Maharashtra</td>
<td>749</td>
<td>7456</td>
<td>1490</td>
<td>7298</td>
</tr>
<tr>
<td>3</td>
<td>North Maharashtra</td>
<td>288</td>
<td>1630</td>
<td>575</td>
<td>2900</td>
</tr>
<tr>
<td>4</td>
<td>Marathwada</td>
<td>1056</td>
<td>2570</td>
<td>2120</td>
<td>10600</td>
</tr>
<tr>
<td>5</td>
<td>Vidharb Nagpur</td>
<td>202</td>
<td>5086</td>
<td>400</td>
<td>2020</td>
</tr>
<tr>
<td>6</td>
<td>Vidharb Amravati</td>
<td>722</td>
<td>349</td>
<td>1440</td>
<td>7200</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>3026</td>
<td>17127</td>
<td>6044</td>
<td>30109</td>
</tr>
</tbody>
</table>

### Table 7: Schemes under Galmukta Dharan and Galyukta Shivar in progress

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Region</th>
<th>No. of On-going Schemes</th>
<th>Estimated Cost Rs. Lakhs</th>
<th>Slit Removed Cum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Konkan</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Western Maharashtra</td>
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<tr>
<td>3</td>
<td>North Maharashtra</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Marathwada</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Vidarbh Nagpur</td>
<td>2</td>
<td>4</td>
<td>231000</td>
</tr>
<tr>
<td>6</td>
<td>Vidarbh Amravati</td>
<td>24</td>
<td>48</td>
<td>330912</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>26</td>
<td>52</td>
<td>561912</td>
</tr>
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</table>

### Table 8: Schemes under Maji Malgujari Tanks, ongoing

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Region</th>
<th>No. of Future Schemes</th>
<th>Proposed Cost Rs. Lakhs</th>
<th>Proposed Irrigation, Ha.</th>
<th>Proposed Storage, TCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Konkan</td>
<td>375</td>
<td>8021</td>
<td>12791</td>
<td>34368</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>375</td>
<td>8021</td>
<td>12791</td>
<td>34368</td>
</tr>
</tbody>
</table>

### Table 6: Jalyukta Shivar ongoing Schemes

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Region</th>
<th>No. of On-Going Schemes</th>
<th>Estimated Cost Rs. Lakhs</th>
<th>Proposed Irrigation Ha.</th>
<th>Proposed Storage TMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Konkan</td>
<td>9</td>
<td>36</td>
<td>19</td>
<td>91</td>
</tr>
<tr>
<td>2</td>
<td>Western Maharashtra</td>
<td>749</td>
<td>7456</td>
<td>1490</td>
<td>7298</td>
</tr>
<tr>
<td>3</td>
<td>North Maharashtra</td>
<td>288</td>
<td>1630</td>
<td>575</td>
<td>2900</td>
</tr>
<tr>
<td>4</td>
<td>Marathwada</td>
<td>1056</td>
<td>2570</td>
<td>2120</td>
<td>10600</td>
</tr>
<tr>
<td>5</td>
<td>Vidharb Nagpur</td>
<td>202</td>
<td>5086</td>
<td>400</td>
<td>2020</td>
</tr>
<tr>
<td>6</td>
<td>Vidharb Amravati</td>
<td>722</td>
<td>349</td>
<td>1440</td>
<td>7200</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>3026</td>
<td>17127</td>
<td>6044</td>
<td>30109</td>
</tr>
</tbody>
</table>

### Table 7: Schemes under Galmukta Dharan and Galyukta Shivar in progress

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Region</th>
<th>No. of On-going Schemes</th>
<th>Estimated Cost Rs. Lakhs</th>
<th>Slit Removed Cum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Konkan</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Western Maharashtra</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>North Maharashtra</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Marathwada</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Vidarbh Nagpur</td>
<td>2</td>
<td>4</td>
<td>231000</td>
</tr>
<tr>
<td>6</td>
<td>Vidarbh Amravati</td>
<td>24</td>
<td>48</td>
<td>330912</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>26</td>
<td>52</td>
<td>561912</td>
</tr>
</tbody>
</table>

### Table 8: Schemes under Maji Malgujari Tanks, ongoing

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Region</th>
<th>No. of Future Schemes</th>
<th>Proposed Cost Rs. Lakhs</th>
<th>Proposed Irrigation, Ha.</th>
<th>Proposed Storage, TCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Konkan</td>
<td>375</td>
<td>8021</td>
<td>12791</td>
<td>34368</td>
</tr>
<tr>
<td>2</td>
<td>Western Maharashtra</td>
<td>622</td>
<td>4898</td>
<td>1841</td>
<td>5458</td>
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</table>
### Table 9: Jalyukta Shivar Future Schemes

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Region</th>
<th>No. of Future Schemes</th>
<th>Proposed Cost Rs. Lakhs</th>
<th>Proposed Irrigation, Ha.</th>
<th>Proposed Storage TCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Konkan</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Western Maharashtra</td>
<td>622</td>
<td>4898</td>
<td>1841</td>
<td>5458</td>
</tr>
<tr>
<td>3</td>
<td>North Maharashtra</td>
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<td>20721</td>
<td>0</td>
<td>0</td>
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<tr>
<td>4</td>
<td>Marathwada</td>
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<td>27448</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Vidharbh Nagpur</td>
<td>1181</td>
<td>17206</td>
<td>13587</td>
<td>32908</td>
</tr>
<tr>
<td>6</td>
<td>Vidharbh Amravati</td>
<td>1211</td>
<td>157</td>
<td>291</td>
<td>1957</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>9970</strong></td>
<td><strong>70430</strong></td>
<td><strong>15719</strong></td>
<td><strong>40323</strong></td>
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### Table 10: Future Schemes under Galmukta Dharan and Galyukta Shivar

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Region</th>
<th>No. of Future Schemes</th>
<th>Proposed Cost Rs. Lakhs</th>
<th>Silt Removed Cum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Konkan</td>
<td>13</td>
<td>0</td>
<td>620</td>
</tr>
<tr>
<td>2</td>
<td>Western Maharashtra</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
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<td>3</td>
<td>North Maharashtra</td>
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<td>4924000</td>
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<tr>
<td>4</td>
<td>Marathwada</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Vidharbh Nagpur</td>
<td>152</td>
<td>197</td>
<td>4161790</td>
</tr>
<tr>
<td>6</td>
<td>Vidharbh Amravati</td>
<td>852</td>
<td>1061</td>
<td>5480464</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>1197</strong></td>
<td><strong>1512.59</strong></td>
<td><strong>14566874</strong></td>
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</tbody>
</table>
Table 11: Future Schemes under Repairs of Maji Malgujari Talav

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Region</th>
<th>No. of Future Schemes</th>
<th>proposed Cost Rs. Lakhs</th>
<th>Proposed Irrigation, Ha.</th>
<th>Proposed Storage TCM</th>
<th>Remarks</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Vidharbh</td>
<td>1200</td>
<td>19894</td>
<td>34625</td>
<td>93014</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1200</td>
<td>19894</td>
<td>34625</td>
<td>93014</td>
<td></td>
</tr>
</tbody>
</table>

Though there is no separate irrigation management Wing with the Department, the WCD is expected to form water users’ associations (WUAs) in the S.S.I. schemes which create an irrigation potential up to 250 Ha. Out of 493 schemes WUAs been formed on 472 Schemes. In case of schemes having irrigation potential between 0 to 100 Ha, out of 27776 schemes, WUAs have been formed on 1416 schemes. Thus, in total, WCD has promoted the formation of 450 WUAs. For the remaining 1439 schemes, the formation of WUAs is in progress.

Summary and Conclusions
Since 1992 the Water Conservation Department has completed 90,455 schemes (Table 12). These schemes have contributed to creation of irrigation of around 17,95,215 hectares of the land across the state. At present near about 4590 S.S.I. Works are in progress through W.C.D. The works have ensured that the goals of the Jalyukt Shivar are fulfilled. The completion of construction of S.S.I. Works and CNB in chains has helped to reduce the flood and erosion of lands. Construction of S.S.I. and CNB in chains have created water storages which has increased the irrigation area. The production capacity of farms has been approximately increased by 15% to 20% due to protective irrigation. These completed series of CNBs have stored the water which improved groundwater table and water table of dug wells around the structures by 10% to 15%. Due to rejuvenation of dead and defunct water bodies the river flow has improved as compared to the previous flows.

Table 12: Achievement of Department since its Formation

<table>
<thead>
<tr>
<th>S.N</th>
<th>Type of Project</th>
<th>Nos. Completed</th>
<th>Irrigation potential Created, Ha.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Minor Irrigation Tank</td>
<td>2109</td>
<td>223650</td>
</tr>
<tr>
<td>2</td>
<td>Storage Tank</td>
<td>539</td>
<td>14203</td>
</tr>
<tr>
<td>3</td>
<td>Percollation Tank</td>
<td>21700</td>
<td>658370</td>
</tr>
<tr>
<td>4</td>
<td>Lift Irrigation Schemes</td>
<td>2660</td>
<td>39494</td>
</tr>
<tr>
<td>5</td>
<td>Kolhapur Type weirs</td>
<td>11588</td>
<td>338482</td>
</tr>
<tr>
<td>6</td>
<td>Maji Malgujari Talav</td>
<td>6340</td>
<td>131657</td>
</tr>
<tr>
<td>7</td>
<td>Village Tank</td>
<td>9597</td>
<td>70980</td>
</tr>
<tr>
<td>8</td>
<td>Diversion Band</td>
<td>16216</td>
<td>193731</td>
</tr>
<tr>
<td>9</td>
<td>Cement Nalla Bandh</td>
<td>19706</td>
<td>124648</td>
</tr>
<tr>
<td>Total =</td>
<td></td>
<td>90,455</td>
<td>17,95,215</td>
</tr>
</tbody>
</table>

Till today Water Conservation Department has completed 90,455 schemes providing 17,95,215 Ha irrigation to farmers across the state. Presently, about 4590 S.S.I. Works are in progress through W.C.D. The details are as shown below.
<table>
<thead>
<tr>
<th>S.N</th>
<th>Type of Project</th>
<th>Nos.</th>
<th>Irrigation potential, Ha.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Minor Irrigation Tank</td>
<td>261</td>
<td>39151</td>
</tr>
<tr>
<td>2</td>
<td>Storage Tank</td>
<td>340</td>
<td>16704</td>
</tr>
<tr>
<td>3</td>
<td>Percolation Tank</td>
<td>414</td>
<td>12667</td>
</tr>
<tr>
<td>4</td>
<td>Lift Irrigation Schemes</td>
<td>30</td>
<td>4439</td>
</tr>
<tr>
<td>5</td>
<td>Kolhapur Type weirs</td>
<td>569</td>
<td>21545</td>
</tr>
<tr>
<td>6</td>
<td>Maji Malgjari Talav</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>7</td>
<td>Village Tank</td>
<td>614</td>
<td>10645</td>
</tr>
<tr>
<td>8</td>
<td>Diversion Band</td>
<td>94</td>
<td>4665</td>
</tr>
<tr>
<td>9</td>
<td>Cement Nalla Bandh</td>
<td>2268</td>
<td>15087</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>4590</td>
<td>1,24,903</td>
</tr>
</tbody>
</table>

While the water conservation department have contributed to the agrarian progress of the state through improved water control brought in by decentralized storages, the department has been constrained from non-availability of separate management organization, large vacancies of existing staff and non-availability of funds for maintenance and repairs.

References:
- M.I. Manual 1983
- M.I. Project information booklet published in July 17 by W.C.D.
- Jaluykta Shivar Abhiyan GR dated 05/12/2014.
- W.C.D. GR dated 06/05/2017.
1. Introduction

Water governance is essential to allocate available resources commensurate with demands from a multitude of water users as well as maintaining of critical ecosystems. Governance measures include formation of appropriate Acts, regulations, standards and their effective enforcement. The Government of Maharashtra took a foresighted decision in 2005 to establish a regulatory body in the water sector. The Maharashtra Water Resources Regulatory Authority (MWRRA) was constituted in 2005. The mandate given to the Authority is to regulate water resources within the State, facilitate and ensure judicious, equitable and sustainable management, allocation and utilisation of water resources, fix the rates for use of water for agriculture, industrial, drinking and other purposes and matters connected therewith or incidental thereto.
Besides the surface water resources, groundwater also contributes significantly to the State’s agriculture production as well as supplying the drinking water needs of the rural and urban population. However, unregulated development of groundwater has been posing serious challenges in its sustainable use. The State Government notified the Groundwater (Development & Management) Act, 2009 in December 2013 and the MWRRA has been entrusted to act as the State Ground Water Authority (SGWA) since June 2014. The objective of the Groundwater Act is to facilitate and ensure sustainable, equitable and adequate supply of groundwater of prescribed quality for various category of users, through supply and demand management measures, protecting public drinking water sources and to establish the State Groundwater Authority and District Level Authorities to manage and regulate with community participation, the exploitation of groundwater within the State.

2. Water Resources Regulatory Authority
Maharashtra is the first State in India to enact legislation and establish a water regulatory authority. The Authority consists of a Chairman and four Members, who are assisted by a Secretary and supporting staff. The four members are expert in the fields of water resources engineering, economics, law, and groundwater management, respectively. The State Government also nominates Special Invitees including one woman representing each of the five major river basins and having field level experience in the subjects of Authority’s domain of work. The functions of the Authority are as follows;

2.1 Key Functions as per MWRRA Act 2005
- to determine the criteria for the distribution of Entitlements by the River Basin Agencies, within each category of use,
- to determine the priority of equitable distribution of water available at the water resources project, sub-basin and river basin levels during periods of scarcity;
- to establish a water tariff system, and to fix the criteria for water charges at sub-basin, river basin and State level,
- to review and clear water resources projects proposed at the sub-basin and river basin level,
- to perform as the Dispute Resolution Appellate Authority in cases of disputes pertaining to issuance or delivery of water entitlements
- to monitor the implementation of removal of irrigation backlog as per Governor's Directive
- to promote efficient use of water, to minimize the wastage of water and to fix reasonable use criteria for each category of use;
- to support and aid the enhancement and preservation of water quality within the State in close co-ordination with the relevant State agencies
- to promote and implement sound water conservation and management practices throughout the State.

2.2 Key functions as per the Maharashtra Groundwater (D & M) Act, 2009
- to notify or de-notify any critical, overexploited and quality affected watershed areas or aquifer area and villages therein
- to prohibit drilling of deep-wells (>60 meter) as well as withdrawal of groundwater from the existing deep-wells within the notified and non-notified areas either for agricultural or industrial use.
- to ensure registration of all the owners of wells both in notified and non-notified areas and monitor registration of drilling rig
owners and operators.

- Issue directives to District Authorities for imposing prohibition on pumping of groundwater from existing deep wells and levy cess on them.
- to monitor measures taken for the protection and preservation of water quality of drinking groundwater sources.
- to refrain from polluting the groundwater sources and to take measures to restore the quality of water to the prescribed standard at the cost of polluters.
- to bring out Groundwater Use Plan and Crop Plan through participation of stakeholders.
- to identify the recharge worthy areas in consultation and to issue necessary guidelines for rainwater harvesting to recharge the groundwater.
- to constitute Watershed Water Resources Committee (WWRC) for the notified area.
- To prohibit sale of groundwater in the notified area.
- to perform the function of Appellate Authority in the matter related to groundwater development, regulation and management.
- to issue guidelines to dis-incentivize the groundwater user for taking water intensive crops.
- to issue guidelines for Rain Water Harvesting (RWH) to recharge groundwater and ensure community participation in RWH.
- Ensure implementation of Integrated Watershed Development and Management Plan (IWDMP) prepared by District Watershed Management Committees (DWMC).
- to take steps for promotion of Mass Awareness and Training Program on sustainable use of groundwater resources.

3. Water Resources of the State

Maharashtra State has about 9% of India’s population but is endowed with only 7% of country’s renewable water resources. Geographical constraints and interstate river water tribunal allocations have further put a cap on the storages / exploitation of the water within the State boundaries. The State constitutes five major river basins and has 126 billion cubic meters of average annual renewable surface and groundwater resources. However, almost 55 percent of the surface water resources are located in only one basin viz., West flowing river basin which has 25 percent of the State's population but only 10 percent of cultivable land. While remaining four basins which together constitutes 75 percent of the State's population and about 90 percent of the cultivable area have to depend on the balance 45 percent of the water resources (Figure 1). This uneven temporo-spatial availability of water resources poses a formidable challenges in meeting the growing demand of water by different sectors.

Ever growing demand for irrigating parched lands coupled with rapidly increasing urbanization and industrialization has further exacerbated the pressure on the limited freshwater resources of the State. Maharashtra has 87 major, 297 medium and 3519 minor dams in the State sector creating a live storage capacity of 43.8 billion cubic meters (BCM). In Maharashtra, the Government policy of water allocation prioritizes the drinking/ domestic use first, followed by the agricultural and industrial uses. The powers of sectoral water allocation are vested with the Government. In the year 2017-18, the total water diversions from the State sector projects was 24.3 BCM, comprising 77 percent for irrigation, 20 percent for domestic and 3 percent for industrial purposes (WRD, 2018). As regards the local
sector, there are more than 90,000 small water storage structures in the State. The average annual groundwater withdrawal is estimated at 17 BCM. Of the total 7,297 MLD sewage water generated, about 54 percent is treated and balance is released untreated in to water-bodies. Disposal of untreated/ partially treated sewage water and industrial effluents in water bodies is a serious concern both for human health and environment.

4. Criteria for Determination of Bulk water Tariff

One of the key functions of the Authority is fixing the criteria for bulk water tariff for agricultural, domestic, and industrial users. Section 11 (d) of the MWRRA Act 2005 empowers Authority to establish Water Tariff System after ascertaining views of the beneficiary, based on the principle that water charges shall reflect full recovery of O & M charges. As per Section 11 (u) : Authority shall review and revise water charges after every three years. The first tariff exercise for the period 2010-13 was carried out and the tariff order was issued in May 2011. The second tariff exercise was taken up in 2017 and the tariff order for the period 2018-20 was issued in January 2018. The proportion of water use and allocation of weightages for determining water tariff among the irrigation, domestic and industrial uses is...
shown in Figure 2. The tariff varies based on the source and location of water supply and varies from season to season in the case of irrigation. There are also incentives for using drip irrigation and for Water User Associations as also for treating of municipal sewage water and its reuse. A typical bulk water tariff for the period 2018-20 for agriculture, domestic and industrial uses is shown in Table 1. Figure 3 shows the bulk water measurement at the head of a secondary canal for supplying water to a Water User Association. The Authority has been using the tariff as a tool to enforce the measures towards prevention/alleviation of pollution of the natural streams and water bodies. The detailed Bulk Water Tariff Order can be viewed at <www.mwrra.org>.

<table>
<thead>
<tr>
<th>Use sector</th>
<th>Rs. per cubic meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture/irrigation</td>
<td>0.045 (Kharif season)</td>
</tr>
<tr>
<td></td>
<td>0.09 (Rabi season)</td>
</tr>
<tr>
<td></td>
<td>0.135 (Hot Weather season)</td>
</tr>
<tr>
<td>Domestic</td>
<td>0.15 (for Grampanchayat)</td>
</tr>
<tr>
<td></td>
<td>0.18 (Municipal councils)</td>
</tr>
<tr>
<td></td>
<td>0.25 (Municipal corporation)</td>
</tr>
<tr>
<td></td>
<td>1.25 (Township)</td>
</tr>
<tr>
<td>Industrial</td>
<td>4.8 (for process)</td>
</tr>
<tr>
<td></td>
<td>Rs.120 (for raw material)</td>
</tr>
</tbody>
</table>

5. Clearance of Water Resources Projects
The Authority also reviews and clears water resources projects proposed at the sub-basin and river basin level prior to their administrative approval by the government. This is to ensure that the new proposals are in conformity with the Hon’ble Governor’s directives pertaining to the removal of regional irrigation backlog besides compliance of economic, hydrological, and environmental viability. So far the Authority has cleared 191 projects. Equity is also to be achieved by sharing distress during
water scarcity equitably by controlling / regulating storages in a basin or a sub-basin so as to have nearly equal percentage of utilizable water in all the reservoirs by the end of October every year.

6. Dispute Resolution
The Authority is also entrusted with the quasi-judicial function of resolving water related disputes. The MWRRA receives complaints from agricultural, industrial, and domestic water users for their redressal. Hearings are held to resolve disputes, during which petitioners and respondents are allowed to put forth their stand. The MWRRA seeks expert legal opinion on the matter and issues its decision in a transparent manner. So far, the Authority has issued 56 Orders on the petitions received. Table 1 shows some key Orders:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Subject of Petition</th>
<th>Date of Order</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Release water into Jayakwadi Reservoir from upstream reservoirs for equitable distribution within the sub-basin</td>
<td>19/09/2014</td>
<td>• Reasonable use criteria for distribution of NI entitlements.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Ultra sonic metering, WW treatment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Conditions for promoting efficient use of water and minimizing wastage.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Making Mandatory to Metropolitan cities, all Municipal Corporations and Councils to get the Water Audit done from Chief Auditor W &amp; I and Publish.</td>
</tr>
<tr>
<td>2</td>
<td>Releasing water to Ujani Reservoir from the upstream reservoirs for equitable distribution in the Bhima sub basin</td>
<td>26/10/2015</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Releasing water from Kukadi Complex into the Ghod reservoir for equitable distribution in the Bhima sub-basin.</td>
<td>27/10/2015</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Releasing water from upstream dams into Girna Reservoir in the Girna sub-basin.</td>
<td>21/12/2015</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Fixation of tariff for treated sewage water released by Nasik Municipal Corporation in to Godvari River to Rattan India Company for its thermal power plant at, Sinnar.</td>
<td>13/10/2017</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Releasing water from Pavana dam to Pavan river for private lifts by prohibiting supply of water through pipeline to Pimpri-Chinchwad Municipal Corporation.</td>
<td>26/02/2018</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Making Provision of Water for Irrigation Purpose by Curtailing the Use of Water from Pench Project Complex for the Nagpur Municipal Corporation.</td>
<td>12/09/2018</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Increased allocation of domestic water supply to Pune Municipal Corporation from Khadakwasala complex.</td>
<td>13/12/2018</td>
<td></td>
</tr>
</tbody>
</table>

Orders issued by the Authority are shown in Table 2, below:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Relevant Statutory Provision</th>
<th>Date of Issue of the Order</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11 (a) 11(q)</td>
<td>September 22, 2017</td>
<td>• Reasonable use criteria for distribution of NI entitlements.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Ultra sonic metering, WW treatment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Conditions for promoting efficient use of water and minimizing wastage.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Making Mandatory to Metropolitan cities, all Municipal Corporations and Councils to get the Water Audit done from Chief Auditor W &amp; I and Publish.</td>
</tr>
</tbody>
</table>
7. Entitlement Programme
As regards the equity in water distribution in irrigation projects, the Authority, through its annual ‘Entitlement Programme’ approves water quota proportionate to each farmers’ land holding on the basis of water availability and commitments to other non-irrigation uses for irrigation projects covered under ‘Entitlement Programme’. Through the entitlements, all farmers get a right to use water. Equity is also achieved by the mandatory provision of delivering water to tail, middle and head reach farmers in that order. With the launch of the ‘Entitlement Programme’ in 6 pilot irrigation schemes in 2006, it has now been up-scaled to 256 schemes covering 1368 Water User Associations (WUAs). The Authority has been promoting Participatory Irrigation Management by encouraging formation of effective Water User Associations (WUAs) and to supply water on volumetric basis to all the WUAs in the State.

8. Reasonable Use Criteria for Distribution of Non-irrigation Entitlements

The Government Resolution (GR) dated November 17, 2016 has decided the sectoral allocation of water under Section 16A of the MWRRA (Amendment and Continuance) Act, 2011. As per the said GR, water allocated at a project level to domestic, industry & irrigation sectors is 15, 10 and 75 percent respectively. With this development, the earlier criteria of November 2012 have now been revised. After extensive stakeholder consultations, the Authority in September 2017 has issued the Criteria for Distribution of surface water entitlements by river basin agencies for domestic and industrial uses. Criteria defines reasonable use limits for domestic and industrial bulk water users. It stipulates certain conditions (in view of promoting efficient use & minimizing wastage of water) to be followed by RBA while distributing the Entitlements. The criteria also provides a formula for sharing of water in deficit years, monitoring Mechanism, and provision for Resolution of difficulties in implementation.

9. State Groundwater Authority
The Maharashtra Groundwater (Development & Management) Act, 2009 was approved in December 2013 empowering the MWRRA to act also as the State Groundwater Authority. The Act has become effective since 1 June 2014 and provides for sustainable and equitable groundwater supply and regulation with community participation. The key functions entrusted to MWRRA include: notification of over-exploited, critical, semi-critical watersheds and groundwater quality affected areas, prohibition of extraction, drilling new wells, protection
and preservation of groundwater quality, and monitoring integrated watershed development and management plan.

10. Way Forward
The Authority being the first of its kind in the country and in absence of similar institutional precedent or prior experience, it was a challenge to evolve new procedures and address their implementation at the ground level. In its decision making process, the Authority lays emphasis on effective participation of all stakeholders through wide public consultations, interactions with NGOs and civil society representatives in a transparent manner. With the given scenario of political, social, economic, administrative set up, we feel that the Authority has met with a good deal of success in setting a pace in the regulation of State’s water resources. We, however, are aware of the challenges of widening water demand – supply gap in all its use sectors and the need. The water challenges ahead of us are multifaceted, uncertain and require ‘out-of-box’ solutions keeping in view integrated and pragmatic approach in addressing those. We feel that it is just a beginning of a long journey and there is a lot to be done towards achieving the goal of equitable and sustainable use of water. ☀️
Introduction

Maharashtra is one of the progressive states in the country. Being the second largest state in India in terms of both population (11.24 Crore- census 2011) and geographical area (3.08 lakh sq. km), it is highly urbanised with 45.2% people residing in Urban areas. The Gross State Domestic Product (GSDP) at current prices for 2017-18 is expected at Rs. 19, 59,920 crore at the rate of 10% growth. For sustaining the above-mentioned growth, electrical infrastructure is important for the services it provides to the Agriculture & allied activities, Industries and Services sectors, which in turn support economic growth by increasing the productivity of labour and capital, thereby reducing the cost of production and increasing profitability, production, income and employment. The robust electrical infrastructures have always supported the economic growth in the Maharashtra. The per capita electricity consumption of Maharashtra is always more than the national average. In FY 2015-16, the per capita electricity consumption was 1247 units for the State and 1075 for the country.

Maharashtra electricity sector has rapidly grown in size and capacity. Still it is struggling to overcome the power quality, supply availability, Distribution losses, and billing issues. The State is sufficient with the power Generation; however, there are several other issues related to financial implications on the Distribution Licensees. Optimization of the resources has been a challenge in the power sector. Agricultural pumping is major contributor to the power consumption in Maharashtra. As per the recent Tariff Order of MSEDCL, 29668 MUs power has been consumed by the agricultural pumping. This is almost 29% of the total consumption in the MSEDCL. There are several efforts taken to promote energy efficiency and Demand Side Management in Maharashtra. In past, MSEDCL has implemented the agricultural demand Side Management Scheme in Mangalavedha, Solapur. Despite of the enabling provisions in the Electricity Act, 2003 and the Regulatory Framework in Maharashtra, the Utilities are struggling to implement the effective Demand

<table>
<thead>
<tr>
<th>Year</th>
<th>India</th>
<th>Maharashtra</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008-09</td>
<td>734</td>
<td>969</td>
</tr>
<tr>
<td>2009-10</td>
<td>779</td>
<td>1054</td>
</tr>
<tr>
<td>2010-11</td>
<td>819</td>
<td>1096</td>
</tr>
</tbody>
</table>
Side Management schemes in Maharashtra at large scale.

Institutional Framework:
The change in legislative framework brought in the reforms in the Indian power Sector. The Electricity Regulatory Commissions Act, 1998 mandated the Regulatory Commission to be formed at Central and State Level. Accordingly, Maharashtra Electricity Regulatory Commission in the year 1999. Further, the enactment of the Electricity Act, 2003 continued the provision of MERC under Section 82 of the Act. The Act mandated the MERC with the primary responsibility of determination of the electricity tariff under electricity price regulation, economic management and reforms of the power sector. The MERC has three-fold functions viz., quasi-judicial, quasi-legislative and executive. The functions of the MERC are very well specified in the Act.

Generation
By 31 July 2015, Maharashtra has 38,372.83 MW of installed capacity. Out of this, 28,145.20 MW generate from thermal (coal & gas) plants, 690.14 MW from nuclear plants, 3,331.84 MW from hydro plants and 6,205.65 from Renewable Energy Sources (RES) like solar, wind etc. Maharashtra Power Generation Company Ltd. (MSPGCL) has an installed capacity of 12,237 MW. This comprises Thermal (nearly 73%, i.e., 8,980 MW) and a gas-based generating station at Uran, having an installed capacity of 672 MW. The Hydro-electric projects in the State of Maharashtra have capacity of 2,585 MW. MSPGCL is simultaneously implementing capacity additions program of about 9,320 MW. Project execution works of 3,230 MW are in full swing and 6,090 MW projects are in advanced stage of planning. It is also working in the area of power generation from non-conventional energy resources, and has clear vision for Green Power for the consumers of Maharashtra. Private sectors have also installed their power generating units in Maharashtra like TATA Power, Adani Power and Reliance Infrastructure etc.

Renewable Energy
The Maharashtra Government has a very proactive approach on Renewable Energy sources. The State Government has been taking various initiatives to increase the power generation through renewable energy. Maharashtra state government established Maharashtra Energy Development Agency (MEDA) to undertake development of renewable energy. MEDA did lot of work in the field of renewable energy focusing on rural areas.

Currently, total installed Renewable Capacity in the state of Maharashtra is 6,145 MW. Maharashtra is one of the top states in India in term of the installed renewable electricity capacity. The state has conventional electricity capacity of 24,105 MW. Renewable energy has 16% share in total electricity generation capacity of the state. Wind energy dominant in all form of renewable energy in the state followed by cogeneration, solar and small hydro. Maharashtra is one of the prominent states considering the installation of wind power projects second to Tamil Nadu in India. Among the renewable sources of energy, solar energy has a huge potential for power generation in Maharashtra. There are 250-300 days of clear sun with an available average radiation of 4 to 6 kWh/sq. meter over a day. There is a capacity to generate 1.5 million units/MW/year through solar photovoltaic systems & up to 2.5 million units/MW/ year through solar thermal systems.

The actual energy shortage in Maharashtra are 0.3% MW of peak demand, lower than the estimated energy surplus of 3.5% in year 2015-16 according to ministry of power. Overall, the electricity scenario is not good in the state and needs further investment to increase power generation. Based on the current status of fossil fuel supply to the power plants, it is difficult to rely on a single source of energy in the years ahead. Renewable energy should be the future
of energy sector in Maharashtra and also in the entire country. And therefore Central as well as state government are providing various subsidies to encourage generation & use of Renewable energy. The collective encouragement to the Renewable energy sector can help to resolve electricity supply position in the state of Maharashtra.

**Power Supplied**

The Energy supplied in the State for FY 2017-18 is shown in the following table:

<table>
<thead>
<tr>
<th>Generation</th>
<th>Energy (MU’s)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maharashtra State Power Generation Co. Ltd</td>
<td>52742</td>
<td>34.20%</td>
</tr>
<tr>
<td>Independent Power Producers (IPP)</td>
<td>36256</td>
<td>23.51%</td>
</tr>
<tr>
<td>RE Generators</td>
<td>6724</td>
<td>4.36%</td>
</tr>
<tr>
<td>Central Sector power</td>
<td>47159</td>
<td>30.58%</td>
</tr>
<tr>
<td>Mumbai Generators (TPC-G and AEML-G)</td>
<td>11335</td>
<td>7.35%</td>
</tr>
<tr>
<td>Short Term Interstate Bilateral</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total Energy</strong></td>
<td><strong>154215</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

As shown in above table, during FY 2017-18, 34.20% of the energy requirement of the State was fulfilled by MSPGCL. Share of Central Sector Power Stations during FY 2017-18 was 30.58%. IPP excluding Tata Power Co. and R Infra contributed around 23.51% of the energy requirement. Around 7.35% of the energy was generated by Tata Power and R Infra.

**Pump Storage Hydro-power Plants**

The basic principle of PPS is to store energy by pumping water from a low level reservoir downstream to powerhouse into a high level reservoir at times when the demand for power is low and then by utilizing the stored water of upper reservoir to generate hydroelectric power during the peak loads periods. The Act provisions are aimed at promoting Generation including captive generation and renewable generation. Since 2003, there has been a significant improvement in the Generation Sector in the State

As a result of this, there has been a significant progress in the Generation Sector in the State of Maharashtra. Many private generating Companies have installed their generating plants in the State of Maharashtra.

**Private players in the State of Maharashtra:**

The Tata Power Company has been operating the State for generating electricity since 1905. Also, BSES Ltd. started its generation in 1996. Thereafter in recent years, many other private players such as Adani Power, Indiabulls Power, Wardha Power etc. have entered into the Generation sector of Maharashtra.

**The list of private companies with installed capacity is tabulated below:**

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Name of IPP</th>
<th>Installed Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tata Power Company</td>
<td>2027</td>
</tr>
<tr>
<td>2</td>
<td>Reliance Infra</td>
<td>500</td>
</tr>
<tr>
<td>1</td>
<td>Jindal Energy, Ramagiri</td>
<td>1200</td>
</tr>
<tr>
<td>2</td>
<td>Wardha Power Company Ltd, Chandrapur</td>
<td>540</td>
</tr>
<tr>
<td>3</td>
<td>Abhijit MADC Nagpur Energy Pvt Ltd, Nagpur</td>
<td>246</td>
</tr>
<tr>
<td>4</td>
<td>Gupta Energy Pvt Ltd, Chandrapur (60 x4)</td>
<td>60</td>
</tr>
<tr>
<td>5</td>
<td>Adani Power Maharashtra, Tirora (660 x4)</td>
<td>2460</td>
</tr>
<tr>
<td>6</td>
<td>Vidarbha Industries Pvt. Ltd. (300x2)</td>
<td>600</td>
</tr>
<tr>
<td>7</td>
<td>Indiabulls Power Amrawati Ltd. (270x2)</td>
<td>540</td>
</tr>
<tr>
<td>8</td>
<td>Ideal Energy Pvt. Ltd. (270x1)</td>
<td>270</td>
</tr>
<tr>
<td>9</td>
<td>Dharwal Infrastructure Ltd. (300x1)</td>
<td>300</td>
</tr>
<tr>
<td>10</td>
<td>Indiabulls Power Amrawati Ltd. (270x1)</td>
<td>270</td>
</tr>
<tr>
<td>11</td>
<td>Other CPP/IPP</td>
<td>491</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9504</strong></td>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

**Fuel mix in generation:-**

Generation mix of MSPGCL based on the fuel type is tabulated below:

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Type of Generation</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Thermal Generation</td>
<td>70.95%</td>
</tr>
<tr>
<td>2</td>
<td>Hydro Generation</td>
<td>23.06%</td>
</tr>
<tr>
<td>3</td>
<td>Gas Based Generation</td>
<td>5.97%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>Total</strong></td>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>
hydro-power and hybrid systems are being established to meet the energy requirements of isolated communities and areas.

**Decentralized Systems:**
Renewable energy technologies are ideally suited to distributed applications, and they have substantial potential to provide a reliable and secure energy supply as an alternative to grid extension or as a supplement to grid-provided power. Renewable energy can offer an economically viable means of providing connections to remotely located places. Some of the renewable energy technologies that are used in villages and rural areas as decentralized systems are:

- Family-size biogas plants.
- Solar street lighting systems.
- Solar lanterns and solar home lighting systems.
- Solar water heating systems
- Solar cookers.
- Standalone solar/ biomass based power generators.
- Akshay Urja / Aditya Solar Shops
- Wind pumps.
- Micro-Hydel plants.

Many of these systems have been found useful in urban and semi urban areas also to conserve the use of electricity and other fossil fuels. Solar water heating systems have helped in Demand Side Management of electricity in various cities and towns during peak hours. Standalone rooftop SPV systems are getting popular for day time diesel abatement in areas where power cuts are very high.

**Agricultural consumption:**
The agricultural power consumption is almost 29% of the total consumption in Maharashtra. However, the revenue collection is not as much to the proportion of the consumption. Section 55 (1) of the Electricity Act, 2003 mandates installation of correct energy meter to the consumer. Hence, in the past, the Commission has issued various directives to MSEDCL for metering of un-metered consumers. Although MSEDCL has not issuing any new connection without proper meter, progress of metering of un-metered agricultural consumers is relatively slower. Although, provisions of Section 55(1) of the Electricity Act, 2003 cannot be overlooked, in meantime other alternatives such as group metering or feeder metering may help in energy accounting and billing of un-metered Agricultural consumers. Hence, as an interim measure, the Commission suggested that MSEDCL should come-up with group metering / feeder metering / DTC metering scheme for un-metered agricultural consumers. Further, the Commission suggested reviewing metering status of un-metered Agricultural consumers in the subsequent tariff filing process.

The major variation in actual sales compared to sales approved in MYT order is in the Agricultural, Residential and Industrial Categories. As regards the Agriculture Category, the Commission has re-estimated the AG Index (kWh/HP/Annum) based on circle wise feeder level data provided by MSEDCL for FY 2016-17. Following table summarizes MSEDCL’s submission and the approved figures of agricultural sales, consumers, connected load and agricultural indices for FY 2016-17.

<table>
<thead>
<tr>
<th>Particulars</th>
<th>MSEDCL’s Petition</th>
<th>Approved in MYT Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Consumers (In lakh)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Un-Metered</td>
<td>15.4</td>
<td>15.41</td>
</tr>
<tr>
<td>Metered</td>
<td>25.38</td>
<td>24.65</td>
</tr>
<tr>
<td>Total</td>
<td>40.78</td>
<td>40.06</td>
</tr>
<tr>
<td>Connected Load (in lakh HP)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Un-Metered</td>
<td>78.32</td>
<td>78.27</td>
</tr>
<tr>
<td>Metered</td>
<td>127.02</td>
<td>127.19</td>
</tr>
<tr>
<td>Total</td>
<td>205.34</td>
<td>205.46</td>
</tr>
<tr>
<td>Energy Sales (MU)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Un-Metered</td>
<td>11,977</td>
<td>10,112</td>
</tr>
<tr>
<td>Metered</td>
<td>15,436</td>
<td>15,421</td>
</tr>
<tr>
<td>Total</td>
<td>27,413</td>
<td>25,533</td>
</tr>
<tr>
<td>AG Index (kWh/HP/Annum)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Tariff for Agricultural pumping:

The tariff of these Distribution Licensees is determined by the Commission as per the provisions of the Act and Tariff Regulations specified. The Commission has introduced Tariff Regulations in Maharashtra by framing MERC Tariff Regulations, 2005 and replaced it by MYT Regulations, 2011 and subsequently 2015. Distribution Licensee recovers its cost through retail Tariff. Under the Regulatory regime, Aggregate Revenue Requirement (ARR) of a Distribution Licensee is approved by the Commission to meet the prudent expenses of a particular year to carry out the distribution business of that particular year including the permissible Return on Equity (RoE). Typical expenses in case of a Distribution Company includes power purchase expenses, operation & maintenance, interest & financing, interest on consumer security, interest on working capital, depreciation, RoE and income tax. A Regulator has to balance between the Distribution licensees’ and consumer’s interest and ensuring recovery of cost of service from consumers to make the power sector sustainable.

Tariff of agricultural consumers are subsidized since beginning and are lower than Average Cost of Supply. Agricultural Tariff is cross-subsidized by other categories such as industrial, commercial and residential consumers having higher consumption. As per the provisions of National Tariff Policy, 2016 regarding reduction of cross-subsidy, it has lower tariff. Besides, the Maharashtra State Government gives subsidy to the Maharashtra State Electricity Distribution Co. Ltd. against agricultural consumers.

Maharashtra Demand:

**Monthly Average of CPD and NCPD for Distribution Licensees in FY 2017 18 (MW)**

<table>
<thead>
<tr>
<th>FY 2017-18</th>
<th>MSEDCL</th>
<th>TPC-D</th>
<th>RInfra-D</th>
<th>BEST</th>
<th>Mindspace</th>
<th>Railways*</th>
<th>Gigaplex</th>
<th>State</th>
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<tr>
<td>Apr-17</td>
<td>18064.54</td>
<td>869.14</td>
<td>1556.55</td>
<td>883.50</td>
<td>15.06</td>
<td>322.21</td>
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<td>May-17</td>
<td>17613.41</td>
<td>894.81</td>
<td>1559.94</td>
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<td>320.72</td>
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<td>Jun-17</td>
<td>16514.98</td>
<td>901.80</td>
<td>1556.70</td>
<td>906.00</td>
<td>15.28</td>
<td>318.75</td>
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<td>14.37</td>
<td>312.91</td>
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<td>1431.61</td>
<td>823.00</td>
<td>13.82</td>
<td>311.86</td>
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<td>Sep-17</td>
<td>15732.42</td>
<td>819.04</td>
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<td>311.23</td>
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<td>1431.88</td>
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<td>13.88</td>
<td>321.09</td>
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<td>1353.70</td>
<td>777.50</td>
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<td>327.40</td>
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<td>20554.63</td>
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<td>690.87</td>
<td>1221.10</td>
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<td>11.61</td>
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<td>1302.20</td>
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<td>341.45</td>
<td>3.62</td>
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<td>13.33</td>
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<td>Mar-18</td>
<td>18392.78</td>
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<td>1533.47</td>
<td>859.50</td>
<td>14.79</td>
<td>338.24</td>
<td>4.61</td>
<td>21973.55</td>
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<tr>
<td>Average</td>
<td>16942.42</td>
<td>806.31</td>
<td>1436.99</td>
<td>826.79</td>
<td>14.03</td>
<td>322.18</td>
<td>3.72</td>
<td>20352.44</td>
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Water requirement for the thermal generation:
The water requirement for a thermal power plant was earlier capped to 2.5 cubic meter of water per megawatt-hour; however, the diluted rules allow plants to use up to 3 cubic meter per megawatt-hour. This means a new thermal plant with a capacity of 1000 megawatts that is operating at 80% efficiency will now be allowed to consume about 21 million cubic meters of water a year (according to the relaxed rules), instead of 17.5 million cubic meter. In an attempt to make thermal power plants water efficient, the environment ministry in December 2015 introduced rules under the Environment Protection Act of 1986 to cap water consumption in all plants starting operation after January 1, 2017 to 2.5 cubic meters per megawatt-hour of electricity generation. The existing old plants, the rules capped water consumption to 3.5 per megawatt-hour and gave them two years’ time till December 2017 to retrofit their technology to meet the new standards. Some super-critical thermal power plants – which have the most efficient technology in terms of generating electricity per unit of fuel burnt – have been consuming as little as 2 cubic meter of water per megawatt-hour of electricity generation. Maharashtra generating companies require approximately 634 Billion Liters of water annually as per the norms specified. This is huge requirement for the thermal Generation.

Challenges:
The major contribution in the power consumption is from agricultural sector. The agricultural pumps and irrigation requirements are growing rapidly. The drip irrigation has initially started well but subsequently, the progress of drip irrigation is not matching with the growth rate of the agricultural pumping. Reasons being the unmetered Tariff, consumer unawareness, inadequate, unreliable and poor quality power supply. Maharashtra Electricity Regulatory Commission is the pioneer in Demand side management activities. MERC has first brought the concept of reduction in costly power purchase by 2% in tariff Orders in year 2007-08 to promote Demand Side Management. The Load management Charges recoverable from Commercial consumers were introduced in the year 2007-08 to promote the energy efficiency. In Order to promote DSM, in 2010, MERC has notified two demand side regulations namely MERC (Demand Side Management Implementation Framework) Regulations, 2010 and MERC DSM (Cost-effectiveness Assessment) Regulations, 2010. MERC became first Regulatory Commission in India to notify the Demand side Management Regulations. Despite of the enabling provisions in the Electricity Act, 2003 and the Regulatory Framework in Maharashtra, the Utilities are struggling to implement the effective Demand Side Management schemes in Maharashtra at large scale. Agricultural Demand Side Management is one of the solutions to mitigate the Demand and Supply challenges. The promotion of the drip irrigation, Agricultural Demand Side management, agricultural consumer Metering are the prominent areas where we should take proactive steps in future. More efforts need to be taken by the stakeholders to implement the agricultural Demand Side Management on large scale.
GROUNDWATER FOR IRRIGATION IN MAHARASHTRA: AVAILABILITY AND CHALLENGES

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Abstract
Groundwater availability in any State varies from region to region and is mainly dependent on the rainfall, topography and the geology. Maharashtra has temporal as well as spatial rainfall variability, very rugged topography and nearly 92% area of the State is occupied by the hard rock including igneous rock, Basalt (82%) and Metamorphic rocks (10%). These rocks have poor groundwater yielding (specific yield ranges from 1 to 3%) capacity, thus restricting the groundwater availability. The report on dynamic groundwater resources of Maharashtra as on 2013-14 estimates the annually replenishable groundwater resources of the State as 31.5 BCM, against which the groundwater use for all the purposes accounts for 17.9 BCM and 90% of it is used for irrigation purpose. Uncontrolled groundwater development by means of deep irrigation borewells, absence of water-based cropping pattern and community-led demand-side interventions in groundwater management are some of the challenges in the groundwater sector of the State, which needs to be tackled by participatory mode of management.

Key Words: Maharashtra, Groundwater, Geology, Specific yield, Participatory Management.

Introduction:
Groundwater has played a significant role in irrigation and drinking water development of the country. In Maharashtra, almost 80% of the rural population and nearly 30% of urban population is dependent on groundwater. Of the total irrigated area in the State, groundwater’s contribution is about 60 percent. During the green revolution era with the objective of food grain production, the pace of digging of irrigation wells simultaneously with the program of energisation of pumps got a boost.
Since there has been a continuous rise in the number of irrigation wells which were 0.5 million during 1969 which are 2.3 million as of today. During this period, many dug wells were replaced and substituted by borewells, the depth of which is increasing day by day. These deeper borewell extracts groundwater from deeper aquifer system which is not annually replenishable. Thus, increased number of dug wells and borewells have been extracting more and more groundwater compare to the annual recharge leading to overexploitation of groundwater resource threatening the drinking water sustainability in many parts of the State.

With this scenario of the groundwater resource in the State, present paper focuses on the constraints of groundwater availability and major challenges in the groundwater management.

Constraints in groundwater availability:

Groundwater availability in any State is mainly dependent on the Rainfall, Topography and the Geology, and hence the groundwater availability has the regional perspectives. Maharashtra has temporal as well as spatial rainfall variability, very rugged topography and nearly 92% area of the State is occupied by the hard rock including igneous rock, Basalt (82%) and Metamorphic rocks (10%). These rocks have poor groundwater yielding capacity.

1. Effect of Rainfall variability on Groundwater Availability:

Rainfall is the primary source for the yearly replenishable groundwater in the State and has a direct impact on groundwater recharge. The variability of rainfall is also reflected into the groundwater availability. Temporal and spatial variations in rainfall pattern, determines the groundwater availability in any region. Average annual rainfall of the Maharashtra State is around 1300 mm but it varies from 350 mm in drought-prone affected area (DPAP) to 5000 mm in high rainfall Konkan region. Along the coastal plains the rainfall is generally between 2000 to 3000 mm. In the higher elevations of Konkan and the Sahyadri Ghats, the rainfall increases between 3000 to 5000 m. After crossing over the Ghats towards east, rainfall drops suddenly along the eastern slope of Maval region to around 800 mm and within a stretch of 50 km eastwards; it further reduces to less than 600 mm (up to 300 mm). Thus the broad rain shadow belt extending from Dhule in the North through parts of Nashik, Ahemadnagar, Pune, Solapur and Satara to Sangli districts in the south where annual rainfall ranges between 350 to 600 mm forms the drought-prone area of the State of about 0.12 million sq.km. To the east of this belt, the rainfall gradually increase in E-NE direction between 700 to 1000 mm through Marathwada and western parts of Vidarbha comprising Buldhana, Washim, Akola, Amaravati and Yavatmal districts. This region is called assured rainfall region. Further eastern parts of the State covering Nagpur, Wardha, Bhandara, Gondia,Chandrapur, and Gadchiroli districts receive average annual rainfall of 1000 mm to 1600 mm (Figure.1).

Droughts of various intensities occur once in 4 to 6 years, which adversely affect the water
resource availability, agricultural produce and economy of the State as a whole. Heavy storms and dry spells of more than 12 days in a month during the monsoon are frequently occurring since last two decades. Heavy storms causes more runoff and less percolation, whereas dry spells compels farmer to withdraw groundwater during the monsoon itself to protect the kharif crops. Thus groundwater abstraction during the monsoon is increasing day by day thereby creating early water scarcity. The rainfall deficit and recharge to groundwater are in inverse proportion. It is observed that for DPAP watersheds, if the rainfall deficit is < 20% then the groundwater deficit amplifies to 35% and for assured rainfall area, with basaltic and metamorphic rocks the groundwater deficit is up to 25%. When rainfall deficit is up to 50% then the groundwater deficit goes up to 50% for DPAP area and 60% for assured rainfall area. During worst hit rainfall years i.e. rainfall < 50%, it is observed that the groundwater deficit shoots up to 60 to 80%. These facts are varying with respect to local rainfall and geology.

2. Topography and Drainage:
Maharashtra by and large form a plateau with the main N-S trending Sahyadri hill ranges in the west and E-W trending Satpura hill ranges in the North of the State. The broad features are the N-S Western Ghats with the eastward offshoots like Satmala-Ajinha Hills, Harschandra- Balaghat hills and Mahadevs Hills (Figure.2). The eastern plateau is traversed by valleys of Tapi, Godavari, Bhima and Krishna. The topography is undulating due to local hillocks and mounds. The entire geographical area is occupied by five river basins namely, Godavari, Tapi, Narmada, Krishna, and West flowing rivers. The five river basins are further divided into 25 sub-basins and further into
On the basis of physiographic variations, Groundwater Surveys and Development Agency (GSDA) has broadly divided the State into three zones as follows:

A. Runoff Zone (Highly Dissected Plateau) (HDP)
   A-Zone (28%, Area = 85258 sq.km)
B. Recharge Zone (Moderately Dissected Plateau) (MDP)
   B-Zone (44%, Area = 135638 sq.km)
C. Storage Zone (Un-dissected plateau) (UDP)
   C-Zone (28%, Area = 86193 sq.km)

Run-off zone comprises compact dense feebly jointed rock and hilly area with steep slopes more than 20%. The recharge zone is a terrain with moderate slope of 5 to 20%. The rocks are also moderately weathered and jointed and favor the groundwater recharge. The storage zone is the terrain with slope less than 5%, which is mainly plain and valleys fills surrounding to river beds. This zone favors the groundwater recharge and storage. This is the good groundwater potential zone amongst all other zones.

