

Rapid Water Balance Assessment of Karjat and Jamkhed Talukas in Ahmednagar District for Water Security



Society for Promoting Participative Ecosystem Management (SOPPECOM) and Advanced Center for Water Resources Development and Management (ACWADAM)

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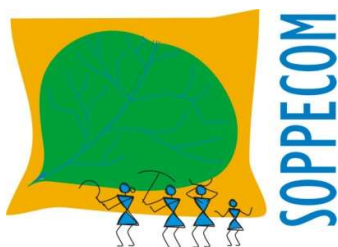
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Executive Summary

Karjat and Jamkhed talukas are drought-prone areas and receive very erratic and less rainfall. Both the talukas are highly dependent on external source of water, like tankers to fulfil their basic drinking and domestic needs. Further, in both these talukas, the number of borewells and dugwells are very high, showing a large dependence on groundwater for irrigation. Implementation of large watershed programmes like IWMP and Jalyukt Shivar has only helped to create large storage capacities to arrest rainwater, yet they have not been able to minimise the effect of drought. Agriculture Development Trust (ADT), Baramati approached SOPPECOM and ACWADAM to carry out a rapid assessment study largely based on secondary data to derive water balance for Karjat and Jamkhed talukas and to understand the water requirement for domestic, livestock and agriculture needs. The field work was completed over a period of two months from mid December 2019 to mid January 2020. According to the understanding between ADT Baramati, SOPPECOM and ACWADAM, the study was divided into three parts as follows

1. Derive the water balance for Karjat and Jamkhed taluka. This included
 - Deriving water balance at taluka scale
 - Deriving water balance at Panchayat gan (cluster level)
 - Deriving water balance for command and non-command areas
2. Carry out assessment to understand the status of the Water User's Association (WUA) in command areas of Kukadi and Sina irrigation projects
3. Carry out detailed hydrogeological assessments of four micro-watersheds (two in each taluka)

The following executive summary highlights the details presented in the report based on the rapid assessment study. The report has been divided into five Chapters. Chapter 1 is Introductory Chapter. Chapter 2 discusses the issues in the command Area and non-command areas based on the field visits and assessments. Chapter 3 presents the detailed hydrogeological and watershed assessment carried out in four selected micro-watersheds, two in each taluka. Chapter 4 details out the water balance in Karjat and Jamkhed taluka and Chapter 5 presents the way forward based on the study.

The study area consisting of Karjat and Jamkhed talukas are located in the south of Ahmednagar district, Maharashtra. The salient features of Karjat and Jamkhed taluka are summarized as below:

	Karjat	Jamkhed
Total geographical area (ha)	155,774.35	87,524
Total population (2020)	266,823	184,167
Panchayat Gan (cluster)	9 Panchayat Gan- Bhambora, Chapadgaon, Jalapur, Karjat Nagar Panchayat, Koregaon, Kuldharan,	5 Panchayat Gan-Aarangaon, Javala, Kharada, Nagar Panchayat Jamkhed and Sakat.

	Karjat	Jamkhed
	Mirajgaon, NimgaonGangarda and Rashin	
Total number of villages	120	86
Average rainfall (mm)	573	636
Actual Rainfall in the reference year (2018-19)(mm)	391	545
Total Cultivable area (ha)	116541	71632
Major crops taken	Kharif: bajra, maize, tur, moong, onion, cotton Rabi: jowar, harbhara, groundnut and vegetables. Perennial: Sugarcane and other horticulture crops like pomegranate, guava and lemons	
Irrigation projects and allocation	Kukadi irrigation project: 5 TMC Sina medium irrigation project: 1.81 TMC	Khairi medium irrigation project: 0.5 TMC

Methodology:

The study is mainly based on secondary data collected at taluka level and field surveys done in selected villages. Detailed field visits were carried out in selected 10 villages (6 in Karjat and 4 in Jamkhed) which included discussion with farmers, women and other stakeholders like Gram Panchayat members and local leaders besides detailed field observations to understand the watershed work carried out as well as the status of the irrigation infrastructure. For the assessment of the WUAs in command area of Karjat taluka, Nimgaon Gangarda and Malthan (Sina irrigation project) and Kumbhefal and Yeswadi (Kukadi irrigation project) were selected. In Jamkhed, Satephal (Khairi irrigation project) and Aghi (non-command area) were selected. For detailed hydrogeological and watershed assessment, Rehekuri and Walvad from Karjat and Shiur and Sarola from Jamkhed were selected. Secondary data received from various government departments and insights from the field visits and assessments was used to derive water balances. Secondary data accessed from various sources including those collected for rainfall, land use and cropping pattern for the year 2018-19 were used for deriving the water balance at various scales while primary field observations were used for validating the findings and understanding the field realities. It also helped in understanding the institutional and technical dimensions of the command areas and the specific watershed development initiatives in the non-command areas.