3. Geology and Hydrogeology:
Geology and hydrogeology plays a very important role in groundwater accumulation and transfer. Hydraulic characteristics of the rocks determine the groundwater availability in a particular region. Maharashtra State is largely covered by hard rock's with 81.25% by Basalt, the volcanic igneous rock and 10.46% by the metamorphic rocks. Out of the remaining area, 5.71% area is covered by Alluvium and 2.58% by sedimentary rocks (Fig-03). Thus 92% of the State is covered by hard rocks, which have very less specific yields (1 to 3%) and only 8% is covered by unconsolidated sediments and soft rocks which are having good specific yields (5 to 10%).
4. Groundwater resource availability and stage of extraction:

Groundwater resource in the State is estimated every after three years as per the methodology laid down by the Central Groundwater Estimation Committee (GEC), which is revised time to time. The report on dynamic groundwater resources of Maharashtra as on 2013-14 estimates the annually replenishable groundwater resources of the State as 31.5 BCM, against which the groundwater use for all the purposes accounts for 17.9 BCM and 90% of it is used for irrigation purpose. This means the stage of groundwater extraction in the State is 54% of the annually replenishable groundwater resource. Though, the State groundwater extraction figure is 54%, yet in almost one fourth of the State, the stage of groundwater extraction is nearly or more than 100%.

As per the report on Dynamic Groundwater Resources of Maharashtra for 2013-14, of the total 1531 watersheds of the State, 74 are categorized as Over Exploited (OE), 04 Critical (CR), 111 Semi critical (SC), 04 poor groundwater quality and rest 1338 are Safe.
the 353 talukas, 09 are Over Exploited, 01 are Critical and 19 are Semi-Critical and 324 are categorized as Safe (Figure 4).

5. Groundwater abstraction for irrigation:
As per groundwater resource estimation database, there are 2.168 million abstraction structures being used for irrigation purpose withdrawing 15.93 BCM of groundwater yearly. This includes 1.92 million dug wells (with pump sets) withdrawing 14.48 BCM of groundwater and 0.25 million borewells withdrawing 1.44 BCM of groundwater. As per the estimates of the 2013, total area irrigated by groundwater is around 3.5 million ha which is derived based on the groundwater applied/used during kharif, Rabi and summer and not on actual area irrigated.

The groundwater development is growing at an exponential rate in the State (Figure 5). Number of dug wells and borewells are increasing years after year. It is evident from the Figure 5 that the number of wells are increasing but the groundwater draft is not increasing accordingly, thus indicating sharing of groundwater rather than increase in well yield. The well yield has been declining because of sharing of groundwater thereby reducing irrigated area per well.

Although the data of only 249,476 irrigation borewells have been reported in the well census, this number could be much higher. Nowadays irrigation dug wells are being replaced by borewells. This trend is quite prominent in Latur, Osmanabad, Nashik, Pune, Solapur, Sangli & Satara districts (Figure 6). However, even after knowing the disadvantages of
irrigation borewells, like low dependability of yield, low discharge and low recuperation rate etc., the farmers are still opting for irrigation borewells. Increasing numbers of borewells and their depth resulted in continuous declining of groundwater levels in 190 watersheds of the State (Figure 7).

6. Challenges in Groundwater management:
Groundwater is a common pool resource and hence there is no definite ownership of the individual on it, but it is being withdrawn as if it is individual’s property. Hence every farmers wish to have dug well or borewell in his/her farm. To develop a sense of groundwater resource as a common community propriety is a big challenge in the groundwater management. Community needs to understand the simplified hydro-geological framework of the resource. This can be achieved by proper participatory groundwater approach and capacity building and training of all users. Another big challenge
towards the groundwater management is to control the race for drilling deeper and deeper borewells. Extracting groundwater from deep borewells is causing groundwater depletion in many parts of the State. Deep borewells are less sustainable than the shallower as deeper aquifers do not get replenished annually. Hence borewell depth shall be restricted to 60 m as per the directive principles of Maharashtra Groundwater (Development and Management) Act, 2009.

Supply and Demand-side interventions of groundwater management shall be understood very well by the planner as well as community. At present more focus is given to supply-side interventions i.e. augmentation of groundwater recharge by water conservation measures, but the other side of the management i.e. water saving practices through demand-side interventions is almost ignored.

Groundwater Surveys and Development Agency (GSDA) has implemented the pilot projects on Aquifer based Participatory Groundwater management in 52 villages from Satara, Jalna, Beed, Buldhana, and Aurangabad districts. Results from these projects show that the Groundwater can be very well managed by participatory approach. It is also learnt that demand-side interventions are more beneficial and contributing than the supply-side interventions. Water conservation measures undertaken in these projects could increase the groundwater recharge by 3-5% of the total recharge whereas the water saving practices of demand-side interventions could save the 20-25% of the groundwater draft. Thus more focus need to be given on water saving practices.

In order to have a sustainable agriculture growth and groundwater development, cropping pattern need to be adopted based on the availability of water in the given watershed. It is also observed in the field that farmers opt for micro-irrigation practices to save water but at the same time they increase the irrigated area. This practice results in increasing irrigated area with no water saving. Thus, real water saving can only be achieved through participatory groundwater management and cultivation of low water-intensive crops.

7. Conclusion:
Groundwater is not an infinite resource although part of it gets replenished annually by rainfall recharge. It is confined by topographical as well as hydro-geological factors. However, groundwater extraction is increasing exponentially more than the annually replenishable availability, thereby continuous decline of groundwater level in many watersheds of the State. Thus it is high time to manage this resource judiciously. Participatory groundwater management is proving to be a good management practice for the common pool resource, but mass awareness and capacity building of the community with respect to groundwater needs to be addressed on a large scale. More focus should be given to water saving practices through demand-side interventions.
1. Prelude:

The rivers are considered sacred in our country and worshipped. The beautiful hymn *Gange cha Yamune chaiva Godavari Sarasvati Narmade Sindho Kaveri Jalesmin Sannidhim Kuru* (Ahnika Sutravai, Verse 106) gives an insight that residents of this region considered the whole country from north to the south and from east to west, as one country and paid abeyance to the rivers. It shows how integrated the country was before foreigners invaded, in wave after wave. Thus, it is of prime importance that this precious resource be inventoried, managed, monitored and conserved using the best of scientific techniques.

Remote Sensing, Geographic Information System (GIS) along with Global Positioning System (GPS), with the latest addition of LiDAR and Unmanned Aerial Vehicle (UAV), provide sustainable tools for real time monitoring and management of the resources. MRSAC has been a premier institution for use and application of geospatial technology and providing valuable scientific support to the various Departments of Government of Maharashtra and Centre for the use of geospatial technology for managing and monitoring of the natural resources for over three decades.

MRSAC has successfully executed many projects in the water resources like mapping of water resources of Maharashtra, both surface water and groundwater, command area, catchment area, irrigation projects and canals, watershed mapping etc. MRSAC has a huge database of resources maps on various themes like soil, slope, geomorphology, lithology, land use/land cover, mangrove status, geology, groundwater prospect, hydrology, forest canopy, surface water, wetlands, drainages etc. There is a huge repository of satellite data of various resolution ranging from 56 m to 1.5 m of different seasons and temporal ranges. The digital elevation data from Shuttle Radar Terrain Mapper (SRTM) is also available. The digital database also contains State, district, taluka, village, cadastral boundaries as well as transport network and present 10k. MRSAC has embarked on an ambitious project of creation of the database of all base features on 4k using very high-resolution satellite (VHRS) data using 50 cm and 30 cm data under the MahaBHUMI project. The availability of satellite data on various resolution has prompted MRSAC to use the data for various applications for creation of thematic layers. The data warehouse at MRSAC related to water resources include water bodies, rivers, drainages and streams, wetlands, mangroves etc.

MRSAC has created a huge database of spatial database on various themes from 50k to the present 10k.
settlement. MRSAC has already executed several water resources projects including:

- Mapping of water bodies on 1:50,000 scale from multispectral data with area more than 2.25 ha
- Mapping of all water bodies below 2.25 ha on 1:50,000 scale as point locations
- Mapping of the pre and post-monsoon water spread
- Mapping of qualitative sedimentation levels for pre and post-monsoon for water bodies
- Mapping of aquatic vegetation in pre and post-monsoon for water bodies
- Mapping of canal network from high resolution satellite data and establishing the hydraulic connectivity
- Mapping of the various cross drainage structures, road bridges, culverts, aqueducts, regulators etc., for the canal network
- Command area map and catchment area maps for selected irrigation projects
- Various resources inputs for the location of dam - based on which actual survey can be taken up
- Mapping of Irrigation Potential achieved based on satellite data as compared to actual, for Accelerated Irrigation Benefit Program (AIBP)
- Preparation of command and submergence maps with cadastral boundaries and inputs from the satellite data giving inundation
- Impact assessment of irrigation projects
- Impact assessment of watershed development programs
- Maps showing status of various irrigation projects in a district and location of new projects
- Mapping and capture of all dams/ projects/ offices/ water resources assets of MWRD using customized mobile applications.
- Basic inputs for location of dam, catchment studies/ command studies.
- Sharing data on web through the geo-portal and querying on the data.
- Mapping of Surface water body and river mapping on 1:10k with proper nomenclature, categorization, codes representing district, taluka, inventory code and latitude and longitude. The mobile application called Jal Shruti, developed forward, already has a module designed on water bodies mapping giving the geographic location, geo-tagged photograph, local name, office which governs the water body usage.
- Categorization of water-bodies into various categories like Major/ Medium/ Minor etc. from point of view of irrigation.
- Creation of complete database of irrigation system along with canal network from high resolution satellite data up to minors and sub minors, nomenclature, hydro-structures, year wise progress in construction, gorge filling and submergence status, land acquired (parcelwise) etc. At each stage if the progress is monitored from high resolution satellite data and field photographs through mobile application, an application can be created to monitor the progress. This can be linked to the chainage wise work code, if available, work allocation date, work completion date, amount sanctioned, amount disbursed, delays, reasons for delay etc.
- Fixing preliminary canal alignment. The drawings of canal network are digitized and put on the satellite terrain data and the canal alignment can be modified accordingly.
- Irrigation scheduling and maintenance of canal
- Interstate waterbody and Intrastate river linking project planning
- Chakwise micro-irrigation system design and implementation. List of beneficiaries, amount of water released direct outlet wise, turnout wise, Water User Association (WUA) wise.
- Well irrigated areas - command wise and non-command wise.
- Mapping of Hydroelectric power projects (HEP) in Maharashtra.
• Mapping of abandoned quarries, water quality assessment and plan to put these to use.
• Mapping of mining areas and water pumped out by mining company, Beneficiary villages (cadastral wise) and plan for creation of water conservation structure so that water is conserved.
• Water Budgeting - watershed wise, taluka wise so that the amount of water available and deficit can be assessed and related to the scheduling of the tanker in case of water deficit in summer
• Mapping of red lines and blue flood lines and the areas/ built-up lying in these areas. Categorization of these areas into danger prone/ less danger prone etc.
• Disaster management w.r.t flood and emergency action plan. Use of elevation data from SRTM, LiDAR or UAV can be combined to make data more authentic.
• Disaster management w.r.t drought and emergency action plan. Use of temporal satellite data and data showing NDVI can be used.
• Land acquisition by WRD for various project with validation using very high-resolution satellite data for encroachment.
• For bigger water bodies, amount of reservoir area lost over a temporal time frame showcasing change in the area with the reason for this change.
• Submergence mapping of reservoir.
• Catchment study of reservoirs.
• Rating of reservoirs into categories like:
  » Highly ephemeral
  » Moderately ephemeral
  » Least ephemeral
• Rehabilitation mapping due to reservoir - (PAP), and the new areas allocated to the people
• Water quality mapping
• Biodiversity mapping especially related to water bodies. Preparation of digital atlas of water bodies.
• Water cess collection for various crops like sugarcane in the irrigation command by properly identifying the signature using multispectral and multitemporal data. Same policy can be followed for all cash crops.
• Result of water testing in various rivers and water bodies and their results in form of trend analysis as a pilot project
• Rejuvenation plan for Koradi lake, using water quality data and temporal data
• Mapping of water quality of various observation wells, and display of the maps as trend lines on portal
• Creation of database showing upstream and downstream location of testing sites for notified rivers and various water testing parameters like the BOD, COD level monitoring, trends and locations of domestic, agricultural and industrial polluting sources along the perennial water channel in rivers.
• Mobile application suite for complete client registration, sample collection, results declaration, money charged and received updates as well as data sharing on web with other offices for .
• Modeling for the point source pollutant and the way and direction in which the pollutant shall affect and the direction of movement, probable areas to be affected.
• Water cess collection from various dams based on water usage to be shown in the form of a geospatial layer linked with MIS (Water Cess Act 1977).
• Data Sharing between the various offices at State and National levels on website of the data created and developed by MRSAC through proper levels of security regarding various resources especially water.
• Modeling with rainwater for dilution of pollutants and trends in which the pollutant can move along the river with MIS and auxiliary data.
• Nag river and Pilli River Monitoring and implementation through evidence-based photographs through mobile application-pilot.
• Modelling shoreline changes for entire Maharashtra.
• Modelling for seawater intrusion in Maharashtra.
• Change monitoring of water-bodies – temporal
• Applications for fisheries to identify those water bodies which are suitable for fish seed, fish fingerlings or cage.

2. Applications:
The various applications developed at MRSAC are elaborated below:

• **Use of Geospatial technology for Monitoring of Water Resources:**
  Maharashtra Water Resources Department (MWRD) entrusted MRSAC with the pilot project to map the water bodies and its offices. MRSAC did a study of the entire MIS system available with MWRD, v.i.z., e-jalseva application. The e-jalseva contains data of the various projects, their components which have been classified as Dams/ barrages, KT Weirs, Lift Irrigation Schemes (LIS), Hydro Electric Power Stations (HEP). Along with this, the offices like the Independent Offices, Irrigation Development Corporations, Region Offices, Circle Offices, Divisional Offices and Sub-divisional Offices are listed. The complexities of the hierarchy of the WRD includes the merger of various offices and the closure of certain sub-divisional offices. A comprehensive study of the way WRD functions was done and it was decided that the inbuilt GPS available on the smartphones would be used to capture the picture from the field. A mobile application called JalShruti was developed by MRSAC with the option to download the master file coming from e-jalseva with data regarding projects, components, offices etc. The dashboard created contains options to capture Dams, Water bodies( not mentioned in the master file), KT Weirs, Canals and Hydro structures, Offices with proper hierarchy using geo-tagged photographs. The entire data is displayed on a portal developed to serve the various thematic layers along with information captured from field like geo-tagged images, and local names of water bodies, no. of needles inserted/ removed in case of KT Weirs and Name of hydro structure, physical status like completed/ In progress.

• **Serving Thematic Data on Web – WRD Geo-portal:**
  MRSAC has a huge repository of databases on various themes like geology, geomorphology, soils, land use/ land cover, water resources, forest cover, wetland and mangroves, transport, industries and administrative boundaries like State, district, tahsil, village and cadaster. These serve as the base for analyzing any data. A portal for serving geographic data called 'geo-portal' is designed so that all the data in MRSAC archive can be put in one place and viewed for various type of applications. The geo-portal also has the facility to display the satellite data from various sources available on the internet as a backdrop and the various themes can be displayed on them. Various geo-processing facilities like overlay, buffering, network analysis, geo-fencing etc., are also provided so that the data can be viewed with respect to the various themes. Facilities to view the data collected from field are provided so that the data can be viewed in conjunction with the data from field. There are options for query and generation of reports. The geo-portal has become a lifeline to the higher authorities of the department and the officials to keep a track of the activities and their day-to-day working and planning with the facility to view so many thematic layers overlaid one on top of the other.

• **PMKSY Project:**
  Government of India is committed to water conservation and management. The Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) is aimed at providing ‘More Crop Per Drop’.
MRSAC was entrusted to do the mapping for 26 projects by MWRD. MRSAC devised the methodology to map the entire canal network including the structures on field using high resolution satellite data. A comprehensive database has been created for these projects like the Dam/ Barrage/ KT Weir, canal network, including off taking, canal length, RDs and chainages, hydro structures, and command. The database contains all details like the canal names, canal type, physical status for that particular year, projected irrigation potential, ICA, type of dam, etc. In many projects, the canals have been converted to piped distribution network (PDN). The maps of these have been geo referenced with very high-resolution satellite data and the tentative database of the PDN has been created. The data is completely served on the web in the WRD geo-portal and can be used by the decision makers to view the status of mapping and progress.

The type of data prepared is very detailed and can be used for minute calculations and monitoring. The projects chosen under PMKSY include Gosikhurd National Project, Bembla Project, Lower Wardha, Dongargaon Project, Khadakpurna Project, Nandur Madhameshwar Project, Lower Dudhna Project, Upper Kundlika Medium Project, Upper Penganga Project, Waghur river Project, Lower Panjara Project, Lower Pedhi Project, Tillari Interstate Project, Bawanthadi Project etc. The detailed map is shown in Fig 1.

- **Accelerated Irrigation Benefit Program:**
  ISRO on behalf of CWC entrusted MRSAC, the project to map the canal network of 6 projects which were funded under AIBP. The entire canal network of each project was marked along with the hydro structures. The gaps in the network were identified. The satellite derived IP was calculated against the projected IP. The reasons for the change in IP against the projected IP was attributed and report generated.

- **Evidence Based Monitoring for Land Acquisition for Dam Construction:**
  The joint measurement for land acquisition for construction of dams, projects poses the new challenge that the affected people, at times, get 4 to 5 feet tall pomegranate or other fruit trees and plant them overnight, the moment the date for JMR is known. This way the land cost increases. TIDC approached MRSAC for the images of the period for similar case in a project. Since the period was backdated, MRSAC approached NRSC for archived very high resolution satellite data. At the same

![Fig.1 Detailed map of irrigation project created under PMKSY](image)
time all sites from which VHR satellite data is available was searched and the data of the period (7 years, 3 years and 1 year) prior to the JMR date was made available and the village wise cadastral map with the necessary survey numbers were georeferenced and overlaid. The cadastre wise presence or absence of the orchards were reported year wise to facilitate the department and provide evidence using the satellite data. This project was readily adopted by other divisions of the WRD.

- Evidence Based Monitoring for Fruit Orchards for Lower Tapi Project Division:
  Temporal mapping of fruit orchard in the cadastral parcels of various villages over a time span of 15 years or more, based on, availability of data. Before the start of JMR, many a times 3 to 4 feet tall pomegranate plants are planted to show the existence of orchards to increase the land cost. WRD approached MRSAC for the solution. MRSAC used archived high-resolution satellite data where ever available to provide evidence-based monitoring of the farm land so as to help MWRD and ascertain that the correct person gets the appropriate land cost.

- Evidence Based Monitoring for Submergence when Dam has FRL:
  WRD faces the major problem of the submergence of agricultural land and rehabilitation due to the gorge filling of the reservoir/ dams etc. Every year the maximum storage is reached at a date before release of the water from the dam. This period is very crucial so that the area submerged can be identified on that date and the lands of the farmers in the affected villages be identified for rehabilitation. This is again done using the very high-resolution satellite data of the period.

- Chak-wise Micro-irrigation Design and Implementation:
  Participatory approach is crucial for management of irrigation projects for conserving and optimal utilisation of resources. Participatory Irrigation Management (PIM) refers to the involvement of Irrigation users in all aspects of Irrigation Management at all levels. In many states of India, Water Users Association (WUA) have been established and registered for this purpose. A Water User Association (WUA) is a Cooperative Association of individual water users who wish to undertake water related activities for their mutual benefits. An efficient and equitable supply and distribution of water ensuring optimum utilisation for improvement of agricultural production is also envisaged for scientific and systematic development and maintenance of irrigation infrastructure. The net effect is the management and maintenance of irrigation.

The maps available from Irrigation department and the booklets on Water User Wise calculation for DO wise and chak wise water supply on micro-irrigation levels are studied thoroughly. Using the drawing of the canal network, the scanned maps of canal, command is georeferenced on to the high resolution satellite data. The canal network is digitized and then updated from the drawing files and all the canals are given proper names, type, physical status, canal types etc. Later geo-referencing of the scanned maps of the various water user association is done. The pipelines, direct outlets and turnouts are digitized and data attached. The database for the farmers, the irrigation given, total irrigated area etc. is created in the cadastral map. The topology is built for each layer and between the various layers. Later the standardization and the compilation of the data is done, maps prepared and published. Entire data has been put on WRD geoportal for viewing along with information on beneficiary farmers. The output with beneficiary is uploaded in geoportal as shown in screenshot in fig. 2.
• **Water Budgeting:**
Water budgeting is essential to assess the availability and deficit of water. Watershed wise, taluka wise, the amount of water available can be assessed. A pilot study was conducted in Warud and Morshi to assess the feasibility of the water budgeting.

• **Jalyukt Shivar:**
Maharashtra Government has launched the “Jalyukt Shivar Abhiyaan” project to make Maharashtra a drought-free state by 2019. The project involves deepening and widening of streams, construction of cement and earthen stop dams, work on nullahs and digging of farm ponds. A mobile application has been developed to map these locations. The data from field is being showcased on the geo-portal with proper reports. The type of query and reports is shown in fig. 3.

• **National Wetland Inventory and Assessment (NWIA):**
MRSAC has done the NWIA project for Maharashtra wherein wetland classes as defined by the Space Application Centre (ISRO) under the aegis of Ministry of Environment and Forest, Govt. of India, using satellite data of moderate spatial resolution on 1:50k. The aim was to map all inland water bodies with an area more than 2.25 ha as polygon and those below 2.25 ha as point. This was done to inventory all the water bodies of the state and micro wetlands which form the roosting of migratory birds. The coastal wetlands were also mapped with major classes like creeks, mud flats, swamps, salt pans, mangroves, etc. Wetland atlas was also prepared and handed over to SAC and is available on MOEF site. The Hon. Supreme Court of India has directed all Govt. to refer to the atlas before taking up any development work which shall harm the wetland ecosystem. The wetland atlas contains pre-monsoon and post-monsoon water bodies spread, wetland areas, rivers and streams, pre and post-monsoon aquatic vegetation and pre and post-monsoon qualitative turbidity.

• **Irrigation Well Mapping:**
A mobile application has been developed by MRSAC to map these locations. The data from field is being showcased on the geo-portal with proper reports. The type of query and reports is shown in fig. 3.

• **Maha Maritime Board:**
The application provides information about the Ports & Jetties in the form of location on map, Port wise time table of ferries, location of water sports, vessel id wise information for vessel search, location and information about cargo ports, district wise location of lighthouses, tidal information of current day and next two days, Emergency module which provides links to INCOISE & Strom Signal Places for emergency advisory services and weather images which provide daily cloud coverage of satellite from INSAT-3D. The project has been awarded by Govt. of India and available on google play store.

• **Watershed Mapping:**
The need for watershed mapping and refinement arose due to the following:
1. Many of the existing watershed boundaries follow the river as boundary which does not fulfill the concept of single pour point
2. Watershed (AISLUS) as development unit of large area, is improper for planning activities.
3. Existing area of GSDA for watershed ranges is from 200 to 300 sq. km
4. Due to development process, number of major and minor waterbodies are constructed.
Fig. 2 Micro-irrigation system with water distribution at chak level for Water User Association

Fig. 3 Jalyukt Shivar dashboard for district/tahsil/village wise/ department wise query
5. Existing watershed boundaries are used for subsurface flow analysis, groundwater estimation and water conservation.
6. With the advancement in the satellite technology, the resource mapping on micro level scale is possible. Using this technology, the refinement of watershed boundaries has been done shown in fig.4.

- **Remote Sensing and GIS Based Mapping for Water Supply And Sanitation (WSS) Using High Resolution Satellite Data**
  - Mobile application to pin-point sources of pollution due to urban areas like hospitals, railway stations, eateries, immersion sites, slaughter houses etc., which pollute water.
  - Location of in-house small-scale industries, built up and the water bodies, streams which get affected (evidence based)
  - Location of new factories, infrastructure projects/ quarries/ built up and the water bodies, streams which get affected (evidence based) to be located using temporal satellite data on a periodic basis.
  - Location of dumping sites of solid waste in urban and peri-urban areas through mobile app.
  - Mapping of the water filtration facilities and the STP. Water quality at the input and the output. Areas where the water is drained.
  - Location of new STP through remote sensing and GIS. The outlet of the STP would be located for use in agriculture/ parks/ malls etc.
  - Development/ rejuvenation plan for the water bodies and rivers after identifying their environmental status including water quality, mapping of the drainages being affected by factories, urban development etc.
  - Promotion of water tourism and planning of necessary infrastructure.
  - Planning of conservation of water bodies attached to temples, pilgrim places and small tanks in villages
  - Conservation and rejuvenation of malguzari tanks which are a part of the rice bowl of Central India.
  - Development of cooling ponds/ tailing points and constant monitoring for water quality.
  - Monitoring of areas affected by soil salinity due to excessive irrigation/ canal leakage.

3. **Epilogue:**
There are many more projects like drought monitoring as defined as accepted under Maha-MADAT, pilot project to fly drone on canal and command and correlation with irrigation cycle, online grievance redressal for water supply-ward wise, crop water requirement calculations etc. MRSAC has thematic layer in the form of drainages with stream ordering using Strahler’s method, and well defined standardized data with proper documentation, and is in the process to do flow analysis watershed wise and monitor and estimate the subsurface flow in the form of runoff, recharge and storage zones. The process is also going on to correlate the data captured from drone with the satellite data to identify the standing crop type and use it to classify the crops for irrigation water cess collection, crop monitoring etc. There are many innovative ways to use the satellite data which is becoming more and more spectrally, radiometrically, temporally and spatially improved. MRSAC has been the leading institute for providing geospatial solution to State for water resources. Coming days are more challenging
with the impact of climate change diminishing the number of rainy days, erratic rainfall, floods and droughts. It is predicted that the third world war shall be due to water. The implications are already visible with the states in India up in arms due to water sharing. The situation is very much like the prose in The Rime of the Ancient Mariner which says “Water, Water Every Where, nor any drop to drink”. If we are not able to “Trap the Water where it Falls”, most of it shall be lost and there shall be very little to conserve. Thus, use of geospatial technology should be adopted for better management of this priceless water resource and conserve, manage and use it sustainably.

Standardized data creation and storage:

Canal Irrigation System with its Vario
Waterbody and River feature class in WRD Project.

River line with ordered Stream by Strahler Method.
g-Governance Project on
Maharashtra Monitoring Agriculture
Drought using Advance Technology
(Maha-MADAT)

- Web based Geo-portal for early warning & drought declaration
- Mobile App for evidence based field data collection
- Integrating data from various sources for visualization, query, monitoring and management
- Dissemination of drought alerts, maps and reports

Drought Analysis based on
5 Scientific Indicators & 14 sub-indicators

Rainfall  Vegetation  Soil Moisture  Hydrology  Area sown

Geo-portal  Mobile App  Drought Triggers & Drought Declaration
Abstract
Doubling farm income in a short period is huge task and needs investigation on the enabling environment for sustainably enhancing the growth potential, identification of sources of farm income, increasing the productivity per unit of farm inputs; and reducing the cost of pre and post harvest operations. Water is the most important but limited input of the agriculture; and major share of water for agriculture is required for irrigation. More than two-thirds of the country’s arable land is rain-fed agriculture. Rainfall variability due to climate variability and climate change adversely influences the agriculture. Hence irrigation is the mainstay for improving the agricultural productivity; and has become the attractive option for producing more food for continuously increasing population of India as the productivity of irrigated agriculture is 2 to 3 times greater than the productivity of rainfed agriculture. However at the same time the share of water for agriculture is reducing continuously. Therefore there is a need to manage the available water for irrigation optimally on sustainable basis for focusing on doubling farm income. This paper highlights the importance of optimum and sustainable irrigation water management for efficient utilization of land and water resources for agriculture. The paper further list outs the different options for the efficient irrigation water management of which adoption of micro-irrigation methods is one such formidable option; and finally presents the efforts of Mahatma Phule Krishi Vidyapeeth, Rahuri for propagating the micro-irrigation technologies.

Keywords: Optimum, sustainable, irrigation water management, doubling farm income, micro-irrigation methods, sprinkler, drip, micro sprinkler, irrigation system

1. Preamble
As outlined by the several thinkers, improvement in farm productivity and resource use efficiency; saving in cost of production, increase in cropping intensity, diversification towards high value crop, adoption of appropriate technologies, reduction in pre and post harvest losses along with others are the important sources of growth in agriculture sectors and can contribute towards doubling farm income. India ranks second worldwide in farm output, but has very low agricultural productivity. Currently in spite of the great efforts put forth for improving the productivity of rice and wheat, India ranks 13 and 14 in the world. India ranks still lower for productivity of other food commodities. If we enhance
our productivity, we can produce more, save land and water resources and improve the soil health by appropriate use of chemicals. As an example, we could produce 2.5 times what we currently do, if we were to produce wheat at the rate at which New Zealand does. Similarly, if we produce rice at Chinese levels, we could halve the amount of land devoted to rice cultivation making available the land for other purposes. Thus productivity needs to be increased to enable the farmers get more remuneration with less resources, maybe it is land, water, labour, fertilizers, chemicals. On 28th February, 2016 while talking at the Farmers’ rally in Uttar Pradesh, the Prime Minister stated that it is his dream to see farmers double their income by 2022 when India completes 75 years of its independence. Thus the goal of the Agriculture University scientists/teachers need to be to produce the technology for doubling the farm income in the realm of current challenges including climate change and climate variability. Precise use and application of inputs including water can provide a way to do it.

In view of growing pressure on the natural resources such as land and water; and in turn the need of their precise use and application, precise use of fertilizers and chemicals to enhance the productivity, maintain soil health and reduce pollution, coupled with the challenges faced by climate change and variability, it is expected that precision agriculture and water management sector which is currently in infant stage in India need to be pursued vigorously to keep pace with the fulfilling the goal of doubling farm income by 2022.

Since establishment of Mahatma Phule Krishi Vidyapeeth, Rahuri 50 years ago, this University made efforts for efficient use of water for irrigation and currently has sufficient and adequate knowledge base for precision irrigation technologies and is on the forefront in India in these aspects. The University has “Precision Framing Development Center” and All India Coordinated Research Project on Irrigation Water Management at its Central Campus. These two centers along with the Departments of Irrigation and Drainage Engineering, Irrigation Water Management, has developed the technologies leading towards precision water management. Notable amongst those are; irrigation scheduling by micro-irrigation methods, crop coefficients, fertigation, ICT technologies for irrigation water management.

2. Importance of Irrigation Water Management

The Government is aware of the roadmap outlined by NITI Aayog for reforms in agriculture sector and doubling farmers income by 2022. The Roadmap presents a quantitative framework for doubling farmers’ income which has identified seven sources of growth. These are [1]:

- increase in productivity of crops.
- increase in production of livestock.
- improvement in efficiency of input use (cost saving).
- increase in crop intensity.
- diversification towards high value crops.
- improved price realization by farmers.
- shift of cultivators to non-farm jobs.

Today the world’s population is increasing at the rate of 1.167% [2]. Currently the world’s population is hovering around 6.669 billion and according to UN, it will rise to 6.830 in 2010; 7.851 billion in 2025 and 8.918 billion in 2050. India’s population is around 1.20 billion and is estimated to rise to 1.447 billion in 2025 and 1.658 billion in 2050. As the population of the world continues to increase the demand for food and fibre for the people also increase. As an example, according to UN-FAO [3, 4], the total cereal consumption in year 2005-06 was 2037.6 million tonnes, it raised to 2062.4 million tonnes in 2006-07 and to 2105.0 in 2007-08. This rate of increase in cereal consumption
is about 2.1%. Similarly, for oils and fats, consumption in year 2006-06 was 146 million tonnes; it rose to 152 million tonnes in 2006-07 and to 157 in 2007-08. The rate of increase in oils and fats consumption is almost 4%. In India the total cereal consumption in year 2005-06 was 193.1 million tonnes, it raised to 197.3 million tonnes in 2006-07. Similarly, for oils and fats, consumption in year 2005-06 was 14.8 million tonnes, it raised to 15.0 million tonnes in 2006-07. The analysis of other agricultural commodities also shows the similar trend.

The productivity of irrigated agriculture is more than 2-3 times the productivity of rainfed agriculture. Hence to satisfy the food demand of continuously growing population, it is essential that more and more land need to be brought under irrigated agriculture. This will also contribute to doubling farm income along with other factors. However competition for water to agriculture from other sectors of society has resulted in more critical situation worldwide. Because of continuously reduced share of water for agriculture, it is not possible to divert water for additional area and at the same time, in most of the continents, especially in Asia all the land that can be economically cultivated is already in use. Therefore, it is very important that maximum output is obtained per unit of water and land utilized and thus the irrigation water management has become now important priority area for water management on sustainable basis.

3. The Share of Water for Agriculture Sector

The agricultural sector is the biggest user of water worldwide and especially in developing countries. According to the statistics revealed by United Nation’s Food and Agricultural Organization (UN-FAO) presented in figure 1, developing countries such as African, Latin American and Asian countries consume 84, 71 and 78% of total utilizable water for agriculture, whereas the developed countries such as North American and European countries consume major share of water i.e. almost half of utilizable water for industries (i.e. almost 50%) followed by agriculture and domestic sectors. Figure 2 shows the share of water for different sectors in 2000 in India and neighboring countries.

The data on water use of different sectors indicate that a share of water for agriculture sector is reducing at rapid pace in developing countries. In India the share of water for agriculture, domestic and industry sectors in 1990 was 92, 5 and 3% respectively and in 2000 it changed to 8.1, 86.5 and 5.5% [3,4].

With the exponential growth of industries and service sectors in India, currently the share of water for agriculture is further reduced to around 80% and it is expected that the share of water for agriculture will reduce at a faster pace. The demand of water for agriculture is expected to increase by 1.2 times to satisfy global demand of food, by 2025. However
above stated facts indicate that in any case the water availability for agriculture will not be enhanced in future and hence the efficient utilization of land and water resources on sustainable basis is necessary.

4. Land and Water Resources of India

Total geographical area of India is 328.726 million hectares. The cultivated area (arable + permanent crops) was 169.270, 169.598 and 169.650 million hectares in 1992, 1997 and 2005, respectively. The data on cultivable area and population show that in 1960, each Indian had an average of 0.21 ha of grain land. By 1999, the average had dropped to 0.1 ha per person, or less than half as much. And by 2050, it is projected to shrink to a meager 0.07 ha per person [3,4].

The total water resources of the country are 1897 trillion m³/year. The figure 3 shows the per capita availability of water in the country. It is observed from the figure that the per capita water availability is decreasing at alarming rate. It is now generally accepted that the countries with annual per capita water availability of less than 1,700 m³/year of water are water-stressed. If the population increases up to 1.658 billion in India, per capita water availability will fall below 1000 m³/year, which is far below the norms [3,4]. Figure 3 indicates that we are already at threshold of water availability and in next few decades, the situation will be alarming. The country will be water scarce even if total available water is taken into account. For feeding a population of 1.658 billion, nearly 450 million tonnes foodgrain would be required in 2050, production of which would be a gigantic task considering the constraints being faced by the irrigation sector. Against this backdrop, the continuing shrinkage of cropland per person as stated above now threaten’s India’s food security. In view of limited land area and water for agriculture and growing demand of food for increased population, higher production from the currently cultivated land area and available water needs to be obtained. About 280 million ha of land is irrigated all over the world in various irrigation projects. The statistics shows that the area under irrigation has almost stabilised.

The ultimate irrigation potential of the country from major and medium projects is estimated at 58.46 M ha and from minor irrigation projects is estimated at 81.43 M ha, of which 17.38 M ha is from surface water minor irrigation schemes and 64.05 M ha is from groundwater schemes. The total ultimate irrigation potential is thus 139.89 M ha, out of which 75.84 M ha is surface water potential and 64.05 M ha is groundwater potential. Against the 95.4 M ha of total irrigation potential created, only 85.4 M ha is being utilised [1,5,6]. However, according to the Ministry of Agriculture’s Land Use Statistics, the gross irrigated area is only 75.55 M ha. Thus according to different sources, there is a gap of 10 to 20 million ha in the irrigation potential created and utilised.

The poor project efficiency (30-50%) is the cause of the huge gap of irrigation potential created and utilised and therefore these projects are unable to achieve their design target. There are several reasons for the gap in irrigation potential created and utilized. These can be attributed to less yield from reservoirs than expected, more non-irrigation use than that planned, higher conveyance losses and less water use efficiency, improper and inadequate means of supplying water to the fields etc.
5. Means of Irrigation Water Management

The poor project efficiency (30-50%) is the cause of the huge gap of irrigation potential created and utilised and therefore these projects are unable to achieve their design target. There are several reasons for the gap in irrigation potential created and utilised. These can be attributed to less yields from reservoirs than expected, more non-irrigation use than that planned, higher conveyance losses and less water use efficiency, improper and inadequate means of supplying water to the fields etc. Thus it is now realized that the irrigation potential created is not being fully utilized and gap exists between the potential created and potential utilized. So, our new challenge is to increase agricultural productivity per unit volume of water, per unit area of cropped land per unit time. This can be only possible with effective and efficient management of irrigation water. There are several ways to improve the efficiency of available water for agriculture to increase agricultural production and productivity. These options are narrated by Gorantiwar and Smout [7]. These include improving hardware of the scheme adopting water-saving irrigation methods and improving software of the scheme.

Improving hardware of the scheme
- Reservoir de-sedimentation
- Raising the dam height
- Developing the catchment area
- Lining of canal network
- Installation of water regulatory and measurement structures
- Repairing and enhancing maintenance of existing water delivery system
- Development of on farm structures
- Land levelling
- Automation

Improving software of the scheme
- Adoption of appropriate water distribution methods such as rotational water supply or on demand water supply
- Developing optimum allocation plans for land and water resources to different crops in the irrigation scheme
- Developing the decision support systems
- Optimal real time operation of irrigation systems
- Institutional reforms
- Improving capital related activities
- Improving crop related management practices

Adopting water-saving irrigation methods
- Pressurized irrigation methods such as sprinkler and drip
- Improvements in traditional irrigation methods such as skip furrow irrigation method, surge flow irrigation etc

These options are generally not alternatives but often applied together. In the late 1970’s ‘hardware’ related options dominated irrigation schemes [8], but now this option can provide only marginal increases in water availability. Recently there has been greater interest in ‘software’ related options and water-saving irrigation methods - that is using every drop of available water to its maximum potential. Some ‘hardware’ related options help to ‘software’ related options for improving the management of irrigation schemes (for example, automation) and thereby enhancing the productivity of the irrigation water. This paper highlights on software related items and water-saving irrigation methods for optimum and sustainable management of irrigation water for irrigation.

6. Efficient Irrigation Methods

The irrigation efficiency of the conventional surface irrigation methods is 40-50%. However the efficiency can be improved with the adoption of sprinkler irrigation method to 75-80% and micro-irrigation methods to 85-95%

6.1 Sprinkler irrigation methods

As in sprinkler method, the water is directly applied in the field and over the land surface and the flow through the system can be
controlled, the losses that are unavoidable in surface irrigation methods such as deep percolation and conveyance are minimized in this system. Depending upon the device used to generate spray (sprinkler nozzle), coverage of the spray and pressure requirement to produce the spray, sprinkler irrigation method has different versions: conventional sprinkler, mini sprinkler, rain gun and central pivot. The results of the experiments conducted at MPKV, Rahuri for different crops indicated that this method has the potential to save water up to 25% and increase the yield up to 10% over the surface irrigation method.

**Conventional sprinkler irrigation:** In case of conventional sprinkler the discharge of the nozzle is 500 to 1500 liters per hour, operating pressure is 2.5 to 4.0 kg/cm$^2$ and the spacing between nozzle and laterals are 6 to 18 m. Mahatma Phule Krishi Vidyapeeth, Rahuri conducted the research studies for knowing the feasibility of sprinkler irrigation methods for different crops (Table 1). The studies indicated the water-saving to the extent of 22 to 42% compared to the conventional surface irrigation methods.

**Table 1. The saving of water due to sprinkler irrigation method for different crops.**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Crop</th>
<th>Water requirement (cm)</th>
<th>Saving of water due to adoption of sprinkler irrigation method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Conventional irrigation method</td>
<td>Surface irrigation method</td>
</tr>
<tr>
<td>1</td>
<td>Summer groundnut</td>
<td>90</td>
<td>62</td>
</tr>
<tr>
<td>2</td>
<td>Kharif chilli</td>
<td>39</td>
<td>26</td>
</tr>
<tr>
<td>3</td>
<td>Kharif groundnut</td>
<td>23</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>Summer onion</td>
<td>78</td>
<td>52</td>
</tr>
<tr>
<td>5</td>
<td>Rabi sunflower</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>Kharif sorghum</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td>7</td>
<td>Wheat</td>
<td>35</td>
<td>21</td>
</tr>
<tr>
<td>8</td>
<td>Garlic</td>
<td>84</td>
<td>60</td>
</tr>
<tr>
<td>9</td>
<td>Cabbage</td>
<td>42</td>
<td>32</td>
</tr>
<tr>
<td>10</td>
<td>Tomato</td>
<td>37</td>
<td>29</td>
</tr>
</tbody>
</table>

**Mini sprinkler irrigation:** The mini sprinklers (figure 5) that have less precipitation rate compared to conventional sprinkler irrigation method is used when more frequent irrigations are needed and soils are light. The mini sprinklers have less coverage area and hence suitable for smaller fields wherein if conventional sprinklers are used, the loss of land due to corner effect is considerable. In case of mini sprinkler the discharge of the nozzle is 40 to 300 liters per hour, operating pressure is 1.5 to 3.0 kg/cm$^2$ and the spacing between nozzle and laterals are 3 to 9 m.
6.2 Micro-irrigation methods

The results of the experiments conducted in Mahatma Phule Krishi Vidyapeeth, Rahuri and other organizations indicated that this method has the potential to save water up to 50% and increase the yield up to 20 to 25% over the surface irrigation method. Depending on the mechanics of water application, these methods are classified as: surface drip, subsurface drip, micro sprinkler, microjet, bubbler and subsurface irrigation methods.

Mahatma Phule Krishi Vidyapeeth, Rahuri conducted the research studies for knowing the feasibility of drip irrigation methods for different crops (Table 2). The studies indicated the water-saving to the extent of 35 to 66% with increase in crop yield from 9 to 86% compared to the conventional surface irrigation methods.

Table 2. The yield obtained and water applied by drip irrigation methods for different crops.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Crop</th>
<th>Water applied (cm)</th>
<th>Water-saving (%)</th>
<th>Crop yield (q/ha) (%)</th>
<th>Increase in yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Drip irrigation method</td>
<td>Surface irrigation method</td>
<td>Drip irrigation method</td>
<td>Surface irrigation method</td>
</tr>
<tr>
<td>1</td>
<td>Tomato</td>
<td>20</td>
<td>37</td>
<td>46</td>
<td>44.78</td>
</tr>
<tr>
<td>2</td>
<td>Chilli (dry)</td>
<td>26</td>
<td>78</td>
<td>66</td>
<td>2.82</td>
</tr>
<tr>
<td>3</td>
<td>Brinjal</td>
<td>37</td>
<td>84</td>
<td>56</td>
<td>39.72</td>
</tr>
<tr>
<td>4</td>
<td>Cucumber</td>
<td>24</td>
<td>54</td>
<td>56</td>
<td>22.53</td>
</tr>
<tr>
<td>5</td>
<td>Watermelon</td>
<td>24</td>
<td>72</td>
<td>66</td>
<td>50.36</td>
</tr>
</tbody>
</table>
Surface drip irrigation: Amongst all the micro-irrigation methods, surface drip (figure 8) is most common method. In a surface drip irrigation system, the emitters and lateral lines are laid on the soil surface. Generally, flow rates are less than 2-8 lph for single outlet point source emitters and less than 12 lph/m for line source emitters. The operating pressure of the emitter varies from 0.8 to 1.2 kg/cm².

Subsurface drip irrigation: In subsurface drip irrigation, water is applied slowly below the soil surface through emitters with flow rates in the same range as that of surface drip system. This system is mostly used for close growing row crops, but can also be used on small fruit crops. This has the potential to save up to 10% additional water over surface drip.

Bubbler irrigation: In bubbler irrigation (figure 9), water is applied to the soil surface in a small stream or fountain from an opening with a point source having flow rates greater than surface or subsurface drip irrigation, but usually less than 225 lph. A small basin is required to control the distribution of water.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Crop</th>
<th>Water applied (cm)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Drip irrigation method</td>
<td>Surface irrigation method</td>
<td>Drip irrigation method</td>
<td>Surface irrigation method</td>
</tr>
<tr>
<td>6</td>
<td>Chilli (green)</td>
<td>29</td>
<td>60</td>
<td>52</td>
<td>10.65</td>
</tr>
<tr>
<td>7</td>
<td>Potato</td>
<td>25</td>
<td>38</td>
<td>35</td>
<td>27.74</td>
</tr>
<tr>
<td>8</td>
<td>Sugarcane</td>
<td>94</td>
<td>236</td>
<td>60</td>
<td>1009.3</td>
</tr>
<tr>
<td>9</td>
<td>Summer groundnut</td>
<td>55</td>
<td>87</td>
<td>37</td>
<td>3.06</td>
</tr>
<tr>
<td>10</td>
<td>Ladies finger</td>
<td>32</td>
<td>54</td>
<td>40</td>
<td>177</td>
</tr>
<tr>
<td>11</td>
<td>Bitter gourd</td>
<td>24</td>
<td>32</td>
<td>25</td>
<td>215</td>
</tr>
<tr>
<td>12</td>
<td>Cabbage</td>
<td>27</td>
<td>66</td>
<td>59</td>
<td>195</td>
</tr>
<tr>
<td>13</td>
<td>Grape</td>
<td>45</td>
<td>110</td>
<td>59</td>
<td>245</td>
</tr>
<tr>
<td>14</td>
<td>Cotton</td>
<td>42</td>
<td>89</td>
<td>53</td>
<td>30</td>
</tr>
</tbody>
</table>
Microjet irrigation: Microjet irrigation (figure 10) is the system of application of water in the form of discrete drops or spray jets on the surface of soil from low height or low angle through air around the crop. Microjet does not have moving parts but have greater flow rate and greater coverage than drippers and bubblers. The flow rate generally ranges from 20 to 70 lph. Operating pressure varies from 1 to 2 kg/cm².

Micro sprinkler irrigation: Micro sprinkler (figure 11) is the application of water in the form of drops or spray on the surface of soil from stake height less than 0.6 m or low angle, through air around the crop. Micro sprinkler incorporates moving parts and have greater flow rates and coverage than drippers, bubbler and microjet. In this method, the discharge of the micro sprinkler is 40 to 120 liters per hour, operating pressure is 1 to 2 kg/cm² and the spacing between nozzle and laterals are 1.5 to 4 m. This method is suitable for the under-tree irrigation and close growing row crops.

Subsurface irrigation: The subsurface irrigation methods (figure 12) that include bi-wall and recently introduced porous pipe irrigation system. In case of bi-wall irrigation, water emits from the tiny holes along the wall of the tubing directly into the root zone and needs the pressure up to 1 kg/cm². In case of porous pipe irrigation, the water is always contained in porous pipe under some desired pressure though low (0.2 to 0.4 kg/cm²) and soil absorbs the water through the porous pipe according to the need of the crop.

A number of benefits have been ascribed to the use of micro-irrigation. In addition to saving of water and increase in yield, the experimentations on adoption of micro-irrigation methods for different row and fruit crops conducted at MPKV, Rahuri showed considerable saving in fertilisers, increase in net benefits, saving in labour and energy cost as shown in Figure 13 as indicative values.
A number of benefits have been ascribed to the use of micro-irrigation. In addition to saving of water and increase in yield, the experiments on adoption of micro-irrigation methods showed considerable saving in fertilisers, increase in net benefits, saving in labour and energy cost.

There are several means of utilizing water efficiently. These include: adoption of water-saving irrigation methods such as sprinkler and drip, optimal allocation of land water resources, canal lining, reservoir delineation, afforestation of catchment area, proper irrigation scheduling (applying water to different crops according to their water requirement). These options are not alternatives to each other but complementary to each other. Most of these options call for the exact estimation of water requirement that varies with crops, their growth stages, climate etc. The knowledge of water requirement is further necessary to match spatial and temporal distribution of water demand with water supply so that water resources are used efficiently. The water is applied through surface, sprinkler and drip irrigation methods. All these methods need water to be applied accurately to minimize the wastage of precious water, enhance the agricultural productivity, maintain and improve the soil health, reduce the environmental hazards and use the available water on sustainable basis. The sprinkler and drip methods of irrigation are being promoted especially for their important characteristic of efficient utilization of water. Efficient utilization of water primarily calls for the estimation of irrigation water requirement that varies as per crops, their crop growth stages, soils, weather and characteristics of the irrigation system being used. However, as often the location specific information on these parameters that vary during the crop growth period; especially weather information is not available, farmers need to rely on the ad-hoc values of the water and irrigation requirement. Hence farmers schedule irrigation on ad-hoc basis or based on their experiences. However these are subjected

7. ICT in Irrigation Water Management

Mahatma Phule Krishi Vidyapeeth, Rahuri developed several ICTs such as desktop and web based applications and mobile apps for precise irrigation water management. One such application is “Phule Irrigation Scheduler” for appropriate irrigation scheduling.

7.1 Challenge

In State of Maharashtra, about 17% of the total cultivated area is irrigated. It is estimated that the irrigated area may reach to 30% if we use all the water resources of the state through construction of new irrigation projects. However, historically as we have harnessed easily and cheaply available water resource, the cost of creating new water resource is high and often not technically feasible. The environmental and social reasons also limit creating additional water resources. Thus, due to technical and social reasons and environmental concerns, it is increasingly difficult to create new water resources. Therefore, the feasible option is to use the available water efficiently so that we can increase the area under irrigation. Moreover by using water efficiently it is possible to save water and water saved is nothing but water created.
to many errors and hence if adopted do not results into appropriate irrigation scheduling. Hence the challenge is to provide the farmers with the information on water and irrigation requirement that depend on varying weather conditions, crop growth stage, soils and specific irrigation systems used by farmers and; the information should be farm specific for reliability and enhancing the adaptability.

7.2. MPKV, Rahuri Initiative

The irrigation water requirement depends on crop, soils, climate and efficiency of the irrigation system. The irrigation water requirement of different crop is different and for a specific crop it varies over the growth season. The irrigation water requirement for the same crop and soil is different for different regions because of variability in the meteorological parameters that govern the water requirement. The basic information that is required for estimating the irrigation water requirement of the crops is the weather parameters that govern the water requirement. The weather data estimates the reference evapotranspiration (ETr) and crop coefficient values when coupled with ETr determines the crop evapotranspiration of the specific crop which in turn enables to estimate the irrigation water requirement of the specified crop.

It is also necessary that water should be applied as per the water requirement and the irrigation system be operated according to the water requirement. The application of water according to the water requirement of crop in terms of quantity and time of operation will not lead to under and over application of water thus avoiding the water stress and water wastage. It is also necessary to know the system requirement of water and system discharge in order to match the available supply with the requirement. However, there were no tools or means to provide the farm specific information on irrigation requirement and time of operation of the system. Hence the mobile app “Phule Irrigation Scheduler” was developed for scheduling the irrigation for different crops by surface, sprinkler and drip irrigation methods in real time by integrating the farm, soil, crop and irrigation system information provided by farmers, real-time weather information from weather data service and scientific information on irrigation scheduling generated by this university.