Specific Issues in the Command area

Chapter 2 details out the insights from the field visits to the villages mentioned in the methodology section. The visits were mainly carried out to understand the conditions of the canal infrastructure and the status of the WUAs in the command areas. The insights are briefly summarized as below:

- It was observed that the allocated water from the irrigation schemes is not fully received in the command due to various factors. Allocated water from the irrigation projects is not given/ met during the reference year (2018-19)

- Water User Associations (WUAs) in the command areas are dysfunctional wherever it is organised and in Kukadi command it is still not organised
- The condition of the main canal, minors is poor and badly damaged in a number of stretches and field channels are non-existent in most places
- Water for domestic need is a critical issue. Most of the villages even in the command area are highly dependent on water tankers (throughout the year in some villages) as the wells are drying early.
- Farmers who can afford are making large investments for safeguarding water for irrigation through farm ponds, private pipelines, purchasing tanker water, etc.

Watershed assessment: existing work and potential

Chapter 3 details out the insights from the watershed assessments carried out in 4 rainfed villages in both the talukas. The field assessment was carried out in order to understand the efficacy of local water harvesting along watershed lines and to what extent it has contributed to meet the water requirements. The major field observations are summarized below:

- The watershed development work in all the villages is mainly drainage centric with very limited area treatment mainly farm bunds
- It appears that ‘ridge to valley’ has not been followed as there is hardly any conservation work done in the ridge areas
- Quality of work on drainage lines is poor
- There are no institutional mechanisms in the villages for maintenance of assets

Water Balance and water requirement for domestic and agricultural needs

Four scenarios were worked out to understand the water balance and water requirements of both the talukas with the objective that the implementing agency has more options to work with as the demand for additional water is also a political issue and related to the overall water availability in the region or the larger basin.

- Annual water balance for the year 2018-19 based on the data available for the year.
- Water balance under the scenario for 100% cultivation in Kharif season and 50% of cultivated area in Rabi season will be irrigated (150% cropping intensity) as recommended by Chitale Commission report (1999)
- Water balance under the scenario where irrigation would be provided for 30% of the area in Kharif and Rabi season
- Water requirement for biomass based approach for securing livelihoods.

The water balance for Karjat and Jamkhed taluka is summarized in the table below

Name of Taluka	Details	Scenario 1 (reference year 2018-19)	Scenario 2 (crop cultivation in 100% Kharif area and 50% of Rabi area)	Scenario 3 (assured irrigation for 30% area under Kharif and Rabi)	Scenario 4 (livelihood needs based on biomass requirement)
Karjat	Total volume of rainfall (TMC)	21.26	30	30	20.78
	Total water required for all demands (TMC)	20.17	16.69	10.24	13.75
	Total water available (surface and groundwater (TMC) and exogenous sources	9.42	9.7	9.71	17.53
	Surplus/ Deficit (TMC)	-10.64	-6.98	-0.52	3.78
Jamkhed	Total volume of rainfall (TMC)	15.93	18.57	18.57	14.28
	Total water required for all demands (TMC)	10.28	5.75	3.13	9.45
	Total water available (surface and groundwater (TMC) and exogenous sources	1.96	1.96	1.96	7.12
	Surplus/ Deficit (TMC)	-8.31	-3.79	-1.17	-2.34

Deficit for scenario 1 is high as the reference year (2018-19) was a very low rainfall year. In other scenarios, the water availability has been calculated on the basis of average rainfall values and therefore the deficit is less compared to the reference year 2018-19. Scenario 2 was derived based on the recommendation of the Chitale Commission report (1999), which stated that about 50% of the area in Maharashtra should receive irrigation in Rabi season. Thus, using the same assumption, the deficit is relatively high compared to Scenario 3 and Scenario 4. Scenario 3 has been developed based on the findings of the Barve Commission report (1962). The Barve Commission Report states that only 30% of the cultivable area in the state can be realistically irrigated. Based on this assumption, the overall water deficits are much lower. Scenario 4 which is a biomass based approach is an alternative approach that can tie both livelihood needs and sustainability needs, thus paving the way for rural revitalisation – both its economy and ecology. The approach is based on equitable access to resources. It assumes that a typical farmer family can either produce or get access to 18 tonnes of biomass (dry weight), then it can meet all its livelihood needs which include food,