7.3 ‘Phule Irrigation Scheduler’ mobile application

‘Phule Irrigation Scheduler’ mobile application (figure 14) estimate the reference evapotranspiration (ETr) by the different standardized methods for the specific form by fetching the required input weather data (maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, wind speed, sunshine hours, etc.) from the IMD/ ‘Open weather’, weather service provider for the current and 3 days ahead. The crop coefficient values are estimated daily from the crop and crop growth stage specific information on crop coefficient generated in this project based on literature and experimentation. The crop coefficient (Kc) is multiplied by the reference evapotranspiration (ETr) rate to determine the crop water use for the specific day. Further by integrating other information on crop and soil, location of farm, irrigation system, the precise irrigation requirement and time of application are estimated.

In these mobile and web-based applications, farmer initially need to register the farm by providing information on location of farm, crop, soil and irrigation system that he/she easily has. Then farmer has to access the mobile application/web-based application at least once in 3-4 days so that the current weather information is registered in the farm. By entering the previous date of irrigation and the
desired date of irrigation, farmer can know the irrigation requirement and time of application immediately and accordingly can operate the irrigation system to provide irrigation water precisely to the farms. In addition to online information on weather fetched from weather data provider, there is also arrangement to input the own weather data for estimation of evapotranspiration in offline mode. This is particularly important, if the users or farmers have their own data/AWS.

![Phule Irrigation Scheduler mobile app](image)

Figure 14. Phule Irrigation Scheduler mobile app

**References**

- Densham, P. J., and Goodchild, M. F. “Spatial decision support system: a research agency”. In: GIS/LIS’89 Proceedings volume 2, American Congress on Surveying and Mapping, Bethesda, MD. 1989
Introduction

Vidarbh is a mainly rainfed farming region largely subjected to the vagaries of monsoon with instability of yields and incomes. In Maharashtra, even after the harvesting of full irrigation potential about 70-75 percent of cropped area remains subject to the uncertainties of monsoon. In Vidarbha about 85 per cent area will depend on monsoon while at present, only 6 to 7 per cent area is under irrigation. Rainwater is most important single requirement for the growth of the plants. Crops can be raised successfully only if water is available in adequate quantity either from rain or subsurface storage. Rainfall in the state is confined mainly to the four rainy months June to September. During the remaining months the water requirement have to be met from ground and surface water resources. The need of applying the protective irrigation for raising the crops during non-rainy periods or when the rain failed was felt even in the distant past. With the growth of population and consequent for the large agriculture production, the requirement of protective irrigation has increased the great deal. Protective irrigation in rainfed agriculture is required not only in low rainfall areas but also during the dry spells/moisture stress in good rainfall areas.

The primary impact of soil degradation is a substantial reduction in the productivity of soil and land directly impacting those whose livelihoods depend on this natural resource. Soil degradation processes are generally insidious and show up only gradually as the problem becomes more and more severe. Impact of soil degradation often extends beyond direct yield losses and in extreme cases the soils can turn unfit for agriculture, seriously affecting farmer’s ability to sustain livelihoods. Therefore, developing and promoting strategies to minimize soil degradation and improving the quality and health of soils are fundamental to secure the agricultural sustainability. Climate change and increased weather variability are already of serious concern in agriculture. The research in future will have to be reorganized in the context of ways and means for mitigating the adverse effects of climate change, uneven and erratic nature of rain and increasing scarcity of water, degradation of land at an alarming rate, stagnation in crop productivity, emerging problems of soil fertility decline and micronutrient deficiencies, need of more resistant cultivars to drought stress, salinity and other adverse conditions, farm
mechanization in view of increasing labour problems, market intelligence in view of globalization and issues of sustainability of soil and water.

The uneven distribution of rainfall resulting into prolonged dry spells is the most crucial constraint for agriculture in the area. As a consequence of climate change in recent years the problem is further aggravated and the intense rains occur at places which lead to severe rainstorms causing accelerated soil erosion. There is simultaneously decline in number of rainy days in this area in spite of higher total rainfall received. The soils are inherently slow in permeability becoming more susceptible to erosion. The surface soil layer becomes hard on dispersion due to more sodium reducing the hydraulic conductivity of soils causing impounding of water on surface causing temporary water logging which has detrimental effect on crop growth. The poor drainage of the soils many times causes crop failure in the valley.

In-situ recharge of rainwater needs reforms in cultivation practices in such a fashion that the maximum rainfall gets infiltrated into the soil profile and it becomes available to the crops during prolonged monsoon break. This requires the participation and involvement of every farmer to adopt the effective cultivation practices to enhance the water use efficiency means to boost the water and crop productivity. Soil water being the very scarce resources and to make farmers water-wise all out efforts have to be undertaking for integrated rainwater management through in-situ & ex-situ conservation and recycling of harvested runoff water.

It is thus very necessary to popularize the soil and water-based rainwater management technologies among the farmers. Although several technologies in this respect have been evolved and promoted by this university time to time. In view to upscale and enhance the adoption level of these technologies there is need to conduct Front Line Demonstrations (FLDs) of such technologies on large scale in participatory mode.

**Recommended Technologies**

1) **Watering through earthen pots for multipurpose and dryland tree species (MPTS) in non-arable lands**

**Background:** In the alternate land use systems on one hand it is necessary to develop perennial plantation on non-arable lands. However on other hand it is also true that due to the scanty and vagarious monsoon the survival of plantation under rainfed condition is difficult. Therefore present investigation were designed by providing the limited quantity of water (5 lit./p) once in a week for the sake of the survival and establishment. Watering through basin, earthen pots and drip irrigation with grass mulching, was studied. Findings generated will be of applicable value for MPTS in rainfed conditions. Results revealed that MPTS like Ramkati (Acacia nilotica), Neem (Azadirchta indica), Ber (Zizyphus Maurita) and Anjan tree (Hardwickia binata) given favourable response in terms of survival and growth for the watering through earthen pots and found superior to other systems of watering.

Similarly the dryland fruit trees like Custard apple (Annona squamosa), Aonla (Emblica officinalis) and Karvand (Carrica carrandus) given the favourable and at par
response in terms of survival and growth for watering through earthen pots and drip irrigations.

For the satisfactory establishment of plantation on CCT’s in non-arable lands it is recommended to provide per plant 5 liters of water once in a week for MPTS and twice in a week for dryland fruit trees at least for first two years through earthen pots with grass mulching under rainfed conditions.

Impact:
■ Higher survival, Enhanced the height and collar diameter, Water saving, Higher water use efficiency
■ Adopted on 25 ha. area at Dr. P.D.K.V. farm and by farmers on 60 ha in water scarce area of Akola & Amravati district.

II) Construction of cement nala plugs in series on drainage line
Background: For harnessing maximum runoff and to have more water recharge into the soil profile through cement nala plug (CNP) for augmenting the groundwater table it is necessary to construct the CNP in series. The investigation indicated that 92 per cent more recharge was attributed to the construction of CNP in series.

For harnessing maximum runoff for higher recharge it is recommended to construct the CNB in series in such a fashion that the full supply level (FSL) of the downside CNB is at least equal to or less than the bottom level of the upper CNB.

Impact:
■ Higher recharge, Enhance groundwater potential, Moderate hydrology of watershed, Rejuvenate the water bodies
■ Adopted at PDKV farm and by state Dept. of agriculture at 3 locations in Amravati, Akola and Buldana district. Ministry of Water Conservation issued the G.R dated June 2013 for the construction of CNB’s in series and included this activities in various Govt. Schemes.

III) Farm pond technology for saline tract of Purna river basin
Background: The soils in saline tract of Purna river valley are saline sodic and groundwater is alkaline. Provision of brushwood inlet spillway and reforms in cultivation practices observed suitable to improve the life span of farm ponds. The soil management in the saline tract of Purna river valley is difficult due to the severe
erosion rate, swelling, cracking and seizing characteristics.

During monsoon with the first intensive storm along with runoff there will be severe soil erosion. Due to the cracking nature of soil piping takes place which causes damages to the farm pond and deposits silt into the farm pond. Due to the high silt deposition rate life of the farm pond drastically reduces. To overcome these problems adoption of insitu soil and water conservation practices like cultivation across the slope, contour cultivation, opening of furrow in between the crop rows and farm pond to harvest and recycle the runoff is beneficial.

Therefore the present investigation was designed to study the improvement in the life span of the farm pond in saline tract of Purna river valley. The findings generated will be of applicable value for improving the life span of the farm ponds. Provision of brushwood spillway and reforms in cultivation practices found most suitable in saline tract of Purna river basin for rainfed agriculture. In the saline tract of Purna river valley it is recommended to adopt across the slope or contour tillage in the catchment and to provide Brushwood inlet spillway to the farm ponds.

Impact:
- Reduced the silt deposition by 35 to 46%.
- Increased the life span of farm pond by 54 to 88%.
- Brushwood spillway was observed more stable and convenient over stone inlet spillway, Clean water available in farm pond for protective irrigation.
- Reduced in soil, nutrient and runoff losses from catchment of farm pond.
- Technology promoted in saline tract through 30 demonstrations in 25 villages from 3 taluka of 2 districts (Amravati & Akola). Presently more than 250 farmers in Saline tract of Purna river valley have adapted on their own.

IV) Deep Cultivation up to 30 cm

Background: Productivity, stability, income generated from rainfed farming are linked with the attempts of drought proofing providing the means of higher and prolonged residual moisture conservation to every farmer is must at least to the part of his holding alone, so that weather vagaries can be considerably modified and will come to the rescue of farmers.

Deep cultivation across the slope up to 30 cm depth retained higher soil moisture during dry spell, enhanced rainwater use efficiency.
and increased yield of sole cotton, soybean and intercrop over shallow cultivation up to 20 cm depth. The results generated will be of applicable value in vertisols and in saline sodic soils of Purna river valley. In medium deep soil, cultivation up to 30 cm depth is recommended for maximum in-situ water conservation.

**Impact:**
- Deep cultivation significantly reduced runoff (9 to 28%), soil loss (10 to 23%), nutrient losses (13 to 30%) and increased yield (8 to 18.22%). Deep cultivation up to 30 cm depth can be easily adopted by farmers using conventional tools or more conveniently by using sub-soiler with added benefits.
- Technology promoted in vertisols and saline sodic soils of Purna river valley through 110 demonstration in 26 villages from 4 taluka of 3 districts (Amravati, Akola & Buldhana) on 315 ha. area. Presently the adoption is on about 5000 ha.

**V) Life of CCT’s in sown silvipasture system**

**Background:** For maintaining the effectiveness and the effectiveness and efficiency of the CCT’s layout, renovation of the system after specific period is necessary. Information about life of the soil conservation structures like CCT’s is necessary for planning and execution of the Watershed Development and Management programme. In this context this investigation was designed and carried out to study the rate of silt deposition, reduction in cross-section and life span of CCT’s in sown silvipasture system.

The findings generated will be of applicable value in watershed development programme mainly focused on the development of silvipasture systems on the shallow degraded and non-arable lands supported with CCTs. Reduction in the depth and cross-section under sown silvipasture system was observed to be 80 to 95 per cent and 75.5 to 90.56 per cent respectively.

In assured rainfall zone of Vidarbha region the life of the CCT’s in sown silvipasture system is recommended up to 10 years. Various Government development departments and NGOs involved in the development, management and rehabilitation of the watershed.

**V) Mono & Two tier Rainwater management system for different cropping pattern in saline tract of Purna river valley**

**Background:** Rainfed area in Purna river valley are highly diverse ranging from resource-rich area with good agriculture potential to
resource-poor area with much more restricted potential with salinity and sodicity.

The swing in onset, continuity and withdrawal pattern of monsoon make crop production a risky proposition. Therefore in-situ conservation of rainwater (Mono tier) and recycling of runoff from farm ponds for protective irrigation (Two tier) during dry spell are necessary which needs the reforms in cultivation practices in such a fashion that maximum rainfall gets conserved into the soil profile and moisture becomes available to the crop during prolonged monsoonic break. The findings generated will be of applicable value for sustainable and economical rainfed agriculture.

For the higher and sustainable return the double cropping system of Green gram – Chickpea and Soybean – Chickpea along with contour and across slope cultivation with protective irrigation from farm pond is recommended for the saline tract of Purna river valley.

Looking to the benefits of mono & two tier systems of water management over the period of 5 years more than 50,000 farmers adopted the technology has been adopted on more than 50,000 ha. area through the network of about 17,000 farm ponds in saline sodic soils of Purna river valley.

VII) Impact of sub-soiling in deep black soils

Background: A significant cause of low production and crop failure in rainfed agriculture is due to lack of water in the soil. This is caused by a combination of low and erratic rainfall, and poor utilization of the available water. Soil moisture management is, therefore, a key factor to enhance water and energy use efficiency and production. This means that the amount of water that enters the soil (infiltration) must be increased in the form of soil moisture. For this, opening the hardpan of deep soils using sub-soiler and allowing water to enter into the sub-strata of the soil is the best option. In view of this, the present study was conducted to find out the effect of moisture conservation by various tillage practices in soybean under rainfed condition.

Results indicate that Subsurface Tillage (1 Subsurface tillage at 90cm horizontal distance + 2 Tyne + 1 blade harrow) in soybean and cotton crop is effective for higher in-situ soil, water, nutrients conservation and improving physical properties of the soil, crop growth, water and energy use efficiency and yield.

Due to compaction the hardpan formed in the medium to deep black soils of Vidarbha for the improvement in physical properties of soil and higher production and benefits of Soybean and Cotton crop, it is recommended to adopt sub-soiling at 90cm horizontal interval up to 55 to 60 cm depth with 2 tyne and 1 blade harrow.
VIII) Impact of rainwater conservation techniques on production and water use efficiency under rainfed condition

**Background:** In-situ recharge of rainwater needs reforms in cultivation practices in such a fashion that maximum rainfall get infiltrated into the soil profile and it becomes available to the crop during prolonged monsoonic break and controls water crises in agriculture by the way of ‘more crop per drop’. In this context the experiment was carried out to study impact of rainwater conservation techniques on production, water and energy use efficiency.

Results indicate that contour cultivation with ridges and furrows in Jawar crop is effective in controlling runoff, soil loss and improving crop growth, production and water use efficiency as compared to other treatments.

For higher in-situ soil and moisture conservation, yield, energy and water use efficiency, contour cultivation with ridges and furrow after 30 days of sowing is recommended for Kharif crops under rainfed conditions.

**Impact:**

a. Reduced runoff by 98.46%, Reduced soil loss by 99.76%, Reduced Nutrient loss by 99.02 to 99.95%, Increased soil moisture by 15.82 to 16.59%, Increased yield by 39.75%

b. Reforms in cultivation practices being initiated like across the slope, contour cultivation and opening of furrows in across the slope cultivation

Opening of Furrow

Across the Slope Cultivation  Contour Cultivation

Impact of rainwater

rainfed agriculture for in-situ soil and water conservation.

Across the Slope Cultivation  Contour Cultivation Opening of Furrow

Special drive being given to the adoption of “Ideal Approach of Rainwater Management” in participatory mode in saline tract of Purna river valley.

c. Promoted the concept of protective irrigation along with reforms in cultivation practices for in-situ soil and water conservation on 18,000 ha through the network of 4,500 farm ponds in vertisols of Purna river valley.

d. During, Kharif with the application of one protective irrigation (sprinkler) from Farm Pond the on-farm yield levels were observed to be enhanced by 129 to 138% in Green gram, 63.8 to 98% in Soybean and similarly during Rabi 113 to 156% in Chickpea and 50 to 56% in Safflower in across the slope and contour cultivation respectively. In cotton with the application of protective irrigation through
sprinklers the yield levels were observed to be enhanced by 182.86% and with drip irrigation enhanced by 212.8% in vertisols over conventional practice.

e. The concept of adoption of contour key line for contour farming is appreciated by the farmers and succeeded in formation of two model villages for the adoption of contour farming and ideal approach for rainwater management in rainfed agriculture.

**IX) Other Initiatives**

i) Promoted the concept of Rehabilitation of Drainage network and desilting of the village tanks for strengthening the water resources in rainfed agriculture in 6 villages (Daryapur, Akot, Murtizapur and Akola tehsil) under the Govt. programme of Jalyukt Shivar Abhiyan in collaboration with the Revenue authorities.

ii) Due to awareness created for protective irrigation through recycling of runoff harvested in the farm ponds, the demands from the farmers increased drastically for construction of the new farm ponds, diesel engine and sprinkler set from various Govt. subsidy schemes.

iii) Adoption of the mono-tier and two-tier system of rainwater management on more than 55,000 ha area through the network of 10,500 farm ponds by about 35,000 farmers in Vidarbha region. The majority of farmers in saline tract of Purna river valley (Amravati, Akola and Buldana districts) adopted the mono-tier and two-tier system of rainwater management.

iv) Village Ramagad has been developed as Model village. Out of the total 250 ha cultivable area 75 ha is under contour cultivation with vegetative contour keyline, 130 ha across the slope and 30 ha BBF for in-situ soil and moisture conservation and farm ponds for harvesting runoff and Protective Irrigation by recycling.

v) 8 (20 x 20 x 3m) and 57 (30 x 30 x 3m) farm ponds were constructed by Agri. Department through Government Subsidy Scheme (100%) which has created the storage up to 1.28 lakh m³ and desilitation of 2 village tanks of 90x90x3 and 110x110x3 m size was undertaken through Jalyukta Shivar Abhiyan of Govt. of Maharashtra in participatory mode, with the storage capacity of 0.55 lakh m³ which has created the irrigation potential on 366 ha.

vi) Due to these interventions the double cropping is assured and Chickpea after Soybean is possible because of water resource developed through farm ponds/ village tanks. Farmers of this village are fully convinced to adopt the two-tier rainwater management system as they are getting benefits in terms of enhanced crop productivity.

vii) Hydro-geomorphometric analysis of the drainage network in Akola district using remote Sensing Technique was carried out and the decision support information has been developed pertaining to the groundwater prospect mapping, land use
cover mapping, Stream number and stream length, drainage density, bifurcation ratio, stream length ratio, elongation ratio, form factor, circularity ratio, etc. of the 1st to 7th order streams of the drainage network in the district for making the tehsil-wise planning and to provide the plan for Jalyukta Shivar Abhiyan Authorities of Govt. of Maharashtra State. The document is found useful to the District collector for rehabilitation planning of drainage network, water bodies and construction of water harvesting structures.

viii) Word Bank team visited the demonstrations of University at farmers’ fields in Akola and Amravati districts. Based on the technologies developed by the University for Rainwater management in rainfed agriculture. World Bank awarded the funds of Rs. 4000/- crores to Govt. of Maharashtra under the project on Climate Resilient Agriculture (PoCRA) in Vidarbha and Marathwada including 1 district in Nashik covering about 18,607 villages (15 districts).

References

AGRICULTURE WATER MANAGEMENT IN MARATHWADA REGION

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1. Water Resources of Marathwada

Marathwada, the semi-arid region of Maharashtra has 64.79 lakh ha of total geographical area out of which 57.0 lakh ha area is under cultivation. With an average annual rainfall of 792 mm, Marathwada region occupies three rainfall zones viz. scarcity rainfall zone (500-700 mm) which includes parts of Aurangabad (Vaijapur, Ganagapur), Osmanabad (Bhoom, Tuljapur, Paranda) and Beed (Ashti, Patoda, Shirur) districts; assured rainfall zone (700-900 mm) covering most parts of the region and the moderate to moderately high rainfall zone (900-1100 mm) covering parts of Nanded district (Kinwat, Bhokar, Mahur). The limited irrigation facility, erratic behaviour of monsoon and constant threat of drought to nearly half of the gross cropped area are the factors inhibiting progress of agriculture in the region. Marathwada lies in Godavari basin where water is in the normal to scarcity zone. Similarly, water utilization pattern in Marathwada shows that 65% of total stored water in irrigation projects is being utilized for irrigation whereas 30% water is used for drinking purpose (Table 1).

Table: Monthwise activities by NETAfIM in Maharashtra during year 2017

<table>
<thead>
<tr>
<th>Type of project</th>
<th>Project storage</th>
<th>Oct 09 Utilizable Water storage</th>
<th>Water use for different sectors</th>
<th>Total water use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Irrigation</td>
<td>Industrial</td>
</tr>
<tr>
<td>Major</td>
<td>5015.49</td>
<td>1005.39</td>
<td>553.91</td>
<td>62.32</td>
</tr>
<tr>
<td>Medium</td>
<td>850.37</td>
<td>445.19</td>
<td>147.19</td>
<td>1.95</td>
</tr>
<tr>
<td>Minor</td>
<td>1230.97</td>
<td>549.41</td>
<td>248.74</td>
<td>0.29</td>
</tr>
<tr>
<td>Total Marathwada</td>
<td>7090.83</td>
<td>1999.99</td>
<td>949.84</td>
<td>64.56</td>
</tr>
<tr>
<td>% of total water use</td>
<td>65.00</td>
<td>4.41</td>
<td>30.35</td>
<td>0.01</td>
</tr>
</tbody>
</table>

(% of UW storage)
Marathwada region consists of eight districts and district-wise water availability indicate that most of the districts and region as whole has deficit water availability (Table 2).

Table 2. Districtwise area and availability of water (mm3)

<table>
<thead>
<tr>
<th>Districts</th>
<th>Geology Area (Lakh ha)</th>
<th>Cultivable area (Lakh ha)</th>
<th>Avg water avail.</th>
<th>Water availability as per 75% dependability</th>
<th>Avail. as per arbitral</th>
<th>Avg. water avail. m³/ha</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aurangabad</td>
<td>10.11</td>
<td>8.56</td>
<td>2588</td>
<td>1755</td>
<td>2124</td>
<td>3023</td>
<td>Normal</td>
</tr>
<tr>
<td>Jalna</td>
<td>7.72</td>
<td>7.38</td>
<td>1623</td>
<td>991</td>
<td>833</td>
<td>2201</td>
<td>Deficit</td>
</tr>
<tr>
<td>Beed</td>
<td>10.69</td>
<td>9.77</td>
<td>2571</td>
<td>1359</td>
<td>960</td>
<td>2631</td>
<td>Deficit</td>
</tr>
<tr>
<td>Latur</td>
<td>7.16</td>
<td>6.78</td>
<td>1822</td>
<td>708</td>
<td>746</td>
<td>2689</td>
<td>Deficit</td>
</tr>
<tr>
<td>Osmanabad</td>
<td>7.57</td>
<td>7.44</td>
<td>1275</td>
<td>510</td>
<td>600</td>
<td>1714</td>
<td>Deficit</td>
</tr>
<tr>
<td>Nanded</td>
<td>10.53</td>
<td>9.16</td>
<td>2844</td>
<td>1784</td>
<td>1528</td>
<td>3104</td>
<td>Normal</td>
</tr>
<tr>
<td>Parbhani &amp; Hingoli</td>
<td>11.04</td>
<td>10.22</td>
<td>2531</td>
<td>1642</td>
<td>1411</td>
<td>2478</td>
<td>Deficit</td>
</tr>
<tr>
<td>Total Marathwada</td>
<td>64.82</td>
<td>59.30</td>
<td>15254</td>
<td>8749</td>
<td>8202</td>
<td>2572</td>
<td>Deficit</td>
</tr>
<tr>
<td>State</td>
<td>307.69</td>
<td>225.42</td>
<td>163820</td>
<td>131562</td>
<td>125936</td>
<td>7267</td>
<td>Normal</td>
</tr>
</tbody>
</table>

Maharashtra is on 17th rank in irrigated area as compared to others states and its expected irrigation potential is 40% of the total cultivable area. However, because of low irrigation efficiency of irrigation projects, the area under irrigation is not increased as expected. Although there is a scope to increase efficiency of canal water, the increasing trend of using groundwater for irrigation is observed. Although the efficiency of groundwater irrigation is comparatively better it is putting more pressure on groundwater. Hence adoption of various groundwater recharge techniques has become inevitable. However, it has limitations due to presence of hard rock formations in the region. Therefore, management of deficient available water for irrigation is essential to maximize crop production and economic returns. All crops require water during their critical growth stages, therefore it is also necessary to concentrate on various water management techniques for obtaining more crop yields per drop of water.

In Maharashtra adoption of micro-irrigation systems using groundwater (well water) is picking up on farmers’ field because of water scarcity in the region. However major challenge is to link canal water with micro-irrigation systems which needs technical interventions with infrastructure like pipe networking. Adoption of micro-irrigation is one of the major technologies which can improve the situation in Marathwada region.

2. Contribution of VNKMV Parbhan in Water Management

Vasantrao Naik Marathwada Krishi Vidyapeeth Parbhan is working on rainwater and irrigation water management through its research and extension works since its inception.

2.1 Technologies for dryland agriculture

Major area of Marathwada is under dryland farming. VNKMV Parbhan has recommended numerous technologies for dryland agriculture including in-situ moisture conservation, compartmental bunding, summer land preparation, use of soil conservation furrow for kharif crops, ridges and furrow cultivation for
cotton and pigeon pea, broad bed furrow for other crops, micro watershed treatments for fruit crops, continuous or staggered contour trenches for sloping lands, graded bunds, nala bund, etc which are being used by farmers. In addition crop and area specific advice has been disseminated for farmers like contour farming, tied ridges, dead furrows, crop rotation, use of intercrops, opening of furrow before or after sowing of crops are also recommended.

2.2 Groundwater recharge techniques
The University has developed open well and bore well technologies which are being adopted by farmers.

2.3 Technologies for irrigated agriculture
Under operational research project (ORP), the University has adopted following sites in the command area of Jayakwadi irrigation project and demonstrated various technological interventions on farmers’ field.

1. Govan Ta: Pathri, Dist. Parbhani Dy No. 57 of PLBC
4. Babultzar Ta: Pathri Dist. Parbhani Dy No. 59 minor 1 & 2
5. Porwad Ta. & Dist. Parbhani Dy. No. 67 Minor ML-4

These interventions include field layouts for irrigation, irrigation schedules for various crops and cropping systems, monitoring of water table fluctuations, socio-economic survey, constraints in adoption of various improved technologies and micro-irrigation for various crops. Demonstrated comparative performance of improved field layouts such as border strip in wheat, alternate furrow in cotton; identified remunerative cropping sequences, improved irrigation practices and adoption and feasibility of drip irrigation on farmers’ field in ORP areas.

2.4 Remunerative Cropping Systems/Sequences
University has recommended cropping systems and sequences for surface irrigation.
Based on the water availability
i) Under adequate availability (80 to 90 cm depth or 13-15 irrigations in summer): Cotton-summer groundnut

ii) Under medium availability (45-60 cm depth or 7-10 irrigations in rabi/summer): Groundnut- R. Sorgghum / K Sorghum-Wheat

iii) Under limited availability (18-24 cm depth or 3-4 irrigations in rabi)Sorghum-safflower/ Soybean- Rabi sorghum / Sorghum-Gram

Based on profitability and groundnut-based cropping sequence
i) Pre-monsoon groundnut (10-25 April) - Rabi sorghum (1-15 Oct)

ii) Pre-monsoon groundnut (10 April) – Safflower (1 Oct)

iii) Pre-monsoon groundnut (10-25 May) – Wheat (1-15 Nov)

iv) Pre-monsoon groundnut (10 May) – Gram (1 Nov)

2.5 Determination of water requirement and designing optimum irrigation schedules
The water requirement of following crops and cropping systems are worked out and optimum irrigation schedules in relation to fertilizer use of crops are suggested under surface and drip irrigation systems.

1. Cereals- Sorghum (kharif & rabi), Maize, Paddy, Wheat
2. Oilseeds-Safflower, Sunflower, Groundnut (pre-monsoon, winter and summer), Mustard
3. Pulses- Pigeon pea, Chickpea, Soybean and Pea
4. Cash crops - Cotton, Bt. Cotton, Sugarcane, Turmeric, Sweet orange and Banana
5. Vegetables - Potato, Tomato, Brinjal, Chilli, Cauliflower, Onion
6. Cropping systems Cotton- Summer groundnut, Pearl millet -Wheat, Soybean -Sorghum/Wheat, Black gram -Sorghum/ Wheat

2.6 Irrigation schedules based on critical growth stages
The preference of irrigations and number of irrigations are suggested based on the availability of water and critical growth stages (days after sowing) of following crops.

Pulses: Pigeon pea, chickpea, green gram, black gram
Oilseeds- Groundnut (summer and rabi), soybean, safflower, mustard
Vegetables: Potato, Chilli, Okra, Cauliflower, Cabbage, Tomato
Cereals: Kharif hybrid sorghum, upland paddy
Cash crops: Bt. Cotton, banana, sweet orange, sugarcane

2.7 Deficit irrigation
Various demonstrations are being conducted on farmers' fields on deficit irrigation such as irrigation through furrows opened after two rows, skip furrow irrigation and alternate furrow irrigation in medium deep vertisols in assured rainfall zone when rainfall or water availability is deficient. These technologies can also be adopted during dry spells of kharif season.

2.8 Modified crop geometry and land modifications
The University demonstrated comparative performance of improved field layouts such as border strip in wheat; alternate and skip furrow in kharif crops like cotton and recommended the basin of 4.5 m – 6.6 m width and 6-12 mm irrigation depth to gram on the basis of yields, water use efficiency and the uniformity of water distribution. Similarly the rectangular planting pattern (0.9 X 1.5 m) X 2.1 m was recommended for banana with water application through drip.

2.9 Evaluation of subsurface drainage system
University has recommended technology for improvement of salt affected vertisols and waterlogged soils.
For improvement of salt affected vertisols the sub-surface drainage was recommended with drainage material as corrugated perforated PVC pipe of 80 mm diameter installed at 1.3 m depth and 75 m spacing. The envelope material should be gravel, coarse sand and fine sand of 7.5, 10 and 10 cm thick layers, respectively along with geotextiles. In addition crop residue incorporation either with sugarcane trash @ 5 t/ha or green manure (dhaincha) @ 20 t/ha was recommended before sowing of kharif crops in a soybean-wheat cropping sequence.

For the waterlogged areas corrugated perforated PVC pipe with envelope material of 5 cm gravel, 7.5 cm coarse sand and 7.5 cm fine sand or geotextile. Clay tiles with an envelope material of 5 cm gravel, 7.5 cm coarse sand and 7.5 cm fine sand also can be used.

2.10 Other recommendations

University has conducted experiments and released findings for farmers on:

i. Quality of irrigation water

ii. Studies on physicochemical properties of soils in the command area of Jayakwadi and Majalgaon

iii. Evaluation of soil water balance under different soil moisture regimes

iv. Surface irrigation design in cereals like wheat and irrigation layouts (Flat bed, ridges furrow irrigation to each furrow, ridges furrow with alternate furrow irrigation, skip furrow irrigation at every 2 furrows).

v. Conjunctive use of rain and irrigation water for Cotton (NHH-44), Rabi sorghum and Soybean

vi. Development of Pan Coefficient for USWB Class A pan for Parbhani

vii. Development of software Software development for evaluation of canal water delivery system

2.11 University’s Contribution in Micro-irrigation

The University is working since beginning on various aspects of micro-irrigation. The advanced irrigation systems such as drip, overhead sprinkler irrigation, micro-sprinkler irrigation, and rain gun irrigation were evaluated on the following crops:

a. Overhead sprinkler irrigation system: Cotton, sorghum, green gram, chickpea, pigeon pea, wheat

b. Rain gun irrigation: Wheat, Sugarcane

c. Micro-sprinkler irrigation: Onion

d. Drip irrigation: Sugarcane, Banana, Sweet orange, Mango, Bt. Cotton, Rabi sorghum, Pigeon pea, Summer groundnut, Maize, Onion, Chilly, Brinjal, Turmeric, Okra, Cabbage etc.

e. Subsurface drip irrigation: Cauliflower

University has devised schedule of sprinkler irrigation based on critical growth stages of various rabi crops and protective irrigation for kharif crops.

For maintenance of drip irrigation system through acid treatment, rate of acid injection
Marathwada region is underlain mostly by hard rocks and therefore rainwater percolation through surface storages do not sufficiently recharge underground water table. Hence Watershed Development programme should include location specific techniques of groundwater recharge.

In addition to regular demonstrations of micro-irrigation on progressive farmers’ field and in ORP area, University has conducted micro-irrigation demonstration in tribal area. The University has implemented 660 demonstrations under Tribal Sub-Plan (TSP) with the financial support of ICAR-Indian Institute of Water Management with the clear objective to empower the Tribal Population and bridging the gap in their socio-economic development. The water management technological inputs such as sprinkler irrigation sets and portable drip systems were supplied to the farmers of six tribal villages in the region. The impact of these interventions and farmers feedback was collected. In addition to saving in water time, labour and energy it was possible
to use sprinkler irrigation for protective irrigation to soybean, red gram, turmeric and cotton in kharif season. Farmers could grow rabi crops like wheat and gram and harvest optimum yields with limited water availability. These villages are developed as hub for rabi sorghum. Field demonstration of portable drip irrigation system for turmeric could make farmers to grow turmeric on raised bed and there is significant increase in yields. Similarly the villages are developed into a turmeric growing area with almost 200 ha of land under turmeric.

3. Challenges and strategy

Marathwada being deficient water availability region, micro-irrigation needs to be advocated for close growing cereals and pulses. For crops like cotton, safflower, gram, etc. alternate furrow irrigation, deficit irrigation concept needs to be used for increasing water use efficiency and water saving. Suitable farm mechanization in irrigated agriculture is required with incentives for that.

There is a need to release canal water during dry spells in kharif season. Canal water can be used through pressure and control irrigation system. Two model projects on use of canal water through controlled/pressure irrigation systems should be established on Jayakwadi Irrigation Project.

The modernization of canal water distribution and management will be a key for efficient water use in irrigation. For scientific water distribution, scheduling and water management, involvement of Agriculture Engineers having knowledge in plant soil water relationship and crop water requirement is required.

Sprinkler irrigation needs to be advocated wherever possible as a controlled irrigation under dry spells of 20-25 days during kharif and as a regular practice during rabi season for close growing crops. The crops like sugarcane and banana must invariably be irrigated with micro-irrigation systems. There is also a need to popularize water soluble fertilizers which will help to avoid surface and groundwater contamination.

Marathwada region is underlain mostly by hard rocks and therefore rainwater percolation through surface storages do not sufficiently recharge underground water table. Hence Watershed Development programme should include location specific techniques of groundwater recharge. Water storage structures/lined farm ponds needs to be provided to store excess canal/rainwater water, and be used through pressure irrigation system in addition to adoption of location and crop specific in-situ soil moisture conservation practices.
Abstract
Konkan region of coastal Maharashtra is characterized by heavy rainfall, hilly topography and highly percolative ferruginous soils. Maximum rainfall received during monsoon season meets sea either through surface or sub-surface runoff, and results in water scarce situation after monsoon. Considering the advantage of heavy rainfall and constraint of percolative soils, DBSKKV, Dapoli has taken the initiatives in rainwater harvesting, water conservation and its saving by adopting efficient micro-irrigation. The university has developed, recommended and promoted the cost-effective rainwater harvesting techniques like Konkan Jalkund, large ponds as well as water conservation techniques like Konkan Vijay Bandhara, tyre bandhara and modified vanrai bandhara. The university also standardized the modified norms for permanent water conservation structures like RCC nala bandh and accordingly these norms are followed for the region under GoM watershed schemes. The university also advocated the adaption of micro-irrigation for water saving and recommended irrigation and fertigation schedules for different crops in the region with the proof of water saving as well as enhancement of crop yield as compared to conventional irrigation methods. These techniques are found very effective in uplifting the socio-economic status of the farmers in the region.

Research on irrigation water management revealed that use of micro-irrigation and fertigation has the potential to save the water in the range of 20 to 80 per cent and it increases the crop yield also to the tune of 5 to 116 per cent as compared to the conventional irrigation method.
1. Background

The Konkan region is a coastal part of Maharashtra state confined between 1506' N and 20022'N latitude and 72030' E and 73048'E longitude covering total geographical area of 3.09 Mha. Konkan receives an annual average rainfall ranging from 2500 to 3500 mm in about 84 rainy days out of which about 90% rainfall occurs during monsoon. This rainfall intensity is about 3 to 4 times that in other parts of Maharashtra. The region has been estimated with total water surplus of 2523.60 mm (Sikka and Singh, 2000) with water availability per capita and for agriculture as high as 6 to 15 times that of availability in other basins of the State (Anonymous, 2013). Rainfall intensity in the region is high, thus, this region has a major problem of soil erosion and due to hilly topography of the region as well as porous nature of the lateritic soil, thus most of the precipitation through rainfall gets washed away to the sea either through surface or sub-surface runoff. Therefore, in spite of high rainfall and high water availability during monsoon season for agriculture as well as domestic purpose there is always water scarcity in the region after monsoon particularly during the summer season. Total cultivable area of the region is 0.86 Mha which is 28.25 per cent of total geographical area of the region. As the region receives heavy rainfall during monsoon season, mono-cropping of rice is generally followed during kharif season followed by pulses in some pockets on the residual moisture. Irrigation potential created in the region is only 4.92 per cent and actual area under irrigation (with all sources) is less than 1.5 per cent. About 73% of irrigated area in the region is irrigated using groundwater which is alarming situation for the over-exploitation of the groundwater. Thus, utilization of surface water for agriculture is one of the best options for the region. The heavy rains received during monsoon can be utilized for increasing the area under irrigation and irrigated horticultural crops by harvesting rainwater in scientific approach. The limitation for storing the harvested rainwater in the farm pond in the region is heavy seepage losses occurring through bottom and sides of the ponds due the percolative nature of the soil. The seepage losses can be reduced by providing lining to the ponds.

The various rainwater harvesting techniques have been demonstrated to the farmers by various developmental agencies of the state but it has failed to achieve its desired level. Verma (1981) revealed that rainwater harvested in small checks dams could be used for providing life-saving irrigation to rain-fed crops in sub mountain region of Punjab. Srivastava (1988) advocated the use of 250 µm black LDPE lining with round smooth stones for construction of water harvesting tanks in hilly areas. Saha et al. (2007) recommended the use of Jalkund made up of clay and cow dung plastering followed by 3.5 cm cushioning with dry pine leaf laying down of 250 µm LDPE black agrifilm covered with 5.8 cm bamboo for storage of rainwater (600-30000 litre capacity) for North Eastern hilly regions. Since, the LDPE sheet is available in 6 m width; it required joints in large tanks. These joints become weaker with passage of time and store water seeps down. Rana et al. (2009) reported that, Silpaulin lined farm pond are more economical than LDPE line and Cement lining form ponds.

The Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli has developed the water harvesting techniques suitable for heavy rain receiving zone (Konkan region) dugout type farm ponds with Silpaulin (250 GSM) lining. The UV stabilized Silpaulin film (250 GSM) proved to be the best lining material for the farm ponds in the Konkan region to control seepage through bottom and sides of farm pond (Kale et al., 2002). Hence, these techniques have potential for harvesting the abundant rainwater and it can be helpful to bring more area under irrigation. The economic feasibility study of lined farm pond was also conducted
for different cropping systems suitable for the region.

Many water saving techniques are advocated by many researchers in which the micro-irrigation is efficient and the crop productivity with its quality are also increased. The university also has taken the initiatives for promotion of this method in the field as well as under protected cultivation.

2. Achievements and initiatives

Considering the constraints and challenge of water scarcity after monsoon season, the rainwater harvesting techniques like Konkan Jalkund and Lined farm pond and water conservation techniques like, Konkan Vijay bandhara, RCC nala bandh, Tyre bandhara and Modified vanrai bandhara were developed by DBSKKV and recommended for Konkan region. The university also standardized the irrigation schedules for the crops grown in the region and suggested the water saving techniques.

3. Water conservation structures

Lined farm ponds

DBSKKV, Dapoli has worked on rainwater harvesting techniques to create both decentralized and centralized water resources for small and marginal farmers in the region and recommended to the farmers. These techniques are suitable for the cropping systems in the region.

Micro-rainwater harvesting technique (Konkan Jalkund) for remote and isolated horticulture

Konkan region has hilly topography and is bestowed with the heavy rainfall ranging from 2500 to 3500mm annually. The climatic conditions in the region are very conducive for horticulture cultivation. The region is famous for horticulture crops like mango, cashew, coconut and spice crops. In spite of the heavy rainfall in the region, water is not retained due to highly percolative soils. The soils are ferruginous in nature, thus, these become very hard after depletion of moisture content. After withdrawal of monsoon season, the newly planted grafts suffer from high soil moisture stress which results in very less survival of grafts. The farmers suffer from double loss in terms of economic and time loss as well as uniformity in plantation is also lost. The farmers have to arrange for irrigation water in the remote areas of the region which is expensive affair for the small farmers.

The most important limitation in the region is remote and hilly topography, thus, creating a huge water resource through rainwater harvesting would be costly and unstable affair involving a lot of alteration of soil profile. Second limitation is of percolative soil, thus, provision of the plastic lining to the structure is essential. Looking into the strengths for horticulture cultivation and limitations for increasing the area under agriculture, the idea of creating the decentralized water resources through rainwater harvesting was emerged, which would be economically helpful to small farmers for survival of newly planted grafts. This would facilitate rainwater harvesting in the small pits utilizing spaces in mango and cashew crops, thus, no extra space is required for this facility. The stored water in these small pits can be utilized for irrigation to newly planted grafts of mango and cashew during non-monsoon seasons.

With these challenges and limitations in the region, the technique of micro-rainwater harvesting and storing water for irrigation, locally known as “Konkan Jalkund”, was generated. The technique was developed for shallow and deep soil profile to finalize dimensions of storage pit. Prior to this, water needed for survival of newly planted grafts was finalized and tested as 10 lit/week/mango graft and 5 lit/week/ cashew graft. Thus, the capacity of each water storage pit was standardized as 4000 litres, which is sufficient to irrigate ten...
grafts of mango or twenty grafts of cashew from third week of November to second week of June (total 28 to 30 weeks). Total 10 storage pits are required for one hectare area. The dimensions of pit for deep soil profile was finalized as 2m (L) x 1m (W) x 2m (D), while for shallow soil profile, the dimensions were 4m (L) x 1m (W) x 1m (D). Percolation loss of stored water was checked by lining the pit with plastic. The dimensions of plastic lining were standardized as 7m (L) x 4m (W) for 4 x 1 x 1m pit size and 7 x 6m for 2 x 1 x 2m pit size with thickness as 250 GSM. Thickness of pre-lining cushioning bed of rice straw bundles along the walls and bottom of the pit to avoid puncture of the lining film was finalized as 5 to 10 cm. Evaporation loss was checked (up to 80%) by covering pit with the grass matting with 75% shade net provided inside the matting. Processes were also formulated for construction of pit and its lining as well as application of water to grafts. Proper distribution of storage pits in the field is recommended to reduce drudgery and provide ease for water application to grafts.

Water application process involves subsurface irrigation through applicators to reduce evaporation loss in the field. Applicator made of earthen pot or bamboo is employed to economize the system. Four applicators in four directions of each graft are buried at about 15cm depth with sufficient FYM at bottom for moisture retention, in which total 10 lit water is poured per irrigation with a frequency of week. Total cost for system process is about Rs. 60,000/- per hectare, which stores about 40000 lit of water. Thus, unit cost of rainwater storage is about Rs. 0.50 per lit of water considering the effective life span of plastic lining as three years. After first three years, the grafts can survive without irrigation also; however, harvested rainwater can be further used as water storage for insecticide spraying purpose.

4. Key results/insights/interesting facts
This technique was tested on the farmers’ field before its recommendation to the State Government and was found very useful for small farmers in the remote hills with acute shortage of water for survival of newly planted grafts. AICRP on Irrigation Water Management recommended the technology to Government of Maharashtra and looking into the effectiveness of this technique, Government of Maharashtra State has declared the 50% subsidy for its wide promotion (Government Resolution No.20090804131235001 of Govt. of Maharashtra).

AICRP on Water Management Dapoli Centre is also promoting this technology through Tribal Sub Plan by constructing more than 500 Jalkund during last five years in the remote and tribal areas of Raigad and Palghar districts. This mission led to an increase in area under irrigation facility by 2.77 folds as well as an area under horticulture crops was increased from 0.11 to 0.49 ha per respondent, increasing area under horticulture crops by 3.45 folds. The overall average survival success rate of mango and cashew grafts was 87.33% and 85.83% respectively after implementation of the intervention during this period as the retention period of rainwater stored in Jalkund was between 116-141 days (Annual Report of AICRP-IWM, Dapoli Centre, 2016-17). An interesting fact in the utilization of Jalkund is that tribal farmers in the region are using these structures not only for cashew and mango
different crops. As the region receives an average rainfall of 3000mm, the depth of pond was standardized as 3 to 3.5m depending upon soil depth. The dimensions of storage pond vary with the type and area under crop (Nandgude et al., 2008). The pond gets filled with rainwater during monsoon season and the seepage loss of water is controlled with the lining material. The crops generally require irrigation facility from November month, thus, the pond is topped up with water from nearby water resource to compensate evaporation losses during these months. The details of construction and its utilization are elaborated below. Stored water can also be utilized for life-saving irrigations to paddy crop during dry spells of its critical growth stages. Judicious utilization of water stored in ponds is advocated by coupling the pond with micro-irrigation. Further, the utilization of solar water pumping system is also recommended to the farmers to conserve the conventional power. The trainings and demonstrations to the farmers of the region are being imparted through RKVY on rainwater harvesting in which adaption of micro-irrigation and solar water pumping systems components are incorporated.

This technique is also propagated by Govt. of Maharashtra all over Maharashtra through the subsidy.

5 Large Capacity Farm Ponds

This technique was developed to create water resource in the fields and irrigate the

Tribal farmers growing jasmine as intercrop in cashew and mango. They irrigated jasmine from water stored in Konkan Jalkund

Design and construction of Lining farm pond

The site of pond should be preferably in the well-drained soils and be located nearby natural

Mr. Baban Mulya Jadhav, Kothurde village, Tal. Mahad, Dist. Raigad cultivated mango grafts with Jalkund technique
stream. The pond should be excavated with the side slope of pond embankment as 1:0.5 (Horizontal: Vertical). Proper sectioning and reshaping of ponds at bottom and sides should be done and cushioning of paddy straw (15 cm thick) should be done at bottom and four sides of pond to avoid puncturing to lining material (silpaulin). A rectangular trench of 0.3 m deep and 0.3 m wide should be excavated at top of embankment for anchoring to the lining material. The UV stabilized silpaulin of 250 GSM thickness is recommended as lining material. While spreading the silpaulin, the edges should be placed in the trenches and anchored by filling and compacting the soil for firmness in anchoring. Surplus arrangement should be provided at one end of the pond to let out the excess water. The cost of rainwater harvesting was Rs. 0.97 per litre by considering the life of silpaulin pond as five years.

Use of harvested rainwater
- The harvested rainwater can be utilized as life-saving irrigation to paddy during dry spells during monsoon, for irrigating the plantation crops and seasonal crops after monsoon season.
- The micro-irrigation (drip and micro sprinkler) should be coupled with rainwater harvesting for precise and judicious water use.
- The freshwater aquaculture can also be taken in the pond.
- The water harvesting pond technology with lining is found suitable for harvesting rainwater and bringing more area under irrigation of the region.
- This technique may help in the employment generation in the rural area. Therefore, this technology is appropriate for sustainable development of the Konkan region.

6. Konkan vijay bandhara
Konkan region receives the heavy rainfall, which concentrated during the monsoon period. However, due to topographical and geographic condition of the region, there is water crisis during the summer season. This problem could be resolved by constructing the series of low-cost temporary structures like Konkan Vijay Bandhara, Vanrai bandhara on the natural streams flowing during the later period of Monsoon.

Konkan Vijay Bandhara is an embankment of loose stones constructed across the stream and it is covered with plastic paper on the upstream side of the bandhara or check dam. It impounds the runoff and excess runoff spills over the structures. Maximum height of Konkan Vijay Bandhara is recommended as 1.0m, however, it depends upon depth available in the stream. The impounded water can be utilized as life-saving irrigation to paddy crop during dry spell periods of its critical stages; it also augments the groundwater recharge and help to increase availability of water through wells for irrigation (Mahale et al., 2003).

Site selection for construction of Konkan Vijay Bandhara
Location of bandhara should be on the streams having bed slope less than 3%. Stream should be straight on upstream and downstream of the structure with availability of sufficient
boulders. Stream shall have well defined banks with minimum depth of stream of 1 to 2 m.

Cross section of Konkan Vijay Bandhara:
Top width- 0.6 m  Bottom width- 1.6 m  Maximum height- 1 m
Side slope (d/s)- 1:1  Side slope (u/s)- 0:1

The Design features of Konkan Vijay Bandhara is shown in Fig. 3.

Procedure for construction of Konkan Vijay Bandhara:
The bandharas are constructed after the complete withdrawal of monsoon. The foundation of 1.6 m wide and 0.15 m depth should be cleaned and dug across the streambed and it should be extended 0.5 m on both banks of stream to get additional anchoring to the Bandhara. After site cleaning and digging for foundation, boulders are placed one over the other to form embankment. Upstream side (u/s) should not be provided any slope while the slope of 1:1 should be provided at downstream side. After construction of bandhara, the plastic paper of 75 GSM should be placed on its upstream side (u/s). To prevent the leakages through the structure, plastic paper shall be anchored at bottom and sides also.

Advantages of Konkan Vijay Bandhara:
1. It does not need empty bags (cement or fertilizer) and soil for construction.
2. It needs boulders of small to medium size available in streambed.
3. Skilled persons are not required for construction.
4. No need to construct every year, if proper care is taken.
5. Cost of Konkan Vijay Bandhara is less than Vanrai Bandhara.
6. It can be adapted effectively through peoples’ participation.
7. Konkan Vijay Bandharas are strong enough to sustain the impounded water, which is also economical as compared to the other structures.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Work details</th>
<th>Total amount, Rs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Site cleaning and foundation excavation</td>
<td>82.32</td>
</tr>
<tr>
<td>2</td>
<td>Excavation of both embankments up to 0.50 m</td>
<td>71.34</td>
</tr>
<tr>
<td>3</td>
<td>Filling of foundation with boulders</td>
<td>82.37</td>
</tr>
<tr>
<td>4</td>
<td>Stone Masonry work above foundation</td>
<td>377.52</td>
</tr>
<tr>
<td>5</td>
<td>Collection of loose boulders within 30 m area</td>
<td>152.94</td>
</tr>
<tr>
<td>6</td>
<td>75 GSM lining material</td>
<td>240.00</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>1006.49</strong></td>
</tr>
<tr>
<td></td>
<td>Miscellaneous expenditure (3 %)</td>
<td>35.37</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>1041.86</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Round up Total</strong></td>
<td><strong>1042.00</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Expenditure per meter</strong></td>
<td><strong>104.00</strong></td>
</tr>
</tbody>
</table>
7. RCC nala bandh

Cement Nala Bandh is very popular drainage line treatment in watershed development programme. In Konkan region this treatment is widely adopted but it has following constraints,
1. The region falls under very heavy rainfall area and heavy flood damaging the structure.
2. Sediment concentration in runoff is high.
3. Cement Nala Bandh become weak due to piping action and seepage through structure.
4. In this region due to the problem of aquatic creature and undermining action through the structure, this adversely affects the longevity of the structure.
5. Structure become ineffective within the short span of life and desired benefits are not achieved.

Due to above fact, it was demand of development departments to suggest alternate structure for cement nala bandh. Accordingly, study on the RCC Nala Bandh was undertaken at Department of Soil and Water Conservation Engineering, College of Agricultural Engineering and Technology, Dapoli since 2005-06.

The details of design is shown in Fig.4.

![Fig. 4 Design diagram of RCC Nala Bandh](image)

1. The headwall is safe against sliding, overturning, compressive stress and tension with factor of safety 1.48, 8.57, 1.47 and safe, respectively.
2. RCC Nala Bandh has hydrological, hydraulics and structural stability in the field condition.
3. The cost of Cement nala bandh of the same location is estimated and found to be Rs 47000/- (Rs Forty seven thousand only), which nearly equal to RCC bandh.
4. RCC Nala Bandh is safe and stable against all forces acting on the structure.

**Advantages of RCC Nala Bandh**

1. RCC Cement Nala Bandh becomes one unit, thus aquatic creatures are not able to damage the structure.
2. The life of structure would be more, as leakages are not observed.
3. Stability against piping and undermining is more.
4. Cost is nearly same as compared to stone masonry cement nala bandh.

8. Modified Vanrai bandhara

It is constructed across the stream using gunny bags refilled with locally available soil or sand. These bags are sealed properly and arranged in the form of a wall barrier. This wall barrier is lined with plastic paper from the upstream side, so that the seepage is stopped. This is a temporary structure built across the water course to collect the water as well as to reduce the velocity of stream.

Site selection: The same criteria should be applied as for the construction of Konkan Vijay Bandhara. In this case, availability of boulders is not essential as the bags are filled with the soil or sand available in streambed.

Material required for constriction:
1. Plastic paper (250 micron)
2. Empty cement bags/gunny bags
3. Gunny bag sealing material

Advantages:
1. It helps in replenishing aquifer below the streambed resulting in increase of groundwater level in the surrounding area.
2. It helps in providing supplementary irrigation to rabbi crops
3. Useful to animals and wildlife.

Table 2. Expenditure required for construction of 10m long Modified-Vanrai Bandhara

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Particulars</th>
<th>Unit/Measure</th>
<th>Quantity/Amount</th>
<th>Amount (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Cleaning of surface area of streambed 10 x 1.8 x 0.15 = 2.70 cu. m.</td>
<td>cu. m.</td>
<td>2.7</td>
<td>97.47</td>
</tr>
<tr>
<td>2.</td>
<td>Purchase of empty gunny bags</td>
<td>No.</td>
<td>650</td>
<td>2925</td>
</tr>
<tr>
<td>3.</td>
<td>Transportation of empty gunny bags to the location of construction site</td>
<td>No.</td>
<td>650</td>
<td>325</td>
</tr>
<tr>
<td>4.</td>
<td>To collect the soil and sand after digging 80 x 10 = 18 cu. m.</td>
<td>cu. m.</td>
<td>18</td>
<td>518.4</td>
</tr>
<tr>
<td>5.</td>
<td>Filling gunny bags with sand and soil and seal the bags</td>
<td>No.</td>
<td>650</td>
<td>1040</td>
</tr>
<tr>
<td>6.</td>
<td>Arrange the filled gunny bags</td>
<td>No.</td>
<td>650</td>
<td>1365</td>
</tr>
<tr>
<td>7.</td>
<td>Lining upstream side with 250 micron plastic paper x 2 = 24 sq.m.</td>
<td>sq.m.</td>
<td>24</td>
<td>480</td>
</tr>
<tr>
<td></td>
<td>Amount</td>
<td></td>
<td></td>
<td>6751/-</td>
</tr>
<tr>
<td></td>
<td>2% Contingency amount</td>
<td></td>
<td></td>
<td>135/-</td>
</tr>
<tr>
<td></td>
<td>Total amount, Rs</td>
<td></td>
<td></td>
<td>6886/-</td>
</tr>
<tr>
<td>8.</td>
<td>Cost of bandhara per cu. m. (with empty gunny bag) (6886/18=382.55)</td>
<td></td>
<td></td>
<td>382.55</td>
</tr>
<tr>
<td>9.</td>
<td>Cost of bandhara per running meter (with empty gunny bag) (6886/10=688.60)</td>
<td></td>
<td></td>
<td>688.60</td>
</tr>
</tbody>
</table>
9. Tyre Bandhara

1. Tyre Bandhara is an embankment of unserviceable tyres constructed across the nala and it is covered with polyethylene sheet on the upstream side of the bandhara.
2. It impounds the runoff and excess runoff spills over the structures.

Site selection criteria for construction of Tyre Bandhara

1. Slope of streambed shall be less than 3%.
2. Stream should be straight on upstream and downstream of the structure.
3. The minimum depth of nala should be 1 to 2 m
4. Nala shall have well defined banks.

Cross section of Tyre Bandhara:

1. Top width- 0.75 m
2. Bottom width- 0.75 m
3. Side slope (d/s)- 0:1
4. Side slope (u/s)- 0:1
5. Height- 0.9 m
**Procedure for construction of Tyre Bandhara:**

1. The foundation of 1.0 m wide and 0.15 m depth should be cleaned and dug across the streambed and it should be extended 0.5 m on both banks of stream to get additional anchoring to the Bandhara.
2. After site cleaning and excavation of foundation, Tyres are placed one over the other to form embankment. Upstream side (u/s) and downstream side should not be provided any slope.
3. Tyres shall be fixed together by GI rods, nuts and bolts. These rod should be inserted horizontally and vertically to interlock the tyres. These rods shall be fixed by nuts and bolts.
4. These tyres need to be filled with stones and rubbles to bring the more stability to structure.
5. After construction of bandhara, the polyethylene sheet of 75 GSM should be placed on the upstream side (u/s) of the bandhara. To prevent the leakages through the structure, plastic paper shall be anchored at bottom and sides.

**Advantages of Tyre Bandhara:**

1. It needs unserviceable tyre of small to medium size.
2. Skilled persons are not required for construction.
3. It does not needs to construct every year, if proper care is taken.
4. The scrap tyres which are hazardous to environment can be utilized for water harvesting.
5. Life of scrap tyres check dam is expected to be 10 to 15 years.

**Rubber Dam**

The rubber dam resembles like drop structure except its headwall is replaced by a textile reinforced flexible rubber for controlled storage of rainwater in the streams. Three rubber dams were constructed on the different streams near the research station Central Experiment Station, Wakawali. The design and construction details were given through NAIP project on Rubber Dam, ICAR-IIWM, Bhubaneshwar. This is an inflatable structure built across a stream used for water conservation, flood control and regulating flow of water in the stream.

**Features**

When the rubber is inflated, it serves as a check dam/ weir and when it is deflated, it functions as a flood mitigation device and sediment flushing. This variable head regulates the depth of stored water as per requirement. It can store water up to 2.00m depth. The dam has a span of 5m and thus, there is smooth passage for water flow with no restriction to debris during flood.

**Advantages**

1. Water level of storage can be occasionally deflated during flood/ high runoff to flush out all sediment to downstream.
2. During dry period/ lean season, the headwall can be easily inflated to store water at desired depth to maximum 2.0m.
3. Due to flexibility of headwall, during the extreme events of high intensity rainfall and extreme flood situation, the structure can be deflated to avoid damage to structure.

![Fig. 9 Twin type rubber dam at CES, Wakawali](image-url)
11. Water Saving

Research was conducted for judicious utilization of water for agriculture and the irrigation schedules were recommended for adaption of micro-irrigation. The response of following crops was evaluated to different irrigation amounts and frequency by using different irrigation methods. The results of the studies are shown in Table 5. The results revealed that there is always increase in the crop yield with significant water saving under the micro-irrigation as compared to the conventional methods. The observed water saving in micro-irrigation ranged from 20 to 80 per cent with the increase in yield in the range from 5 to 116 per cent. Water use efficiency was also very high for vegetable crops as compared to the field and fruit crops. Thus, it can be concluded that the vegetable crops respond very well to micro-irrigation and fertigation. It is obvious that the income from crop in the shednet cultivation are highly profitable and the required area for cultivation is also very less as compared to open field crop cultivation. However, the cost involvement and intensive care are the major constraints. As the average water saving of at least 50 per cent in micro-irrigation is assured as compared to the conventional irrigation methods, it is obvious that at least 50 per cent more area can be brought under irrigation with the same amount of water required for the conventional irrigation methods.

Table 5. Irrigation schedule, water saving and yield increase for various crops under open field and protected cultivation

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Crop type</th>
<th>Water requirement (cm)</th>
<th>% Water saving over conventional method</th>
<th>WUE (q/ha-cm)</th>
<th>Yield (q/ha)</th>
<th>Per cent increase in yield</th>
<th>B:C</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A)</td>
<td>Ginger</td>
<td>67</td>
<td>20</td>
<td>0.55</td>
<td>30.41</td>
<td>41</td>
<td>1.19</td>
<td>MS Spacing with Spacing 1.5 m x 1.5 m</td>
</tr>
<tr>
<td>2</td>
<td>Sweet corn</td>
<td>46.3</td>
<td>--</td>
<td>5.60</td>
<td>191.4</td>
<td>42</td>
<td>2.89</td>
<td>Drip irrigation with cost-effective layout</td>
</tr>
<tr>
<td>3</td>
<td>Dolichus bean</td>
<td>40.7</td>
<td>60</td>
<td>2.42</td>
<td>99.7</td>
<td>33</td>
<td>1.61</td>
<td>Micro-sprinkler with Spacing 1.5 m x 1.5 m</td>
</tr>
<tr>
<td>B)</td>
<td>Cabbage</td>
<td>57.6</td>
<td>33</td>
<td>9.32</td>
<td>537.1</td>
<td>116</td>
<td>6.92*</td>
<td>Micro sprinkler 1.5m x 1.5m * Number of curds more due to close spacing. More market acceptability for curd size</td>
</tr>
<tr>
<td>5</td>
<td>Okra</td>
<td>28</td>
<td>61</td>
<td>6.03</td>
<td>169.7</td>
<td>69</td>
<td>1.54</td>
<td>Cost-effective drip layout and fertigation</td>
</tr>
<tr>
<td>6</td>
<td>Brinjal</td>
<td>39</td>
<td>80</td>
<td>21.11</td>
<td>323.4</td>
<td>42</td>
<td>2.41</td>
<td>Cost-effective drip layout</td>
</tr>
<tr>
<td>Sr. No.</td>
<td>Crop type</td>
<td>Water requirement (cm)</td>
<td>% Water saving over conventional method</td>
<td>WUE (kg/m²-m)</td>
<td>Yield (kg/m²)</td>
<td>Per cent increase in yield</td>
<td>B:C</td>
<td>Remarks</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------</td>
<td>------------------------</td>
<td>----------------------------------------</td>
<td>---------------</td>
<td>---------------</td>
<td>-----------------------------</td>
<td>-----</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Color and green capsicum</td>
<td>54.4</td>
<td>39</td>
<td>9.00</td>
<td>4.9</td>
<td>262 *</td>
<td>3.16</td>
<td>Drip fertigation (weekly split) Spacing 0.30 x 0.45 m Shednet house (50%) *Wilt problem occurred in furrow irrigation. Yield level is minimum in control.</td>
</tr>
<tr>
<td>2</td>
<td>Broccoli</td>
<td>30</td>
<td>46</td>
<td>3.81</td>
<td>1.1</td>
<td>--</td>
<td>12.12</td>
<td>Drip fertigation (weekly split) Spacing 0.30 x 0.45 m Shednet house (50%).</td>
</tr>
<tr>
<td>3</td>
<td>Kohlrabi</td>
<td>31</td>
<td>50</td>
<td>9.72</td>
<td>3.0</td>
<td>89.30</td>
<td>1.59</td>
<td>Drip fertigation (weekly split)</td>
</tr>
</tbody>
</table>
12. Challenges

The challenges for water manager to conserve water and utilize it precisely are listed below.

<table>
<thead>
<tr>
<th>Emerging challenges</th>
<th>Soil and water management processes to meet challenges</th>
</tr>
</thead>
</table>
| Huge water resources to the tune of 1806 TMC is available in Konkan region, however, its storage and utilization is the biggest challenge. | ✓ Rainwater harvesting techniques  
✓ Construct series of check dams  
✓ Use of micro-irrigation  
✓ Distribution of irrigation water through pipe network and micro-irrigation |
| Highly percolative soils                                 | ✓ Adaption of plastic lining for water storage                                                                         |
| Fragmented and small land holding                        | ✓ Cost-effective micro-irrigation                                                                                     |
| Watershed development                                    | ✓ Acceleration of watershed program by adapting revised guidelines and norms with location specific structures         |
| Sustainable development of natural resources             | ✓ Capacity building and peoples’ participation                                                                       |
| Less than 10% irrigation potential is utilized           | ✓ Awareness program  
✓ Capacity building of trainers and field staff  
✓ Crop diversification suitable for region                    |
| Meager adaption of micro-irrigation                      | ✓ Capacity building  
✓ Growing cash crops  
✓ Cost-effective design  
✓ Establishment of operation and maintenance outlets       |
| Frequent flash flood                                     | ✓ Use of rubber dams                                                                                                  |
| Heavy rainfall with intensive storms                     | ✓ Increasing vegetation                                                                                                |
| Ferruginous soils become very hard under reduced moisture conditions | ✓ Use of mulch to reduce stress due to moisture depletion                                                             |
| Coastal saline soils (Khar land development)             | ✓ Adaption of rubber dam for control of tidal ingress  
✓ Rainwater harvesting structure  
✓ Micro-irrigation  
✓ Conjunctive use of saline and freshwater                   |

References:

Sugarcane is cultivated in more than 100 countries in the world, although the 10 largest producers are responsible for around 80 percent of the global production. In India, this crop is grown in over 5 million ha area plays a dominant role in the country’s economy. It is also important cash crop of Maharashtra responsible for overall socio-economical development of rural community. The crop is grown on around 10 lakh ha area. The variation in area is cyclic in nature depending upon the ups and down in rainfall in the state. The large variations in cane yields are noticed from year to year and place to place due to untimely availability of irrigation water as per the need of the crop and the yields in the state are stagnant at around 85 t/ha.

The water has become the most costly and scarce input in Maharashtra State because of erratic and uncertain monsoon, poor recharging of groundwater table and ever depleting soil water levels because of excessive groundwater lifting. The irrigation in the state needs to be enhanced by through various water conservation measures and adoption of micro-irrigation technology. The water application efficiency is very less under conventional irrigation. Under canal and lift irrigation command, the problems of water logging, salinity and alkalinity have been aggravated because of excessive irrigation. This has not only degraded the soil fertility but also reduced the cane yields substantially. Under well-irrigated area, there is acute shortage of irrigation water especially during summer season resulting in decline in cane yield substantially.

As the water for agricultural irrigation is becoming increasingly limited and therefore the cultivators of Maharashtra are micro-irrigation techniques in sugarcane crop for efficient water management. These techniques not only improve cane productivity but also increase the water use efficiency. Looking to the importance of micro-irrigation systems in sugarcane agriculture, the strategic plan is required to bring entire sugarcane area in the state under this technology.

**Introduction**

The drip irrigation is an advanced method of
irrigation with high frequency of water application as per the need of the crop. In drip irrigation, water is not applied to bare soil areas between the plants, but concentrates its application at the root zone of the crop. It does not in any way reduce or curtail the water requirement of the crop but only the losses such as conveyance, seepage and irrigation to unwanted areas are avoided. A typical drip irrigation system consists a network of pipes along with a suitable emitting device either emitters or jets. This is an advance method of irrigation used for many crops throughout the world including sugarcane. The adoption of drip irrigation is on increasing side in long duration with high water requirement crop like sugarcane and around 0.13 million ha sugarcane area is under drip irrigation in Maharashtra state.

Sprinkler is an accepted method of irrigation not only in the developed countries but also in developing countries. In India, there is increasing trend for adoption of sprinkler irrigation in various crops. The Raingun sprinkler irrigation being accepted by the cultivators in sugarcane crop due to advantage of covering more area at a time by replacing many small sprinklers with one raingun. It can cover about 1500 to 3000 sq. m. area under sprinkling from one position at a pressure of 2 to 5 kg/cm². The labour requirement in shifting of system also can be greatly reduced. The rainguns give gentle rain, which matches with the infiltration rate of soil and hence there is no erosion or stagnant water. Raingun sprinkler has a potential in sugarcane crop due to its advantage of achieving higher water and fertilizer use efficiencies compared to surface irrigation. The fertilizer use efficiency is low under conventional irrigation because of faulty application methods. Adoption of drip irrigation in sugarcane offers an opportunity for placement of fertilizers in soluble form at the root zone of the crop along with irrigation water to increase fertilizer use efficiency. The fertigation through drip irrigation is also gaining a momentum in the state, as this technique have advantage of application of fertilizers at appropriate rate and in desired concentration. It also provides flexibility of fertilization which enables specific requirements of the crops to be met at different stages of its growth. The injection of fertilizers through micro-irrigation systems gives better crop response than banded or broadcast application under surface irrigation. The frequent and proper amount of water application under micro-irrigation systems results in maintaining the soil air ratio at an optimum for higher uptake of nutrients. The fertilizer losses such as leaching, volatilization and denitrification are avoided and there is improvement in fertilizer use efficiency. Selection of fertilizers is important for crop response and prevention of detrimental impact on micro-irrigation systems. Fertilizer use and application efficiencies are higher, plant behaviour is better and the quality & quantity of the produce is better with fertigation. The operational aspects of micro-irrigation systems need monitoring from time to time for higher uniformity of water application. Combining fertilizer with irrigation implies the forcing of fertilizer solution into a water line operating under pressure by selecting appropriate equipments. Proper scheduling must be planned as to provide nutrients at a time when plants require them.

**Research work on Micro-irrigation systems at Vasantdada Sugar Institute**

VSI is doing research and development on Micro-irrigation system for sugarcane since last three decade and given various recommendations to the farmers for adoption of this technology and also to the state and central Government for taking policy decisions. Some of the experiments conducted at Vasantdada Sugar Institute, Pune are highlighted below;

**Performance evaluation of drip and raingun sprinkler irrigation in sugarcane crop**

An experiment on performance evaluation of Drip and Raingun Sprinkler Irrigation (RGSI) in comparison with surface irrigation in sugarcane...
crop was conducted during 2007-09 for a plant cane and ratoon crop. The quantity of irrigation water utilized cane and sugar yield levels obtained and water use efficiencies achieved in each irrigation system were studied. The observations regarding the uniformity of water distribution in drip and RGSi were also recorded. The experiment was conducted with a sugarcane variety Co 86032. The paired row planting with row spacing of 90-180 cm was used for drip and RGSi, while 90 cm row spacing was used in surface irrigation. The standard recommended practices of cultivation were followed throughout the crop growth period.

The results revealed that the quantity of water applied in drip, raingun sprinkler and surface irrigation was 1243, 1731 and 2496 mm respectively. The water-saving of 50.20% was recorded in drip irrigation while 30.65 % in RGSi as compared to surface irrigation. The cane yield obtained in drip and RGSi was 153.25 t/ha and 145.50 t/ha respectively. The cane yield was increased by 23.40% in drip irrigation while 17.16 % in RGSi as compared to surface irrigation (124.19 t/ha). The sugar yield recorded in drip and RGSi was 23.71 t/ha and 22.19 t/ha respectively. The sugar yield was improved by 21.46 % in drip irrigation and 13.68 % in RGSi as compared to surface irrigation (19.52 t/ha). The water use efficiency achieved in drip RGSi was 0.1233 t/ha/mm and 0.0840 t/ha/mm respectively. The water use efficiency was improved by 2.48 times in drip and 1.69 times in RGSi as compared to surface irrigation. The uniformity of water distribution was higher in drip irrigation (92.13%) than raingun sprinkler (75.26%). The drip and raingun sprinkler irrigation systems showed better results regards saving of water and fertilizers, increase of cane yield and higher water use efficiency as compared to surface irrigation. These irrigation systems are being increasingly adopted in commercial sugarcane plantation as the cultivators are confirming the gain in productivity along with saving in water and fertilizers.

Effect of water application through drip and RGSi on cane and sugar yield and water use efficiency (Pooled data for Plant cane and ratoon crop)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Irrigation systems</th>
<th>Quantity of water applied mm</th>
<th>Cane yield t/ha</th>
<th>Sugar yield t/ha</th>
<th>Water use efficiency t/ha/mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Drip irrigation</td>
<td>1243</td>
<td>153.25</td>
<td>23.71</td>
<td>0.1233</td>
</tr>
<tr>
<td>T2</td>
<td>Raingun sprinkler irrigation</td>
<td>1731</td>
<td>145.50</td>
<td>22.19</td>
<td>0.0840</td>
</tr>
<tr>
<td>T3</td>
<td>Surface irrigation</td>
<td>2496</td>
<td>124.19</td>
<td>19.52</td>
<td>0.0497</td>
</tr>
</tbody>
</table>

Fertigation under drip irrigation
The fertigation studies to optimize the N and K fertilizer dose application through drip irrigation for sugarcane was conducted during 2003-2006 for two plant cane and one ratoon crop with seven treatments and four replications in randomized block design. The fertilizers levels were varied as compared to 340 kg N, 170 Kg P2O5 and 170 kg K2O per ha of the recommended dose. The experiment was conducted with a sugarcane variety Co 86032 in medium deep black soil. The paired row planting of 90-180 cm was used for drip irrigation while 90 cm row was used for surface irrigation. In treatments T3 to T7 the N and K2O fertilizers were applied through drip irrigation in thirteen equal splits up to six months of crop age while P2O5 was applied through soil application as per the recommended practice. In treatment T1 and T2 the NPK fertilizers were applied through soil application as per recommended splits. The standard recommended practices of cane cultivation were followed throughout the crop growth period.

The cane yield changed significantly in response to irrigation method and fertigation. The yield levels obtained in treatments T2, T3, T4, T5 and
Experiments concluded that drip irrigation was effective in sugarcane crop for saving of irrigation water to the tune of 50% along with increase in cane yield of 23%, saving of N and K fertilizer by 30%, increase in sugar yield by 22% and improving water use efficiency by 2.5 times.

T6 were significantly superior to treatment T1 (control). The fertilizer level of 70% N and 70% K₂O of recommended dose application through drip irrigation along with 100% P₂O₅ application through soil produced a cane yield of 170.08 t/ha, which was 19.08% higher than the control. The reduction of fertilizer dose to 70% N and 55% K₂O of recommended dose application through drip irrigation along with 100% P₂O₅ application through soil resulted in cane yield of 148.25 t/ha which was non-significant compared to control. The data indicated that 30% N and K₂O fertilizers can be saved if applied through drip irrigation for sugarcane.

Effect of NPK fertigation under drip irrigation on cane yield (Pooled data for two plant cane and one ratoon crop)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>NPK fertilizer levels</th>
<th>Cane yield t/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>100% of recommended NPK dose through soil under surface irrigation (Control)</td>
<td>142.82</td>
</tr>
<tr>
<td>T2</td>
<td>100% of recommended NPK dose through soil under drip irrigation</td>
<td>163.88*</td>
</tr>
<tr>
<td>T3</td>
<td>70% N + 115% K₂O through drip and 100% P₂O₅ through soil</td>
<td>170.32*</td>
</tr>
<tr>
<td>T4</td>
<td>70% N + 100% K₂O through drip and 100% P₂O₅ through soil</td>
<td>169.43*</td>
</tr>
<tr>
<td>T5</td>
<td>70% N + 85% K₂O through drip and 100% P₂O₅ through soil</td>
<td>175.50*</td>
</tr>
<tr>
<td>T6</td>
<td>70% N + 70% K₂O through drip and 100% P₂O₅ through soil</td>
<td>170.08*</td>
</tr>
<tr>
<td>T7</td>
<td>70% N + 55% K₂O through drip and 100% P₂O₅ through soil</td>
<td>148.25</td>
</tr>
<tr>
<td>SE ±</td>
<td></td>
<td>2.12</td>
</tr>
<tr>
<td>CD at 5%</td>
<td></td>
<td>6.24</td>
</tr>
</tbody>
</table>

* Significantly superior over control

Fertigation under raingun sprinkler irrigation

To optimize the dose of NPK fertilizer application through RGSI for sugarcane, an experiment with five treatments replicated four times in a randomized block design was conducted during 2003-06 for one plant cane and two ratoon crops. The fertilizer levels were varied as compared to 315 kg N, 140 kg P₂O₅ and 140 kg K₂O per ha of recommended dose. The wider spaced sugarcane planting of 1.2 m was used for the experimentation. The NPK fertilizers were applied in the form of urea, di ammonium phosphate and muriate of potash. Fertilizers were applied in four equal splits up to 4.5 months of crop age in treatments T1 to T4 and by soil application as per recommended splits in treatment T5. The standard recommended practices of cane cultivation were followed throughout the crop growth period.

The cane yield obtained in treatments T1, T2 and T3 was significantly superior to control treatment T5. A fertilizer level of 75% of recommended dose through RGSI produced a cane yield of 151.79 t/ha, which was 14.81% higher than the control. The reduction in NPK dose to 50% resulted in a cane yield of 137.30 t/ha, which was non-significant compared to control. The data obtained indicated that 25% of NPK fertilizers can be saved if applied through RGSI for sugarcane.
Effect of NPK fertigation under RGSI on cane yield  
(Pooled data for plant cane, first and second ratoons)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>NPK fertilizer levels</th>
<th>Cane yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>125% of recommended dose through RGSI</td>
<td>156.05*</td>
</tr>
<tr>
<td>T2</td>
<td>100% of recommended dose through RGSI</td>
<td>154.09*</td>
</tr>
<tr>
<td>T3</td>
<td>75% of recommended dose through RGSI</td>
<td>151.79*</td>
</tr>
<tr>
<td>T4</td>
<td>50% of recommended dose through RGSI</td>
<td>137.30</td>
</tr>
<tr>
<td>T5</td>
<td>100% recommended dose under surface irrigation (Control)</td>
<td>132.21</td>
</tr>
</tbody>
</table>

SE ± 2.47  
CD at 5% 7.46

* Significantly superior over control

The results of the above experiments concluded that drip irrigation was effective in sugarcane crop for saving of irrigation water to the tune of 50% along with increase in cane yield of 23 %, saving of N and K fertilizer by 30 %, increase in sugar yield by 22 % and improving water use efficiency by 2.5 times compared to surface irrigation while raingun sprinkler irrigation was found superior over surface irrigation in sugarcane crop for saving of irrigation water by 31 %, increases in cane yield of 17 %, savings in NPK fertilizers by 25 %, increase in sugar yield by 14% and improving water use efficiency by 1.7 times compared to surface irrigation.

Promotion of Micro-irrigation in Sugarcane and future perspectives

To promote micro-irrigation in sugarcane at farmer’s level, various schemes under Department of Agriculture and Cooperation,

Govt. of India, State Agriculture Departments are being implemented. To tap the full potential of the micro-irrigation systems, appropriate policies are to be adopted. This invites integrated approach and endeavour on the part of both central and state government agencies. The major steps required are:

- Motivation to all potential sugarcane growers by central and state Government and the sugar mills for adoption of these micro-irrigation systems to increase the productivity and production per unit of land and water use.
- Supply of standard material to confirm Indian Standards at cheaper rate
- Prompt after sales customer services for maintenance systems with availability of adequate spares by manufacturers and their dealers.
- Development of skills and confidence in farmers about micro-irrigation Through training programs
- Operational research studies to prepare the ready reckoner of daily water requirement considering the age of crop, season and soil types of major locations in sugarcane producing states of the country.
- Fertigation should be mandatory part of micro-irrigation system rather than optional one.

To enhance the area under micro-irrigation in sugarcane, the support of government agencies, research institutions and manufacturers are equally important. The total area can covered in a phased manner, there is no need for horizontal increase in the area for production of sufficient sugarcane to suffice the installed crushing capacity of all the sugar mills in the state. The efforts being made at all levels may be further refined and strengthened for promotion of micro-irrigation technology in sugarcane crop.
Drip Irrigation Material Testing Laboratory:
Vasntdada Sugar Institute has established Drip Irrigation Material Testing Laboratory for testing the irrigation laterals, emitters and emitting pipes as per relevant IS specifications. This Laboratory is accredited by National Accreditation Board for Testing and Calibration Laboratories (NABL), New Delhi since 2005. This laboratory provides the testing services to the farmers, Commissionerate of Agriculture, Govt. of Maharashtra and Sugar mills for monitoring of quality of drip irrigation systems.
1. Introduction

1.1 India, with 2.4% of the world's total geographical area and 18% of the world's population, has only 4% of the world's total freshwater resources. With about 4000 billion cubic meter (BCM) of annual rainfall, the estimated utilisable water resources is only 1123 BCM (28%), mainly due to hydrological, topographic and other physical constraints. Of the available utilisable resource, 690 BCM is from surface water sources and the remaining 433 BCM is from replenishable groundwater sources. As against this, the cumulative water utilization by all sectors of the economy is 702 BCM (2010) of which, agriculture sector alone consumes around 78% of the total water utilization. This is despite the fact that more than 55% of agriculture in India is rainfed and depends on the vagaries of monsoon.

1.2 With rapid population growth, urbanization and improvement in the living standards, the water requirement for all sectors is increasing giving a challenge for fair allocation of water. The National per capita annual water resource during 2001 was 1816 cubic meter which fell to 1544 cubic meter in 2010 (CWC, 2015). As per International standard, a situation with less than 1000 cubic meter per capita is considered to be water scarcity situation. It is estimated that by 2050, the total water demand by all sub-sectors (1180 BCM) will surpass the total utilisable water resource.
of the country (CWC, 2015). This means that improving water use efficiency is one of the key priorities of Indian Agriculture. Presently, the average efficiency in respect of surface water irrigation is 35-40% whereas the same is around 55% in the case of groundwater irrigation.

1.3 The ultimate irrigation potential of the country has been estimated to be 139.90 million hectare (mha)(64.05 mha from groundwater and 75.85 mha from surface water). Further, additional irrigation potential of 35 million ha could be created through implementation of Inter Basin Water Transfer proposals, taking cumulative potential to 175 mha. As against this, irrigation potential for 113.24 million hectare has been created up to end of XI Five Year Plan i.e. up to March 2012 of which, 89.94 m.ha has been utilized, leaving a gap of around 23.30 million ha which is yet to be utilized.

1.4 Water has been an important enabler in increasing the agriculture output of Maharashtra. Agriculture sector is the highest user of freshwater, withdrawing more than 80% of the water (Blue water) available to the State. The ultimate irrigation potential in the state was estimated at 12.6 million ha, comprising 8.5 million ha by surface water and 4.1 million ha by groundwater (MW&IC, 1999). In 2014, about 3.7 million ha were irrigated through surface water and about 3 million ha through groundwater. As regards the groundwater irrigation, it is estimated that about 1.5 million ha are irrigated by conventional surface irrigation methods and about 1.5 million ha through drip/sprinkler systems.

1.5 The annual groundwater draft in the State is 17.07 BCM and stage of groundwater development is 54%. Out of 353 blocks, 9 have been categorized as ‘Over-exploited’, 1 as ‘Critical’, 19 as ‘Semi-critical’ and remaining 324 as ‘Safe’. There is scope for further development of water resources in the safe blocks in a sustainable manner.

2. Financing Irrigation Development

2.1 Investing in irrigation, a proven strategy for improving and stabilizing incomes, can alleviate distress while smoothening the year-to-year variability in growth in Gross Value Added (GVA) from agriculture. NABARD therefore accorded high priority for expanding irrigation and improving water-use efficiency. NABARD has been supporting the efforts of Government, by creating necessary framework for promoting institutional credit based on technical assessment, credit absorption capacity of a given region and banking system, developing irrigation infrastructure, setting up of technical standards for investments by financial institutions and undertaking promotional/developmental initiatives for enhancing the demand for credit, etc.

Apart from facilitating credit flow for creation of on-farm irrigation infrastructure by the individual farmers, NABARD is supplementing the resources of the Govt. of India/State Govt. for creation of large irrigation networks and command area management through Rural Infrastructure Development Fund (RIDF), Long Term Irrigation Fund (LTIF) and NABARD Infrastructure Development Assistance (NIDA).

2.2 With the view to achieving the objective of doubling of farmer’s income by 2022 as envisioned by the Govt. of India, NABARD

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5 “Experiences in Irrigation Reforms in Maharashtra” by Dr. Suresh A Kulkarni, ICID Publication
6 Dynamic Groundwater Resources of India (as on 31 March 2013), CGWB, Published in June 2017.
has initiated several measures to ensure access to irrigation facilities and improved water use/irrigation efficiency in irrigated agriculture. Some of these initiatives include preparation of area-specific/district specific credit plans based on water budgeting, model projects for accelerating credit for promoting on-farm irrigation structures, solar based irrigation pump sets, promotion of climate-resilient agriculture, appropriate crop diversification, water-efficient technologies for judicious utilization of water, strengthening of community-based institutions such as Water User Associations (WUAs) and encouraging community-led development models for achieving the scale in water resources management.

3. NABARD’s Role in financing water resources development

3.1 Sectoral Credit planning, monitoring and Coordination
Institutional credit under private sector mainly flows for the development of minor irrigation facilities through groundwater resources, including micro-irrigation systems and solar pump sets. NABARD prepares potential credit plans for all districts including estimation of credit potential under minor irrigation which forms part of the District level annual credit plan. This plan is monitored by the District Plan is monitored through District Level Coordination Committee. NABARD has been playing proactive role in promoting feasible investments under minor irrigation sector.

The Potential Linked Credit planning estimate for Maharashtra underwater resources sector (minor irrigation activities) for year 2018-19 is Rs.5554 Cr and for year 2019-20 it is Rs.5714 Cr.

3.2 Unit Costs of major Investments
State specific unit cost for various MI investments are finalized by NABARD Regional Offices based on the technical and financial assessment of given investment activity as well as wide consultation with the stakeholders and the same forms the basis for assessment of the credit potential for these investments.

3.3 Preparation, Implementation, Monitoring of ADS
Considering the location specific and agro-climatic situation based focus required for investment credit under minor irrigation sector, NABARD has been developing Area Development Schemes (ADS) specific to sector/investment activities. The Schemes are formulated based on the assessment of technical feasibility and financial viability of the investment activity for a given area taking into consideration the required backward and forward linkages. The schemes are implemented in a focused manner through financial institution as part of the credit planning process.
In Maharashtra 11 ADS have been specifically prepared for promoting drip irrigation with an outlay of Rs. 321.13 cr for implementation during 2018-23. The progress under these schemes is being regularly reviewed at the DLCC, to ensure necessary credit linkages.
3.4 Bankable Model Projects
NABARD has been supporting the development of bankable model projects for various irrigation investment. These model projects include guidance for techno-economic and financial analysis of the investments and has been found to be useful by the bankers, farmers as well as entrepreneurs. The model bankable projects are made available through NABARD website.

4. Financial Support for Irrigation Development
4.1 Refinance to financial institutions
4.1.1 Development of minor irrigation particularly groundwater schemes are largely dependent upon mobilization of institutional investment and on private investment. NABARD has been serving as an apex refinancing agency, steering various irrigation developmental policies and programmes related to credit with a view to boosting ground level credit (GLC) flow through various rural financing institutions.

4.1.2 NABARD provides refinance support to all banks for financing MI structures like wells, community tube wells, energy efficient pump sets including solar-based pump sets, pipelines, water courses, lift irrigation schemes, micro-irrigation structure, check dams, etc. to the extent of 100% of their finance During 2017-18, at All India level, out of aggregate refinance support of Rs.65,240 crore to banks for their long-term lending, the share of minor irrigation was Rs. 1513 crore (i.e. 2.32%).

4.1.3 Drip irrigation for sugarcane: There is an increase in area under sugarcane cultivation in Maharashtra. It is estimated that the cultivated area under sugarcane was 6.5 lakh ha, 9.2 lakh ha and 11.62 lakh ha during 2016-17, 2017-18 and 2018-19 respectively. Since sugarcane consumes huge amount of water, this
puts pressure on the already precarious position of water availability in the state. A solution could be using drip irrigation in sugarcane which will save up to 40% water. A scheme for financing of the drip in sugarcane through the DCCBs to the farmers has been designed by the State Govt. which also envisages the State Govt providing 4% interest subvention and the sugar mills bearing 1.25% of the interest so that the farmer pays only 2% rate of interest for the loan. The scheme can be further popularized by combining the same with the available capital subsidy scheme under PMKSY.

4.2 Direct Financing

4.2.1 RIDF Support to State Governments
As on 31 March 2018, at all India level about 31.62 m ha irrigation potential has been created/stabilized through the irrigation projects sanctioned under Rural Infrastructure Development Fund (RIDF) in India. Out of total financial assistance sanctioned for various infrastructure projects, the share of irrigation projects is around 35%\(^7\). The same has contributed substantially for creation of tangible benefits in terms of improved productivity and income of the farmers in the command areas.

NABARD has been financing to the State Govt. for creating irrigation infrastructure out of Rural Infrastructure Development Fund (RIDF) created during 1995-96.

In Maharashtra 884 projects have been sanctioned with a loan amount of Rs. 5530 Cr under RIDF. These projects could bring an area of 5.70 lakh ha under irrigation, changing cropping pattern and improving production and productivity.\(^8\)

Considering the huge investments made out of the RIDF for rural infrastructure over two decades and in order to assess the physical & financial progress, implementation process, quality of assets created, socio-economic impact of the projects, etc.; studies were conducted through Institutes of repute. The major findings\(^9\) of the study in respect of Irrigation Sector are summarized below:-

i. **Change in the cropping pattern form traditional crops like paddy, cotton, bajra (Pearl millet), wheat to high value crop like vegetables, fruits, soybean, sugarcane, etc., in Maharashtra**

ii. **More than 30% increase in irrigated area and 50% increase in cropping intensity.**

iii. **Quality of life and standard of living improved.**

iv. **Increase in Credit Flow.**

NABARD has also been supporting micro-irrigation programme through NABARD’s own infrastructure development fund NIDA. A micro-irrigation project was sanctioned to Telangana State Horticulture Development Corporation amounting to Rs. 874 crore.\(^10\)

Formation of WUAs is an important aspect for all irrigation projects. NABARD has been promoting the development of WUAs under irrigation commands of infrastructure projects. The efforts are also being made to make these WUAs financially viable and operational through encouraging development of producer’s organization out of these WUA.

4.2.2 Long Term Irrigation Fund (LTIF)
The Govt. of India during 2016-17 set

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\(^7\)Source: NABARD Annual Report 2017-18

\(^8\)NABARD State Focus Paper – Maharashtra 2018-19 and 2019-20 (Draft).


\(^10\)NABARD Annual Report 2016-17
up Long Term Irrigation Fund (LTIF) in NABARD with an initial corpus of Rs. 20,000 crore for fast tracking of incomplete major and medium irrigation projects. With a view to incentivising the states, loans are extended for 15 years under LTIF including moratorium of three years on principal repayment and at an interest rate of 6 per cent per annum. In order to ensure funding at 6 per cent per annum there is a mechanism for blending of resources directly raised by NABARD with those raised through GOI- Service Extra Budgetary Resources (EBRs) in required proportion. LTIF is envisaged to fast track the completion of the 99 identified irrigation projects, spread across 18 states in mission mode by December 2019. Subsequently, GoI approved the funding for the Polavaram project in Andhra Pradesh and Central and State shares for the North Koel project in Bihar and Jharkhand under LTIF. In Maharashtra, State Government was sanctioned a loan amount of Rs.11483.02 crore under LTIF for completion of 23 projects. A cumulative disbursement of Rs.4972.24 crore has been made under this fund for these projects of which Rs 1959.26 crore was disbursed during 2017-18 and Rs.1289.40 crore has been disbursed during the current year 2018-19 . With availability of ready funds, it is expected that these projects would be completed by 2018-19 and bring an area of 8.65 lakh ha under irrigation.

4.2.3 Micro-Irrigation Fund (MIF):
In order to achieve the national objective of enhancing water use efficiency in agriculture sector and bringing about desired growth, the Govt. of India had set up a dedicated fund in NABARD titled “Micro-irrigation Fund (MIF)” with an initial corpus of Rs. 5000 crore to be utilized from the year 2017-18 onwards. The main objective of the fund is to achieve overall improvement in water use efficiency by about 20% and to cover at least 10% of command area of surface irrigation projects. The fund, on operationalization, would be used for providing loans at reasonable rate to the State Govt. who are the major stakeholders for meeting the state’s share in the projects.

4.2.4 Umbrella Programme for Natural Resource Management (UPNRM)
Umbrella Programme for Natural Resource Management (UPNRM) is a unique programme envisaging credit financing for protection and conservation of natural resources. Unlike other development programmes, UPNRM is extending financial support in the form of loans with a need based grant component at competitive market interest rates to NRM based projects. UPNRM successfully practices credit financing for sustainable utilization, protection and conservation of natural resources combined with capacity building and other technical support. This is a paradigm shift from the traditional approach of implementing development projects primarily by means of grant and subsidies.

Under this programme some of the innovative projects under implementation are directly linked to building water security and better management of water resources through community
involvement. Out of 191 projects under implementation, 28 project are linked to irrigation efficiency, whereas one project is linked to drinking water (use of reverse osmosis at community level for safe drinking water through payment/ water charges by community).

Drip irrigation has been promoted in Maharashtra which is prone to successive spells of droughts. Today, the area under drip irrigation covering water intensive crops like sugarcane and banana is around 0.45 million ha which is about 28 percent of the total drip irrigated area in the State. Sustainable Sugarcane Initiative (SSI) covers 520 ha of land in five different projects, mostly with drip irrigation which helps in saving water and reducing use of fertilizer and pesticides during cultivation.

Innovative solutions under UPNRM such as replacing old inefficient pumps with new efficient pumps under partnership of Bangalore Electricity Supply Company Ltd. (BESCOM) and Enzen Global Solutions Private Limited are conserving electricity used for irrigation. The project addresses the core issues of inefficient energy management and depletion of groundwater. The project’s two-pronged approach intervenes at the individual villager and community level: Project interventions at the individual level included 1) Capacitate farmers through trainings on water recharging techniques and the pump sets’ maintenance, 2) Train local youth in extension activities; and local technicians in the installation and maintenance of pump sets, 3) Promote the adoption of efficient irrigation pumps and improved agricultural practices among farmers, project interventions at the community level viz. 1) Demonstrate water recharging methods on dry open wells and dry bore wells. 2) Install an information kiosk that provides farmers information related to agriculture and markets. Under the project 234 farmers adopted the efficient irrigation pumps resulting in specific energy consumption reduction of about 30% or 1,958,441 kWh over 18 months. This innovative partnership design has a great potential for replication across India.

4.3 Other developmental interventions

4.3.1 Watershed Development

NABARD has been implementing watershed development projects since 1992 with an aim to improve agricultural development by capturing scarce water resources and managing the soil and vegetation both in rain-fed and semi-arid regions. As on 31.03.2017, 1935 watershed projects were implemented across 19 States covering more than 5 lakh households and 1.9 million ha area.

NABARD’s watershed development programme in Maharashtra has, in fact, served as pioneering effort in participatory watershed management for implementation of similar programmes in other parts of India. The watershed projects implemented by NABARD so far cover more than 4.2 lakh ha area in the State. Total 317 projects under NABARD’s Watershed Development Fund (WDF) cover 2.96 lakh families with an outlay of Rs. 345 Cr.

These efforts have resulted in important learning under participatory watershed management approaches for drought
proofing and climate change resilience. Though these projects have helped in augmentation of surface and groundwater resources, enhanced cropping intensity/crop productivity and also promoted the water governance through participatory irrigation management & water budgeting there was a felt need to integrate sustainability aspects under these projects. In view of this, NABARD has started integrating sustainable development programme under these projects. As indicated by various independent evaluation studies taken-up under these projects, the interventions under watershed development programme of NABARD have sustainably reduced the farmers’ distress in rain-fed areas, stabilised crop yield and improved the farmers’ income levels.

NABARD under Watershed Development Fund (WDF) launched a new programme on Springshed Development in North Eastern Region including Sikkim in February 2017. Further, the programme was also made applicable to Maharashtra from year 2018-19. In Maharashtra considering potential for springshed development particularly in Western Ghats and Kokan region three projects have been identified for further development under the programme. Springshed are the main source of drinking for many villages in these region, however, owing to destruction and degradation of natural resources especially forests and adverse impact of climate change over a period of time, these springshed are getting dried up causing severe water scarcity in the hilly region. Though the region receives high rainfall, there is no waters security in the region. There is an absolute need for breaking the cycle of abundance and scarcity through conservation and storage of water through scientific springshed development approach. The major objective of the scheme is to revive the dying springs and enhance agriculture production, productivity, income and livelihood of farming community in the region.

4.3.2 Participatory Planning - Water Conservation Campaign 2017: NABARD launched a major Water Conservation Campaign during April-June 2017 to create mass awareness about the need for conservation/preservation and efficient use of water through available technologies by the rural community. More than 1 lakh villages were covered under the campaign, including 6962 villages in 16 vulnerable districts of Maharashtra. The campaign essentially focused on creating awareness among the rural community about the methods of water conservation/preservation and its efficient utilization at various levels using the modern technologies like micro-irrigation (more crop per drop), traditional water management practices, adopting improved package of agronomic practices, etc. The campaign was designed to engage with major stakeholders at different levels including Govt. departments, banks, Agricultural universities/KVKs, PRIs, Resource NGOs, local water champions and other volunteers. To make the campaign effective, area-specific contents covering different water management practices.
applicable to local conditions for various agro-climatic regions, with emphasis on community participation, were developed for sharing with the community.

4.3.3 Campaign on Efficient Use of Water 2018: The campaign was implemented by NABARD in August 2018 in 10 districts of Maharashtra, viz., Kolhapur, Sangli, Solapur, Ahmednagar, Osmanabad, Aurangabad, Nandurbar, Washim, Nagpur and Yavatmal. The emphasis of the campaign was on promotion of drip irrigation in sugarcane complementing the efforts of the State Government to promote micro-irrigation in a mission mode for sugarcane crop. The people centric campaign had close collaboration with the concerned Departments of Government of Maharashtra, sugar industry, NGOs and micro-irrigation product manufacturers.

4.4 Financing Resilience building to tackle Climate Change Impact on Water Resources

Projections based on climate models indicate that on a global scale, temperature will continue to rise over the next century causing rise in sea levels and change in circulation pattern that affect precipitation. Water will get biggest hit in terms of availability and extremes of floods and droughts. Further, though the global scale projections indicate a possible increase in precipitation in India, certain areas would receive lower rainfall due to considerable spatial variations. The impact of climate change will essentially be reflected in terms of water availability, changes in agricultural water demand, hydrologic extremes of floods & droughts, changes in water quality, salinity ingress in coastal aquifers, modifications in groundwater recharge and other related phenomena. NABARD as NIE for Adaptation Fund and Green Climate Fund, has been making efforts for accessing climate finance to address adverse impacts of climate change through adaptation actions as also climate proofing of the existing investments in various sectors of economy including the water sector.

NABARD has been making efforts for channelizing national and international climate finance under funding arrangements, viz., Adaptation Fund (AF), National Adaptation Fund for Climate Change (NAFCC) and Green Climate Fund (GCF). Under these funding arrangements, as of now, in India, 35 projects with fund support of about USD 250 million (total project outlay of USD 530 million) benefitting about 7.1 million people have been sanctioned. NABARD is also making efforts for development of feasible project concepts for mitigation sector under GCF. Under NAFCC, one project has been sanctioned for Maharashtra, viz., “Project on Efficient Water Management and Agriculture Technology Adoption for Climate Adaptive and Resilient Farming System in 51 Villages of Nandurbar and Buldhana Districts of Maharashtra” for implementation through Vasundhara Watershed Development Agency (VWDA), Govt. of Maharashtra.

5. Conclusion- Issues and Approaches

5.1 Financing water resources development needs to address the critical issues related to sustainability as well as the challenges posed by climate change. The same requires further analysis of social and environmental parameters in design and implementation of these projects.

5.2 According to World Bank report almost half of South Asia’s population, including India, now lives in the vulnerable areas and will suffer from declining living standards that could be attributed to falling agricultural yields, lower labor productivity or related health impacts. Some of these areas are
already less developed, suffer from poor connectivity and are water stressed. Seven out of the top 10 most-affected hotspot districts belong to the Vidarbha region of Maharashtra. This poses challenges in terms of irrigation as well as drinking water security and necessitates need for applying climate lens for climate proofing of investments as well as management of the resources. NABARD has successfully demonstrated implementation of climate proofing approaches for projects such as watershed development, small water conservation measures as well as investment activities in livelihood sectors linked to dry land agriculture. There is need to develop tools and approaches for integrating climate change linked challenges in design development and management of water resources projects.

5.3 Despite being pioneer in application of micro-irrigation technologies, the gross area under drip and sprinkler irrigation in Maharashtra is around 2.3 Million Ha, with average area expanded by about 100,000 Ha in the last five years. Considering that the State’s total area under agriculture is more than 20 Million Ha and only about 20% of it is covered under formal irrigation system, at the present rate it would take decades before micro-irrigation systems can be installed in every farmer’s field in the State. Further, state has rapidly increased its area under cash crops such as Cotton and Sugarcane over last five decades. Sugarcane which has received significant attention in India for its high water consumption is also growing rapidly in Maharashtra in the last decade with a CAGR of area at about 3.84%. There is a need to rapidly cover the area under sugarcane with drip irrigation system, since this crop which is cultivated on less than 4% of the total cropped area of the state, consumes 70% of the irrigation water. There is a need to consider the water productivity aspect of the crops also in designing of irrigation commands as well as promoting the cropping patterns. Financing of micro-irrigation needs further impetus and development of suitable value chain linked financing models as in case of the sugarcane-tie up loans.

5.4 Inadequate and erratic power supply and delays in energization of irrigation structures is also impacting the financing of water resources development as well as its viability. There is increased focus on promoting solar energy for irrigation. NABARD has successfully demonstrated use of canal rooftops for solar power generation which can also result in reduction in evaporation losses. However, there is a need to ensure that access to energy does not result in over-exploitation of water resources under decentralized power generation scenario. This necessitates sensitization and capacity-building of farmers with regard to efficient use of water resources and associated benefits in terms of better water management coupled with financing of these investments.

5.5 Considering the fact that more than 80% of the area is under rainfed condition soil and water conservation under watershed management approach assumes importance for Maharashtra. Government has given due importance for implementing watershed programme under IWMP as well as recent programmes such as Jalayukt Shivar Abhiyan also aims at augmenting surface and groundwater resources. However, there is need to integrate water saving measures to improve water use efficiency under these programme as an integral part. This would also require collaboration with between the various government department as well as financial institutions. Civil Society Organizations can play an important role for capacity building at grass root level.
Introduction:
After independence, in the pursuit of achieving increased food production, Indian Agriculture Sector went through an Era of Green Revolution. We poured high yielding varieties of seeds, chemical fertilizers and pesticides in the farming industry and increased the agricultural output to gain self-sufficiency in food. Today, our agricultural produce of food grains has touched a figure of 285 million tonnes.