fodder, fuel and recirculable biomass for the agriculture system. Over and above it also gives 3 tonnes of surplus biomass as cash income. Thus, under this scenario, there was an overall surplus of 3.78 TMC in Karjat taluka. The estimated surplus was mainly because of the exogenous water from the Kukadi project that is coming into Karjat taluka. However, Jamkhed taluka shows a deficit of 2.34 TMC as it is mostly rainfed.

Way forward

Chapter 5 details out the critical issues and presents strategies for sustainable management of water resources in the study area. The recommendations have been summarized as below:

Water use prioritization

The following hierarchy of principles should be followed for evolving allocation principles across states and sectors.

- First, *water for life*: providing adequate water of acceptable quality for meeting the drinking, cooking and sanitation needs of all the people and animals in the basin,
- Second, *water for the ecosystem*: ensuring adequate water flows and water in the river system for aquatic life and other ecological functions,
- Third, *water for sustaining livelihoods*: enabling productive activities while ensuring equitable use and protecting public health, and
- Fourth, *water for adaptation to change*: keeping reserves and margins for ongoing and future demographic, economic and land use changes and climate change.

Ensuring the access to the committed water from irrigation projects

The villages in the command area should get their entire quota of committed water. The measures that need to be taken are:

- To repair and make the existing defunct infrastructure functional
- Construct the planned but non-existent minors and field channels
- Bringing in technological innovations to improve irrigation efficiencies in both Kukadi and Sina irrigation projects. For example, installing closed piped systems for minor and field channels with volumetric flow measuring devices for better regulation of water supply

In addition to ensuring committed water, the following measures should be taken to ensure additional water security and overcome the observed deficit.

- Desilting of local water reservoirs for improving the storage capacity
- Promote area treatment, soil fertility management and improved agronomical practices for improving and increasing in-situ water (green water), especially in non-command and dryland areas
- Integrated water resources management strategy should be used to manage conjunctive use of exogenous, ground water and local surface water.

- Conduct a rapid technical survey with Participatory Resource Appraisal (PRA) at village level to understand the extent of watershed development and scope for improvement

Managing the demands:

There is a lot of scope to improve the water-use efficiency through demand side management at field level

- Promoting micro-irrigation practices for sugarcane and horticulture crops
- Adoption of better agronomical practices like mulching, inter-cropping, improving bio-soil fertility
- Promoting innovative agronomical practices like sustainable sugarcane initiative (SSI) to conserve water use for sugarcane cultivation
- A management system to regulate abstraction of groundwater through a participatory approach and pooling of resources.

Governance and institutional arrangements:

- In the command areas WUAs under the MMISF act, 2005 need to be formed
- Capacity building of the WUAs about the MMISF act, 2005 and their roles and responsibilities is needed to ensure institutional strengthening
- In non-command and dryland areas, Watershed Development Institutions need to be formed to ensure that there is regular maintenance of the assets and accountability

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Abbreviations

ACWADAM- Advanced Center for Water Resources Development and Management

ADT- Agriculture Development Trust

CB- Compact Basalt

CCT- Continuous contour Trenches

CD- Check dam

CNB- Cement nala bandh

ET- Evapotranspiration

FGD – Focused Group Discussion

Ft- Feet

GIS- Geographical Information System

GSDA – Groundwater Survey Development Agency

Ha - Hectare

HH- Household

IPEU- Integrated production cum energy generation unit

IWMP- Integrated Watershed Management Programme

JSA- Jalyukt Shivar Abhiyan

Kg- Kilogram

Km- Kilometer

Km²-Square kilometer

KT weir - Kolhapuri type weirs

LBC- Left bank Canal

LPCD - Litres per capita per day

m- Meter

M³- Cubic meter

MCft – Million cubic feet

MCM- Million cubic meter

MIS- Minor irrigation schemes

mm- Millimeter

MMISF- Maharashtra Management of Irrigation System by Farmers

MWIC- Maharashtra Water and Irrigation Commission

Panchayat gan- Constituency of Panchayat samiti

RL- Red Layer

SC- Scheduled Castes

SOPPECOM- Society for Promoting Participative Ecosystem Management

ST- Scheduled Tribes

T- Tonne

TMC - Thousand million cubic feet

VAB- Vesicular Amygdaloidal Basalt

WALMI - Water and Land Management Institute

WHO – World Health Organization

WUA- Water User Association

Chapter 1: Introduction

Ahmednagar district, situated in the central part of Maharashtra, is the largest district with a total geographical area of 17.41 lakh hectares (ha). The district is divided into 14 talukas. Karjat and Jamkhed talukas are located in the south region of the district having a total geographical area of 155,774.35 ha and 87,524 ha, respectively (Census, 2011).