Water plays a key role in the agricultural industry. The country is subjected to seasonal rainfall which is very much erratic in its behavior and undergoes variations of extreme nature both in space and time. To combat this nature-made situation, large number of water resources development projects comprising of reservoirs, lifts, canals and distribution network were undertaken almost in every part of the Country and it became possible to regulate the outflows from the reservoirs in a need-based way to enable to grow more than one crop on a piece of land. The area bestowed with such man made facility was termed as irrigated area. Other major source of water was groundwater. Bailing out groundwater through wells of different types viz. dug wells, bore wells, tube wells, etc. by pumping machinery and supplying the same to the crops is also being practiced on a large scale all over the country. The contribution of groundwater in developing irrigation may not be less than half. The great endeavor put in by planners, builders and managers of water resources has brought an area (gross cropped) almost hundred million hectares under irrigation.
Usage of Water:

Human civilization have always grown around sources of water, which is an essential requirement for survival of mankind. Serious doubts are being raised about adequate availability of water in the future. The requirement of water for food production to feed the rapidly growing population, for drinking, household and industrial purposes has increased in multiples, while the availability is on the decline. Ecological changes are also affecting rainfall patterns with a cycle of floods and droughts with frequent intervals. The drought of 2009-10 is one amongst three worst droughts of the last century. In 1918 the rainfall was 25% short, in 1972, it was 24% less and in 2009-10 it was 23% below the normal. In the initial period of 21st century the state of Maharashtra suffered successive droughts during the years 2001, 2002, 2003, 2012, 2014, 2015 and 2018. The drought of 2015 was severe most in the mid portion of Maharashtra i.e. Marathwada wherein it was required to deploy railway wagons for transportation of water over a distance of about 350 km for drinking purposes to the city of Latur. The year 2018-19 might face equally bad situation on account of failure of return monsoon.

Untreated effluent emanating from industrial and thickly populated urban centers is polluting the fresh water of streams and rivers, thereby making it unfit for consumption / any usage. Lowering of water table due to over extraction, contamination due to underground pollution are adding to shortage of potable water. Availability of free / subsidized power to the lifting devices has been a curse to the environment. The farming sector covers around 80 to 85% of water which is harnessed by various methods from surface as well as ground reservoirs. The existing pattern of farming which is highly water intensive also contributes to excess consumption of water. Cash crops like sugarcane and banana and cereal crop like paddy consume almost 75% of irrigation water. This is a skew equation and it nurtures a sense of disparity in the society. Careless use of water also adds to the shortage. Wasteful use of precious and filtered drinking water for arboriculture, gardening, vehicle washing, ground wetting etc. in cities is not warranted. The politically powerful cities like Pune snatch the water of rural areas, which otherwise could be used for irrigating vast tracts of land prone to deficit rainfall. The per day per capita consumption in cities at places touches a figure of 250 liters. This could be termed as a criminal waste particularly in the areas suffering from water shortage. Their comfort zone is not more than 100 liters.

Various options to face the water scarcity are being considered. Rainwater harvesting, recycling of wastewater, sea-water desalination, storage of water during rainwater runoff, interlinking of rivers to bring water from surplus areas to water deficient areas could be a few of them. The suitability of options and usefulness on a sustainable basis needs to be considered taking into account engineering and technological challenges and the economic and environmental aspects. It is essential to regulate the use of water, pattern of usage through a legal framework to avoid water waste.

We often say India is an agricultural country. It is a land which belongs to farmers who live in rural parts and their number exceeds 150 million.
A recent estimate indicates that there are around 260 million farmers in the country. This may be inclusive of landless farmers. At national level, the population engaged in farming, inclusive of landless laborers may be around 1000 million. In Maharashtra, the number of farmers is around 13.7 million and the population dependent on farming would be not less than 72 million. Thus, agriculture is the biggest industry in the country.

**Fragmentation of Land:**
Over the years the division of families caused the agricultural land to get fragmented in pieces. The overall scenario of the land holding is, about 85% of the farmers hold land less than two hectares and 60% own land less than one hectare. In view of this, the individual farming has become unviable. The farmer can neither maintain a pair of bullock nor can he adjust to mechanized farming. The social structure, quite complex in nature and engulfed with caste, creed, religion, politics and so on doesn’t allow two farmers to come together. The concept of cooperative farming, community farming has therefore remained a far cry.

About 60% of the farmers operate on less than one hectare with an average land holdings of 0.40 hectare (one acre) each. In Maharashtra 40% hold land less than 0.40 hectare. Most of them are poor and food insecure. The income of these tiny landholders is less than that of landless families. Due to the population explosion, the per capita availability of land is falling below 0.15 ha. In China this has already reduced to 0.1 ha or so. This small piece of land per individual will be required not only to produce as much as available for every individual in the past but will also have much more than that to provide for the increased demand resulting from the improved standard of living. Areas which do not increase their productivity at the rate higher than the growth of population become net importers of food in a major way and cause a set back to overall economy. Demand for food by 2050 may rise to 480 million tonnes in view of increase in population exceeding a figure of 1500 million and there is a likelihood of mismatch between need and production of food grains, is the recent assessment. Hence every unit of available resource i.e. land, water, fertilizer has to be used more carefully and efficiently for maximizing production. This is the need of the hour. Technologies are required to be evolved in this new direction. Maximization of output while minimizing inputs is a requirement of agriculture sector too. This has to be achieved through agricultural and management science.

**Input-Output:**
The land available for cultivation is shrinking on account of its diversion to several non-agricultural purposes. Water available for agriculture has also been shrinking progressively because of competing demand from municipal and industrial users. Hence it is necessary to look into the entire gamut of water and land management operations in the context of changing scenario. The countries which stood to the challenges through the necessary scientific, technological and managerial skills for improving farm productions have been able to provide a stronger economic base for their societies by ensuring food security and a sustained supply of primary inputs like cotton and so on and have also achieved increased...
exports of agricultural commodities. The difference in the productivity of advanced countries and that of less developed countries is quite high, both in respect of industrialized products and production at the primary level on the farm.

**Productivity:**
India inherited a very poor status in terms of agricultural productivity on account of neglect of agriculture during almost seven centuries of aggression and political instability. Maharashtra stands below the national average in respect of per hectare yield of wheat, rice, cotton and so on. There is a need to focus on yield increase per hectare-crop area, and per unit of water used, with a scientifically well managed agricultural system. The aim will have to be 10 tons per hectare for a single crop of cereal.

Water plays the most critical role in the vigorous growth of the plant. It is to be made available in the right quantities, at the right place and at the right time. The skill in the management in agricultural water lies in managing its presence in the soil in such a manner that only the right degree of moisture and chemical concentrations exit around the root zone of the plant according to the requirements of the different stages of the plant growth. A better understanding of the root system and the physiology of the plant is essential for proper nurturing of the plant. Irrigation has therefore to be a properly engineered effort for providing soil moisture in a desired manner. Scientific innovations have shown that even deserts can bloom if the physical inputs required for the growth of the plant can be properly managed. The Rajasthan canal changed the so called desert area into a land of high potential for production of crops.

Nutrient and chemicals in the soil move through the soil along with water. It is inappropriate to talk about management of land or management of water separately, because of the very close linkage of the water and land on this earth. There has to be an integrated approach to land water management. The productivity of an agricultural farm truly depends on how land and water are managed together in a scientific manner. Water is a dominant element of environment and a powerful solvent of chemicals and nutrients. Land is a relatively static factor and soil is described as the stomach of the plant and it sustains life through millions of useful bacteria / microbes. Water introduced on the farm is a very dynamic factor. It is in continuous motion on the land, in the soil mass, through the body of the plant. It is like a human body and therefore you can not afford to dump any amount of inputs (water, fertilizer, etc.) and expect a healthy and prosperous life. Soil must have a balanced diet. The excess if forced in to, drains-off or evaporates, damaging the soil body. It is therefore, necessary to be very scientific and methodical in dealing with soil and water in relation to productivity concept.

It would be worthwhile here to cite an example of diffuser technology coupled with drip irrigation for maximizing the productivity of horticultural crops. It is gaining ground mainly in horticulture sector in different parts of the state of Maharashtra. If farm practices are proper and scientific, maximum returns are obtained. The quality of the produce is also improved. This technology is a breakthrough for fruit crops as it ensures an assured production and relieves the grower/cultivator from various problems such as shortage of water, power, temperature variations etc. Some of the principles employed have been listed below.

- **Production targets based on canopy area:**
  Technically it is possible to produce 6 to 7 kg of mango, grapes, pomegranates from one sq. m. of canopy/leaf area. It means that 12 tonnes of fruits can be produced from one acre of land (about 2000 sq. m. canopy area) with diffuser technology.

- **Nutrition support programme for targeted production:**
  Fruits are formed out of 13 elements collected from roots and 3 elements (H, O and C) collected from air and water. These 3 elements and
Water account for almost 98 to 99% of total weight of fruits. For one tonne production of grapes 10 kg of 13 elements are required. For targeted 12 tonnes (from one acre), plants need to absorb from bearing to harvesting, 120 kg of nutrients. The uptake by the plants over a period is taken care of by the diffuser practice.

- **Subsurface fertigation**: The water requirement of the plant is equal to its transpiration requirement and it amounts to around 2 litre per sq. m. of canopy area per day. Fertigation means application of water and fertilizers to the plants below ground, i.e. at root zone.

- **Integrated water and nutrition management**: The plant growth is a function of nutrients absorbed by the plant. Nutrients dissolved in water are absorbed by the plant to fulfill transpiration requirement and thus water and nutrients are fed together at the root zone in a predetermined proportion so as to get the targeted production.

- **Law of minimum i.e. supply of 13 elements in right combination**: Proper balancing of nutrients leads to proper metabolism and improves the quality of fruits.

- **Zero defect production/ total quality management in agriculture**: Defects in product develop due to defective agricultural process. The process is improved and better quality of produce obtained.

- **Attaining 90% fertilizer use efficiency**: Water and fertilizers are applied at the root zone and hence subjected to no loss. The efficiency is enhanced.

- **Fertilizer dosing in ppm and with maximum splits**: The required quantity of nutrients based on the targeted production is applied in parts (splits) to get maximum output.

- **Nutrients uptake management**: The conditions at root zone are created, conducive to uptake by the plants.

- **Optimum root wet area with minimum of water input**: Due to subsurface irrigation this becomes possible.

- **Productivity of Water**: The productivity of all other inputs viz. fertilizer, labour, land etc is directly proportional to the productivity of water. 1000 liters of water enables to earn around Rs.200/- in horticulture farming.

- **Optimum growth conditions at root zone level**: Proper root zone management is the crux of ideal farm practice and same is taken care of.

At the country level about 1/3rd of the land suffers from the phenomena of recurring droughts. A sizeable portion of south east is subjected to submergence on account of floods. The water availability in Ganga, Brahmaputra basin is remarkably high. In Maharashtra, the areas have been classified into five water zones viz. highly deficit-water availability less than 1500 m³ per ha, deficit - 1500 to 3000 m³ per ha., normal 3000 to 8000 m³ per ha., surplus - 8000 to 12,000 m³ per ha. and abundant exceeding 12,000 m³ per ha. The small Kokan belt of Maharashtra has water more than 40,000 m³ per ha. Based on this, it is seen that almost 80% of the area is water short and 20% is in surplus. This acute disparity in water availability both at country and state levels makes the crop management a complex exercise. This automatically made us mandatory to focus on the cropping pattern to be adopted in the different zones. Surplus in water availability has been considered as the comfortable position for the plant growth. Water saving techniques were called for in the water short areas. Water saving was thus, considered as the production of water in the crop management.

India is very rich in growing varieties of crops on account of different agro climatic zones that exist. Maize is grown in almost all parts of the country. The country ranks second in the world for sorghum production and production of fruits and vegetables. Wheat and rice are...
widely grown in the large part of the country. India is the largest producer of the pulses. It produces about 400 million tons of sugarcane over an area of 5 million ha annually, during a good year. Floriculture is giving leadership to India to meet the world requirements. The range of fruits produced is very large. The varieties of vegetables are 70+. The way forward is to promote varieties of crops and not to stick to traditional crops.

So far scientists have been advising the farmers to focus on productivity of land for the overall growth of agriculture sector. The concept of productivity of water was not discussed with respect to agricultural science and science of management. In the agricultural sector the productivity of all other inputs viz. fertilizer, labour, land pesticides is directly in proportion to productivity of water. It is not that matters how much water is supplied to the plant, but it matters very much, how much, the plant has taken up/absorbed. The focus is on supply of right amount of nutrients as per the needs of the plant (canopy area) to achieve targeted productivity level. The agricultural language is, water of certain ppm (parts per million) in liters and not a plain water in mm$^3$. This principle has not been understood and hence there is a poverty. The modern technology which is simple in its understanding and also implementation, enables an agriculturist to earn Rs. 150/- to Rs. 200/- (3 to 4 US$) from one thousand liters of water. It is a technology quite amenable to poor rural farmer of this vast country. Thus the concept of productivity of water solves the water problem in its totality. It improves the productivity and reduces the cost as well. Plant growth is the manifestation of nutritional elements absorbed through water. Water is thus an instrument. These elements are absorbed through roots. The absorptions of elements is related with the conditions prevailing at the root zone of a plant. Proper root zone management is the crux of ideal farm practice. This factor is generally neglected in traditional farming system.

The uptake of water by plants is governed by the climatic condition and more so by rate of evaporation. More the canopy, more will be the transpiration and more will be the intake of water and hence more uptake of nutrients. This goes without saying that the excess water than this is of no use to the plant and on the contrary it dilutes the nutrient concentration and reduces its uptake by the plants as the nutrients are absorbed by the plants through water alone. The growth is suffered, productivity comes down and fertilizer use efficiency is reduced to a figure of 30% are so and rest 70% drains off to river water. A farmer has to sustain all these losses with reduction in output. We therefore have to devise a irrigation / farming method / practice which will enable to supply right quantity of water at the root level. This is the fourth input (water, fertilizer, pesticides) which is more important. This is achieved by sub-surface irrigation through an appropriate technology. The diffuser technology is catching up the ground gradually. A modified version of drip technology and porous pipes also give desired results. The micro-irrigation system (drip) has done revolution in agriculture. Drip will continue to grow unabated in the days to come. It is the requirement of the time. There is a need to go one stop ahead to catch the roots of the plant in order to increase the productivity of water and also quality of the produce. Crops in the state are being grown with this modern technology. As of today the area under micro-irrigation is around 12% of the irrigated area.

Thus the micro-irrigation system is for productivity and quality. It also saves water and cuts down the cost of input. The focus should be on productivity of water and not on its availability. The rain on the farm area needs to be harvested and conserved underground. A farm pond over 5% area is the need of the day. Agriculture is a science and there is a great amount of technological input needed to maximize the yield. The yield per unit area, per unit of water and per unit of labour input
is governed by the efficiency of handling the various types of inputs such as water, fertilizer, cultivation practices and so on. In short, a farmer is to know the intricacies of science of farming. The farmer is to be friendly with the up-to-date farming knowledge or else, he lands in a precarious situation. There are numerous suicidal deaths of farmers, the country is experiencing today.

We have to make a forward journey with a scientific approach in the field of irrigation. A farmer is to irrigate the roots of the plants / crops and not the plants or the fields. This is to be understood by the farmers community whose number runs in several millions. The technology is required to be very simple and easily amenable to illiterate farmers. We need not be overconfident about the adoption of scientific methods of farming by the large masses of Indian agriculture. Indian farmer who owns a sizable piece of land does not cultivate the fields by himself. Doing labour work in the field is considered, a job below dignity.

The reality on the ground is, the agriculture industry is handled at rural level by the old people and the illiterate young kids belonging to the landless families. The working force is totally unskilled. In the good old days, the farmer was assisted by a skilled force like carpenter, blacksmith etc. known as Balutedars and they were paid in kind. This tradition has gone out of use and the farmer has become dependent on things in market which are utterly expensive and low in quality.

Present scenario:
There has been a mass unrest amongst farmers across the country over last few years. This was reflected openly in the October – November 2018 March in Delhi leading to clashes with the police etc. The tens of thousands of farmers with the participation of 208 farmers’ organizations made their journey to the capital to get their demands heard by the government at center. The rally included sugarcane farmers from UP and Haryana who are affected by the nonpayment of dues, farmers from Maharashtra and Karnataka who are facing crop failures due to drought, farmers from central India who are facing water contamination due industrial emissions, farmers from Tamilnadu who are facing crop destructions due to stray animals, climate change and rising input costs and farmers facing indebtedness. There were Dalit farmers who are facing landlessness, women farm workers who brought up the issue of unequal pay and Adivasi farmers who spoke about land dispossession despite having cultivated the same for thousands of years. Many of these concerns were linked to corporatization of the farm sector processes. The land is being accumulated by the few corporate bodies, by luring the poor farmers with high price. Farm distress has been on top of the agenda and record shows more than 3 lac farmers have killed themselves in the last two decades. Indebtedness was cited as the reason for more than 55% of farmers’ suicides in 2015. Maharashtra, which saw the highest number of farmers’ suicides has 60% of its farm families in debt with each owing around RS.50000/- . The southern states like AP and Telangana where levels of indebtedness are around 90%, the average debt on each hovers around Rs. One lac. Almost 70% of the agricultural families spend more than they earn and around 25% of all farmers live below the poverty line. Almost
all of them borrow loan from private money lenders with heavy rate of interest for livelihood struggle, leave apart loan for some urgent cause. The census data for 2011 show the number of cultivators who own land have been overtaken by landless workers. Many of the agricultural workers earn less than Rs.150/- a day by working in the farm and the failure to secure jobs in other parts of the developmental sectors like industries, services etc. in rural areas gives them nil options.

All governments in power are engrossed in giving short term solutions viz. government loan waiver, subsidies, increased support prices to the crops, procurement by government etc. for immediate political gains. This is not a permanent solution and everyone is aware about this. The reasons for mass unrest include the increasing fragmentation of land, average plot sizes are barely more than one hectare, a lack of post production infrastructure in the form of godowns, cold storages, agro processing industries, marketing mechanism and supply chains. The issue of import – export of farm produce is handled with a casual attitude at the government level. The industrial and service sectors have not been promoted to decentralize in rural areas for generating alternative jobs which led to mass migration to few cities. The input (fertilizers, pesticides etc) costs on the other hand have gone up. A small piece of land even of 2 ha, supported with seasonal irrigation and cultivating traditional crops (almost 80% of farmers cultivate the same) does not support the farmer’s family, is the ground reality.

The agricultural sector alone does not sustain the load of population made to engage in it. There is an urgent need to disperse the manpower in other developmental sectors (industry, services etc.), to be promoted in rural areas only. The fragmentation of land into small pieces has made the farming totally unviable. There is a need to take over the farming of such small pieces by community, group, contract, corporate farming. The mindset of the farmers is to be changed by safeguarding their land ownership rights. Few farmers could be engaged in high tech farming (poly house, horticultural and floriculture on micro-irrigation etc.) with direct access to marketing. These could be the few options to combat the alarming situation arose in the country. This prompts to educate and guide the farmers in masses.

Educate Farmer:
There is a big gap between what we try to achieve through agriculture and the quality of the manpower deployed in farming. To tide-over this alarming situation, in a small way through humble efforts a mass literacy programme in irrigated agriculture / agriculture has been launched in Maharashtra. It is almost 26 years (since 1992) or so. Maharashtra Sinchan Sahayog, a movement in irrigation sector, is initiated mainly to educate and help farmers in the areas of efficient use of water, fertilizers, increased water availability by adopting modern irrigation methods and participating in cooperative, community, contract farming by sharing experiences from fellow farmer. The Maharashtra Sinchan Sahayog organises ‘two day irrigation conferences’ once in a year and irrigation Sammelans several in number annually in different parts of the State. Woman is very sensitive to handling of water and therefore Sinchan Sahayog provides an opportunity to her
to participate in water management. A large no. of people from different disciplines related to water viz. farmers, agricultural scientist, water experts, social workers, scientists, politicians, Government Officers, educationists and so on come together to participate in the deliberations and share the experiences.

The Sahayog provides a platform to farmers wherein farmers in groups gather together, share the experiences and learn things on their own. Over the last 26 years, the Sahayog has been successful in spreading this movement among 100,000 + farmers. This is not a big achievement but certainly, a modest beginning for the good cause and change. The Sahayog is a voluntary organization and it retains its non-governmental and non-political character. The extraordinary feature of this movement is, an experienced farmer shares his observations with his co-farmers and this is how the unskilled workforce is trained and educated. The irrigation conferences and the Sammelans are organised at the instance of support from local institutions like Agricultural universities, Private Education Institutes, Research & Training centers, NGO’s and so on. Farmers contribute in a little way towards the actual expenses. Looking to the importance of the service rendered by the Sahayoga, state Government in Water Resources Department has been encouraging this movement since its beginning. The staff from top to bottom is allowed to participate in the deliberations. This is also an education to the people in government organization. The Sahayoga does not work for the welfare of their members but endeavors a lot for the betterment of farming community.

The central themes deliberated during the last nineteen parishads (conferences) are enlisted below: The theme which is relevant to the region is chosen for deliberations.

<table>
<thead>
<tr>
<th>Conference No.</th>
<th>Year</th>
<th>Theme</th>
<th>Place</th>
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<tbody>
<tr>
<td>1st</td>
<td>2000</td>
<td>Irrigation for increased production.</td>
<td>Agricultural University, Parbhani.</td>
</tr>
<tr>
<td>2nd</td>
<td>2001</td>
<td>Irrigation in 21st Century</td>
<td>Agricultural University, Akola</td>
</tr>
<tr>
<td>3rd</td>
<td>2002</td>
<td>Modern Irrigation methods, techs and specs.</td>
<td>Agricultural University, Kokan.</td>
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<tr>
<td>4th</td>
<td>2003</td>
<td>Economic approach for Irrigation Development.</td>
<td>Agricultural University, Rahuri.</td>
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<tr>
<td>7th</td>
<td>2006</td>
<td>Changes in irrigation sector.</td>
<td>Nashik</td>
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<tr>
<td>8th</td>
<td>2007</td>
<td>Role of Irrigation in regional development.</td>
<td>Vardha.</td>
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<tr>
<td>11th</td>
<td>2010</td>
<td>Water management for fruits crops</td>
<td>Aurangabad</td>
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<td>12th</td>
<td>2011</td>
<td>Irrigation management for pulses and oilseeds.</td>
<td>Washim</td>
</tr>
<tr>
<td>13th</td>
<td>2012</td>
<td>Combating drought</td>
<td>Shirpur, Dist: Dhule</td>
</tr>
</tbody>
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The process is aimed at making the farmer self-reliant, making the society stronger, helping prosper the state and ultimately the Nation. Some thoughts serving as light post come to the fore through such ideological excursions / deliberations. We call them as conclusions and recommendations of the parishad. It is the joint responsibility of all of us - the farmer, the Government, stakeholders, agricultural bodies - to tread our path in the light of these findings. With a view to enhance a healthy spirit to improve upon the farming process for increased productivity an award named Maharashtra Sinchan Mitra Puraskar is conferred on an eligible farmer / organization in the parishad. The event is also used to celebrate the anniversary of an irrigation project in the vicinity in reorganization of the service rendered by the device. This enables to take a complete review of the performance of the irrigation project in the area chosen and helps the water managers to improve upon by rectifying the omissions noticed. To enthuse farmers in large numbers a few more Puraskars/Prizes have been instituted by the Maharashtra Sinchan Sahayog. Such awards are conferred on both men and women farmers whose performance have been found to be exemplary and noteworthy. The Sahayoga has published seven books, covering articles of eminent personalities on different topics related to water, irrigation, agriculture etc. The activities of the Maharashtra Sinchan Sahayoga can be described in nutshell as, it organizes annual irrigation conferences, undertakes qualitative performance review of local irrigation projects, helps the local Sahayoga to organize irrigation conventions/Sammelans, felicitates farmers for their exemplary contributions, arranges study tours to the places of importance and disseminates the compiled and published literature at low cost. The 19th conference was concluded in October 2018 at Soygaon. The outcome of the 19th conference has shown that there is a dire need to educate the farmers and build their capacities to take up the challenge of upheaval in the agricultural sector right from production, to agro-processing and marketing. The farmers voiced against the inadequacy of the training and extension arrangements being provided by the universities, Agriculture department and WALMI like training centers managed by Government. Government has several functions to perform and it has its own limitations. Let us not rely totally on Government. Let the Government function as a facilitator and we the farmers should contribute our bit to succeed in reaching the target of prosperity through irrigated agriculture.
Background
Jain Irrigation Systems Ltd (JISL), the largest agricultural conglomerate in the country has a long and inspiring history. The company was started by late Dr Bhavarlalji Jain in 1963 with a family savings of just Rs. 7,000 and ultimately after a very hard struggle, emerged as the second largest manufacturers of drip and sprinkler irrigation systems (micro-irrigation) in the world with an annual turnover of over Rs. 80,000 Million in 2018. The company initially did trading activities in the field of seeds, fertilizers, tractors, motorcycles, PVC pipes and started manufacturing of PVC pipes in 1979. In those days there was primarily rain-fed farming in Maharashtra and in some areas flow irrigation was practiced, particularly in Jalgaon, Nasik and Western Maharashtra belts. Here the Grapes, Banana, horticulture and sugarcane crops were irrigated with flow irrigation. In agricultural universities, drip and sprinkler irrigation was for namesake, just for the research trials to compare the water use by flow, drip and sprinkler irrigation systems. There were couple of mushroom companies of drip irrigation. But they were just dumping the material at university campuses, research institutes and some of the progressive farmers’ fields. There was no service component involved in the exercise. Therefore the micro-
irrigation technology was not only unknown but had a bad name also because of absence of integrated and holistic approach. Farmers were for flow irrigation and reluctant to adopt micro-irrigation technologies. There was no support to the farmers from the government to buy these expensive technologies.

The year 1987 came with new rising star, Jain Irrigation Systems Ltd was floated in this year. The company started trading in micro-irrigation technologies with full back up support to Maharashtra farmers. The company signed collaboration agreement with world known Australia based company called Hardie Irrigation. JISL initially imported the drip/ sprinkler irrigation material and offered it to the Maharashtra farmers on hire basis with full technical back up including survey, design, installation, aftersales services and agro-advisory services. This concept selling in integrated and holistic manner did wonders and the farmers got substantial yield increase and water savings. They not only purchased the systems, but also expanded in their fields. These farmers also become ambassadors of Jain Irrigation and prompted other farmers to buy the systems suitable for their fields. In the meantime, government of India announced the centrally sponsored scheme for subsidy support to the farmers to buy drip and sprinkler irrigation equipment. This changed the whole scenario in the market and soon drip and sprinkler irrigation adopters increased in multi-fold. The micro-irrigation systems became popular among the farming community of Maharashtra and other neighbouring states too.

Initially Jain Irrigation introduced the systems for high value horticulture crops such as Grapes, Banana, Pomegranate, Mango, Citrus, Custard Apple and also for Sugarcane and vegetable crops. The farmers got support and encouragement from National Horticulture Board to cultivate horticulture plantation crops by way of back ended subsidy. They also got financial assistance up to 50% of the indicative costs from Centrally Sponsored scheme to buy drip and sprinkler irrigation equipment.

**Technology for small holders**

Average Indian farmers have the land holdings of 1-1.1 Ha. Substantially large volume of farmers come under this category. Therefore if the company was to succeed they could not ignore the small farmers. The company therefore developed small filters (screen filters/ sand filters and hydro cyclone filters), venturi to apply fertilizers through the systems and many such a components which were suitable and required for small holders. The company gave full technical support to the farmers by providing all the requisite services. The company maintained complete file of each and every farmer and a complete history of the farmers fields with respect to acidification and chlorination treatments, fertilizer application, irrigation scheduling, maintaining soil health cards and so on. This brought the success to the company because ultimately the bottom line was to increase the farmer’s net annual income.
**Integrated approach**

For popularising the concept of micro-irrigation, Jain Irrigation adopted integrated approach. It was not just selling the hardware components, but was concept selling with all the required services. The package of services offered by the company is well described in the following pictorials:

**Basic Services:**

- Preliminary reconnaissance
- Preliminary survey.
- Benchmarking survey.
- Problem identification and need assessment of the project area.
- Assessment of feasibility.
- Preparation of feasibility reports.
- Topographical Survey.

- Collection of soil and water samples and their analysis.
- Collection of engineering, climatic and agronomic data.
- Assessment of water sources.
- Assessment of power sources.
- Hydraulic and agronomic design of the project.
- Preparation of DPR (Detailed Project Report).
- Formulation of Water User Groups (WUG).
- Supply of material as per Bill of quantities.
- Verification and validation of designs.

**Support Services:**

- Installation of hydraulic system as per project design.
- Erection of civil structure (e.g. pump house, control room, sumps etc.) as per project requirement.
- Installation of control & operation system like automation, control valves, safety valve etc.
- Hydraulic testing of the project.
- Trial run of operation and control system.
- Agronomic Support & Training for WUG’s & Farmers.
- Engineering support
- Extension activities.
- Training on GAP (Good Agriculture Practices)
• Agricultural Practices).
• Support for market linkage & trading farmers produce as per project requirement.
• Publishing literature in local languages.
• Establishing demonstration farms in project area.
• Operation and maintenance of the project for pre-specified period.
• Successfully handing over the project to WUG.

Everything under One Roof
Jain Irrigation has always followed one principle that whatever we do, should be excellent. Therefore to avoid fitment problems, delays and quality issues, they have brought everything under one roof. They themselves do production of all the components required for complete micro-irrigation systems. As far as possible they do not depend upon vendors and create their own in-house facilities. It may be for manufacturing of pipes, driplines, emitters, fittings or filters. They have their own in-house facilities. Not only this but they have their own modern well-equipped tool room, CNC machines, Injection Moulding Facilities, extrusion facilities, fabrication and development workshop etc.

Area Covered
In Maharashtra, out of total cropped area of about 225 Lack Ha area, some 44 lakh ha is irrigated. Out of this 44 Lakh ha area, about 20 lakh Ha would be drip irrigated. It is estimated that JISL has about 50% of the market share even as of now in Maharashtra. That means JISL must have covered more than 1 million ha in Maharashtra alone. The geographical coverages includes all districts in Konkan to districts in Eastern Vidarbha region.

Table 1: Division Wise area Covered under Drip and Sprinkler Irrigation from 1986 to March 2017.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Division</th>
<th>Drip, Ha</th>
<th>Sprinkler, Ha</th>
<th>Total, Ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Konkan</td>
<td>13344</td>
<td>290</td>
<td>13634</td>
</tr>
<tr>
<td>2</td>
<td>Nasik</td>
<td>482581</td>
<td>28317</td>
<td>510898</td>
</tr>
<tr>
<td>3</td>
<td>Pune</td>
<td>340102</td>
<td>42763</td>
<td>382865</td>
</tr>
<tr>
<td>4</td>
<td>Kolhapur</td>
<td>114096</td>
<td>35347</td>
<td>149443</td>
</tr>
<tr>
<td>5</td>
<td>Aurangabad</td>
<td>194611</td>
<td>41210</td>
<td>235821</td>
</tr>
<tr>
<td>6</td>
<td>Latur</td>
<td>186827</td>
<td>116283</td>
<td>303110</td>
</tr>
<tr>
<td>7</td>
<td>Amaravati</td>
<td>169444</td>
<td>253337</td>
<td>422781</td>
</tr>
<tr>
<td>8</td>
<td>Nagpur</td>
<td>27321</td>
<td>61275</td>
<td>88596</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>1528326</strong></td>
<td><strong>578822</strong></td>
<td><strong>2107148</strong></td>
</tr>
</tbody>
</table>

Crops Coverage
In Maharashtra, JISL has covered almost all the crops including horticulture/fruit crops, vegetables, plantations, spices, flowers. They have so far covered more than 45 crops in the state. The major crops covered are Grapes, Banana, Papaya, Pomegranate, Citrus, Mango and most of other fruit crops, cash crops like Sugarcane and, Cotton, Vegetable, Spices, flowers and plantation crops.
Canal Command Areas

Traditional Flood Irrigation:
In old days farmers were used to provide water through flood irrigation then slowly shifted to flow irrigation (organized way of flooding), check basin irrigation, sprinkler irrigation and nowadays using Drip System (Micro-irrigation System).
In flood, flow or even in check basin irrigation, water is applied to the soil in uncontrolled manner where there are huge conveyance, evaporation, deep percolation losses and wastage of water. In these methods water is not applied to the crops as per their requirement or demand. The water is generally conveyed to the topmost elevation in the field and then it is allowed to flood in the field by gravity in an un-organised way or through furrows in a little organised manner. Even though as compared to rainfed crops, the productivities of irrigated crops are much higher, this type of uncontrolled irrigation have been proved to be most inefficient and unscientific way of irrigating crops. The efficiencies of canal - flow irrigation in the country are as less as 35-40%. That means in lay person’s language, to apply 35 litres of water to the crops, one would be required to release 100 litre of water from the dam! In order to overcome this problem, the government of India has now taken up a programme to increase the overall efficiency of Irrigation at least by 20%.
Selected indicators of agricultural development in India shows that out of total agricultural land available in India (which is about 169.5 M Ha), about 33.8% is irrigated as compared to the global figure of 18.5% (Table 7.4, Agricultural Statistics at a Glance 2010, GoI)
Drawbacks of the Conventional Irrigation Method:

<table>
<thead>
<tr>
<th>First Three Days After Irrigation</th>
<th>Middle Three Days</th>
<th>Last Two Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>During first three days of irrigation soil pores are saturated with water. In this condition, total air in the soil is replaced by water &amp; field capacity level is not maintained in the soil. The excess water condition suffocates the roots of the plant &amp; water absorption by roots is totally ceased. As the plant is under suffocation the growth is hampered.</td>
<td>During next three days, due to evaporation &amp; percolation losses, the excess soil moisture is reduced &amp; soil comes to field capacity level wherein air, moisture &amp; nutrients are available at optimum level. Plant growth takes place only during this phase.</td>
<td>In last two days, the moisture level in the soil goes below the root zone hence, plant is under stress condition in this period. Even though air and nutrients are sufficiently available in the root zone they can not be taken easily by plant as the plant is under stress and hence growth restricted.</td>
</tr>
</tbody>
</table>

Conclusion: It is very clear from the above phenomenon that for the plant growth, optimum moisture level available is only for about three days out of 8 days’ cycle. Rest of the time plant is either under stress or suffocation condition, hence growth is restricted thereby yield is reduced.

In India, Conventional Irrigation Method (Flood Irrigation) is used to irrigate the crops. In this method, the water is distributed through ridges and furrows or allowed to flow freely by gravity in the field. In this system, the irrigation efficiencies are too low up to 40%. This method is a rotational method of supply of water, in which water is applied to the crop in a cyclic way. Hence if the rotation is of 10 days, in the initial 3-4 days the soils are saturated with water and plants cannot uptake nutrients. In the last three-four days, plants suffer because of water stress. Only middle 4-5 days, soil is at field capacity levels. Thus half of the rotation period, the plants do not grow or they suffer for the want of water or air. In case of micro-irrigation systems, soils are always maintained at field capacity levels and there is a very good balance of water, air, nutrients and media. Hence there is a good growth of plants during this period.

Because micro-irrigation is a demand based system and water is available based on demand from the customers.

Sprinkler Irrigation:
Sprinkler Irrigation is the method in which water is applied in the form of rains/showers under pressure. Even though, in sprinkler irrigation water is applied to the soils, it is a controlled way of flooding only. Irrigation depth is controlled in Sprinkler Irrigation. Even though, it is an advanced method of irrigation, it has certain demerits such as high evaporation losses, higher energy consumption and manpower requirement, shifted wetting patterns in case of high wind velocities etc. The efficiencies of sprinkler irrigation systems are generally in the range of 70-75%. As per the statistics of 2005, India had about 16.34 Lac Ha area under sprinkler Irrigation systems (Global Scenario of Sprinkler and Micro Irrigated Areas by SA...
Sprinkler irrigation is a method of applying irrigated water in a manner similar to rainfall. Water is distributed through a system of pipes, usually by pumping, and then sprayed into the air saturating the ground with small water drops. Sprinklers can provide efficient coverage for both small and large areas and are suitable for a wide range of properties and irrigable soils since they are available in a wide range of discharge capacities. Table 2 shows the advantages of adoption of sprinkler irrigation systems. It is observed that there is saving in water up to 50% and increase in yield up to 100% over the conventional flow irrigation.

### Table 2: Benefits of Sprinkler Irrigation (Advantages de irrigation par aspersion)

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Crop</th>
<th>Yield (T/Ha)</th>
<th>% Increase</th>
<th>Water Used (mm/Ha)</th>
<th>% Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>TRI</td>
<td>SIS</td>
<td>TRI</td>
<td>SIS</td>
</tr>
<tr>
<td>1</td>
<td>Wheat</td>
<td>1.5</td>
<td>3</td>
<td>100</td>
<td>600</td>
</tr>
<tr>
<td>2</td>
<td>Maize</td>
<td>1.5</td>
<td>2.5</td>
<td>66</td>
<td>600</td>
</tr>
<tr>
<td>3</td>
<td>Vegetable</td>
<td>6</td>
<td>10</td>
<td>66</td>
<td>600</td>
</tr>
<tr>
<td>4</td>
<td>Wheat*</td>
<td>3.8</td>
<td>3.8</td>
<td>-</td>
<td>303</td>
</tr>
<tr>
<td>5</td>
<td>Groundnut*</td>
<td>0.8</td>
<td>0.9</td>
<td>11</td>
<td>475</td>
</tr>
<tr>
<td>6</td>
<td>Coffee**</td>
<td>4</td>
<td>7.8</td>
<td>95</td>
<td>600</td>
</tr>
</tbody>
</table>

* These are result of experiment conducted on various research station viz. Hanumannagar, Brore and Loonkaransar in Indira Gandhi Canal Area. Paper presented by S.K. Mathur & M.S. Shekawat, Krishi Bhavan, Bikaner, Rajasthan during June 1996 at Institution of Engineers, Bangalore-Sprinkler Workshop (Ce sont des résultats d’expérimentation menée sur le savoir la station de recherche différents. Hanumannagar, Brore et Loonkaransar au Indira Gandhi, Canal Zone. Document présenté par S.K. Mathur & M.S. Shekawat, Krishi Bhavan, Bikaner, Rajasthan pendant Juin 1996 à l’Institution des ingénieurs, Bangalore-gieleurs atelier)

** Result of the experiment conducted at Regional Coffee Research Station, Chundale, Wynad, Kerala (Résultat de l’expérience menée à la station de recherche sur le café régional, Chundale, Wynad, Kerala)

** Micro-irrigation:**

To overcome almost all the demerits of flood, flow, sprinkler irrigation, Drip(Micro) irrigation was introduced in the country during 1990s. Drip(Micro) Irrigation water is applied directly to the root zone of the plants by way of drops under very low-pressures using plastic emitters and tube network as per the water demand/requirements of the plants on daily basis. Benefits of this method include suitability to all crops, increase in crop productivity and better quality produce, saving in water and power, high fertilizer efficiency, ease in operation, savings in other inputs costs, etc… The efficiencies of Micro-irrigation systems are up to 90%. In exceptional cases and also in case of subsurface drip, these can go up to 95-97%. As per the statistics of 2005, India had about 5.89 Lac Ha area under Micro-irrigation systems (Global Scenario of Sprinkler and Micro Irrigated Areas by SA Kulkarni, F.B. Reinders, and F. Ligetvari). However recently there has been substantial increase in Micro Irrigated areas of the country. It is estimated that this figure by the end of 2016 would be in the range of 40 Lac Ha. This is mainly because of the economic benefits achieved after installation of the systems by the farmers.
Principles of Micro-irrigation

• Water is applied to the root zone of the plant directly.
• Water is applied at frequent intervals (daily) in controlled quantities as per requirements of the plants.
• Water is applied through a low-pressure network including main, submain and lateral lines with emitters/drippers spaced along the lateral lines.
• Water is essentially passed through a filtration system to prevent suspended impurities, which may block the emitters.
• Water soluble fertilizers and nutrients can also be applied along with micro-irrigation through a fertilizer tank and/or venturi.

Why Micro-irrigation

• The productivity of irrigated land is low compared to its potential
• The productivity per unit water is very low.
• Water available for irrigation is becoming scarcer.
• Cost for generating water source is ever increasing.
• The predominance of soils with low water retention capacities and very low hydraulic conductivity’s makes the Arid & Semi-arid regions an ideal case for light and frequent irrigations i.e. Micro-irrigation.
• Micro-irrigation will increase the irrigation cover using the existing available water.
• Micro-irrigation with fertigation will enhance production per unit input in these nutrient-poor low dense soils

Components of Micro-irrigation introduced by JISL

Drippers/ Emitters; Emitting Pipes & Fittings; Micro Sprinkler & Sprayers; Impact & Floppy Sprinklers; Filtration Units; Fertigation Equipments; Control Valves; Poly Tubes & Fittings ; PVC / PE Pipes & Fittings; Quick Release Coupling (QRC) Pipes & Fittings; Automation System.

Economic Benefits of Micro-irrigation:

• Increase in Productivity of Crops: In Micro-irrigation water and fertilizers are applied to the crops as per their demand on daily basis. This ensures balanced water and nutrients in the root zone of the plants which ultimately results into increase in vegetative and reproductive growth of the plants. Hence the yields obtained under micro-irrigation are very high compared to flow irrigation or rainfed crops. Nabcons’s report
on Evaluation study of Centrally Sponsored Scheme on Micro-irrigation conducted during March 2009 says that adoption of micro-irrigation resulted in significant increase in yield in all major crops to the extent of 19.4% (AP) to 50% (Gujarat) in Ground nut, 19.1% in Sweet Orange, 33%(Gujarat) to 42.1%(AP) in vegetable, 17.1%(AP) to 25% (Karnataka) in banana in comparison irrigation.

- **Water saving**: It is a proven fact that there is a substantial saving of water(up to 50-60%) in case of micro-irrigation as compared to conventional irrigation since the water is applied exactly near the root zone of the plants and there is no wastage of water due to deep percolation, seepage, conveyance or evaporation etc. The water is applied in exact quantities required by the plant to replace daily evapotranspiration. Hence the excessive use of water is easily avoided. This will ultimately result into increase in irrigated areas and will also save the cost of creating additional storages.

Table 1 shows the advantages of adoption of drip irrigation systems. It is observed that there is saving in water up to 68.5% and increase in yield up to 66.6% over the conventional flow irrigation.

<table>
<thead>
<tr>
<th>CROP</th>
<th>LOCATION</th>
<th>YIELD (T/Ha)</th>
<th>WATER USE (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>TRI</td>
<td>MIS</td>
</tr>
<tr>
<td>Ashgourd</td>
<td>Jodhpur</td>
<td>10.8</td>
<td>12.0</td>
</tr>
<tr>
<td>Bottlegourd</td>
<td>Jodhpur</td>
<td>38.0</td>
<td>55.8</td>
</tr>
<tr>
<td>Tomato</td>
<td>Udaipur</td>
<td>14.4</td>
<td>17.5</td>
</tr>
<tr>
<td>Watermelon</td>
<td>Jodhpur</td>
<td>29.4</td>
<td>88.2</td>
</tr>
<tr>
<td>Onion</td>
<td>Delhi</td>
<td>28.4</td>
<td>34.2</td>
</tr>
<tr>
<td>Okra</td>
<td>Delhi</td>
<td>36.0</td>
<td>48.0</td>
</tr>
<tr>
<td>Cotton</td>
<td>Coimbatore</td>
<td>2.6</td>
<td>3.3</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>Delhi</td>
<td>92.0</td>
<td>119.0</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>Pune</td>
<td>128.0</td>
<td>170.0</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>Navsari</td>
<td>70.6</td>
<td>116.1</td>
</tr>
<tr>
<td>Groundnut</td>
<td>Udaipur</td>
<td>9.1</td>
<td>34.7</td>
</tr>
<tr>
<td>Pomegranate</td>
<td>Hyderabad</td>
<td>3.4</td>
<td>6.7</td>
</tr>
<tr>
<td>Papaya</td>
<td>Coimbatore</td>
<td>13.0</td>
<td>23.0</td>
</tr>
<tr>
<td>Banana</td>
<td>Kharagpur</td>
<td>29.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Banana</td>
<td>Bhawenisagar</td>
<td>27.7</td>
<td>32.9</td>
</tr>
<tr>
<td>Banana</td>
<td>Ludhiana</td>
<td>57.5</td>
<td>87.5</td>
</tr>
<tr>
<td>Grapes</td>
<td>Ludhiana</td>
<td>26.4</td>
<td>32.3</td>
</tr>
</tbody>
</table>

• **Fertilizer Saving:** In Micro-irrigation systems, Water Soluble Fertilizers can easily be given along with water through fertigation equipment such as venturi, fertilizer tank or fertigation pump. The fertilizers are applied exactly near the root zone of the plants and therefore there is no loss of fertilizers on account of broadcasting. The fertilizers are applied effectively and efficiently to the crops.

• **Savings in Input Costs:** Nabcons’s report on Evaluation study of Centrally Sponsored Scheme on Micro-irrigation conducted during March 2009 says that cost of cultivation was found to have been reduced in horticultural crops like Mango 13.3% (AP) to 16.98% in Gujarat, groundnut 10.82%(Gujarat) to 17.0% in AP, however it increased in intensive crops such as Vegetable and Banana.

• **High Field Application Efficiency:** Micro-irrigation systems have application rates generally ranging from 0.5 LPH to 8 LPH. This ensures uniformity of water application and precision placement of water, thus offering very high field application efficiencies up to 95%.

• **Better Control of Root Zone Environment:** In Micro-irrigation, soil is maintained at field capacity level all the time. This helps in maintaining favorable moisture conditions near the root zone of the plants, which ultimately results into vigorous vegetative and reproductive plants growth.

• **Quality Improvement of Produce:** Timely and precision application of water and nutrients results into enhanced and improved quality of the produce.

• **Improved Disease Control:** Precision water application on demand does not pollute the environment and this results into better disease control.

• **Discourages Weed Growth:** In Micro-irrigation, space between two laterals is keep dry, this results into control of weed growth.

• **Lesser use of Power:** In micro-irrigation, there is a saving of water to the extent of 50-60%. Since power requirement is a function of water quantity to be pumped and head, the net effect is savings in electricity up to 25-30%.

• **Reduced Labour Costs:** Micro-irrigation is a pressurized irrigation system. Therefore land preparation activities such as preparation of ridges and furrows are not required. This results into savings of labor costs.

• **Suitable for Difficult Land Terrain:** Use of difficult and undulating land terrain is possible. In case of flow irrigation, the area at higher elevation is normally left out as uncommon, Ideal for Marginal Lands.

• **Maintains Soil Health:** Use of excessive water for water guzzling crops like Rice, Sugarcane has resulted into degradation of land. Adoption of Micro-irrigation maintains soil health.

• **Suitable for inferior quality water:** Salty water can also be used through micro-irrigation.

• Apart from the above major benefits, adoption of micro-irrigation has also brought other benefits such as employment generation in rural areas, reduction in migration of rural youth to urban areas, power savings, use of salty water and saline and alkaline soils, use of undulating terrains, quality produce, reduced pest and diseases etc.

• Since Micro-irrigation is the most advanced and scientific method of irrigating plants and giving optimum returns to the growers at optimum costs, it ultimately makes the
perfect techno-economical farm model. This is very clear from the Onion model shown in the following picture. Due to introduction of micro-irrigation and technologies such as fertigation, the input costs of Onion Cultivation have gone down substantially and because of higher yields achieved, farmers income has gone up considerably. In Jalgaon District of Maharashtra state, this Contract Farming model has been very successful. The farmers income levels have gone up to Rs 100,000 per acre per season from the level of Rs 30,000-40,000 in case of traditional farming.

Integrated Model of Gravity Pipelines and Solar Powered Micro-irrigation:
In this innovative scheme, water is brought up to individual farm level by way of Gravity Pipelines with a residual head of up to 1m. Thus to bring the water up to individual farm level no power would be required. The water would then be delivered to a small individual sump having suitable capacity or farmer’s own open wells. Then it would be delivered to the crops through Solar Powered Micro-irrigation Systems in the individual farmers fields.

Advantages:
a. Water can always be brought to individual fields by gravity through piped network. This will ensure higher conveyance efficiency.
c. No Recurring Expenses.
d. No need of creation of electrical infrastructure Green Power, complimentary to nature

JISL’s Focus on Irrigation Efficiency, Water Productivity and Value Creation Efficiency

Irrigation Efficiency:
It is a ratio of water utilized and water supplied. It is measured in % terms. The losses such as evaporation, conveyance, seepage and deep percolation are taken into consideration while calculating overall Irrigation efficiency. Higher Irrigation efficiency results into increase in irrigated area and ultimately results into higher water productivity.

Water Productivity:
Presently the irrigation projects are designed mostly with the low value crops. This is done basically with the intention that maximum number of beneficiaries are covered. Most of the time water is not adequate to irrigate such expanded areas, the irrigation cannot take place to the fullest satisfaction of the crops. Also the water is not sufficient for two/three seasons, therefore projects are ultimately designed only for one season. Thus the investments are done fully, but they are utilized partially. In the process important criteria/factors such as Water Productivity and Value Creation are totally ignored. Moreover, traditional systems are supply based systems hence due to unreliability of water supply, farmers do not grow cash crops. Only low value short duration crops are grown. Yields of such crops suffer due to unreliability of water supply. Hence, this ultimately results into poor water productivity and poor Value Creation from the project. Sometimes, unfortunately, projects are designed without considering the returns/value creation and or economic viability.

In order to bring the reforms in irrigation sector to benefit all the stakeholders in the society we need to improve the above situation. We should prepare our projects based on higher water productivity, higher value creation and higher energy efficiency. The cropping pattern and other cultivation practices are selected carefully to deliver higher water productivity and also higher Value Creation. In order to achieve this objective, we may have to select cash crops/fruits and vegetables. There is a possibility that under the name of food security, this approach could be opposed by some people. However considering the huge area under cereals, pulses and oilseeds, this will have hardly any impact
on food security issues. We are investing huge amounts on irrigation projects and they must create more value in terms of monetary gains from irrigation projects. Then and only then we will achieve the higher economic growth.

The concept of water productivity is related to the biomass production and is the ratio between biomass produced in kg to the water consumed by the plants in m³, both under rain-fed and irrigated conditions. This can be achieved either by 1. Increasing the marketable yield of crops for each unit of water transpired, 2. Reducing outflow/losses, 3. Increasing effective use of rainfall. All the three ways lead to Good Agricultural Practices (GAP) which includes reduced water consumption, better yields, better fertilizer efficiency, better soil health, better crop growth and ultimately better Water Use Efficiency and better Water Productivity. It is measured in terms of yield of crops in kg per m³ of water consumed. In the cash crops like sugarcane and cotton, the crop productivity is normally double as compared to flow irrigation because the water consumption is just 50% and yield increase is more than 50%.

**Value Creation Efficiency** : This is defined as crop income generated from unit volume of water. It is measured in terms of Rs/m³. “Increased Water Productivity and ultimately increased value creation” should be the major criteria for any public irrigation schemes.
Introduction
NETAFIM is the global leader in drip and micro-irrigation solutions (MIS) for sustained productivity. With 28 subsidiaries, 17 manufacturing plants and more than 4500 employees worldwide, Netafim delivers innovative solutions in over 113 countries across the globe. Founded in 1965, Netafim pioneered the drip irrigation revolution, creating a paradigm shift toward low-flow agricultural irrigation. Today, Netafim offers a wide range of state-of-the-art irrigation, nutrigation, automation, digital farming and complementary solutions for agriculture, landscaping and mining. From drippers and dripper lines, through sprinklers and micro-emitters to digital farming solutions (DFS) and greenhouse systems, Netafim’s market-leading products and services enables cost-effective irrigation for optimal and sustainable results. Netafim India is a wholly owned subsidiary of Netafim, established in 1997, offers a wide range of micro-irrigation, greenhouse and Digital farming solutions. With three
manufacturing plants, over 1000 employees and more than 18 lakh acres of land across diverse agro-climate in the country, suitable for a wide range of crops. Netafim India & Maharashtra offers extensive agronomic, design, after-sales support and agri-extension services to ensure sustainable prosperity to over 6 lakh farming families and this journey is still on. Netafim India is an active partner in several Government projects like GGRC, APMIP & TANHODA. In Maharashtra Netafim has about 300 employees and network of 400 dealers for catering the services to the farming community.

Agriculture Scenario in Maharashtra

Out of 307 lakh ha geographical area of the state, 56% is agricultural land, 17 % is forest & 27% is barren non-agricultural land. Maharashtra is known as horticulture hub having grapes, pomegranate, citrus, mango, guava as main crops. Sugarcane, cotton, banana and vegetables as cash crops are also grown on substantial area in diverse agro-climatic zones of the state. Maharashtra is pioneering state for adoption of micro-irrigation technology in various crops and thus, oldest and most matured market for micro-irrigation systems, known as trend settler in Indian markets. Around 23.05 lakh ha area in the state has been brought under micro-irrigation, of which 73.60 % i.e. 16.97 ha is under drip irrigation and remaining 6.59 lakh ha (26.40%) is under sprinkler irrigation. Drip amiable crops area as follows:

<table>
<thead>
<tr>
<th>Crops</th>
<th>Area Million ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>4.06</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>0.93</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>3.31</td>
</tr>
<tr>
<td>Vegetables</td>
<td>0.45</td>
</tr>
<tr>
<td>Spices</td>
<td>0.11</td>
</tr>
<tr>
<td>Fruits</td>
<td>1.54</td>
</tr>
<tr>
<td>Plantation</td>
<td>0.2</td>
</tr>
<tr>
<td>Total</td>
<td>10.63</td>
</tr>
</tbody>
</table>

Mass adoption of Micro-irrigation

The main stakeholders in the promotion & adoption of micro-irrigation systems are both central & state government’s agriculture & water resources departments, Financial institutions, NGOs, Agriculture universities, Research institutions, farmers and Micro-irrigation system manufacturers. Government’s support in the form of allocation of subsidy to the growers has played a crucial role in adoption of technology. Transparency & governance has helped a lot in accelerating the adoption rate with the help of research findings from agriculture Universities & research stations. Banking institutions are pivotal in providing timely and sufficient financial support. NGOs have helped the small & marginal farmers to
adopt micro-irrigation systems and improved their lives. Entire ecosystem is interdependent and mutually beneficial. Hence close coordination & cooperation amongst all the stakeholders would surely help mass adoption of MIS creating win-win situation for all.

NETAFIM's Success factors for adoption of MIS

- Appropriate product offering: Based on the detailed survey, crop, soil data and considering the need of the farmer, Netafim suggests the right system with appropriate mix of the products and correct installation for longevity of the system in the field with more Returns on Investment consistently.
- Optimal Design: Considering ground data a correct and economical design with all standard items without compromise on the quality of accessories is the key for success of the system in the field.
- Agronomical support: is the strength of the NETAFIM. Agronomists provides all the technical & cultivation back up to the farmers from land preparation, crop & variety selection to harvesting & marketing of that crop to fetch attractive prices & make his farming more remunerative. Agronomists starve hard to create success stories in various crops with the farmer’s participation & guidelines to other growers to follow.
- After sales service & maintenance: The farmers are properly trained & guided regarding operation of the system as per the schedule & nutrigation as per the crop growth along with regular maintenance after the installation of the system in his farm. The ASTS Staff visits the farms for maintenance as per the requirement of the farmers. This assures the smooth operation of the system on continuous basis for longer period as desired.
- Better customer relationship management (CRM): for selling of the right products rather than pushing the products. Through CRM activities proper business relationship is established & maintained with the staff, dealers & growers.

NETAFIM’s Initiatives in Maharashtra

In addition to installations of micro-irrigation systems on more than 2 lakh ha area in various crops like sugarcane, cotton, grapes, pomegranate, vegetables & other crops, the NETAFIM has the following new initiatives in Maharashtra.

1. Subsurface Drip Irrigation (SDI)

NETAFIM Irrigation takes the pride in

<table>
<thead>
<tr>
<th>Sr#</th>
<th>Initiative</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Enquiry Generation-SMS</td>
<td>21051</td>
<td>5344</td>
<td>748</td>
<td>27143</td>
</tr>
<tr>
<td>2</td>
<td>Face to Face meeting</td>
<td>5547</td>
<td>16709</td>
<td>12453</td>
<td>34709</td>
</tr>
<tr>
<td>3</td>
<td>Missed Call</td>
<td>0</td>
<td>8718</td>
<td>4112</td>
<td>10630</td>
</tr>
<tr>
<td>4</td>
<td>System installation SMS</td>
<td>1106</td>
<td>6323</td>
<td>5946</td>
<td>13375</td>
</tr>
<tr>
<td>5</td>
<td>ASTS</td>
<td>CMT Visit &amp; Services</td>
<td>3078</td>
<td>6276</td>
<td>10303</td>
</tr>
<tr>
<td>6</td>
<td>Agronomy Services</td>
<td>920</td>
<td>0</td>
<td>1032</td>
<td>5648</td>
</tr>
<tr>
<td>7</td>
<td>Complaint Management</td>
<td>464</td>
<td>0</td>
<td>391</td>
<td>1340</td>
</tr>
<tr>
<td>8</td>
<td>SMS through Vendor</td>
<td>8374</td>
<td>186248</td>
<td>0</td>
<td>194022</td>
</tr>
<tr>
<td>9</td>
<td>Inhouse SMS connect</td>
<td>47662</td>
<td>0</td>
<td>439619</td>
<td>958338</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>88222</td>
<td>68987</td>
<td>701058</td>
<td>1256308</td>
</tr>
</tbody>
</table>
introducing Subsurface Drip Irrigation first time in Maharashtra in crops like sugarcane, vegetables, grapes etc. Subsurface Drip Irrigation (SDI) has been found most appropriate irrigation system for growing the sugarcane crop with higher water and nutrient use efficiency resulting in more cane yield and sugar recovery. With SDI installation in Sugarcane it is easily possible to grow one plant cane and minimum five ratoon crops in the same field which results in reduction in cost of cultivation and increase in profitability to the cane growers.

**Benefits of Subsurface Drip Irrigation**
- Highest water use efficiency than any irrigation system – Water losses through evaporation, runoff, and deep percolation are virtually eliminated.
- Water saving up to 55 to 60% as compared to conventional furrow irrigation and 10 -15% more as compared to surface drip irrigation.
- Increase in yield by 30% as compared to conventional furrow irrigation.
- Adapts to field size, shape, and topography – SDI adapts to any field size and shape, irrigating 100% of the field, maximizing production and minimizing waste. Using pressure compensating drippers, hills and slopes are irrigated with high uniformity.
- Improves crop quality and bottom-line results – Water and nutrients are used more efficiently, reducing input costs. Uniform water and fertilizer application throughout the drip system result in a more uniform crop and higher overall yields.
- Reduces maintenance costs – SDI is minimally exposed to the weather and therefore is barely damaged by weather conditions & hence maintenance costs are reduced.
- Long lasting performance – When properly maintained, a high quality SDI system can last 10 years or more. One plant cane and minimum four ratoon crops can be easily harvested under SDI.
- Reduces operation costs – In non-SDI systems, run-off, evaporation, and deep percolation require pumping more volume
for a longer time. SDI is the most efficient irrigation system. By using less water and fertilizer, it cuts down on operational expenses. SDI is also well adapted to Minimum till, reducing cultivation costs.

- Mechanized sugarcane cultivation including planting, inter-culturing and harvesting is possible as the system components are buried.

**Depth of SDI**
Several factors affect at what depth dripperlines are to be buried below the soil surface. The major factors are:
- Depth of the crop root zone
- Soil type
- Cultivation practices

For sugarcane, the depth of placement of SDI in different soil types should be as follows:

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Depth of placement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep soil</td>
<td>20 cm</td>
</tr>
<tr>
<td>Medium Deep soil</td>
<td>15 cm</td>
</tr>
<tr>
<td>Shallow soil</td>
<td>10 cm</td>
</tr>
</tbody>
</table>

**Selection of Drip line for SDI**
- In undulating terrain, pressure compensating driplines are recommended.
- In normal levelled fields, non-pressure compensating Aries 16 mm driplines with 0.8 mm or 0.5 mm thickness can be effectively used.
- Depending upon soil types, the dripper spacing and discharge varies. The recommendation is as follows:

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Dripper Spacing (cm)</th>
<th>Dripper Discharge (LPH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep soil</td>
<td>50</td>
<td>1, 1.6 or 2</td>
</tr>
<tr>
<td>Medium Deep soil</td>
<td>40</td>
<td>1 or 1.6 or 2</td>
</tr>
<tr>
<td>Shallow soil</td>
<td>30</td>
<td>1</td>
</tr>
</tbody>
</table>

**Maintenance of SDI**
- The flows and pressures of each irrigation zone controlled by a single valve must be thoroughly and accurately inspected and recorded once installation and commissioning is completed.
- Conduct fortnightly flow rate and pressure tests before and throughout the entire season. Compare it with the baseline values.
to ensure optimal operation.

- It is most important to check dripperlines ends. A uniform flow of water should be seen when opening end lines. If low or no flow is evident, there is clogging, a leak, or a disconnection along the dripperline and it should be repaired.
- Dripperlines must be flushed once in a month, so that dirt and sediments can be expelled out of the dripperlines. The sub-main should be flushed before flushing the dripperlines. Continue flushing an end line or flushing manifold until clear water is constantly flowing out.
- To prevent root intrusion into the system, regular Treflan treatment, applied is performed annually throughout and/or at the end of the growing season, preferably in dry soil. If Treflan is not available Pendimethalin treatment is also recommended.

2. NETAFIM’s Drip irrigation work with the sugar mills in Maharashtra
Netafim believed to have alliances with the sugar mills for adoption of drip irrigation in sugarcane on larger area with the financial assistance from Banks or NAFA (Netafim Agriculture Finance Agency) and the support from Government’s subsidy schemes. Since 2009, NETAFIM has agreements with 50 to 55 sugar mills every year with market share of about 40%. NETAFIM’s coverage in sugar mill alliances since 2009, is on more than 54,000 ha. The total sugarcane coverage through alliances and through dealers is on more than 90,000 ha. NETAFIM is a market leader in subsurface drip irrigation (SDI) in sugarcane covering more than 8,500 ha area.

Alliance for Drip irrigation between the sugar mill & NETAFIM is a win – win model, the synergies of which extends beyond the two parties and also benefits the farmers at large.

Benefits to Sugar mills
Higher cane production per unit area; Improved cane quality i.e. sugar recovery ;Assured fresh cane supply; Stable area under cane; Longer crushing period; Sustainable water resource; Less transportation cost; Early crop maturity; Mechanized cultivation under SDI; Impetus to goodwill; Serving the social objective

Benefits to farmers
Higher yield ; High profits, saving of water, power, labour cost; Low risks; Sustainable development with simple technology

Benefits to the Sugarcane Crop
Optimal soil water & air relations; Nutrient availability throughout the crop growth period; Sunlight interception for higher growth rates; Control over water & nutrient supply as per the crop growth stages

Benefits to NETAFIM
Sustained business model for helping the sugar mills & the farmers to grow “More with Less”.

3. Community Irrigation:
Community Micro-irrigation is a solution of providing micro-irrigation technology through surface water and to the large community of farmers at large. It is a project solution wherein ‘Water Conveyance is integrated with On-Farm Water Productivity, resulting in significant in form of better water use efficiency, higher yield, higher output to a community of farmers.

Advantages of Community Irrigation Project:
- Equitable distribution of water
- High Water Use Efficiency (80to 90%)
- High Fertilizer Use Efficiency
- Judicious use of precious resources like water, energy, fertilizers etc
- Increase area under irrigation with same available water
- Improve the crop quality and productivity
- Significant increase in Irrigated area with same available water
- Improve standard of living of farming community
1. Some of the projects completed by NETA FIM on lift irrigation schemes in Maharashtra state are listed below:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Name of the project</th>
<th>Particulars</th>
</tr>
</thead>
</table>
| 1.      | Mahadeo Co-operative lift Irrigation Scheme, Gotkhindi, Tal.: Walwa, Dist.: Sangli | - The first Community irrigation project on lift irrigation scheme in Maharashtra & India started in Year 2011  
- Area: 608 Acre  
- No. of farmers benefited: 350  
- Main crop: Sugarcane  
- Uniqueness: Alert SMS to individual farmers about their daily irrigation schedule  
- Cabled automation for equitable water distribution  
- Increase in productivity: 30 to 40%, some of the farmers are harvesting the cane yields more than 100 tonnes per acre.  
- The automatic drip irrigation for last eight years has resulted in decreased EC & pH of the soil & increased soil physical & biological fertility. |
| 2.      | Krantiagrani Dr. G D Bapu Lad co-operative Lift Irrigation Scheme, Bambavade, Tal.: Palus, Dist: Sangli | - Community irrigation project started in year 2014  
- Area: 750 Acre  
- No. of benefited farmers: 475  
- Crops: Sugarcane, Grapes, vegetables  
- The first wireless automation drip irrigation project on lift irrigation scheme in India & Maharashtra where the first drop of water lifted from river was given to crop through drip system only  
- Centralised filtration system  
- Increase in productivity: 30 to 40%  
- Increase in sugarcane production from 2000 tonnes to 35000 tonnes from the command area of the scheme |
| 3.      | Dudhganga Lift Irrigation Scheme, Kasba Sngaon, Tal: Kagal, Dist: Kolhapur | - Community project started in year 2012  
- Area: 450 Acre  
- No. of farmers benefited: 145  
- Main crop: Sugarcane  
- Cabled automation  
- Centralized filtration  
- Increase in productivity: 30% |
- Area: 165 Acre  
- No. of farmers benefited: 101  
- Main crop: Sugarcane  
- Cabled automation  
- Centralized filtration  
- Increase in productivity: 30 to 35% |
4. Mechanization in Sugarcane

Planting with Mechanical Sugarcane Seedling Planter

- Traditional method of sugarcane sett planting involves preparation of field, making of ridges and furrows, cutting of cane into setts, applying insecticides and fungicides to the setts, transporting the setts to the field, placing the setts in a line at proper spacing, pressing the setts and covering with the soil. This complete process is time consuming and labour intensive.

- Under this scenario, there is an urgent need to mechanize the planting operation and hence NETAFIM Irrigation has brought the Mechanized Sugarcane Seedling Planter from Italy.

- The extensive field-testing and demonstrations of the mechanical sugarcane seedling planter were carried out at three fields of farmers from Kisanveer SSK Satara (area 10 acres), at Porwal farm Lhasurne, Dist: Pune on 50 acres and at Chafalkar farm, Taradgaon, Dist: Satara on 30 acres.

Planter description and working

NETAFIM brought sugarcane seedling planter is a single row planter operated by tractor of 45 HP or more. The planter covers two operations at a time i.e. placing the seedlings at desired / set spacing at appropriate depth and laying of surface / subsurface integral drip line at a time. It has a mainframe designed in MS pipe with a platform for storing the seedlings, one seat for a labour for placing the seedlings in the rotating drums. The seedlings are conveyed to soil through guard. The planted seedlings are covered with the soil by roller attached on a rear side. The planter requires total six persons for the planting. One tractor driver, 2 male labours for placing the seedlings & dripline and 4 lady labours for transporting the seedlings. The planter covers 4 Acres of planting in a day of eight hours. It is suitable for maintaining proper / desired spacing between two seedlings and two rows of a sugarcane by adjusting the gear ratio.

Results of the field-testing

During 2015-16 the systematic field-testing of the mechanical sugarcane seedling planter was carried out at three fields of farmers from Kisanveer SSK Satara (area 10 acres), at Porwal farm Lhasurne, Dist: Pune on 50 acres and at Chafalkar farm, Taradgaon, Dist: Satara on 30 acres. The planting was done with surface and subsurface drip irrigation at 150 cm between the two rows and 45 cm between the two seedlings. The total time required for mechanical sugarcane seedling planter to complete the planting of one-hectare area with row spacing of 150 cm was recorded as 4.08 hrs. The survival of planted seedlings was observed to be more than 96%. Till today about 900 Acres sugarcane is planted with the mechanical planter.

Economics

The cost of planting per acre with mechanical sugarcane planter is Rs. 1730.00 as against Rs. 4300.00 in manual sett planting and Rs. 3200.00 in manual seedlings planting. There is saving of 59.77% as compared with manual sett planting and 45.94% as compared with manual seedlings planting.
Mechanized Sugarcane Harvesting
Under the scenario of shortage of harvesting labours, their ever-increasing wages, timely availability and efficiency, there is an urgent need to mechanize the sugarcane harvesting operation. Hence, NETAFIM Irrigation in collaboration with foreign manufacturer has taken a lead to design, develop and conduct the field testing of whole cane sugarcane harvester during 2016.

At present about 200 mechanical sugarcane harvesters are being used in the sugar industry of our country. Most of them are chopper / billet harvesters and are used mostly in southern states and Maharashtra. Considering the pain points in the chopper harvester, we are proposing to develop Whole cane harvester.

- Whole stalk sugarcane harvesters are quite suitable for those areas where sugarcane crushing is not possible in limited hours. Delay in transport, loading, unloading, waiting at one or other stage is unavoidable.
- Use of whole stalk sugarcane harvesters is also useful for those areas where green tops recovered are used for cattle feed.
- Proposed machine will be tractor operated with a separate Detrasher and loader.

NETAFIM has developed the Tractor drawn Whole Cane Sugarcane Harvester in Collaboration with Israel firm and its field testing is in progress.

5. Extension Activities to generate the awareness about Drip irrigation, Nutrigation & Automation

NETAFIM always takes a lead in conducting the field activities such as big & small farmer meetings, Trainings, Pre & post visits to drip adopting farmers and participates in agriculture exhibitions at all levels. In farmer meetings & training programs, NETAFIM covers about 47 to 50,000 farmers of Maharashtra every year.

<table>
<thead>
<tr>
<th>Month</th>
<th>Fertigation schedules</th>
<th>Farmer Meetings</th>
<th>In-house Trainings</th>
<th>Farmer Tours</th>
<th>Campaigns</th>
<th>Chai pe charcha</th>
<th>Write ups</th>
<th>Exhibitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>103</td>
<td>551</td>
<td>62</td>
<td>1,476</td>
<td>14</td>
<td>337</td>
<td>14</td>
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<td>Feb</td>
<td>112</td>
<td>730</td>
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<td>3,086</td>
<td>4</td>
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<td>4,443</td>
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<td>2,373</td>
<td>6</td>
<td>193</td>
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<td>May</td>
<td>97</td>
<td>611</td>
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<td>5,084</td>
<td>11</td>
<td>525</td>
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<td>55</td>
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<td>June</td>
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<td>773</td>
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<td>1,672</td>
<td>9</td>
<td>160</td>
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<td>July</td>
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<td>1645</td>
<td>39</td>
<td>2,663</td>
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<td>148</td>
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<td>Aug</td>
<td>136</td>
<td>997</td>
<td>52</td>
<td>9,113</td>
<td>10</td>
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<td>52</td>
<td>4,165</td>
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<td>55</td>
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<td>Nov</td>
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<td>176</td>
<td>10</td>
<td>147</td>
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<td>Dec</td>
<td>136</td>
<td>998</td>
<td>37</td>
<td>2,162</td>
<td>6</td>
<td>203</td>
<td>7</td>
<td>52</td>
</tr>
<tr>
<td>Total</td>
<td>1,388</td>
<td>10,625</td>
<td>839</td>
<td>44,210</td>
<td>86</td>
<td>3,071</td>
<td>141</td>
<td>1,350</td>
</tr>
</tbody>
</table>
6. Digital Farming Solution

Automation of Drip Irrigation

Automation is an operation of any process with minimum or even no involvement of a human being. In Agricultural automation is implemented for control of Irrigation, Fertigation and Climate control in protected cultivation. With availability of advanced technology in sensors and internet a new era in Automation of Agricultural is not far away.

Why Automation:
In today’s world, optimization and precision are keywords in all sectors to make business profitable. An AUTOMATION is the only way to achieve it. Agriculture is facing a situation where there is shortage of skilled and unskilled manpower, irregular & limited power supply availability, rising prices of resources like Fertilizers, labor Electricity, Water etc.

Advantages of Automation:
Reduction in labor cost & maintenance of irrigation System, Ease and flexibility of operation (Electricity Schedules & availability of water, Different Crop Patterns etc.). Preciseness & optimization of resources due to automation, results in Greater Yield, Better Quality, Better Go to Market Timing and ultimately High Profits.

Another Greatest indirect advantage is Conservation of an Environment. (Due to optimized use of Water, Electricity & Fertilizers).

Scope of Automation:
Main Pump/s Operation, Filter Back flushing (Cleaning), Fertilizer stock solution preparation & injection, plot wise valves operation for watering, Monitoring of field conditions.

Types of Automation:
Time based: Basic level and low cost. The task is executed only on time basis. There is no feedback from the field and hence there is always probability of error.

Volume based: A water fed to the field is continuously monitored and measured with equipment like water meter. The advantage is precise & programmed amount of water is supplied. The system also monitors flow deviation, if any, and raises an alarm. The proportional fertigation is based on flow.

Sensor based: A advanced and precise way. Based on real time feedback from different sensors, an irrigation program is executed. In other words, it is “Irrigation as per Demand”.

Different sensors like Soil Moisture Sensor (SMS), Tensiometers, Solar Radiation, Weather Station, ET are commonly used for the purpose.

The Automation System:
To automate the farm certain components are to be installed in the field.

Solenoid Control Valves: An electrically operated Valves. It Opens or Closes as per signal from the controller. In addition to Open & Close, the Pressure Reducing, Sustaining or Relief features are available with addition of Pilots. Valves are available from ¼” to 12” and more.

Controllers: The Brain of the system. The Controller executes the task monitors the process and take corrective action whenever required as per program fed to it.

It maintains the history of operations, Sensor readings, Alarms, quantity of Water, Fertilizer for future reference. The vast range of controllers is available to cater the need of any system, from smallest plot of few Sq. Mtrs to Hundreds of Acres, simple time based to most sophisticated real time sensor based systems for desired operation and control.

Dosing Machines: A variety of means available for Fertilizer injection. e.g. Venturi, Fertilizer tank, piston / Diaphragm pumps, multi-channel dosing machines etc., Each one has its own advantages.

The multichannel dosing machines are used for injecting no. of fertilizers at a time. The
advantage is EC & pH of delivered water can be maintained.

**Connectivity:** With advanced Technology now it has become easy to monitor and control the farm from anywhere in the world.
The Latest cloud based systems connects the user to the system in the farm by Smartphone, i-pad or PC without any expensive software or installing computer near the controller in the farm at remote place.

**A Next Generation Automation:** The companies are in pursuit to make Smart & Intelligent Control Systems.
One need to input location of his farm and Crop. The system will automatically get Real Time Data of Weather, Soil etc., use BIG DATA & IoT available on Internet. Combine it with available Agronomical Intelligence, make analysis and decide/ suggest the course of action and program controller directly.
NetBeat™ is the first irrigation and fertigation management system to integrate real-time monitoring, smart analysis, and control - in one closed-loop, mobile platform.

### 7. NETAFIM’S Growing method of Rice under Drip Irrigation
- **Row spacing:** 15-20 cm
- **Plant spacing within row:** 10-15 cm
- **Lateral spacing:** 90-100cm
- **Dripper spacing in lateral:** 40 cm
- **Dripper flow rate:** 2 l/h
- **Adoption of optimal varieties to ensure high yields with drip irrigation**
- **Crop coefficient at peak water demand:** 125% of class A evaporation pan.
- **Results of Field Trials:**
  - Rice can grow to yield 8-12 tons/ha with 700-850mm water –including rain
  - 125-150kg/ha N
  - Plant population is different in short-season and long-season cultivars
  - Shallow subsurface drip increases rice yield and quality
  - Rice can be grown on slopes
  - Rice can be grown under drip irrigation even where rice is no longer grown due to soil salinization

<table>
<thead>
<tr>
<th>Sr. Parameters</th>
<th>Flood irrigation/ acre</th>
<th>Drip irrigation/ acre</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Water Saving</td>
<td>48 Lakh Liters</td>
<td>18 Lakh Liters</td>
<td>30 Lakh Liters</td>
</tr>
<tr>
<td>2 Land Preparation</td>
<td>Rs. 2000</td>
<td>Rs. 2000</td>
<td>Nil</td>
</tr>
<tr>
<td>3 Puddling</td>
<td>Rs. 4000</td>
<td>Nil</td>
<td>Rs. 4000</td>
</tr>
<tr>
<td>4 Seed cost</td>
<td>25 kg (kg seed Rs. 30)</td>
<td>15 kg Rs. 450</td>
<td>Rs. 300</td>
</tr>
<tr>
<td>5 Sowing cost</td>
<td>Rs. 200 in nursery</td>
<td>Rs. 700 in main field</td>
<td>Rs. 500</td>
</tr>
<tr>
<td>6 Transplanting</td>
<td>Rs. 3000</td>
<td>Nil</td>
<td>Rs. 3000</td>
</tr>
<tr>
<td>7 Fertilizers</td>
<td>Rs. 3780</td>
<td>Rs. 1625</td>
<td>Rs. 2155</td>
</tr>
<tr>
<td>8 Weed Management</td>
<td>Rs. 4000</td>
<td>Rs. 3000</td>
<td>Rs. 1000</td>
</tr>
<tr>
<td>9 Plant Protection</td>
<td>Rs. 7000</td>
<td>Rs. 3500</td>
<td>Rs. 3500</td>
</tr>
<tr>
<td>10 Irrigation (Total 150 days, per day labour cost Rs. 50)</td>
<td>Rs. 7500</td>
<td>Rs. 3000 (Drip/ season)</td>
<td>Rs. 4500</td>
</tr>
<tr>
<td>11 Harvesting</td>
<td>Rs. 2500</td>
<td>Rs. 2500</td>
<td>Nil</td>
</tr>
<tr>
<td>12 Cost of cultivation/ acre</td>
<td>Rs. 34730</td>
<td>Rs. 19675</td>
<td>Rs. 15055</td>
</tr>
<tr>
<td>13 Yield (35 bags- 1 bag 75kg)</td>
<td>Rs. 47250</td>
<td>Rs. 47250</td>
<td>Nil</td>
</tr>
<tr>
<td>14 Net Results/ acre</td>
<td>Rs. 12520</td>
<td>Rs. 27575</td>
<td>Rs. 18055</td>
</tr>
</tbody>
</table>
8. NAFA - Netafim Agriculture Finance Agency

Netafim Agricultural Financing Agency (NAFA) is a non-banking finance company conceived with the core objective of offering various customized Financial Solutions to farmers and various stakeholders in the value chain of Micro-irrigation. Keeping in line with its core purpose, NAFA endeavours to reach out to small and marginal farmers of the country with easy and efficient financial solutions either directly or through stakeholders in the value chain, in a timely and efficient manner.

NAFA is promoted by Netafim Ltd., Israel; a global leader in smart drip and micro-irrigation solutions. In addition to Netafim Ltd. It has two more shareholders having significant experience in International and domestic financial services sector.

NAFA was incorporated in August, 2011 and was granted license during March, 2013 by the RBI as a non-deposit taking NBFC and with its Head Office in Navi-Mumbai, Maharashtra. The first commercial operation of NAFA commenced during April-May, 2013.

NAFA believes in making every effort in achieving realistic, long-lasting and sustainable results by enabling the farmers to get easy access to adequate and timely finance in a flexible manner. It promises to deliver customized and efficient financing solutions to enable prospective farmers to adopt smart drip and micro-irrigation solutions to generate more yields and produce better quality crops with less resources.

In a short span, NAFA has been able to reach out to around 3000 individual customers in the rural hinterlands as of date. Based on the experiences and the overwhelming responses received from various value chain (of Micro-irrigation) stakeholders, NAFA has planned to reach out to a larger customer base across geographies going forward.

9. Tie up with Banks

As per the Government policies, the subsidy to the farmers goes in their account (DBT) after installation of drip irrigation system in their farms. To facilitate the farmers for initial investment for purchase of Drip irrigation system, NETAFIM has taken a step forward and done the tie-ups with Banks for providing loans to the growers for drip irrigation. NETAFIM tie-ups are with the following banks:

- State bank of India
- Bank of Baroda
- Ratnakar Bank
- Bank of Maharashtra
- Maharashtra Gramin Bank

10. Creating Success stories with the farmers for attaining higher yields

Agronomists of NETAFIM work in close association with the farmers for creating success stories with timely agronomical support for harnessing higher yields of different crops under Netafim drip irrigation systems and create the examples for other farmers to follow.

Some of the examples are quoted below:

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Name of the farmer &amp; location</th>
<th>Crop</th>
<th>Yield under Drip System (tonnes/ha)</th>
<th>His Yield under Conventional irrigation before (tonnes/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Mr. Sanjay Anna Birewar Village: Tupa, Dist: Nanded</td>
<td>Papaya</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>2.</td>
<td>Mr. Madhukar Rumale Village: Barbadi, Dist: Wardha</td>
<td>Cotton</td>
<td>35</td>
<td>20</td>
</tr>
<tr>
<td>Sr.</td>
<td>Name of the farmer &amp; location</td>
<td>Crop</td>
<td>Yield under Drip System (tonnes/ha)</td>
<td>His Yield under Conventional irrigation before (tonnes/ha)</td>
</tr>
<tr>
<td>-----</td>
<td>------------------------------------------------------</td>
<td>---------</td>
<td>------------------------------------</td>
<td>----------------------------------------------------------</td>
</tr>
<tr>
<td>3.</td>
<td>Mr. Dhananjay Surendra Gunde, Village: Pattankodoli, Dist: Kolhapur</td>
<td>Banana</td>
<td>46</td>
<td>30</td>
</tr>
<tr>
<td>4.</td>
<td>Mr. Ajit Shamrao Pisal Village: Nanebai Chikhali, Dist: Kolhapur</td>
<td>Capsicum</td>
<td>128</td>
<td>88</td>
</tr>
<tr>
<td>5.</td>
<td>Mr. Sanjay Kadam Village: Kherad Wangi, Dist: Sangli</td>
<td>Sugarcane</td>
<td>292.5</td>
<td>200</td>
</tr>
<tr>
<td>7.</td>
<td>Mr. Sharad Ingle, Village: Jaysingpur, Dist: Kolhapur</td>
<td>Sugarcane</td>
<td>297.5</td>
<td>125</td>
</tr>
<tr>
<td>8.</td>
<td>Mr. Laxman Kaldate, Village: Ranjani, Dist: Osmanabad</td>
<td>Sugarcane</td>
<td>250</td>
<td>137.5</td>
</tr>
<tr>
<td>9.</td>
<td>Mr. Kumar Udage, Village: Latur, Dist: Latur</td>
<td>Sugarcane</td>
<td>212.5</td>
<td>112.5</td>
</tr>
<tr>
<td>10.</td>
<td>Mr. Diliprao Deshmukh, Village: Parbhani, Dist: Parbhani</td>
<td>Sugarcane</td>
<td>250</td>
<td>137.5</td>
</tr>
</tbody>
</table>
ROLE OF NGOS IN PROMOTING WATER CONSERVATION AND SAVINGS IN MAHARASHTRA

K J Joy Neha Bhadbhade Sarita Bhagat
Society for Promoting Participative Ecosystem Management, Pune

Introduction: The rationale for water conservation and water saving
Water conservation and water-saving are becoming an important global agenda mainly because there is an increasing realisation that the freshwater resource is limited and humans need to meet their needs with less and less water. Water is the most critical input in agriculture and is also the largest sector in terms of water consumption. Though India has about 10% of world population, it has only about four percent of the global freshwater resources. The per capita water available has been declining over the years. For example, in 1951 the per capita water availability was 5,137 m³ in 1951 and by 2015 it came down to 860 m³. It is further compounded by the fact the available water is unevenly and unequally distributed. Though agriculture presently accounts for more than 70% of the available water, the demands by other uses – especially urban domestic water use and industrial water use – have been on the increase giving rise to inter-sectoral water conflicts. This is putting tremendous pressure on freshwater resources – both surface and groundwater. Groundwater has been the main provider of drinking water. Now agriculture is also getting increasingly dependent on groundwater (DDWS, 2009; Ministry of Agriculture, 2013; Narain, 2012). Currently the total renewable water in India is estimated to be 1869 BCM (Billion Cubic Meters). Of this, about 1121 BCM¹ (690 BCM surface water + 431 BCM groundwater) is utilisable for various uses. The current utilization of water for agriculture sector alone is about 672 BCM (Gujja, 2018). If the trend of water utilisation continues, the projected water demand is expected to reach 840 BCM by 2025 and 1180 BCM by 2050. This would mean that demand for water by 2050 would exceed the total utilisable water.

In Maharashtra, out of the available water resources about 60 to 70% water is used for irrigation. Still only about 17% of the cropped area in Maharashtra is covered under irrigation. Because of the frequent droughts in the state there is an increasing awareness in the state to plan the agriculture water use in a more efficient manner. This is the main reason for pushing micro-irrigation in the state as ‘an effective technology in saving more water at the same time maximizing the area under the irrigation’ (MWRRA, 2015). According

¹ However, this number is being contested by many researchers. For example, Narasimhan has said that the utilisable water is much less as the evapo-transpiration is as high as 60% and not 40% as assumed by the official agencies.
The main focus is on sugarcane as it is the most water-intensive crop in the state as the total water requirement for growing the sugarcane crop is 25000 m³/ha. Currently, the land under irrigated sugarcane crop is 9.42 lakh ha. Out of this, 2.25 lakh ha land is brought under micro-irrigation. It is estimated that by using drip irrigation about 30-50% water can be saved that comes to a saving of about 7500 m³ to 12500 m³ per ha. The MWRRA order says that all the irrigated land under sugarcane will have to implement micro-irrigation which has received administrative approval. The immediate plan is to bring 3.05 lakh ha of sugarcane area under drip irrigation in phases. In 2017-18 1.5 lakh ha was brought under drip irrigation. In 2018-19, another 1.55 lakh ha will be brought under drip irrigation (MWRRA, 2015).

Changing rainfall patterns and the frequency of droughts, owing to climate change, has added new levels of complexity as well as uncertainty to the agriculture sector. For a country like India that is still predominantly dependent on rainfall for agriculture, the future availability of water for agriculture would become more and more sensitive to climate change and the resultant extreme rainfall events. Also, even to maintain the present level of agriculture production more water would be required as the evapotranspiration would go up with increasing temperatures. This would further exacerbate conflicts among different sectors and regions and would also significantly impact the food security and livelihoods vast sections of the peasantry.

Thus, water conservation and efficient use of the available water by all water uses, especially agriculture, is the need of the hour. However, in this paper we argue that water conservation and water-saving need to go beyond the government’s approach of technological fixes like drip and sprinklers. Though water-saving technologies like drip and sprinkler are important, they need to become part of a much more comprehensive and integrated approach with a much larger basket of options to mainly bring down the water footprint of agriculture. The role and mandate of Non-Governmental Organisations (NGOs) need to be located in this larger agenda.

### Unpacking water conservation and saving in agriculture

#### Change in mindsets: land productivity to water productivity

In conventional agriculture discourse one talks only about land productivity. For example, we talk about what is the productivity per unit of land, say productivity per one ha. Very often no attention is paid water productivity meaning how much is produced per unit of water utilized by crops or plants. As Paranjape and Joy (1995) have pointed out if limited quantities of water and other inputs are used in a sustainable manner then the biomass (all parts of plants and crops and not only the harvestable portion) productivity is directly proportional to the water utilised by the plants.

In intensive and external input-based systems the land productivity may be high. However, the productivity per unit of input, including water, would be low as compared to sustainable and regenerative systems. Examples of this include sugarcane, paddy in Punjab and summer paddy under the green revolution paradigm and their productivity in biomass terms (dry weight) is as low as 7 kg/ha-mm, 8.33 kg/ha-mm and 7.5 kg/ha-mm (ha-mm = 10,000 liters = 10m³). Ecosystem productivity studies show that with judicious and sustainable use of limited inputs a productivity of about 30 to 40 kg/ha-mm could
be achieved for all types of vegetation well adapted to the ecosystem. The difference in productivity between high input agriculture and low input, sustainable systems is about four times. This is not a very high figure as in good rainfall years (well-spaced out rains that does not lead to any moisture stress) almost all rainfed crops show such a productivity potential (Paranjape and Joy, 2005). In fact, this is also a shift away from the approach of comparing different irrigation systems like flood irrigation versus drip or sprinkler irrigation. In this type of an approach the emphasis is on how much more area can be irrigated with a given unit of water. In the alternative approach discussed above water use efficiency is measured in terms of the amount of biomass produced for every unit of water applied. Thus, the first issue that comes up in relation to water conservation and water-saving is this change in mindset – change from land-based productivity to water productivity and how we can increase the water productivity and bring it closer to 30 to 40 kg-ha mm.

**Crop based water-saving to basin-wide water-saving**

There is a lot of debate on water use efficiency in context of irrigation. According to the earlier definitions water use efficiency was ratio of the quantum of water required and consumed by the crop to the water available in the reservoirs (Bos and Nugteren, 1982). However, there is also the argument that all the water applied to the field and not necessarily consumed by the crops is wasted (Perry, 2007). However, this also may not be necessarily true. All the water that is not utilised by the crops may not get lost entirely. The water that is not used by the crops, partly get evaporated, partly get consumed by the weeds and partly infiltrates into the soil to recharge the aquifers. Eventually this water ends up in streams and rivers or then can be tapped as groundwater for irrigating crops. Therefore, irrigation losses cannot be perceived as entire loss of water and this is something that the proponents of improvements of ‘water use efficiency’ miss.

In older irrigation parlance there was this concept of ‘conjunctive use’ meaning using the canal and groundwater in an integrated manner. This was never put into practice as part of project design, though farmers in their own way have always done it. The Second Maharashtra Water and Irrigation Commission (Chitale Commission) reports that nearly 30% of the groundwater irrigation takes place in the irrigation commands in Maharashtra (GoM, 1999).

A good example of this conjunctive water use can be seen at Ozar (Nashik district) where participatory irrigation management (PIM) is practiced and is managed by the Water Users’ Associations (WUAs). Here, they have constructed small check dams on the streams crossing the command area. These check dams harvest rainwater and also store a part of the water they get from the Waghad dam. The water from the check dams also recharges the wells in the command area and has formed an assured water system for the farmers. They have devised a rotation system in which they alternate between canal and well water. This

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has also pushed water use efficiency in the command area (Paranjape and Joy, n.d.)

Therefore, improving conveyance efficiency by lining of the canals or through piped systems and field application efficiencies by alternatives to flood irrigation would decrease the infiltration to groundwater and that will have its impacts on the users of groundwater in the command area. Very often lining and piped water distribution system can be expensive. The other option, as the Ozar experience has shown, is to have the canal and well combination where the seepage water is tapped through wells. Of course, this needs a high degree of social for this type of a combined system to work.

This also brings us to the argument that water use efficiency needs to be seen at the sub-basin or basin scale as the so-called water “lost” actually forms part of the water cycle within the basin. Crop-centric conception of water use efficiency often misses this larger picture. This is not to argue that the irrigation water need not be used efficiently within in irrigation commands or crop-centric efficacy is not important. The water that is brought into the irrigation commands comes with a high cost – both economic and social – and both the conveyance efficiency as well as crop productivity per unit of water needs to be improved. However, all these efforts to improve water use efficiency need to be placed within the overall context of water availability a and use within the basin. Otherwise the very same efforts to conserve and save water can create negative externalities.

International Water Management Institute (IWMI) popularized the slogan “more crop per drop” in the mid-1990s. IWMI has been seriously involved in research to improve the productivity of water for agriculture at basin scale. In fact, it went beyond the crop-centric approach as the key research question for them has been: “How can we grow more food and sustain rural livelihoods with less water in a manner that is socially acceptable and environmentally sustainable”? (Giordano et al, 2006). Probably this is the approach that needs to be taken in the context of water conservation and water-saving in agriculture. The slogan, ‘more crop per drop’, has now been extended to mean ‘more income per drop, ‘more livelihoods per drop’, etc.

**Does water-saving technologies actually save water? What happens to the saved water?**

One of the critical questions that we need to address is whether the water conservation and water-saving measures ultimately bring down the overall water footprint or not. A related issue is what happens to the “saved” water. Experience in India shows that the “saved” water is used to expand irrigated area. A farmer who was irrigating, let us say two acres of sugarcane, prior to the adoption of drip now irrigates four acres of sugarcane post drip. Very often these technologies are subsidies by the government. The saved water is not pooled together and made available to those who do not have access to water. Nor does the saved water goes back to nature to have better environmental flows. Promotion and incentivization of water-saving technologies should carry conditionalities which can further the cause of equitable access, sustainable use with an overall aim of bringing down the water footprint in agriculture resulting in better environmental flows which is important for the health of the riverine ecosystem (and aquifers) and the livelihoods of the downstream communities.

**Going beyond drip and sprinklers: a larger basket of options for water-saving**

In order to tackle the growing water crisis, the central and the state governments have been promoting the micro-irrigation systems, like drip and sprinkler. Micro-irrigation is slow application of water to the crops, to the root
zone as in the case of drip: a slow delivery system under low pressure which is controlled and managed. Micro-irrigation has become a priority among the policy-makers, especially the new scheme Pradhan Mantri Krishi Sinchai Yojana (PMKSY), which aims at harvesting ‘More Crops Per Drop’. Over a decade (2005-2015), the area under micro-irrigation has increased from 3.09 million hectares to 7.73 million hectares. Of this, 7.73 million hectares (MHa), 3.37 MHa is drip irrigation (43.62%) and remaining 4.36 MHa is sprinkler irrigation (56.38%) (Indian Council of Food and Agriculture, n.d.).

Though drip and sprinkler irrigation are important for water-saving, there is a need to look beyond these and offer a larger basket of options for farmers to choose from to save water. These could include watershed-based water and soil conservation, land use planning as per land capability classification, demand side management, institutional innovations related to access and regulation of water use, cropping pattern suitable to the agro-climatic conditions, agronomical practices, specific water-saving technologies like drip, sprinkler, Siriram Fertigation method, etc. All of them together should form part of an integrated approach to water conservation and water-saving. Instead of the top down approach of the government prescribing and incentivizing certain type of water-saving technologies the communities should be free to make informed choices about the type of practices and technologies that they want to adopt.

The watershed-based development in Hivre Bazar in Ahmednagar is a good case of such an integrated approach. It has all ingredients that we discussed above. Land not suitable for crop production they brought under trees, shrubs and grasses; there is no water-intensive crops like sugarcane and banana and the village also decided not to use bore wells for irrigation. They have also developed thumb rules with regard to water use as per the rainfall. They have also gone for better agronomical practices and have selectively used water-saving technologies like drip. As a result of these measures Hivre Bazar, which receives only about 300 mm of rainfall is self-sufficient in water.

**Social mobilization, resource literacy and institutional arrangements to precede technological interventions**

There is an increasing tendency to solve all water problems with technological solutions. Issues of access and regulation cannot be solved with technological interventions. Even for the technological interventions to succeed there is a need for an informed social carrier. Communities need to understand the resource availability and constraints and also the optimal ways to use the resource. They need to be exposed to various options available to conserve and save water so that they can chose from these options the ones that suit their requirements. Norms and institutional arrangements around water sharing and regulation need to be worked out. What would happen to the saved water needs to be discussed and decided. Only then meaningful participation of people can come forth as well as the saved water can further the goals of equity and environmental sustainability. “Technology development and improved system of the resource evaluation and monitoring are useful tools, but in the ultimate analysis it is the social awareness and community organisation which are important for equitable access as well as for optimising the aggregate and individual productivity and income levels through an optimised hydrological planning” (Paranjape et al, 1998).

**Options for water conservation and water-saving in Agriculture in Maharashtra**

**Sugarcane centric use**

It is said that though Maharashtra has the highest number of large and medium irrigation projects, only about 17% of its cropped area is under irrigation whereas in India it is close to
More than 50% of this 17% is irrigated by groundwater. One of the main reasons for such a low percentage of area under irrigation is the sugarcane centric water use in the state. Currently the land under irrigated sugarcane crop is 9.42 lakh ha. Out of this, 2.25 lakh ha land is brought under micro-irrigation. Total water requirement for growing the sugarcane crop is 25000 m³/ha (Government of Maharashtra, 2018). This amount to a total water use of approximately 24 BCM. The total water use estimated in agriculture is about 56 BCM (2030 Water Resources Group, 2015). Thus, the share of sugarcane crop alone is 42% of the total water used in agriculture. There are many who also say that through sugarcane occupies only about 4% of the total cropped area in the state, it gulps down about 70% of the irrigation water.

Table 1 below gives the land and water productivities for the four major irrigated crops, namely, rice, wheat, sugarcane and cotton for the state of Maharashtra.

### Table 1: Average land and irrigation water productivity for four major crops in Maharashtra

<table>
<thead>
<tr>
<th>Crop</th>
<th>Average yield of irrigated lands kg/ha</th>
<th>Applied irrigation water productivity kg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>1672</td>
<td>0.17</td>
</tr>
<tr>
<td>Wheat</td>
<td>1766</td>
<td>0.63</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>87747</td>
<td>4.48</td>
</tr>
<tr>
<td>Cotton</td>
<td>1710</td>
<td>0.46</td>
</tr>
</tbody>
</table>

Source: Sharma et al, 2018

In the case of rice, the yield is 1672 kg/ha and the water productivity is 0.17 kg/m³. This translates to 9835 m³ of water per hectare to produce that yield. Now the total area under rice cultivation in Maharashtra is 14.1 lakh ha and therefore the water requirement for rice is about 14 BCM. Similarly, the water requirement for sugarcane is about 24 BCM for an area of 9.42 lakh ha. Therefore, the total water consumed by rice and sugarcane alone are 38 BCM corresponding to about 67.8% of the water.

One of the paradoxes of Maharashtra water scenario is that sugarcane coexists with droughts. We saw this in 2016 when parts of Marathwada had to be supplied with water brought by water train from Miraj. In 2018 too, we are facing more or less the same situation. All these call for a critical look at cropping pattern and agronomical practices if we have to engage meaningfully with water scarcity issues in Maharashtra.

### Need to continue with the integrated watershed management approach

For many decades Maharashtra was in the forefront of integrated watershed development and management to conserve soil and water. Outstanding success stories like the Hivre Bazar, Ralegaon Siddhi, some of the villages under the Indo-German watershed programme are all products of this. However, over the last few years the watershed development approach seems to have been given a good by and instead quick fix solutions in the form of Jal Yukt Shivar (JYS) are being promoted. Under the JYS the emphasis is on stream (nallah) deepening, widening and straightening and not on the integrated treatment of the catchment. There is a need to bring back the integrated watershed approach as the mainstay of water conservation in the state. This approach can tie together various components like water and soil conservation, proper land and crop planning, innovative agronomical practices, demand side management, regulation of water use, maintenance of soil moisture throughout the ecosystem, introduction of water-saving

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3 This is also because only 3% of the total area under cotton in Maharashtra which is about 3.54 Mha is irrigated. This is also one of the reasons for continuous distress among cotton farmers.
technologies, institutions to regulate and manage water, etc. The aim should be to cover the entire Maharashtra, including the present command areas, under the integrated watershed management programme over the next 10 years or so.

**Sustainable Sugarcane Initiative (SSI)**

As a second step towards water conservation and water-saving, we need to turn our attention to the most water-intensive crops in the state like sugarcane and rice. As both of them together account for most of the water used in agriculture, a discussed earlier, saving in the water use of these two crops can make a tremendous difference in the overall agriculture water use in the state.

Of the two crops, sugarcane is the number one water guzzler in the state. Interestingly most of the sugarcane cultivation takes place in the drought-prone regions of Maharashtra (Economic Times, 2015). Sugarcane is seen by many as the main villain and there have been even demands to shift away from sugarcane as a way for drought eradication. Though there is some truth in this, it is also true that a shift away from sugarcane is not going to be that easy. If it was easy this shift would have taken place long back. There are many structural reasons why people still persist with sugarcane though they know very well that sugarcane is not the most remunerative crop. One, it has a stable price unlike most of the other crops. Two, there is a well laid out processing/value addition facility in the form of sugar factories. Three, the public irrigation systems very often provide water rotations only once in three or four weeks and most of the other crops like vegetables cannot tolerate such long gaps as they need light but high frequency irrigation. Unless all these three things are taken care of, the demand for a shift away from sugarcane would remain as a rhetoric. This is not to say that there should not be regulation on the cultivation of sugarcane in the state as part of the strategy to conserve water and drought proof the state.

There have been many efforts in the state (and outside) to find ways to reduce the water footprint of sugarcane. In the 1990s there have been some experiments at pit method of sugarcane cultivation which allowed intercropping and also brought down the water intake by at least one-third. The latest and more systematic effort has been the Sustainable Sugar Initiative (SSI).

SSI involves the use of less seed material, less water, proper use of fertilizers and which gives higher yields of sugarcane. Studies show that SSI saves at least 22 per cent of the water at the planting stage, as against the conventional method of sugarcane cultivation. SSI involves wider spacing between two rows, which also helps to accommodate drip irrigation further saving 20–25 per cent of water (Biksham and Hajara, 2018). Thus, sugarcane cultivation can be made more water efficient while increasing its productivity. SSI produces at least 20 per cent more; in fact, many farmers reported an increase of more than 60 per cent of production. If SSI is implemented along with drip irrigation, it can save about 13,000 m³/ha of water⁴. Therefore, the total water usage of sugarcane in Maharashtra can be brought down by almost 54%. Similar approaches can be applied on many other crops and they can be grown with more efficient methods. These methods of ‘More Production for Less Water’ are being practiced in India and many other parts of the world (SRI-Rice 2014).

**System Rice Intensification (SRI)**

Rice is one of the main crops cultivated in India. Out of the 44 Mha of irrigated area in India, 55% is under paddy and this consumes about

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⁴ Drip irrigation saves up to 12500 m³/ha of water. However, we have assumed the low case scenario of 7500 m³/ha. Therefore, water-saving efficiencies can be much higher.
60% of the total water drawn by agriculture (Gujja and Shaik, 2018). In Maharashtra too, Rice occupies significant irrigated area. The productivity of rice in India is 3.5 tonnes/ha. The main challenge In India is to increase the productivity of rice using less water. The use of System of Rice Intensification (SRI) technique has proven to be effective and is catching up with many farmers in India. It can reduce the water use at least by about one-third. It has also reported very high productivity. For example, in Andhra Pradesh in the case of Kharif crop the productivity reported in 2003 was 8.4 T/ha whereas in the case of conventional cultivation the productivity was 4.9 T/ha (ICRISAT, 2008). In many states like Tamil Nadu, Andhra Pradesh, Telangana and Bihar, the technology has been implemented with the help of local NGOs, which helped to promote it extensively among the farmers. Some of the state governments have also been promoting this.