The general climate of these two talukas is hot and dry. According to the agro-climatic zones of Maharashtra as defined by National Agriculture Research Project (NARP), the area comes under the Western Maharashtra Scarcity Zone (MH-6) (Central Research Institute for Dryland Agriculture, 2011). The average rainfall in Karjat and Jamkhed talukas is 573 and 636 mm, respectively. The average minimum and maximum temperatures for Karjat taluka are 13.7°C and 33.4°C and that for Jamkhed taluka are 18°C and 34°C. Both Karjat and Jamkhed are drought prone areas and receive good rainfall once in every 3-4 years. The two talukas are drained by the Sina River and its tributaries. Karjat and Jamkhed talukas are located in the Upper Bhima sub-basin of the Krishna river basin. Around 54 villages of Karjat taluka receive water for irrigation from the Left Bank Canal (LBC) of the Yedgaon dam of the Kukadi major irrigation project. Another 21 villages receive water from the Sina minor irrigation dam. However, these regions receive only about 30-40% of the allocated water from these two irrigation projects.

Geology

Regional geology

The broad regional geology of Maharashtra is dominantly a basaltic terrain covering major portion of the geographical area. The basalts are primarily horizontally disposed flows popularly termed as the 'Deccan Traps'. The other prevalent rock types are hard, crystalline metamorphic rocks which hosts Maharashtra's economic minerals. These are the oldest rocks in the region underlying the eastern districts of the state, namely, Nagpur, Bhandara, Chandrapur, Gadchiroli and Gondia. In addition to these, some recent deposits are found along major rivers basins as alluvial deposits and a few along the coastal regions as laterites.

District geology

The District Resource Map (DRM) published by the Geological Survey of India (GSI), 2001 was studied to understand the geology. The entire district forms a part of the Deccan Volcanic Province comprising of horizontal basaltic lava flows. However, the physical and chemical characteristics of these basalts vary from place to place making them locally diverse. One of the varieties is vesicular and amygdaloidal in character while the other is hard, compact and massive, devoid of any voids. Apart from the basalts, small linear bodies of recent alluvial deposits are found along river Godavari, Mula, Pravara and their tributaries.

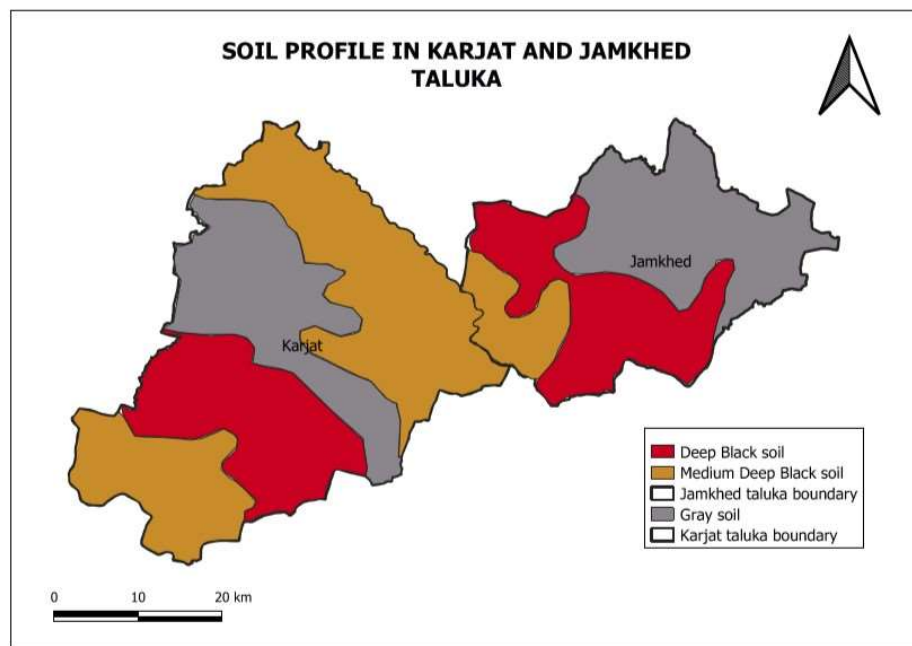
Other than the geological rock types, the structural pattern of the district also varies spatially; the north-west region is more structurally diverse compared to the other regions of the district. These structural features include faults, lineaments and dykes. There are two major lineaments- the Godavari Lineament and another one to the South-west of the district and numerous faults trending NW-SE in the western portion. However, the dykes have variable