There are also a number of local innovations that have taken place in the SRI like the zero till Conservation Agriculture method or the Saguna Rice Technique, which leans towards a more organic and biomass-based approach for rice cultivation, with minimal use of water. Such technologies not only save water but also reduce the drudgery of the farmers and prevent the loss of silt during puddling. SRI has the ability of improving the yields even on degraded soils. SRI is also known as System of Root Intensification and is being used for other food grain crops like wheat, millets, etc.

Role of NGOs
The role of NGOs needs to go beyond the propagation of certain water-saving technologies like drip and sprinkler and need to be located in the above discussed broader
agenda for water conservation and water-saving in Maharashtra. This broader agenda gives lot of scope for the involvement of NGOs in the water sector in Maharashtra. In fact, many NGOs have been involved watershed development, participatory irrigation management, groundwater management and so on. We would like to reiterate once again that mere technological measures cannot work unless there is a conducive environment through proper social arrangement for its realization. Over a past few decades our experience has shown that if water related problems in India are to be resolved or least addressed in a more meaningful manner the role of the NGOs is crucial. CSOs not only highlight the problems, implement pilot efforts, or help in implementing state programmes, but also has helped, through their sustained efforts, to shift the water discourse and practice from state-led, centralised solutions (such as large dams) to more decentralised, democratic and equitable efforts such as watershed development, participatory irrigation management, etc.

The role of NGOs in the area of water conservation and water-saving can broadly encompass the following:

- Development of an integrated water conservation and saving plan
- Resource literacy and capacity building
- Social mobilization and institution building
- Participatory Technology Building (PTD)
- Setting up monitoring systems

Development of an integrated water conservation and saving plan

One of the first and foremost roles of NGOs is to help the communities make a scientific and participatory assessment of the available water resources at a micro-watershed and/or village scale, evolve a water security plan by matching water availability with the various needs ensuring both equity and sustainability. Within this overall water use plan measures for water conservation and saving could be incorporated. Very often the water-saving technologies are promoted in a de-contextualized manner as they are not based on a resource assessment and utilization plan. If the communities can be shown that unless they go for water conservation and saving measures their needs would not be met unless they adopt water conservation and water-saving measures then there would be an internal conviction to adopt such measures. In the absence of such internal conviction and commitment water conservation and saving measured need to be propped up by state subsidies as it is being done today. As discussed earlier, the water conservation plan should be part of a larger basket of options that include water and soil conservation programme on a watershed scale, demand side management options like proper land use and cropping pattern and water-saving agronomical practices that also improve the water holding capacity the soil and also specific (micro-irrigation) technologies like drip, sprinkler, Sri Ram Fertigation method (used in widely spaced horticulture orchards like the mango orchards in the Konkan), etc. Hivre Bazar, as mentioned earlier, is a classic example of such an integrated approach of water conservation and saving plan. The villagers of Hivre Bazar have been able to conserve and manage water, such that water is available for irrigation even during the drought seasons (Hindi India Water Portal, 2012).

Resource literacy and capacity building

The second role that NGOs can play is to take up a large-scale water resource literacy programme and also capacity building of the local communities. Such a programme would help the local communities understand water in

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* NGOs is a very broad category and there are different types organisations included in it – ranging from those implementing projects to those who are involved in research and policy advocacy, technology development, mobilisation of people, etc.
terms of both availability and demands. We have found Participatory Resource Mapping (PRM) using village cadastral map as an important tool for resource literacy. Here the villagers are involved in collecting important landform, land use, cropping and water related data using their own cadastral maps. As the maps have scale, they can quantify the collected data, and also identify the problem areas on the map and get a good understanding of land and water related problems in their village and then decide on what type of interventions they should make. It also helps to integrate the experienced based knowledge of the people with modern knowledge systems and through this synthesize new possibilities for water conservation can emerge.6

NGOs that have internalized the understanding of water can demystify this knowledge to the local communities. NGOs can help the communities:

- To understand broad water balance at watershed or sub-basin level so as to understand where the water is coming from, how and where it is getting stored and where is it leaving
- To understand the linkages between groundwater and surface water, land use, climate change and rainfall intensities and their effect on cropping patterns
- To get to know various water-saving technologies
- To engage with the ideas of water for environment through environmental flow and health of aquifers
- To engaging with issues around equity in water allocation and use

NGOs can also train the water users in understanding different options for water conservation and saving. This would help them to make informed choices between different options instead of the present top down, prescriptive approach. The NGOs can create a socially conscious and managerially capable social carrier for the water conservation measures and water-saving technologies through capacity building.

Social mobilization and institution building

Presently adoption of water-saving technologies is an individual-centric activity incentivised by state subsidy. This has led to two types of problems: one, the saved water does not form part of a common pool and; two, it is the rather well to-do farmers who have been benefited by such programmes. Because of these social issues like equity and bringing down overall water footprint do not get centre-staged. Making water conservation and saving a collective/group activity can also open up avenues cost-effective options bringing the per ha cost down. One of the important issues the water users need to decide collectively is what happens to the saved water?

There are many issues that need a consensus building prior to the adoption of specific technologies. What is the overall water conservation plan for the watershed/village? What could be the specific water-saving technologies that can be adopted? How the water users can shift to volumetric supply and pricing as it has been proved that such a shift from area and crop-based approach can result in water-saving? Ozar WUAs have shown this. How can the efficiency of the water conveyance and distribution system can be improved? How can they move away from water-intensive crops and shift to water efficient crops? How can everybody get certain minimum access to water? How can the saved water be pooled together and made available to those who do not have access? Or can the saved water be used to regenerate ecosystem? All these need to be discussed and agreed upon collectively prior to

6 For details of PRM and how this can lead to resource literacy and watershed based development planning please see Paranjape et al, 1995.
the adoption of water conservation measures and technologies. All these call for a very high level of social mobilisation and engagement with the communities which the NGOs can do. If water conservation and saving have to become a collective endeavor then it needs an institution to hold it together. Since WUAs have been legally mandated in the state with water management through the Maharashtra State Farmer Managed Irrigation Systems Act, 2005 the WUAs could be the legitimate institutions at the village level to anchor the water conservation and water-saving efforts. However, if the WUAs have to take on this function then need to be re-oriented and strengthened through capacity building. Though Maharashtra has been in the lead in participatory Irrigation Management (PIM) in the country over the years and given rise to such good examples like the Ozar WUAs, studies show that the overall performance of the WUAs in the state has been far from satisfactory (SOPPECOM, 2012). NGOs need to work with WUAs to streamline their functioning as well as strengthening them through training.

**Participatory Technology Building (PTD)**
The water-saving technologies presently promoted are ready-made ones that are universally available and promoted by companies that produce them. The actual users are not in any way involved in the development of such technologies. In fact, in the 1980s and 1990s there was an interesting initiative to develop technologies in a participative way and was known under the name of Participative Technology Development (PTD). ‘Participatory technology development and dissemination (PTD&D) is a process which combines the knowledge and research capacities of local communities (i.e., indigenous knowledge) with that of research and development organizations in an interactive learning process. It involves identifying, generating, testing, adapting and promoting improved or new techniques or institutional arrangements to help solve local problems” (Saha and Ira, 1998). In India, Agriculture Man Ecology (AME) Foundation, led this initiative and developed many agronomical practices along with farmers especially in the area of Low External Input Sustainable Agriculture (LEISA). PTD helps to move away from context-independent, ready-made solutions and helps farmers to be more experimental and also evolve their own solutions. This is an area that the NGOs can make huge contributions.

**Setting monitoring systems**
NGOs also need to set up participatory monitoring systems to continuously monitor the progress of the commonly agreed upon programme for water-saving and also to see where the saved water is actually going. This would also help in making corrections as and when required. If a commonly agreed upon protocol for monitoring can be agreed upon then the data generated through this can be aggregated at different scales like micro-watershed, sub-basin and basins and see what is happening with regard to water conservation and saving at different hydrological scales.

**Conclusion**
In this essay we have tried to argue that NGOs can play a crucial role in promoting water conservation measures and water-saving technologies provided there is a broader agenda that go beyond technological fixes like drip and sprinkler. This is not to say that such technologies have no role to play. And for

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This they need to be part of an integrated and socially acceptable plan for water conservation at different hydrological scales. This is possible only if there is a shift from the present mode of individual centered programme to one of a collective/group effort. Similarly, the saved water needs to be pooled together and made available to those who have no access to water or should be used for ecosystem regeneration. The present-day subsidies need to be re-oriented to promote such a programme.

**References**


Abstract

In the rain-dependent dry lands of India, erratic rainfall and drought result in a drastic fall in agricultural production and acute water scarcity for domestic and livelihood needs. Traditional knowledge and lack of local water governance practices in rural communities increase risks and losses. Hence, it is necessary to equip villages with knowledge and tools to take informed decisions at the farm, enterprise and community levels that enhance resilience and adaptive capacities. This paper is based on lessons learnt and observations from implementing a Water Stewardship Initiative (WSI) that seeks to facilitate a cognitive and organizational shift by bringing science, policy and governance together at the level of practice and community action. This initiative was launched by Watershed Organisation Trust, a not-for-profit organisation, in 100 villages in Maharashtra State, India. In the WSI, the approach adopted is of ‘co-production of knowledge for behavioural and institutional change’ towards building the communities’ knowledge and capacity to effectively face varying weather conditions. This article presents the approach; key concepts and processes applied in the WSI and highlights its potential to be taken forward in other similar regions. It has significance to influence state policies in the water sector.

Keywords: Behavioural change, equity, drought, governance, resilience, sustainability, water budget, water security, water stewardship

1This article is a modified version on the chapter titled, “Building Resilience to Climate Change: Water Stewardship in Rainfed Agrarian Villages in Maharashtra, India.” by Eshwer Kale and Marcella D’Souza, published in “W. Leal Filho (ed.), Handbook of Climate Change Resilience, by Springer Nature Switzerland AG 2018. The original version of the paper is available at https://doi.org/10.1007/978-3-319-71025-9_51-1 and the permission is taken from the publisher to reproduce the modified version.
1. Introduction
In the rain-dependent drylands of India, acute water scarcity for drinking and a drastic drop in agricultural production is increasingly experienced due to frequent droughts. Models indicate that by 2025, climate change alone will bring scarcity to many places. Increase in population is a greater threat. In the absence of appropriate demand-side management, the combination of population growth and climate change will create water scarcity far and wide (Roger P 2008).

Today, India is a water-stressed country with its per capita freshwater availability at 1545 cubic meters per person per year, which was above 5000 cubic meters at the time of independence in 1947 (Singh Y and Rahal A 2011; Khurana I and Sen R 2012; Prakash A et al. 2013). In this critical situation, it is necessary to equip people and communities with the knowledge and tools to make informed decisions at farm, enterprise and community levels so as to build adaptive capacities and enhance their resilience.

1.1 Key challenges for the water sector and rainfed agriculture
Maharashtra, the third largest state in India has a total geographical area of 30.76 million hectares (mha) of which 52 % area of the state is prone to drought (GSDA 2014). In groundwater dependent arid and semi-arid regions, the multiple demands from livelihoods, food and water requirements of an increasing population; an increasing area under agriculture and groundwater dependent irrigation put the groundwater at risk, which is aggravated by changes in the rainfall regime. On the one hand, users are barely literate about water resources and their appropriate use, and on the other, groundwater is still considered a private good. The lack of appropriate and effective governance mechanisms for water resources have established the rule of capture resulting in anarchy in groundwater management (Shah T 2009). The general understanding in India is that water beneath the land belongs to the owners of land (Ballabh V et al. 2008), which is well described by Ramaswamy Iyer (2003) as, ‘water is attached like a chattel, to the land property’. This has led to mismanagement of groundwater resources particularly by the better-off of the rural society, coupled with the dependency syndrome that ‘the state has to provide water for all users’, while negating the responsibility of communities to manage their locale specific resource. Market price fluctuation for farm produce and the shift to high external input cash crops further worsens the groundwater crisis and farmers’ woes putting not just farmers’ livelihoods under threat, but also water for domestic use and sanitation, while increasing the workload of women.

1.2 Groundwater, the backbone of arid and semi-arid regions
Groundwater is the backbone of India’s agriculture and drinking water security, contributing to 84 % of the total net irrigated area in India (Shah M 2013) and 90 % of the rural water needs being met by it (Prakash A 2013). In the 1950s and 1960s, the share of surface water in irrigation was around 60 %, which reduced to less than 30 % in 2007, while the groundwater share increased to around 60 % in 2007 (Shankar V et al. 2011). A recent report of the Groundwater Survey and Development Agency (GSDA) indicates that since the past five years in many regions of the state, the water level in the month of October drastically drops: of the 353 blocks, in 230 blocks (10167 villages) the water level has dropped by over one meter while in 2587 of these 10167 villages, the groundwater level has dropped by over 3 meters. The report warns that 7139 villages in 132 blocks may face water scarcity for drinking water during 2018 (GSDA 2017). The CGWB report (2017) states that in the last ten years, groundwater levels have fallen in around 50 % area of Maharashtra (TOI 2018).
1.3 Impacts of climate change on groundwater resources

In water resources management today, climate change and global warming are of growing concern and India is one of the largest and important regions of high overall human vulnerability (Thow A and Blois M 2008). With global warming is likely to intensify, the climate change phenomenon may accelerate or enhance the global hydrological cycle (IPCC 2008). Precipitation forecasts for India under climate change scenarios suggest higher but more variable rainfall, except in the drier parts, where rainfall could decrease. While intensity of the rainfall may increase, the actual number of rainy days may decrease and the changing patterns of rainfall and runoff are expected to significantly impact groundwater recharge and availability (Zbigniew W et al. 2009). In water-scarce years, farmers and other users are likely to depend on groundwater options to compensate for inadequate rainfall and surface water supplies. The scenarios also indicate that after good rainfall years, the dry period of low or no rainfall which is currently of 2 to 3 years may increase 4 to 5 years. With the average global temperature rising, the rate of evaporation of the surface water will also increase. Therefore, in the rain-dependent drylands of India within which much of Maharashtra falls, erratic rainfall and drought will result in a drastic fall in agricultural production and acute water scarcity for drinking and livelihood purposes. Hence it is necessary to prepare and equip rural communities and farmers with knowledge, skills and means to address these challenges.

This article is based on the experiences of implementation of the Water Stewardship Initiative (WSI) by the Watershed Organisation Trust (WOTR) with an aim to facilitate a cognitive and organizational shift by bringing science, governance and policy together at the level of practice and community action. The approach adopted in WSI is of “co-production of knowledge and learning for behavioural and institutional change” towards building community knowledge and enhancing their capacities to effectively deal with varying weather conditions.

2. Overview of the Water Stewardship Initiative

This section provides the overview of experiences of local water governance in India and in particular, the WSI that the Watershed Organization Trust (WOTR) has implemented in 100 villages in Maharashtra.

2.1 The Water Stewardship Initiative, the SDGs and policy

The WSI provides important contributions for achieving the Sustainable Development Goals - SDG 6, 12, 13, 16 - in the context of climate change where 2°C temperature rise is expected by the end of the 21st century (IPCC 2014). Moreover, the Maharashtra Groundwater Development and Management Act 2009, calls for urgent community management of their groundwater resources.

2.2 Water Governance: The concept and Indian experiences

The concept of people managing water resources is not new in India. Groundwater depletion and its consequent misery have triggered attempts to create a new social order of ‘community based natural resource management’ (CBNRM). The argument behind the CBNRM is that there exists a certain kind of cooperation and community solidarity within village communities that sustains with endogenous or exogenous stimuli when the expected outcomes are for the benefit of the concerned group (Lopez-Gunn E and Cortina L 2006). These ideas are echoed in experiments by social entrepreneurs like Anna Hazare and Popat Rao Pawar which are perhaps the best-known examples of community revival through participatory watershed and water resource management in Maharashtra (World Bank 2010). Besides these, in Maharashtra there are
numerous successful participatory watershed development projects where NGOs put community at centre. The work of Hardevsingh Jadeja in Rajsamadhiala village near Rajkot, Rajendra Singh of Tarun Bharat Sangh in Rajasthan, the late Vilasrao Salunke’s Gram Gaurav Pratishthan in Pune, Swaminarayan Sampraday and Swadhyaya Pariwar in Saurashtra, Gujarat are few pioneering voluntary, self-regulated and community based experiments towards sustainable use of groundwater (Shah T 2009). Triggered by groundwater scarcity all these experiments went beyond just harvesting rainwater, to invoking visions of sustainable and judicious use. However, most of the instances are characterized by the presence of a charismatic leadership and/or are location specific; therefore do not offer a process-based approach or a model that can be taken to scale. The Andhra Pradesh Farmer-Managed Groundwater Systems Project (APFAMGS) stands apart it shows how carefully designed community based approaches hold significant promise for addressing groundwater overexploitation issues, especially in hard-rock aquifers. At the same time, the achievement of this initiative challenges the underlying assumptions in the discourse and practice of groundwater management in India that ‘legal and policy reform is a necessary first condition for attempting groundwater management in the country’ (World Bank 2010).

At the international level, for maximizing the economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems, the Integrated Water Resource Management (IWRM) promotes a coordinated development and management of water, land and related resources (UNEP-DHI 2009; Harsh 2012). In many developed countries, the IWRM framework is practiced by allocating water through regulation and incentive mechanisms such as water pricing (Shah A and Prakash A 2010) which increases the efficiency of water use and allows for better maintenance of the water-related infrastructure. However, in countries, like India, the challenge in applying IWRM practices is mainly in formalizing the existing informal water economy (Shah T and Koppen B 2014) where the number of water users is huge and water resource management is compartmentalized into surface and groundwater at the level of departments and agencies. Apart from this, a large proportion of the population in India does not have access to the most basic facilities of safe and adequate drinking water and sanitation, hence putting a price on water for these sections is not considered justifiable and possible (NWM 2010). In promoting IWRM practices, the financial, infrastructure and human capacities of countries to fulfil the responsibility of water governance matters a lot, however in India these resources are inadequate (Azhonia A et al. 2017). Although, in many countries the IWRM approach is not very successful (ADB 2007), it has provided an important framework for integrated water management and a tool for establishing multi-stakeholder dialogue.

2.3 Rationale for and the objectives of the Water Stewardship Initiative
Considering the above discussion, there is an urgent need to move forward following the

The WSI provides important contributions for achieving the Sustainable Development Goals - SDG 6, 12, 13, 16 - in the context of climate change where 2°C temperature rise is expected by the end of the 21st century (IPCC 2014). Moreover, the Maharashtra Groundwater Development and Management Act 2009, calls for urgent community management of their groundwater resources.
supply-side enhancement from participatory watershed development (WSD) across the country, towards the demand-side management and improvement in water governance at the local level. This is the underpinning of the Water Stewardship Initiative. In these 100 villages, soil and water conservation measures and or WSD have either been completed or are on-going, and while water availability and agriculture productivity shows a marked increase (Vani S et al. 2007), these villages also experience water shortage for irrigation and domestic use in summer. Because of the shift to cash crops and the absence of effective regulations on water use, lifting of groundwater for agriculture has increased, particularly by the better endowed farmers. Watershed Development Committees have not been proactive and are not confident enough to set up water use norms and practices and impose them. Unequal water access in villages have reached to an extent where better-off farmers have water available in their farm ponds (promoted through government schemes), even in the dry season and drought periods, while in the same period the lesser endowed farmers and women struggle to fetch water for their basic needs from public tankers (Kale E 2017). There appears to be an assumption in rural areas that the state is responsible for addressing the various needs regarding water of individuals, and communities do not have any responsibility in this regard. Community action which is the key to village development and progress is lacking. At another level, healthy dialogue and cooperation between government officials and village communities does not occur besides the implementation of government schemes, e.g. in the water context, those who have water resources can construct farm ponds and apply for micro-irrigation, both of which are beneficial to the resource rich. Moreover, water extraction for agriculture generally lacks relevant scientific information and knowledge of the agro-climatic and hydrogeological conditions that are essential for planning appropriate water use.

2.4 The Water Stewardship Approach

To address above discussed challenges, WOTR designed the ‘Water Stewardship’ approach that brings key local actors into a dialogue to achieve mutual cooperation and then for preparation and implementation of an action plan. The ‘Water Stewardship’ approach treats different water users, not as passive beneficiaries, but as water ‘stewards’ and considers them important stakeholders having the potential to be ‘good water managers’ who also protect the resource base and ensures it’s sustainable, judicious and efficient use (AWS 2014). This concept considers that needs of every individual, for domestic, livelihoods and livestock and the ecosystem, have a right to water. This right comes with a responsibility and accountability to oneself and the community, for its appropriate management.

In WSI, the water resource is seen as public trust rather than private entity. Hence this approach necessarily brings different users/stakeholders together on one platform to be informed and to dialogue, so as to come to a consensus in preparing a plan and executing the same. There three sets of important actors: 1) the primary stakeholders i.e. all households within a given geography of a village / aquifer who are the water users for different purposes. 2) The secondary stakeholders are the neighbouring villages that affect or are affected by the water availability of a particular village e.g. the downstream and upstream villagers, and 3) the tertiary stakeholders are the decision makers.
makers, administrators (government officials), water experts, donor agencies, civil society agencies, who influence the water related efforts at the village level. These diverse stakeholders need to come together on one platform for building consensus and collective planning for sustainable management of this precious resource. The WSI requires not just a set of actions to be carried out by the primary and secondary stakeholders, but also needs to be provided with sound scientific knowledge so as to make informed decisions. Consensus building through dialogue and workshops (stakeholder engagements) are important where perspectives, desires and conflicts between the different groups are encouraged to surface and sustainable solutions are sought.

The experience of WSI in 100 villages in Maharashtra is spread over 5 blocks in 3 districts (Figure 3). It attempts to find pathways to address the critical balance between supply and demand-side management and achieve water security in varying weather situations such as low rainfall, droughts and drought-like conditions, increase in annual and summer temperature. It aims to develop a scalable model for semi-arid regions, regularly affected by drought and heavily dependent on groundwater for agriculture and domestic use. The goal of the WSI is to ensure as far as possible, that water at the local (village) level is managed in a responsible manner that is socially equitable, environmentally sustainable and economically efficient in climate varying conditions.

In line with the above goal, the five specific objectives to achieve Water Stewardship are: (1) to build skills and capacities of villagers to prepare the Village Annual Water Budget that ensures water availability for domestic and livelihoods needs and that minimizes crop losses. (2) Based on the water budget, the village (households of all land and water resource owning categories) is motivated and facilitated to prepare plans for harvesting rainwater through new structures or repair of old structures and for increasing water productivity (“more crop per drop”) through adoption of water efficient technologies and practices. (3) The village – either at the Grampanchayat or a sub-committee – is encouraged, organized and guided to formulate norms for water management to implement effective water governance such that it ensures equitable access to and availability of water for domestic use for its inhabitants throughout the year. (4) To promote a common understanding and trust between the different stakeholders related to the water sector i.e. the primary, secondary and tertiary stakeholders. (5) Develop workable operational guidelines to upscale the initiative in similar conditions (arid and semi-arid regions) with appropriate contextual modifications.

3. Key-components and processes adopted in the WSI

This section provides the processes, tools and activities adopted in WSI considered important for achieving the tangible and intangible results. While implementing these components, conscious efforts are made towards achieving quantifiable targets as well as ensuring the richness and quality in processes, especially skills and capacity development of the villagers.

3.1 Institutional Development and Capacity Building

Institutions are the ‘pillars of governance’. In the WSI the Village Water Management Team (VWMT) is important for promoting water stewardship. Jal Sevaks (water caretakers) support and guide the VWMT for meeting the goal of sustainable water management.

3.1.1 Jal Sevaks (Water Caretakers)

Jal Sevaks - committed and motivated rural youth with a passion for the progress of their village, play a crucial role in this initiative as organizer, facilitator, and motivator to village communities for the preparation and implementation of water
stewardship plans. They are capacitated to handle various challenges in the water sector at the level of village and cluster of villages. Jal Sevaks mobilize villagers of all land and water owning categories to be organized for: (1) formation of Village Water Management Team (VWMT); (2) to conduct a baseline inventory of the existing soil and water harvesting structures with detailed measurements; (3) to facilitate and guide the VWMT to prepare water stewardship plans, and (4) motivate villagers to implement the same. The Jal Sevaks use various motivational tools and methods to promote water literacy and its management. By engaging rural youth (Jal Sevaks) and building their capabilities, WSI develops a cadre of motivated and skilled water stewards who can take forward water management practices in villages.

3.1.2 Water Stewards at village level – The Village Water Management Team (VWMT)

The WSI believes that villagers can be ‘water-managers’ rather than passive ‘beneficiaries’ or ‘target’ groups. Provided with adequate information and knowledge of the different aspects of water as a ‘good’ essential for life and that it needs to be used and protected, the VWMT is motivated and provided with information to understand that they need to take responsibility of governing their water resource effectively. The roles and responsibilities of VWMTs are to create a positive and encouraging environment for adoption of water stewardship; ensure that the Gramsabha (village general body

Figure 1: Locations Map of the WSI project villages

Legend
- Project Villages
- Project Talukas
- Project Districts
meeting) is actively develops water use plans and set rules/norms at village level to implement the plans. It plans to engage the government departments, corporates and other NGO's to obtain the necessary support for convergence and to realize the water stewardship plans.

As all water users are water stewards of their respective water resource, they necessarily need to take responsibility for adopting effective water management practices. Hence representatives of different categories of households within a village e.g. landownership groups, landless, women and other water dependent livelihood group are selected and form part of the VWMT.

3.1.3 Bringing together the diverse players through Stakeholder engagement events

For better water management, diverse stakeholders (primary, secondary and tertiary, as well as different categories of villagers) who have a shared problem are engaged at village / clusters of villages / aquifer levels. It is during such events that sharing of local scientific information and data (eg of the cluster of villages; of the aquifer and even of the block) is useful to develop a common understanding of the landscape, the water resources, climate variability – all of which affect the livelihood of various groups within villages. Stakeholders begin to understand the link between one village and the others and how together they can take decisions to improve crop production while managing the available water sustainably. Bringing the respective government officials, experts and facilitating agencies (tertiary stakeholders) to these engagements further strengthens the WSI. Stakeholder Engagement workshops foster free and healthy discussions and interaction between participants, and helps uncover the sticky problems.

3.2 Preparation and Implementation of the Water Budget

Once the VWMT is motivated to take concrete action for improving their village water health and to address the water related problems, they are guided to prepare the village water budget. The Water Budgeting tool presents a practical and tested method at village and micro-watershed level of approximately 1000 to 2000 hectares. It facilitates the preparation of appropriate crop plans based on the available water, after ensuring water for domestic use and livestock for all households throughout the year. It provides the possibility for villagers to consider water scarcity in drought years as groundwater is the main source for both domestic use and livelihoods.

3.2.1 Preparation of the Village Water Budget

The Water budget preparation is done twice during the agriculture year. Around month of March, the first water budget is prepared to calculate the requirement for the whole year i.e. water use for agriculture (in the monsoon, winter and
summer seasons), and for domestic use and livestock. The purpose of calculating the requirement for the whole year is to assess the amount of water that can be harvested within the village from structures that were earlier constructed and/or to identify those that require maintenance. The second water budget is prepared early in October, to calculate the available water at the end of the monsoon and to plan its use for all needs particularly for agriculture in the winter and summer seasons. Currently, water for ecosystem services is not being factored in the water budgeting tool applied in the WSI, as estimates of water requirements for ecosystem services in the Indian context, is not yet available. Based on the water available for agriculture including perennial horticulture, villagers discuss and decide the types of crops to be sown and the area that can be taken up for these crops. Often, a water budget results in deficit water because people cultivate a greater area than planned; besides they may also cultivate water guzzling crops. An understanding of the water available provides them the opportunity to revise their crop plans so as to minimize the deficit and thus loss.

A Water budget exercise may result in either surplus water in the village, or a deficit, after meeting all water requirements. This exercise presents to the VWMT and villagers, an overall picture of the water use plans for agriculture. It gives them the opportunity to understand the village water resources, the potential and the different water needs of the members of all categories of households of their village. People become aware that the agriculture planned is often more than the water available - which then leads to crop and investment loss and they become aware that they often compromise the water needs of livestock and domestic use. Thus, this exercise is an eye opener to villagers. As a first response to deficits, the VWMT and villages make efforts to revise the total water required for crops by reducing the area under water guzzling crops. However, if a deficit remains, the water stewardship plans provide them with options of supply as well as demand-side measures, as also governance mechanisms: 1) additional water harvesting plan; 2) water-saving plan, and 3) application of social governance rules to ensure efficient water use.

3.2.1 Preparation and execution of the water-harvesting plan:
To address the water deficit in the budget, a water harvesting plan gives the inhabitants an opportunity to increase the water potential within the village by repairing defunct / damaged structures and where appropriate, to undertake new soil and water conservation measures.

3.2.1.2 Water-saving plan:
Villagers assess the existing water use practices and identify initiatives to save water, using water-use efficiency measures for irrigation along with soil quality and biomass enhancing practices. These are micro-irrigation, organic and vermicompost and mulching to increase the biomass content of soil. The VWMT motivates its farmers and assists in linking them with the different government schemes.

3.2.1.3 Setting up norms for governance:
For the implementation of crop plans based on the water budgeting exercise and regulating water-use in a sustainable, equitable and efficient way, it helps
when villagers themselves formulate the rules. The rules assist in controlling the behaviour and practices of farmers who do not use water judiciously. Initiated by the VWMT, the rules are decided by the Grampanchayat and ratified by the Gramsabha, so that it becomes obligatory for all households of the village. Some examples of rules prepared are: 1) no direct lifting/pumping of water from surface water bodies such as check dams and percolation tanks; 2) the government norms for the depth (of not more than 200 feet) for borewells to be complied with; 3) a ban or limit on the area for water-intensive crops. Thus, the water stewardship plan is a comprehensive tool that motivates villagers for water governance for both supply and demand-side.

3.3 Piloting the key principles of the Maharashtra Groundwater Act, 2009
The Maharashtra Government’s Groundwater (Development and Management) Act 2009 (henceforth referred to as the 2009 Act) (GoM 2013) came into force in the state in December 2013. The broad objective of the 2009 Act is to protect drinking water sources and to promote the proper management of groundwater for irrigation. To achieve this it proposes an institutional structure for community participation - the Watershed Water Resource Committee (WWRC). Besides this, some important measures proposed are: restriction on the depth of borewells (max 200 feet); securing drinking water throughout the year; have the people prepare prospective crop plans based on groundwater budgets. Based on the groundwater levels / water stress, the blocks are categorised as: (i) Notified area (ii) scarcity area-within notified area, and (iii) non-notified area (GoM 2013). In the WSI, the following key principles of 2009 Act are tested on a pilot basis with the intent to operationalize the Act.

3.3.1 Prospective crops plans:
The Act mandates preparation and implementation of Prospective crop plans based on the available water stock. In the WSI, in all project villages, capacities and skills of the VWMT and the villagers have been developed to prepare and execute water budgeting plans, which prepare both supply and demand-side plans and measures while ensuring drinking water availability. These plans are prepared and executed by the VWMTs.

3.3.2 Institutional governance at aquifer level:
The Act proposes to form WWRC comprising of even 11 villages if these are identified by an aquifer boundary. These work together to benefit from, while managing the aquifer in a sustainable manner. The application of aquifer based management is piloted in the Bhokardan block of Jalna district, where representatives from 14 villages that share a common aquifer, are brought together and form the aquifer management committee. They are capacitated to prepare water use plans at the aquifer level. Water resource literacy is undertaken using the tool CoDriVE-

Around month of March, the first water budget is prepared to calculate the requirement for the whole year i.e. water use for agriculture (in the monsoon, winter and summer seasons), and for domestic use and livestock.
The second water budget is prepared in October, to calculate the available water at the end of the monsoon and to plan its use for all needs.
Visual Integrator-CDVI- (WOTR 2013) in a 3 dimensional model of the landscape above and the shallow aquifer characteristics below surface level.

3.3.3 Rules for water use:
In the Act, important provisions regarding the ban on sinking deep well (below 200 feet) and the levy of a cess on extracting groundwater below 60 meters in non-notified areas are made, however these are barely monitored. As an encouragement to initiate governance, in the WSI the approach, communities make their own rules rather than externally enforced ones. However, strict rules at the state level are necessary to create a supportive governance environment for motivating villagers to frame their Grampanchayat and aquifer level rules. In the project, through the intensive stakeholder engagement process at the cluster of villages’ level, and by informing villagers of the key provisions of the 2009 Act, the VWMTs were motivated to frame rules considering their local context. In more than 80 of the 100 villages, the VWMTs have framed such rules that have been ratified by the Grampanchayat. The rules are mainly regarding the ban on directly lifting of water from water harvesting structures; putting a ceiling on the depth of borewells or/and the ban on borewell drilling in the village and a ban on growing water-intensive crops.

3.3.4 Registration of groundwater abstraction structures:
In the Act, registration of all wells is a precondition for applying the regulations. In some WSI villages, an inventory has been completed of all water harvesting structures, wells and borewells.

3.4 Results and outcome of the WSI
The execution of different components of the WSI resulted in improving water management, specifically in regard to the supply and demand and the institutional environment to govern it. These impacts are observed in the behaviour of the water stewards regarding water-use access, practices and crop management which are considered an outcome of this process.

3.4.1 Changes in the behaviour of the Water Stewards
Feedback from the primary stakeholders from the different districts shows that discussions and scientific information provided during stakeholder engagement workshops have changed the perspective of many villagers with regard to water issues. As shared by a few villagers, the stakeholder engagement workshops provided them an opportunity to deliberate and discuss water issues as a ‘shared problem’, putting aside all other differences and dynamics within the village. They have learnt how to calculate the water budget and to use it efficiently. Others shared that they now understand water as a common property and that everyone has a right over it; therefore water should be used judiciously. Mrs. Meera Shinde, a VWMT member from Lingewadi village, Jalna, describes how the situation has changed in her village: “Earlier, for fetching drinking water, no private well owners allowed others to draw water from their wells. After exposure and learning about this in stakeholder engagement workshops and discussions of the same within the village, now, some well owners switch on their private pumps to allow others to take water for home use. As water is needed for all, even for the animals and birds, we have made special water-troughs for the animals in a remote the
hilly area where monkeys, wild boar and deer face difficulties in finding water in summer. They now frequently come and drink water from these troughs”.

Although, framing and enforcing rules regarding water use is challenging, in some villages, people have taken the initiative. Kisan Icche, VWMT member and village Sarpanch from Kotha Jahangir, explained how the stakeholder engagement workshops motivated their VWMT to make rules at the village level. “Getting motivated through Stakeholder Engagement workshops, we passed a resolution in the gramsabha banning drilling of new borewells and changing the crops to be grown in rabi season. We tried to convince every irrigated farmer to use sprinkler and drip instead of flood irrigation and by this year (2017-18), almost 60 to 70% farmers installed drips and sprinklers. Because of the rule, not a single borewell was drilled during this year in the village”. In Kotha Jahangir, the Gramsabha passed a resolution banning the drilling of borewells deeper than 150 feet, and farmers require permission from the Grampanchayat before drilling a borewell. They have also passed a resolution banning sand extraction from the river bed. Such rules, suitable to local conditions, are made in more than 80 villages. Thus, stakeholder engagement workshops have succeeded to an extent in building a common understanding and consensus, changing perspectives and motivating villagers to work together towards efficient and judicious use of water.

3.4.2 Actions towards local water governance

In all 100 villages, VWMTs have been formed and ratified by the Grampanchayats. Most of the VWMT members participated in the stakeholder engagement workshops where they prepared water stewardship plans that include the Jal-Arogya takta (Water...
Health Chart), water budget, water harvesting and water-saving plans. In many villages, the VWMT successfully mobilized their people for ‘Shramdaan’ (sweat equity) to repair defunct/damaged water harvesting structures. The VWMT framed rules for better water management at the village level, which is a major contribution. This is of relevance as, currently, even state agencies struggle to enforce external regulations on villages for water management. The VWMTs in most of the villages have compiled their water stewardship plans and have submitted the same to district authorities. This is an important exercise where government authorities also find an encouraging environment at the village level to implement their schemes. Villagers too have found a space to interact and dialogue with government authorities.

The 24 Jal Sevaks (Water Stewards) played a crucial role in facilitation and motivation of the VWMTs in these 100 villages. They collected relevant data on time regarding soil and water harvesting structures and other socio-economic details of the villages. Water budgets displayed on boards in a prominent location are regularly updated for the respective season. In all villages, two simple rain gauge units were installed, and the VWMTs record the rainfall. The activities resulted in creating important spaces for villagers to discuss and share their interest and concern regarding water management practices.

3.4.3 Benefits: Increase in water availability and improved governance

Village communities in 100 villages annually brought 38 billion litres of water stored in different water harvesting structures under governance through creating water budgets and local rules. In more than 60 villages, people provided shramdaan to repair defunct water harvesting structures and constructed new structures (61 sand-bag dams across streams) and followed up for the completion of soil and water harvesting projects of government and other funders – a convergence initiative. Through these harvesting efforts, 8.95 billion litres of additional water harvesting potential has been created in these villages. More than 2000 farmers in this initiative have adopted practices of micro-irrigation (drips, sprinklers, and mulching), and through this, saved 3.24 billion litres of water.

The WSI has promoted a community-embedded scientific method of water budgeting at the village level supported by appropriate governance practices. This enables villagers to better face the water crisis especially in times of low rainfall and drought. Ultimately, the water security achieved by this exercise contributes to an increased and sustained production of crops and livestock, as well as water for households and livelihoods. Stakeholder engagement workshops brought together hundreds of ‘Water Stewards’, researchers, scientists and administrators and resulted in an important forum where different aspects of water scarcity and climate change, impacts on livelihoods and ways to adapt and address these were discussed. This has helped villagers to understand how climate change impacts them and helps prepare them to better adapt to climate variability. These various actions and interventions work towards building resilience of villagers and the farming community, reduce the impacts of climate variability and enhance the
adaptive capacities of local communities and respective stakeholders.

4. Lessons learnt, Challenges and Recommendations
This concluding section highlights the learnings from the WSI; discusses the challenges faced and presents the recommendations based on the experiences garnered during implementation of the WSI.

4.1 Lessons Learnt
The important gleanings from the experience of the WSI are highlighted below,

(1) The WSI treats water users as important stakeholders - ‘water stewards’ -with responsibility, rather than as passive beneficiaries, recipients and opportunists.

(2) Authentic locale specific scientific information plays an important role in generating discussions, dialogue and preparing plans at the village level. This information is important for informing the water stewards so that they take appropriate decisions regarding their village water use practices.

(3) It builds the skills and capacities of farmers, village leaders and local youth to prepare water budgets, plan their cropping pattern accordingly, ensure drinking water availability throughout the year and adopt water efficiency enhancing technologies.

(4) The Water Budget approach followed allows for a balanced and integrative approach to water management. In the WSI, both aspects - supply and demand-side - are addressed. This helps mitigate risks, reduce agricultural losses and secure drinking water supplies for the community which is particularly important in the context of climate variability.

(5) The WSI is in line with the Maharashtra Groundwater (Development and Management) Act, 2009, which is an important policy intervention to improve the overall level of groundwater management in the State of Maharashtra (over 80% of Maharashtra’s agriculture water needs are met from groundwater reserves). This Act, however, faces hurdles in its implementation; the WSI provides an opportunity to pilot major components of the Act and identify strategies and practices that can bring about behavioural and institutional changes envisaged in the Act.

(6) It has a direct policy and institutional connect. The multi-stakeholder engagement workshops not only facilitate cross learning and consensus building but also present ‘ground realities’ and practices that work to officials and decision making channels. It thus contributes to improving the institutional and programmatic environment while building capacities of development administrators and practitioners.

(7) The approach and impacts realized through this people-led project provides incentives to them to adopt and adapt the best suited effective practices. It is noted that many neighbouring villages are willing to work together to address their water problems having observed how farmers in the WSI project villages have benefitted after changing their water-use and cropping practices.

Discussions and scientific information provided during stakeholder engagement workshops have changed the perspective of many villagers with regard to water issues.
4.2 Challenges and Recommendations

From this WSI implementation experience, the following recommendations are proposed:

1) While promoting water stewardship, the biggest challenge faced is in motivating villagers to shift their focus from supply-side interventions to demand-side management. This is precisely because almost all state programs and NGO-Corporates projects provide support to increase surface water harvesting which is ‘visible’. Hence, there is an urgent need to create a strong policy and institutional framework supported by aligned programs which promote effective demand-side water management.

2) The Maharashtra Groundwater (Development and Management) Act 2009 has many important progressive provisions. However, considering the high variation in agro-climatic, biophysical, land typology, and hydrogeological features in the state, enforcement of common rules (such as ban deep wells-below 60 meters and the levy of cess on extracting water below 60 meters) does not seem practically feasible. Hence, in the WSI, villagers were motivated to make and enforce village specific rules/norms of water use which seems a practical way acceptable to the local people.

3) Bringing villagers together from different villages (more than 11 as suggested in 2009 Act) along aquifer lines, and building consensus between them for aquifer based crop planning is challenging. Each village insists on their individual priorities. Hence, a practical way in this regard is to be worked out locally, with the local administration providing facilitation, regulatory and enforcement provisioning to realize these plans.

4) The WSI is in line with the state policy as enunciated in the Act 2009. The learning and strategies evolved from this pilot and executed in 100 villages can serve as a blueprint for operationalizing and implementing the 2009 Act across the state of Maharashtra. It also helps inspire and inform similar efforts in other states.

5) Promoting water stewardship and building the capacities of communities regarding water budgeting and effective governance is a continuous and on-going process which needs, at the least a medium term perspective. In a project mode of generally of 2 to 3 years, success will be limited. Hence, medium-to-long term committed efforts are necessary in order to achieve sustainable breakthroughs, particularly given the fact that villages face constant changes from exogenous factors.

6) Considering the existing gender inequalities and biases in society, as well as limited participation of women in public programs, conscious and well-focused strategies are required to ensure their active participation. Being important stakeholders, gendered perspectives will enhance the chances of good water management practices being adopted.

7) The promotion of water literacy and water budgeting is the need of the hour. The Jal Sevaks play an important role in this. Water management can be scaled up with the support of Jal Sevaks. Similarly, capacitated and empowered youth can be engaged in the various water management programs of the state, such as the Jalyukt Shivar and other Watershed Development Programs.

8) The tested WSI approach and strategy which is science-based, participatory and inclusive needs to be up-scaled by the State. It engages all key actors across levels; helps build support for the cause and disseminates learnings to policy makers, administrators as well as those tasked with project formulation and implementation.
In a situation where the climatic regime leans towards increasing water stress and scarcity, the WSI is a timely response to a crucial and urgent social, economic and ecological need. The WSI approach can help provide equitable access and sustainable use of water for life, livelihoods and nature. The WSI offers a “do-able” operational and implementation strategy to the existing legislative framework that seeks to regulate water use. Hence, there is an urgent need to promote the WSI, widely adopt and replicate it, especially in arid and semiarid regions.

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**While promoting water stewardship, the biggest challenge faced is in motivating villagers to shift their focus from supply-side interventions to demand-side management.**


GROUNDWATER: REIMAGINING ITS ROLE IN WATER SECURITY

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This paper, has been prepared as a compilation of thoughts and logic from ongoing work by ACWADAM with relevance to Maharashtra in particular but India in general. The inferences and conclusions in various sections of this paper are not necessarily complete and are ‘work in progress’. However, the ideas and concepts are based on long-term understanding, research and analysis by ACWADAM on groundwater, aquifers and participatory groundwater management. Many of our colleagues, friends, partners, collaborators, mentors, teachers and students have contributed to this understanding. It is important for readers to understand this concept. We thank everyone who has contributed to this journey regarding the understanding of groundwater that we
have developed from grass root experiences across the State of Maharashtra and from locations across nearly all the regions of India.

Note: A large part of this paper has been adapted from a paper by Kulkarni and Patil (2015) and published in a special book called Knowledge for Change, published in memory of N. K. Sanghi. The paper has been modified with newer data and arguments.

Introduction
As much as 70-90% of all water consumed on an annual basis globally is used in irrigated agriculture (Lopez-Gunn et al. 2011). Some 82% of India’s water is used for agriculture as against 14% in rich industrialised countries (Anon (2009) cited in Narain (2012)), with this picture unlikely to change, at least in the near future. Clearly, the problem of unsustainable levels of groundwater extraction is going to be more acute in those areas where the groundwater is the life support for large sections of the population. Rising demand for groundwater irrigation is clearly a significant cause for rising groundwater resource vulnerability. By the turn of the century, South Asia alone had more area under ‘groundwater irrigation’ than the rest of the world combined; at the beginning of the last decade 30% of the global area under irrigation was in South Asia (Shah, 2009). India’s groundwater extraction has increased more than 30 times since independence; India became the largest user of groundwater resources in the world in the 1980s with a continuously increasing trajectory of extraction since then (Shah, 2009). Given India’s great dependency on groundwater in agriculture, rural domestic water supply and in urban water supply, many regions have witnessed groundwater extraction in excess of the potential annual recharge to aquifers, leading to a situation of overexploitation. In many regions of the country, groundwater contamination has also emerged co-terminus to acute groundwater scarcity. There is need for a special discussion on India’s aquifers, which must not be looked at only from a classical ‘development’ lens, but must from the basis for aquifer based participatory groundwater management in the context of extreme events like floods and droughts and more specifically in the context of reviving rainfed agriculture across the country even while paying serious attention to groundwater and ecosystems.

Rainfed agriculture is becoming increasingly sensitive to changes in weather patterns, as is reported from many of the field sites where ACWADAM is working on groundwater across India. So is the stock of drinking water towards the end of a typical Indian summer, following erratic monsoons and changing winters. In between, there is the larger question of groundwater and the complex nature of its usage. Whether weather changes are part of changing climate may be a point of debate. The results, however, are not so debatable. Impacts include huge losses to crops and economies even over short time frames and endangered domestic water security, a feature that is becoming common to many regions of Maharashtra almost every summer and sometimes even just after a failed monsoon. Crop losses for the usually predictable rainfed, kharif crop were far more severe in parts of India in the good rainfall years of 2005...
and 2006 (when rains played havoc, causing flooding, and disrupting not only agriculture but all walks of life). In many ways, such changes have endangered agricultural livelihoods and have also led to further stress on groundwater resources, despite groundwater being less sensitive to natural vagaries, than surface water. This paper discusses the importance of aquifers, particularly in the context of Maharashtra’s hydrogeology and agricultural growth in the years to come.

Groundwater resources: are dependency and vulnerability two sides of the same coin?

Variability in both incomes and risks in agriculture is often a function of the dynamics of water resources systems. Reliability of water supply implies assured yields and incomes, although other factors also play a role. In developing countries such as India, increased access to groundwater has served as the primary mechanism for poverty alleviation, whereby small farmers even in deep interiors have gained access to irrigation through their own private investments (Shah, 2009). At the same time, the water-level declines caused by intensive development now threaten the livelihoods of millions of such small farmers. Similarly, while increased use of groundwater for domestic water supplies has ensured some degree of domestic water security and reduced exposure to pathogens, emerging quality problems such as arsenic and fluoride represent a major threat to the health of the same millions. The Central Groundwater Board (CGWB), India’s lead organization dealing with groundwater resources, makes ‘national-level’ assessment of groundwater resources from time to time. The primary basis for classification of assessment units (largely administrative, mostly ‘blocks’ but large watersheds in the case of Maharashtra) into safe, semi-critical, critical and overexploited categories is the relationship between pumping and annual replenishment. Within the span of less than 10 years – 1996 to 2004 - the proportion of districts in the semi-critical, critical and overexploited categories has grown from 9% to 31%, the area under these categories from 5% to 33% and the population affected from 5% to 35%. This jump shows that the groundwater crisis had deepened considerably and we need to now urgently address the challenges that impede the sustainable management of groundwater resources in this country. Dramatic as this change would appear, we must be cautious to remember that such a change could partly be on account of a reformed methodology and probably newer, improved data-sets (Kulkarni and Shankar, 2010). However, these figures present only a part of the picture, in that they point to the problem of ‘scarcity’ and the degree of exploitation, giving the assessment a ‘quantitative’ dimension.

A lumped picture of groundwater development and quality is useful to understand groundwater “vulnerability” in India. Vulnerability here implies potential danger to drinking water sources, either in terms of the quantity of water available or the quality of available water or as a compounded effect. Taken together, serious issues of scarcity and water quality imply that groundwater vulnerability is now visible in about 60% of the districts of the country (Kulkarni et al, 2015).
Further, using the share of groundwater in total irrigated area (Kulkarni et al., 2015.), districts are classified as those with high groundwater dependence and those with low dependence. Groundwater dependence is high if groundwater accounts for over 50% of the irrigated area of the district (Figure 1). Comparable data for 540 districts is used from CGWB (2017) based on the 2013 national level groundwater assessment and the ratio of groundwater irrigation (GWI) to net irrigated area (NIA), for the latest year for which data is available from Ministry of Agriculture - land-use statistics (MoA, 2014). Of the total of 540 districts, 280 (52%) are in the high dependence category while 260 (48%) are in the low dependence category (Table 1). We also classify districts on the basis of their Stage of Groundwater Development as “Safe” (SGD less than or equal to 70%) and “Unsafe” (SGD greater than 70%) (Figure 1). This ‘quick analysis’ based on secondary data allows us to make some broad-sweep observations:

1. The Himalayan and the Sub-Himalayan region, including the North-eastern States of India show significant data-gap in terms of ‘groundwater assessment’ making it difficult to hazard any guesses regarding groundwater resources development for this region. It is perhaps this very reason why groundwater irrigated area shows up as ‘zero’ or less than 50% in the map (Figure 1b), giving a somewhat biased impression that the region is largely rainfed. It is not, given that spring water, and even well-water provides some percentage of irrigation in the region.

2. There are two major pockets of overexploitation that have emerged in India – one in the northwest portion of the country and the other in the southeast, perhaps two diverse settings in terms of geology, socio-economics and ecosystem characteristics. However, central Indian states and the western states like
Maharashtra have begun to show districts with emerging trends that fall into semi-critical and critical categories.

3. Hence, except large regions Odisha, West Bengal and some northeastern states, much of India has irrigation from groundwater, surface water irrigation notwithstanding. Hence, against popular notions of large regions of India being rainfed, it is really difficult to fathom the precise distribution of the proportion of irrigated to rainfed areas at the scales of districts.

Figure 1
District Wise Stage Of Development In India And Degree Of Groundwater Dependence In Agriculture

Source: (a) CGWB, 2017 and (b) Land Use Statistics Reports, Directorate of Economics and Statistics, Department of Agriculture and Cooperation, various years

| SGD Less than or Equal to 70% (“Safe”) | Low Groundwater Dependence (GWI/NIA < 50%) Category 1: 240 (44%) | High Groundwater Dependence (GWI/NIA >50%) Category 3: 137 (25%) |
| SGD More than 70% (“Unsafe”) | Category 2: 20 (4%) | Category 4: 143 (27%) |

TABLE 1
Cross-Classification Of Districts On The Basis Of Degrees Of Groundwater Development And Groundwater Dependence
We must further view this analyses in the context of the large-scale groundwater dependency of the country. Nearly 98% of rural drinking water comes from groundwater (Ministry of Drinking Water and Sanitation, 2018), while 70% of water in agriculture is groundwater (Ministry of Agriculture, 2013), not to mention the nearly 50% urban water supply that is through groundwater (Narain 2012). Hence, in many ways, the great dependency on groundwater and emerging trends of exploitation (and contamination) present themselves as the first challenge in developing hardy groundwater management solutions. Moreover, while, such statistics are useful to draw some broad policy recommendations, they offer limited succour with regard to developing comprehensive strategies in groundwater management. This is especially crucial to the India-context, given the fact that the groundwater story has unfolded on millions of farms, at the village level and also at larger scales such as in watersheds and river basins, almost as an integrated puzzle with many pieces. It is these pieces that hold the key to good strategies of groundwater management.

A close look at a typical water demand in an Indian village with 100 households and a cultivable area of 500 to 1000 ha with mixed, seasonal cropping systems (based on data from different locations where we are working on the concept of participatory groundwater management), shows the skewed proportions of the demand across domestic and seasonal water uses. We call this an estimation of the ‘demand-side’ water balance (Figure 2). The non-irrigation demands are quite low and the total for human drinking water, household domestic water and water for livestock are only about 2.5 mm when compared to potential irrigation water of nearly 550 mm. It is interesting to also note here that a typical unconfined basalt aquifer, the traditional lifeline of rural water supplies in Maharashtra, holds about 20 to 150 mm of water in micro-watersheds admeasuring 200 to 500 hectares.

**FIGURE 2**
Demand-Based Water Balance In A Typical Indian Village Dependant On Groundwater
Therefore, disaggregation holds the key to accurate understanding of groundwater problems in India. Current sets of data are far too ‘gross’ to constitute good decision-support systems for strategy formulation on decentralised groundwater management. Whether in the case of groundwater overexploitation or groundwater contamination, it is important to ‘typologise’ the groundwater situation in an area. Such typology emerges as a consequence of mapping aquifers, understanding their behavior through space and time, understanding patterns of use and exploring opportunities for people to come together and manage groundwater resources collectively (Kulkarni et al, 2009 ii). It is only the micro-picture that can truly capture the dynamics around a resource from which usage is highly decentralized.

Deccan basalt aquifers of Maharashtra: rapid development of heterogeneous aquifers
An assessment of groundwater in a specific hydrogeologic setting requires an understanding of the physical framework within which groundwater occurs, i.e., aquifers. Accumulation and movement of groundwater in an aquifer depends on its physical properties, thickness, spread, extent of weathering, structural features (such as fractures, folds and faults) and their transmissivity (coefficient representing the flow-component of an aquifer) and storativity (coefficient representing the storage-component of an aquifer). The variability in aquifers is particularly high in the crystalline and volcanic rocks (often referred to as “hard rock” formations) on account of their low primary porosity (Kulkarni, 2005; COMMAN, 2005) and variable permeability. Groundwater resources in hard rocks are characterised by limited productivity of individual wells, unpredictable variations in productivity of wells over relatively short distances and poor water quality in some areas. India became the largest user of groundwater in the 1980s, when bore well drilling made it possible to extract groundwater from depths and rural electrification in large regions of India, including Maharashtra brought in possibilities of a variety of pumping systems that could be installed in such wells. As more wells were drilled in Maharashtra with such pumping systems, yields increased but over a time, the number of wells were just too much to carry forward any more yield increase, so much

FIGURE 3
The Trade-Off Between Well Numbers And Yields: Trends In Groundwater Demand For Maharashtra (1960-2010)
so that after 1990, the yield – indicated through the average daily abstraction per irrigation well – has kept on declining (Figure 2). Such declines also indicate the degree of competition between sources. With more than 2.5 million wells in the state currently, the competition goes on unabated.

The near-invisibility of groundwater not only hides the context of aquifers but also hides the transitions taking place in an aquifer over a time-frame. This time dimension is also important when one adds the ‘typology’ of socio-economic conditions surrounding groundwater resources in Maharashtra. Aquifers seldom exist in pristine isolation. The complex layering of rock strata with varying aquifer properties gives rise to specific groundwater typologies (Kulkarni et al, 2009 i) even at local scales. We must remember that while the physical structure is often useful in identification of properties of rock strata, the typologies are not just entities in physical space. They go with a historically governed pattern of access to groundwater and the social processes that regulate its use.

Basalt aquifers are perhaps the most heterogeneous aquifer system in the world leading to extreme distress even when all users have access to groundwater.

The large-scale exploitation of groundwater resources is a consequence of three factors (Planning Commission, 2007; Kulkarni and Shankar, 2010):

a) an ever-growing demand for groundwater mainly from within agriculture, but increasingly now from growth in industrialization and urbanization;

b) the economics of crop-choice and intensification have not always matched the availability of groundwater resources; and

c) existing power-subsidy regime that promotes competitive and uncontrolled pumping of groundwater, especially from heterogeneous aquifers such as the Deccan basalt aquifers of Maharashtra.

In most demand-supply discussions, the availability of groundwater in an aquifer, is usually ignored. Figure 1 provides a schematic view of the relationship between availability, demand and supply of groundwater in any region (Kulkarni and Shah, 2013). The availability (within a hydrologic/hydrogeologic unit) defines the upper limit for demand and supply, an aquifer in the case of groundwater resources. In many rural areas of India, a single village usually has different episodes of water supply – in other words, water supply schemes that simply try to keep pace with the ever-increasing demand. Most supplies are engineering-based, techno-fixes that cater to a specific ‘demand range’. Hence, they work for a certain period in time, after which demand outstrips the supply range and a deficit is created, for which another scheme (supply-
step) is created. All of this builds into a scenario where an unregulated demand not only creates a scarcity of freshwater but the quality of water also progressively deteriorates. When continuously on the rise, demand would eventually outstrip supply when all available (local) supply options are exhausted. This would necessitate getting water from “external” sources, needing transfer of water across long distances either through piped systems or through tankers. We have seen this situation in many urban areas of the state, especially with respect to drinking water and now see the same situation gradually unfolding in many rural areas as well. Such water transfers increase almost exponentially, when a region faces drought, such as what large parts of Maharashtra face frequently. Active social regulation, through community-based, participatory forms of management of groundwater, can ensure that water availability remains within the boundary of available supply clearly according some sustainability of the supply-side interventions like managed aquifer recharge. In other words, with demand management, a water supply scheme in a village or a town will tend to be operational over a longer period of time. This conceptualization sets the theme for a strong articulation of demand management of groundwater in the current context.

Rethinking water security through CPR based PGWM
Water security should be redefined within the framework of what is available locally and how does availability change through both, intra-

Measurement of groundwater levels through participatory processes empower communities in owning their data and in facilitating decision making on groundwater management
annual periods (seasons) and through inter-annual cycles. Understanding aquifers both in terms of their quantity and quality profiles becomes important in this regard. Given that aquifers are a common pool resource (CPR) it becomes important to derive the definition of water security through the socio-economic perspective of communities. Participatory groundwater management (PGWM) is both a means and an end to managing aquifers as CPR. The focus of PGWM is to address the goal of water security at local levels by working on three important aspects:

- Improving equity in water access and distribution at the community level
- Redefining efficiency beyond a conventional ‘crop-per-drop’ water application paradigm, by including an index of aquifer capacity and optimized recharge through concepts like Managed Aquifer Recharge (MAR)
- Working through the above two, towards the goal of sustainability that balances domestic, productive and ecosystem roles of an aquifer

Participation of community institutions in the process of groundwater management not only helps setting up a protocol of decentralised, aquifer-community integrative groundwater management but enables cooperation in the management and governance of groundwater resources. Groundwater governance itself that becomes more collaborative (between communities and the State) and includes key parameters listed below:

- Social fencing that is not only normative but has evolved through a democratic process involving village institutions
- Formal regulation or some form of legislation that is inclusive of socially derived norms rather than contradictory to these norms; moreover, the robustness of the legislation itself will have to be a function of how it protects equitable, efficient and sustainable social norms of groundwater management from any externality
- The ability of formal institutions of governance to take decisions around mobilizing resources through the strategic convergence of various programmes of the government

Water level decline, aquifer depletion and
groundwater contamination all have a significant bearing on drinking water security, soil-moisture, soil-health, livelihood water security and ecosystem water security. In simple terms, sustained availability of water at local scales is affected in many ways. There is reason to believe that as the groundwater storage within a shallow, unconfined aquifer depletes, net soil-moisture also depletes. It would be interesting to study the precise nature of such depletion, particularly as to how the vadose zone responds to the depletion (and also to the contamination) of a shallow unconfined aquifer.

Concepts and experience are the foundations for strategic decision making (Moench and Stapleton, 2007). Adaptations occur, often as much in response to changes in the groundwater conditions as to those happening in the purely social and economic contexts; such adaptations are beginning to emerge into a formal regime, both within the larger “risk” arena of extreme events and climate change but also within a rapidly globalizing context (Moench and Dixit, 2004). Changes in climate conditions are bound to have major, but difficult-to-predict implications for weather and climate at more local levels. Arguably, groundwater systems themselves are more stable than climate and weather systems, but patterns of groundwater use are extremely sensitive to climate and weather as they are to human stressors, mainly changes in demand. Recharge and other flows will be influenced by climate changes (at least in the long term) as a direct consequence of water available for recharge and use but probably more on account of the way groundwater is used under various scenarios that emerge as a consequence of the impacts from climate change.

The availability of groundwater in an aquifer, at any given time, is a function of the natural state of the aquifer, its properties and the impacts of use (pumping, contamination and a complex set of socio-economic conditions that determine how supply and demand match each other).
Hence, adopting management strategies for sustainability and equity around groundwater resources requires an understanding of how each groundwater system behaves under various scenarios. Each scenario is defined by components of diversity, variability and the overall impact created by the climate at a certain point in time. In other words, groundwater system behavior with regard to rainfall, infiltration-recharge, aquifer conditions and characteristics along with patterns of use, will define the framework for such scenarios. Strategies of groundwater management can then be modeled out from each such scenario. A unique attempt to understand such scenarios has been made through the example presented below.

Behaviour of two typical aquifer systems (both from hard-rock aquifer settings in central India) were compared under 5 different scenarios:

1. An aquifer with partially developed wells under normal rainfall conditions
2. A fully developed but desaturated groundwater system under normal rainfall conditions
3. A fully developed and nearly desaturated groundwater system under drought conditions (following a normal rainfall year)
4. A fully developed and completely desaturated groundwater system under a normal rainfall year (following a drought)
5. A fully developed and completely desaturated groundwater system under a sub-normal rainfall year (following a drought) or under two consecutive droughts

Table 2 is a conceptual model showing a comparison between the two systems under the five scenarios mentioned above.

### TABLE 2
Summary Of Results From Scenario Modeling Of Two Basalt Aquifer Systems From A Typical Rural Setting Of Maharashtra State, India (Adapted From Kulkarni Et Al, 2015)

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Rainfall in mm</th>
<th>Water availability in mm</th>
<th>Recharge required to restore aquifer to ‘normal post-monsoon’ level (as % of rainfall)</th>
<th>Rainfall in mm</th>
<th>Water availability in mm</th>
<th>Recharge required to restore aquifer to ‘normal post-monsoon’ level (as % of rainfall)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>802</td>
<td>36</td>
<td>4.5</td>
<td>500</td>
<td>64</td>
<td>13</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>802</td>
<td>56</td>
<td>7</td>
<td>500</td>
<td>90</td>
<td>18</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>400</td>
<td>38</td>
<td>9.5</td>
<td>250</td>
<td>59</td>
<td>23</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>802 after a drought year</td>
<td>56</td>
<td>7</td>
<td>500 after a drought year</td>
<td>90</td>
<td>18</td>
</tr>
<tr>
<td>Scenario 5</td>
<td>400 after a drought year</td>
<td>28</td>
<td>14</td>
<td>250 after a drought year</td>
<td>45</td>
<td>36</td>
</tr>
</tbody>
</table>
The table shows how, under each of the five scenarios compared for illustrative purposes, water availability and required recharge vary. Similarly, the table also shows the difference in values under a single scenario for the two aquifer systems. Interestingly, AQUIFER SYSTEM B, despite falling under a low rainfall regime, has the capacity to store larger volumes of water than AQUIFER SYSTEM A. This illustration is just a crude manner of explaining the concept of scenarios, a process that holds great potential in groundwater management strategy development. More such examples need to be undertaken by adding dimensions such as actual groundwater use, cropping patterns, soil conditions etc.

**The way forward**

India’s groundwater situation is complex, being a function of aquifers, groundwater flow patterns, chemical profiles, patterns of use and the impact of climate change. The complex nature and diverse contextual regime of groundwater problems in India compel the development of a strategic approach to groundwater management. The fugitive nature of the (groundwater) resource and the open-access domain in which it is commonly used, pose major challenges in implementation of the principles of Common Pool Resource Management in the practice of groundwater management. In this light, the development of strategies to respond to groundwater over-use and deteriorating groundwater quality require a process-based approach that incorporates the potential impacts of a changing climate on one side and the impacts stemming from a growing demand on a depleting-deteriorating resource on the other.

Recognising and managing aquifers, especially heterogeneous aquifers, such as Maharashtra’s Deccan basalt aquifers is important in ensuring water security to hundreds of thousands odd rural habitations in India. In this light, therefore, a few clear recommendations emerge in evolving a fresh paradigm for managing groundwater resources in India, particularly with regard to groundwater and agriculture and keeping in mind Maharashtra’s unique position in terms of both its hydrogeology, its agro-climatic diversity and its legacy in irrigation. While this list can be made more comprehensive, the following elements are quite important and require discussions, debate and a deep understanding of various issues, aquifers and groundwater characteristics of a region being the most significant. Going forward, it makes sense for policy-makers in Maharashtra to keep the following factors in mind when designing discussions, programmes and policy that include groundwater management and governance at different scales.

1. The push for “disaggregation” to local scaled management must increase despite the clamour for centralised water supply. Centralising water supply ignores and trivialises the management of groundwater but turning an ‘ostrich-like’ blind eye to the problem on hand. For doing so, it is crucial to develop a ‘micro-scale’ understanding of aquifers and groundwater usage patterns that are linked to databases that are more ‘local’ than ‘regional’

2. Recognising that groundwater systems are not only varied in their character but their diversity is a consequence of
differences and similarities across a wide, spatial typology of impacts. Recognising this diversity involves identifying the precise nature of the problem (e.g. type of scarcity, type of salinity etc.) and the seasons in which problems are most severe, analysing the scale of the problem itself – in space and time, understanding resource characteristics such as the aquifer properties and groundwater quality and last but not least interpreting the features of different uses (domestic, livestock, agriculture, ecosystem etc.) and users (e.g. landless, small, marginal, large farm holders).

3. Understanding temporal changes in resource behaviour as a consequence of natural fluxes like climate or simply due to overexploitation of the resource due to changes in demand for water; changes in the resource itself or changes in supply of water against the changing demand and so on...

4. Using predictive scenarios that are a consequence of diversities and variabilities in factors such as hydrogeological conditions, land-cover, socio-ecological settings and the relationship between rainfall, recharge and groundwater extraction, on a variable range of aquifer stocks and flows.

5. Re-prioritising groundwater use in the following order
   o Low, but perennial volumes of secure and safe drinking water must be ensured first
   o Domestic water
   o Water for livestock
   o Water for ‘protective’ irrigation in securing rainfed cropping
   o Winter crops
   o Summer crops

6. Developing a groundwater governance mechanism through a highly decentralized structure empowering communities to integrate science and participation in their decisions

7. Calling for a robust framework of legislation that moves away from ‘command and control’ and encourages the management of groundwater as a common pool resource, is protective of good practices of community-based groundwater management and can be applied to a wide range of socio-hydrological conditions in different types of aquifer system.

References:


Abstract:
Water use efficiency is at the core of agriculture productivity and associated economic and social development. Conventionally, the public, private and civil society has worked towards benign development pathways that were not aligned with the individual actions. Recognizing the common developmental goals in the agriculture sector, the 2030 Water Resources Group activities focus on developing unique partnerships. Learning from the global partnership – 2030 WRG – hosted at The World Bank, the Government of Maharashtra created a formal partnership to analyze, convene and transform water-use efficiency in the agriculture sector. This paper reports the foundational work carried out by the 2030 WRG and the Water Resources Department of the Government of Maharashtra that resulted in creation of a unique off-farm and on-farm water efficiency improvement approach in the command area in the state.
1.0 Introduction:
The 2030 Water Resources Group (2030WRG) is a unique public-private-civil society collaboration established in the year 2009 to facilitate open, trust-based dialogue processes to drive action on water resources reform in water-stressed countries in developing economies. 2030 WRG works in about 13 countries/states including Karnataka, Maharashtra and Uttar Pradesh in India. Currently hosted at The World Bank, the 2030 WRG is governed by an international board comprising of representatives from the public sector, private sector and civil society organizations. At the national level, 2030 WRG is a lead partner to the Ministry of Water Resources, River Development and Ganga Rejuvenation (MoWRRD & GR) to develop a blueprint for water accounting in collaboration with key national and international partners (CWC, IHE-Delft, NIH, IITs, India-EU Water Partnership, IWMI, others), including water quality indicators. 2030 WRG is supporting Water Accounting and Productivity trainings along global best practice. 2030 WRG has supported MOWR RD & GR to develop the PPP pre-feasibility and financial structuring for Wastewater Treatment and Reuse in Mathura-Vrindavan. Primary motivation of the 2030 WRG activities is to create equal voice for the public, private and the civilian society partners to implement programs and projects emanating from its Analyze-Convene-Transform or an ACT framework.

2.0 Context:
In Maharashtra, the Government Resolution dated 18th May, 2017 issued by the Water Resources Department constituted the Steering Board of a Multi Stakeholder Platform (MSP) to facilitate optimal, sustainable and efficient approaches and solutions in water management in the state. The MSP brings together key public, private, and civil society stakeholders to assess priorities and develop concrete proposals in the state while offering opportunities to innovate in program delivery – all measured as water savings per year as a metric. Through a consultative process, the first meeting of the MSP Steering Board held on 7th August 2017 under the chairmanship of the Hon. Chief Secretary, Government of Maharashtra approved the formation of the following Workstreams: (i) Water and Livelihood Security in Rain-fed Agricultural Areas (ii) Command Area Water Productivity and (iii) Wastewater Reuse and Management. 2030 WRG acts as the secretariat for the MSP and the workstreams. In addition, work on two other cross cutting themes is also undertaken by 2030 WRG under the aegis of the MSP. The Institutional structure of the MSP is presented below (figure-1).

Figure-1: MSP Structure in Maharashtra

These workstreams are an outcome of the Maharashtra Hydro-Economic Analysis on ‘Opportunities to Improve Water Use in Agriculture,’ conducted in 2014, which informed the stakeholders of priorities in the state.
The main focus of the workstream, headed by Maharashtra Water Resources Regulatory Authority (MWRRA), is on enabling reuse of treated wastewater for different applications, so as to reduce demand for fresh water.
4.0 Wastewater Reuse And Management Workstream
The Main Focus Of This Workstream, Headed By Maharashtra Water Resources Regulatory Authority (Mwrra), Is On Enabling Reuse Of Treated Wastewater For Different Applications, So As To Reduce Demand For Fresh Water. A Special Emphasis Is Placed On Reuse Of Treated Wastewater In Agriculture Sector, Especially For Food Crops, As Water Used For Growing Food Crops Needs To Meet Higher Level Of Quality Standards. Another Innovation In The Workstream Is The Development Of Tradeable Wastewater Reuse Certificates. This Is Early Stages Of Development Through Discussions With Key Stakeholders From Ulbs, Industries, Csos, Technology Experts Etc.

5.0 Water Use Efficiency And Productivity Workstream
The Workstream On Command Area Water Productivity (CAWP) Was Tasked To Find Effective Solutions To Improve On-Farm Water Use Efficiency And Productivity, Including Understanding The Current Status Of Micro-Irrigation And Ways To Improve The Same. Two Rapid Assessments Were Carried Out To Understand The Prevailing Status Of Adoption Of Micro-Irrigation In Command Areas, With A Focus On Sugarcane Cultivation And Understanding The Readiness Of Private Sector In Participating In Promoting Integrated Water Management Approaches, Including Promotion Of Micro-Irrigation And Off-Take In Command Areas.

The Main Findings Of The Assessment Of Adoption Of Micro-Irrigation Systems In Sugarcane Cultivation In The State Are Listed Below.

- Only About 24% Of The Sugarcane Crop In The State Is Under Micro-Irrigation, With Regional Variations, As Shown Below (Figure-2).
- While Mi Is Being Adopted By Individual Farmers, There Are A Few Cases Of Groups In A Given Area Coming Together (Through Cooperatives) To Cover An Entire Area. A Case Study Of The Group Mis Adoption Is Given Below.
- Financing For Adoption Of Mi Is Coming Through Goi/Gom Schemes, Bank Loans And Support From Sugar Factories (Ex-Sangli And Latur Districts).
- Several Studies Point That Adoption Of Mi In Sugarcane Cultivation Could Lead To Saving Of About 50% To 60% Water Applied And About 30% Increase In Yield.

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1 Sugarcane is one of the major crops in Maharashtra cultivated over 1 million hectares of land. While this is 5% of the total agriculture land the crops consumes about 60% of water.
2 This study was carried out by M/s NABCONS Consultancy Services Pvt. Ltd, a subsidiary of NABARD
3 There Are Several Cooperative Lift Irrigation Schemes In Maharashtra. As Per The Study, There Are About 925 Cooperative Lis In Sangli, Satara And Kolhapur Alone, Covering About 180,447 Hectares.
4 Gom Adopted A New Policy Of In July 2017 Of Providing Interest Subvention To Sugarcane Farmers In Place Of The Subsidy Available To Other Farmers. Till Then Eligible Farmers Availed Subsidy Available Under Pmksy And Other Schemes.
5 Isam 2013, Sustainable Sugarcane Imitative By Nabard Etc.
Box 2: Comprehensive lift to drip irrigation system in a cooperative

Sampatrao Deshmukh is the only cooperative LIS scheme that has progressed to drip irrigation in canal command area. This initiative has been promoted by Cane Agro Pvt. Ltd sugar factory. This is also the biggest scheme in terms of area covered under drip irrigation (around 2000 Acre). The biggest challenge in canal command is the lack of storage tanks to store and lift water for drip irrigation. Cane Agro sugar factory had the advantage of balancing tank near the factory from the main Tembhu Canal and hence, the scheme could be implemented on a large scale. The other major challenge is the high project cost for drip implementation with automation (Rs. 0.18 million/acre). The Cane Agro sugar mill provided upfront loans to farmers, which was later adjusted against the payable for selling sugarcane to the factory. This is one of example of private sector participation on promoting MI systems adoption.

Despite Known Advantages, The Uptake Of Mi In Sugarcane Is Low Owing To Several Reasons. The Key Points, As Analyzed By The Study Are Reflected Below.

- Individual Farmers Find That Cost Of Adopting Drip Is High And Net Effective Subsidy (Including GST) Is Only About 35% Of The Cost And Hence Poor Farmers Can’t Afford The Upfront Costs. The Other Major Reasons Are Water Availability And High Maintenance Cost Of The Mi Systems.
- As Mentioned Only A Few Cooperative Liss Moved To Adopting Mi Systems As A Collective. The Major Reason For Farmers’ Not Opting For Drip Irrigation On Group Basis Was High Cost Of Creating Off-Farm Structures And The Availability Of Funds For The Same. Delay In Receiving Subsidy Was Another Important Reason. Not Finding Like-Minded Farmers For Group Mis Was Another Important Reason For Not Opting Of Drip On Group Basis.

In Parallel CAWP Carried Out Preliminary Market Assessment To Understand The Potential For Private Sector Participation (Ppp Model) In Fast Tracking Mis Systems Adoption, Including Activities Related To The On-Farm And Off-Farm Infrastructure Creation And Maintenance In An Integrated Manner. The Main Findings Are Listed Below.

- There Is Initial Interest In Investing In Micro-Irrigation In Sugarcane- With Almost Half Of The Respondents Interviewed Indicating Their Interest In Considering Investment Opportunities, Subject To Specific Transaction Structures Being Available And State Government Playing Some Role.
- Different Investment Cycles And Risk Profiles For Civil And On Farm Components- Both The Off-Farm And On-Farm Components Have Different Investment Needs, O&M Costs And Risks. The Potential Investors Feel That The Risk Profile And Cash Flows For The Two Components Are Substantially Different And Ideally Should Be Packaged In Different Contracts. The Companies That Can Execute Both Components Are Very Few, Among The Group Of Potential Investors. While There Is A Possibility Of Companies Forming Consortium To Offer An Integrated Execution Package, The Difference In Risk Profiles And Cash Flows For The Two Components May Make The Consortium Skewed.
- Preferred Length Of Contract- The Potential Investors Are Of The Opinion That Based
While the public sector and private sector are important players in enabling water use efficiency, the third major player is the farmer and/or her associations. In the command areas, these association take the form of ‘Water User Associations’.
Structured Effort/ Programs To Build Capacities Of WUAs To Play The Role Entrusted To Them. While About 5000 WUAs Have Been Established In The State, Most Of Them Lack The Skills And Capacity To Undertake The Managerial And Regulatory Role Designed For Them. Hence, Capacity Building Of WUAs And Establishing Links With Financing And Markets Is A Very Crucial For Overall Development Of The Farming Communities In Command Areas. All These Assessments And Consultations With Key Stakeholders Informed The CAWP Workstream That Promoting Effective Adoption Of Mi Systems In Command Areas Require An Integrated Approach For Off-Farm And On-Farm Infrastructure And Its Maintenance. While The Government Is Undertaking Several Projects To Speed Up The Off-Farm Works, There Is A Need To Integrate The Same With On-Farm Activities And Establish Mechanisms For Equitable Distribution Of Water And Its Efficient Use. The On-Farm Activities (Promotion Of Mi Systems, Technical Advice Etc) Are Being Carried Out By Agriculture Department And Coordination Between Both The Interventions, Especially In Command Areas, Is Weak.

The CAWP Workstream Members Then Decided To Design And Implement Innovative Integrated Pilot Projects That Bridge This Institutional Gap And Promote Water Use Efficiency And Productivity In Command Areas In Maharashtra. Such Piloting Needs Adequate Capacity And Dedicated Time To Hold Field Assessments, Engage Key Stakeholders (Farmers To Private Sector), Design Innovative Projects And Handhold Its Implementation And A Decision Was Taken To Establish A Dedicated Project Implementation Unit (PIU) For The Same, Within The WRD6. The PIU Will Be Staffed With Senior Officers From WRD, Agriculture Department, Water Conservation Department And Experts Drawn From Market. 2030 WRG Will Be Acting As An Advisor To The PIU And Bring Expertise Available Within The World Bank Group To The PIU Functioning And Closely Work With Them. The Envisaged Integrated Approach Is Shown Below (Figure-3)

![Figure-3: Integrated Approach to promote water use efficiency and productivity in command areas in Maharashtra](image)

6.0 Future Action Plan

- Strengthen The PIU With Requisite Skill Sets, With Support From Partner Organizations
  - Strengthen Cotton Water Platform.
  - Promote Sustained Private Sector Participation Across All Three Workstreams.

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6. Government Order Dated 8th October, 2018
• Scaleup Of Implementing Integrated Projects, Applying The Watershed++ Approach, Including Promotion Of MI Systems And Reuse Of Treated Wastewater
• Expand The Scope To The Entire State.

7.0 Conclusion
2030 WRG Has Been Collaborating With The Government Of Maharashtra Since 2014 And Has Been Consistently Supporting Various Initiatives That Aim To Ensure Water Security For All In The State. The Institutional Mechanisms Of MSP And Workstreams Is Now Set, Important Areas Have Been Studied And Action Plans Are Developed. A Major Achievement Thus Far Has Been Bringing Key Stakeholders Together And Working Together In Improving Livelihood And Water Security In Both Rainfed And Command Areas Within The State. Innovative Concepts Like Watershed++, Integrated Command Areas Management, Cotton Water Platform, Wastewater Reuse Certificates Etc Have Been Introduced And Are Being Developed Into Policy/ Regulatory Adoptions, Financing Instruments, Capacity Building Vehicles Through Collaborations. All These Actions Will Lead To Improved Water Security In Near Future. 🌊
Introduction
The major challenge facing irrigated agriculture today is producing more food using less water per unit of output i.e. increasing water productivity in both irrigated and rainfed agriculture. The goal will only be achieved if the appropriate water saving technologies, management tools and policies are in place. The objective is to encourage development and implementation of innovative technologies, agronomic innovations, improved management practices and institutional reforms to bring higher crop productivity, higher farm income and preservation of the land, water and the environmental resources for irrigated and rainfed agriculture ensuring sustainable development.
All those involved in irrigation water management – managers, farmers, workers need to be encouraged and guided, through appropriate policies and incentives, to save/conserve water and to minimize wastage to mitigate negative environmental impacts.
To encourage irrigation professionals to undertake research and development and its dissemination to various stakeholders to improve various aspects of Agricultural Water Management, ICID instituted the WatSave Annual Award(s) in 1997 to recognize outstanding contributions to water conservation or water saving in agriculture in four categories, namely (i) Technology award (ii) Innovative Management award (iii) Young professional award; and (iv) Farmer award.
Nominations for the awards are received from the National Committees of ICID through an announcement circulated at the beginning of every calendar year. Each of the award consists of an honorarium of US$ 2000 and a Citation. The Awards given to individuals or a team of individuals are made in respect of actual realized savings and not for promising research results, plans and/or good ideas/intentions to save water.
ICID recognised the outstanding contributions in WatSave awards from Maharashtra state, located in the western region of India, highlighting achievements and showing how water can be better used ranging from more precise and productive irrigation at one end of the spectrum, to improved techniques of conservation agriculture at the other. The winners receiving the awards were not confined to water engineering, but demonstrated a knowledge of the whole processes of water savings to project the world better ways of “managing water for sustainable agriculture.”
A succinct account of the research work of
the winners from Maharashtra state presented the WatSave awards in various categories are described below:

**A. INNOVATIVE WATER MANAGEMENT AWARDS**

The award is presented for promoting non-technological interventions and/or innovative land and water management/techniques for increasing the availability of water for different uses; Promoting research that leads to substantial savings in water applications or uses; or Promoting development of new policies/approaches for water saving leading to cost effective and beneficial use of water.

(i) **Title:** An initiative towards saving of water and sustainable Irrigation Management in Maharashtra State, India.  
**Name of the winner:** Mr. S.V. Sodal  
**Secretary (CAD), Irrigation Department, Government of Maharashtra, India**  
**Year:** 2004

Maharashtra State is the third largest state in India. The state has created irrigation potential to the tune of 3.812 Mha. But the state lags in utilisation of created potential. As irrigation consumes 75% to 80% of water resources, organisation of water for irrigation would benefit other sector. Water saving measures are also more important in the context of growing population and water scarcity. To improve upon performance of irrigation sector, which is wholly governed by government, a total approach has been adopted. An approach involving policy reforms, technological and managerial interventions have been undertaken. All-round measures which includes capacity building of personnel as well as institutions, also public awareness campaign to promote participation of users, have been undertaken.

Irrigation is a key element for agricultural sector. The state has achieved a landmark in irrigation potential creation, but performance in potential utilisation remains comparatively low.

It was high time to work upon minimising gap between the two, and conserve irrigation water to make best use of available water resources.

To improve water use and overall performance, all-round measures have been initiated, which includes policy reforms, technological and managerial intervention at appropriate time. A strategic planning and effective implementation coupled with timely monitoring and evaluation has resulted in improvement of performance. No doubt, the conducive environment building to bring desired change has played important role. Development of human resources, improvement of institutional capabilities, are key to successful implementation. With consistent efforts during last two consecutive year, O&M expenses are fully recovered through recovery of water charges. A beginning in performance improvement will go a long way in making irrigation sector of the state, self-sufficient and sustainable one, in years to come.

A total approach to improve the water use efficiency of irrigation has resulted into remarkable improvement in efficiency, with water saving of 3482 Mm$^3$. In other words irrigating same area with 21% less water as compared to previous years. Each drop of water saved is water generated and in water scarcity situation its importance is even more valuable. With timely and appropriate reforms and application of state-of-art technology, Maharashtra state has set a new paradigm in water resources management.

**Source link to access the paper:** http://www.icid.org/ws1_2004.pdf

(ii) **Title:** “Transformation of irrigation through management transfer”  
**Name of the winner:** Messrs Shahaji Manikrao Somawanshi, Bharat Kawale and Sanjay Madhukar Belsare  
**Year:** 2009

Participatory Irrigation Management (PIM)
approach was introduced in India in 1990s. The Government of India has been promoting the PIM in many irrigation schemes, especially in major and medium scale, with an objective of improved operation and maintenance of irrigation schemes, reducing fiscal burden on the States, increased cost recovery, and higher crop production through better water management. As a result more than fifty thousand Water User Associations were formed all over the country. However, the contemplated benefits of PIM are yet to be realized due mostly to institutional weaknesses. PIM is still looked with suspicion by many. Yet there are some examples of successful WUAs who can act as role models for others to follow. Waghad Irrigation Scheme of Maharashtra State is one among those.

Waghad Irrigation Scheme located in Nashik district of Maharashtra State was commissioned in 1981. The scheme’s cultivable command area is 9642 ha but only one-third of it (3212 ha) was irrigated as farmers in tail reaches were deprived of the irrigation water. In 1990, the Samaj Parivartan Kendra motivated farmers to come forward in taking over the operation and management of the scheme. At the outset only 3 Water User Associations were formed at the tail area of the canal command. Enthused with the success of the 3 WUAs, farmers from the entire command gradually formed 24 WUAs. As a step forward, in the year 2003, all the WUAs joined their forces to take over the operation and management of the entire irrigation scheme by forming an apex organization called Waghad Project Level Water Users Association (PLWUA). The PLWUA undertakes the water management with technical guidance and support from Water Resources Department. Water is supplied volumetrically at the head of canal and subsequently the PLWUA distributes the water among 24 WUAs as per their demand and entitlements. WUAs further distribute water among their members. As average land holding of farmers is very small (0.5-1.0 ha), volumetric supply to each farm holding is difficult, so farmers have devised innovative way to share water on time basis. The PLWUA collect water charges from its member associations. Management transfer to PLWUA has resulted in 100 % utilization of irrigation potential, saving in water, crop diversification, and 100 % collection of water charges.

Innovative Water Management by PLWUA in Waghad Project resulted into saving of 13 million cubic meter of water in the irrigation year 2008-2009 which is almost 1/3 of water diverted for the irrigation. This model of efficient management by Waghad Project Level Water Users Association (PLWUA) can be very well replicated at different locations in the country as well as in developing countries of the world.

Source link to access the paper: http://www.icid.org/ws1_2009.pdf

(iii) Title: “Participatory Rainwater Conservation in Rainfed Agriculture”

Name of the winner: Dr. Subhash Madhawrao Taley

Year: 2011

Rainfed farming more popularly known as “dryland agriculture“ is spread in four continents covering almost 48 countries. If we do not improve the water use efficiency (WUE) in rainfed agriculture, we will potentially face food insecurity for basically one-third of the
world’s population. Agriculture in Maharashtra state and that in particular Vidarbha region can be characterized by low irrigation (17% and 7%) and low rainfall. Approximately 85 percent of cultivated area (17.64 million ha in MS and 4.99 million ha in Vidarbha) is rainfed and agricultural performance is significantly influenced by the monsoon.

In Vidarbha, the rainfed farming largely subjected to the vagaries of monsoon with instability of yields, incomes and water use efficiency in the present situation involving the farmers and motivating them to undertake more responsibilities to enhance the rainwater use efficiency by reforming the cultivation practices for the benefits and welfare envisages in their attitudes mind sets and enhancing their skill and capacities towards in situ soil and water conservation, safe disposal of runoff, storage of runoff in farm ponds and recycling of water for protective irrigation during moisture stress. Since major agriculture is rain dependent the appropriate rainwater management play very vital role in sustainable rainfed farming.

The on-farm study in participatory mode was undertaken during 2007-10 and the impact of the rain water management technologies was monitored scientifically with participation of the farmers. The study indicated that in deep cultivation the water use efficiency (kg/ha/mm) enhanced from 1.24 to 1.49 and from 0.98 to 1.09 in sole crop of soybean and cotton respectively. Similarly in intercrop of cotton and soybean water use efficiency enhanced from 0.54 to 1.09 in cotton and from 0.81 to 1.11 in soybean. The yield levels in deep cultivation were found increased by 11 to 36.95 percent runoff and soil loss were decreased by 8 to 12.69 percent and by 17 to 30.90 percent respectively over shallow cultivation.

In across the slope cultivation under sole crop of cotton, soybean, green gram hy, Sorghum and intercrop of green gram/soybean+ pigeon pea enhanced the yield levels from 20 to 50 percent and water use efficiency from 0.55-2.67 to 0.74-3.26 kg/ha/mm. Similarly in contour cultivation the yield levels were found enhanced by 38.88 to 87.50 percent and water use efficiency from 0.55-2.67 to 0.89-3.71 kg/ha/mm.

Harvesting of runoff from the cultivated fields in to farm ponds and utilized to provide protective irrigation during prolonged monsoonic break in kharif and moisture stress in rabi enhances the crop yields and water use efficiency. One protective irrigation from farm pond through drip system enhanced the yield of pigeon pea by 66.66 percent and water use efficiency from 0.89 to 1.38 kg/ha/mm. Two protective irrigations through drip systems to cotton enhanced the yield level 51.37 percent and water use efficiency from 1.61 to 2.13 kg/ha/mm. The results reveal the on farm improvement in land and water productivity in terms of enhanced crop productivity and water use efficiency which only because of linking the rainfed farming with attempts of drought proofing.

From the results it was concluded that the adoption of the modified land configurations like deep cultivation across the slope contour cultivation and opening of furrows and bed furrows, green manuring square basin layout etc. can store the rainfall properly in the soil profile and further effectively utilized in
rainfed agriculture in terms of enhanced soil moisture, crop yields and water use efficiency and reduction in runoff, soil and nutrient losses. Involvement of farmers in rainwater management towards “more crop per drop” indicated the more diffused impact by changing their thinking about how water is and should be managed and meet out the weather vagaries in rainfed agriculture to solve the water crises by way of more crop per drop.

Source link to access the paper: http://www.icid.org/ws1_2011.pdf

B. FARMER AWARDS

(i) Title: “Group Farming and Micro Irrigation A Way To Prosperity”
Name of the winner: Dr. Bhagvan M. Kapse
Year: 2015

In India, Agriculture is still mainstay of majority of population and almost 55% to 60% population is engaged in agriculture. Agriculture has recorded a spectacular growth in past two decades. In the post Green- revolution era, intensive agriculture was promoted and adopted on large scale. It has resulted in record increase in both production and productivities in food grains oilseeds & also in fruits & vegetables. However we are facing some “Side-effects” of this era of intensive agriculture, in spite of use of imported technology, in most of crop the yields are just stagnant and, declining in some of the crops. The cost of production shoot up in most of the crops & issues of profitability become critical. Agriculture become input oriented, expensive & farmers became completely dependent in respect of seed, fertilizer, implements, labourers. On other hand with increase in population we are witnessing rapid fragmentation of land. The average size of land holding declined from 4.28 ha (1970-71) to 1.65 ha in 2001; leading to economically non-viable small farms. These small farmers are unable to bear the high cost/ investment for adoption of modern technologies in order to sustain the higher productivity levels, with growing small farms & small farmers the issues of productivity, profitability, adoptability & sustainability are becoming sharper. Now it’s high time to address these issues as early as possible. Various strategies are being developed & several approaches are being tried. Thus Dr. Kapse, is involved to organize small & resource poor farmers in to groups, developing groups of assetless farmers & building them as service providers & thereby generate better livelihood facilities & reduce poverty.

Dr. Kapse not only promotes group farming for just survival but as a bridge to prosperities. Through better income generating options, efficient application of technical interventions & thereby increasing the cost, benefit scenario in favor of farmers. As groups small farmers can
come together to adopt modern technology & produce higher quality agri-produce & thereby can capture the emerging domestic markets as well as enter into world market. These groups can undertake the processing, value additive marketing activities united. Some of the objectives of group farming as conceptualized by Dr. Kapse are as narrated below:

- Farmers should come together to help themselves.
- Identifying the common needs, opportunities and potential & then orientation of farmers to come together.
- Bringing together small farmers in clusters & developing the groups.
- Adoption of suitable common cropping pattern on large scale by these groups & federation of these groups in cluster of villages.
- Adoption of modern technology by the group farmers’ use of a common technology for production of high quality produce.
- Adoption of advance irrigation systems like drip and sprinkler in cluster and increasing water use efficiency
- Conservation of land & water resource on community basis & thereafter judicious use of these resources in a sustainable manner.
- Bringing all crops including cereals under Drip Irrigation, no drop of water will be given to the field without Drip or Mirco Irrigation.

The Group Farming has covered farmers from about 17 villages spread across in Jalna District, Aurangabad and Buldhana Districts in Maharashtra, India. The first attempt of group farming led by Dr. Kapse by forming Indico Falotpadak Sangh Jiradgaon. In the project he has undertaken successful plantation of Kesar Mango on area 1000 Acre with ultra-modern technique i.e. high density, modern insitu, method of plantation which has been developed by Dr. Kapse and popularised as a Jiradgaon Method of Insitu Mango Plantation. In the second phase the crops like Pomegranate, Sweet Orange, Aonla & Custard Apple were also included in the project. Dr. Kapse took the various initiatives for dissemination & adoption of modern technology of irrigation system, construction of farm ponds & protective cultivation. Dr. Kapse guided to growing various crops like soybean, chickpea, wheat, pomegranate, intercropping i.e. cotton and pigeon pea, pigeon pea and soybean. The most of the farmers were not aware about use of sprinkler irrigation system and they have doubt in their mind. However Dr. Kapse and University Scientist advised to farmers regarding use of sprinkler irrigation during critical stage of crop and that increased the 2.5 – 3 times yield.

Source link to access the paper: http://www.icid.org/ws_farmers_2015.pdf

(ii) Title: “A Zero Till, Conservation Agriculture Technique for Rice Based Farming”

Name of the winner: Mr. Chandra Shekhar H. Bhadsavle, Mr. Changdev K. Nirguda and Mr. Anil D. Nivalkar

Year: 2016

Saguna Rice Technique is a unique new method of cultivation of rice and related rotation crops without ploughing, puddling and transplanting (rice) on permanent raised beds. This is a zerotill, Conservation Agriculture (CA) type of cultivation method evolved at Saguna Baug, Neral, Dist. Raigad, Maharashtra, India. The technique has been accepted by Government of Maharashtra for their PPP-IAD programme where about 1200 farmers have reported overwhelming satisfaction and about 500 farmers have not reported yet.
It reduces water requirement by 50% for rice (3000 litres water required to produce 1 kg of rice) cultivation, reduces back breaking labour by 50%, cost of production by 40%. It also stops emission of greenhouse gases and effectively does carbon sequestration to improve soil fertility. Above all it brings joy and confidence to the rice farmer which is reversing the trend of farmers giving up farming.

The Rhizosphere, which is the natural ecosystem around the roots benefits greatly by the permanent raised beds system. The most important friends of any plant growth are aerobic microorganisms and earthworms. These essentially need oxygen and organic carbon for them to flourish. The raised beds further facilitate the adjustment of moisture to optimum levels. Together these conditions promote vigorous, hairy whiteroots and vibrant, wider leaf lamina resulting crop to grow uniformly vigorous and gives considerably higher yield.

**Important Principles:**
1) SRT insists that all roots and small portion of stem should be left in the beds for slow rotting.
2) Weeds are to be controlled with weedicides and manual labour. No ploughing, puddling and hoeing is to be done to control weeds.
3) This system will get the crop ready for harvesting 8 to 10 days earlier. Take this into consideration while choosing a variety to avoid getting harvesting caught in receding rain.

The SRT iron forma (the tool will be better soon) facilitates planting of crop in predetermined distances enabling precise plant population per unit area. Absence of puddling and transplanting of rice makes it possible for “Not dependent on erratic behaviour of SRT A Zero Till, Conservation Agriculture Technique for Rice Based Farming rain.” This means ‘No more waiting for Rain God to shower just optimum rain for best transplanting operation’. Similarly if rain vanishes for few days during crop season it doesn’t lead to cracking of land or ‘crop kill’ immediately.

Source link to access the paper: [http://www.icid.org/ws_farmers_2016.pdf](http://www.icid.org/ws_farmers_2016.pdf)

(iii) **Title:** “Effective Water Management in Drought Prone Area”
**Name of the winner:** Dr. Vijay Sharad Deshmukh
**Year:** 2017

Over the past several decades’ erratic rainfall, shrinking river levels has substantially reduced the water table in the region (western districts of Vidarba in Maharashtra state of India), thus, posing a major threat to its primary sector and thus socio-economic status of inhabitants. Lack of irrigation facilities left farmers to depend on rain-fed farming. Poor viability of agriculture left many to farmers to migrate to cities for work and few committed suicide, which is an aggravated problem in Western Vidarba. Once known for its rich agricultural produce, the region is struggling with grave issues like effective water management. In this context this water saving initiative is very unique and is helping to change the agriculture landscape in Warud.

The farmers collectively came through an institutional set up “Dr.Sharad Drip Irrigation Water Utilization Co-operative Society Limited” at Warud. The members discussed the disadvantages of existing system and decided to modify using their own capital. They borrowed and invested Rs. 11,457,205 from local financial institution (Union Bank of India and Bank of...
Maharashtra) and built distribution chambers along the way, invested heavily into piping and filtration systems. They decided to avoid water loss from earlier system by using drip irrigation method. By bringing water from 11 kms via 200 mm pipeline the distribution chamber was built in such a way that it provided natural head for the drip irrigation system, thus eliminating the use of electricity/diesel pump. Four water filtration units were installed which used sand to filter the water.

To increase the transparency, water meters were provided at the off take. At present 0.5 million meter cube of water is reserved for this project. One of the features of this project is that during the high monsoon period the added water is also diverted to the wells so that ground water table can be recharged. In addition, the government gets added revenues using water metering mechanism.

In 2011, the first test was conducted and the results were encouraging. Today, the area under irrigation has doubled to 145 Ha and number of beneficiaries has increased to 165 which is an outstanding growth. The availability of water has increased their socio-economic status. From the government’s stand point the revenue collection has gone up as the water use is metered. Rise in economic status has led to prompt payment of water dues by all the beneficiaries. The project is currently being operated on cooperative basis and all day to day decisions are made by the committee.

Source link to access the paper: http://www.icid.org/ws_farmer_2017.pdf

C. YOUNG PROFESSIONALS AWARDS

The award is presented for promoting water saving technologies, innovative water management practices, original research leading to substantial water saving/conservation etc. by young professionals (below 40 years).

(i) Title: “Participatory Irrigation Management in Katepurna Irrigation Project: A Success Story”

Name of the winner: Er. Sanjay Belsare
Year: 2001

Katepurna irrigation project was completed in 1975, having the storage of 86.35Mm³ and in last 25 years project could provide irrigation hardly to 2027 ha. averagely. Due to less utilization of water for irrigation, non-irrigation reservations have increased from 25.20 to 46.82 Mm³ it amounts 54 % of the live storage and therefore the water available for irrigation is reduced from 49.45 Mm³ to 27.83 Mm³ as a result irrigation potential reduced to 5967 ha.

With the poor water utilization scenario, efforts were made to identify and analyze the worst affected situation. Accordingly the strategies have been finalized to solve the problems and to improve, water utilization scenario step by step. The strategies adopted for the system improvement were:
- Engineering Measures
- Agronomic Measures
- Management Measures
- Public Awareness and Involvement

With persistent effort mentioned above, for participatory irrigation management during the year 1998-99 to 2000-2001, average irrigation in the command of Katepurna project raised from 2027 ha, to 3646 ha with yearly water saving of around 7.71 Mm³. There is a record irrigation of 5909 ha with almost complete utilization of reservoir water. For the first time in history of Katepurna project, the project achieved irrigation equal to its present potential with 86% live storage. The benefits were extended from 2000 to 3970 number of beneficiaries. There is good yield of cotton and wheat in command to the tune of 1.2 billion rupees during 2000-2001. Katepurna experiment was also tried, in other projects within Akola district of Maharashtra State. There are 25 projects having present potential of 21,530 ha, with live water storage of 199.25Mm³. The formation of 38 water user associations are under progress covering 9203ha, area (43 % of total command area). The actual
irrigation increased from 6626 ha to 12229 ha with water saving of around 15.50 Mm³. The water saving observed through efficient use of water in irrigation projects under author jurisdiction has been quantified to possible extent. But there is also possibility of larger amount of water saving by community due to water saving awareness program.

At present the movement of participation of beneficiaries in irrigation management is in full swing. In next year, it is expected to bring at least 60% command area under water user association management. The transfer of management to beneficiaries will result in to sustainable, efficient and economic water use. The Akola experiment could prove as a milestone in individual as well as collective efforts in water saving.

Source link to access the paper: http://www.icid.org/belsare_2001.pdf

D. WAY FORWARD

Of the world’s total land of 13000 million hectare, about 1553 Mha are arable and cultivated lands, of which some 19% (299 Mha) are irrigated producing 40% of the production and engaging 30% of population, whereas 1254 Mha is rain fed producing 60% of production and should engaging 70% of population.

As far the world population is concerned, it took about 50 centuries for the world, from the dawn of civilization, to reach the population of 1 billion around 1830. It took another century to reach 2 billion mark in 1930. Three billion people occupied the world in 1960, 4 billion in 1975, 5 billion in 1986 and 6 billion in 1999. The world population reached 7 billion in 2011 and now totals 7.6 billion (2018). The United Nations Population Division has projected a higher population of 9.9 billion by 2050 due to higher birth rate in Africa/Asia.

Water security is fundamental to sustainable development. With agriculture using 70% of global water supply, water management in agriculture becomes the key deliverable for sustainable development. Agriculture is the engine of food security, the largest global user of water and an important source of employment for poor people in developing economies. By 2050, global food production will need to increase from 60 to 100 percent above production in 2005. Over this same period, demand for water in other sectors, such as energy, industry and domestic use, is set to rise by 55% globally (IWMI, 2018). Given above, feeding the people who live in Asia by 2050 will require more food than the region currently produces. Experts estimate that demand for food and animal feed crops will double during the next 50 years as income rise and diets change and shift towards greater demand for animal based protein. Growing this extra food, and meeting consumer demands, requires better management of existing irrigated lands and to help overcome increasing water scarcity. It is therefore imperative to develop and promote water saving practices on large scale in agriculture to cope with water scarcity.

There could perhaps be no single solution or a blueprint for the future challenges in agriculture water management. The water positives presented here is an attempt to highlight the scope offered by some of the innovations developed by ‘Water Heroes of Maharashtra’.

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