orientations and are hard and compact as stated in the map. Both Karjat and Jamkhed form a part of the Deccan basalts which are primarily constituted of alternating units/layers of compact and vesicular varieties of basalts.

Soil

Generally the dominating soil type found in Karjat taluka is black cotton soil and that in Jamkhed is gray soil. Black soil has a higher water retention capacity.

Figure 1: Soil profile in Karjat and Jamkhed taluka



Demography

According to 2011 census, the population of Karjat taluka was 235,792 and that of Jamkhed taluka was 158,380. In Karjat, 14.4% of the total population belongs to Scheduled Castes (SC) and 1.4% belongs to Scheduled Tribes (ST). In Jamkhed the total SC and ST population comes to 13% and 1.4%, respectively. Based on 2011, the annual growth rate was estimated and the current population is projected at 266,823 for Karjat and 184,167 for Jamkhed. Around 80% of the population in the Karjat and Jamkhed talukas live in the rural areas and agriculture is the main source of livelihood.

Land use

According to the data received by the Revenue Department (2018-19) for Karjat and Jamkhed talukas, the total cultivable area for Karjat and Jamkhed talukas is 116541.67 ha and 71632.41 ha, respectively. This is about 78.5% and 86.5% of their respective total geographic areas. The non-cultivable area for Karjat is 31962.41 ha (21.5%) of which the forest area is 10478.94 ha (7%). Similarly, the non-cultivable area for Jamkhed is 11219.52 (13.5%) of which the forest area is 4025.14 ha (4.9%). In 2018-19 the total area in Karjat taluka under Kharif was reported at 65067.28 ha and that under Rabi was 66158.60 ha. That is about 56% and 57% of the total cultivable area in Kharif and Rabi season respectively. In Jamkhed

taluka the total area under Kharif was 57681 ha and that for Rabi was 27377 ha. That is about 81% and 38% of the total cultivable area in Kharif and Rabi reason respectively.

Cropping pattern

The major Kharif crops are bajra, maize, tur, moong, onion and cotton and the major Rabi crops are jowar, harbhara, groundnut and vegetables. Sugarcane and other horticulture crops like pomegranate, guava and lemons are grown throughout the year, especially in the years of good rainfall. According to the cropping pattern data received from the agriculture departments, approximately 74% of the crops are under cereals and food crops and 26% are under cash crops in Karjat taluka. In Jamkhed taluka around 92% of the crops are under cereals and about 8% are under cash crops. Groundwater is the main source for irrigation and also drinking water. Due to the climatic conditions, the wells usually dry-up by February and people are highly dependent on tankers and deep borewells for their drinking water supply.

Rationale of the study

As mentioned earlier, Karjat and Jamkhed talukas are drought-prone areas and receive very erratic and less rainfall. Both the talukas are highly dependent on external source of water, like tankers to fulfil their basic drinking and domestic needs. Further, in both these talukas, the number of borewells and dugwells are very high, showing the large dependence on groundwater for irrigation¹. Implementation of large watershed programmes, like Integrated Water Management Programme (IWMP) and Jalyukt Shivar has only helped to create large storage capacities to arrest rainwater, yet they have not been able to minimise the effect of drought. Agriculture Development Trust (ADT), Baramati approached Society for Promoting Participative Ecosystem Management (SOPPECOM) and Advanced Center for Water Resources Development and Management (ACWADAM) to do a water balance study for these two talukas. The main objective of the study was to derive water balance for Karjat and Jamkhed talukas based on secondary data and carry out detailed hydrogeological assessments of 4 micro-watersheds (two in each taluka). The study report shows water balances derived at the following scales:

- Water balance at the taluka level
- Water balance for command and non-command areas in Karjat and Jamkhed
- Water balance at the Panchayat Gan (cluster) level

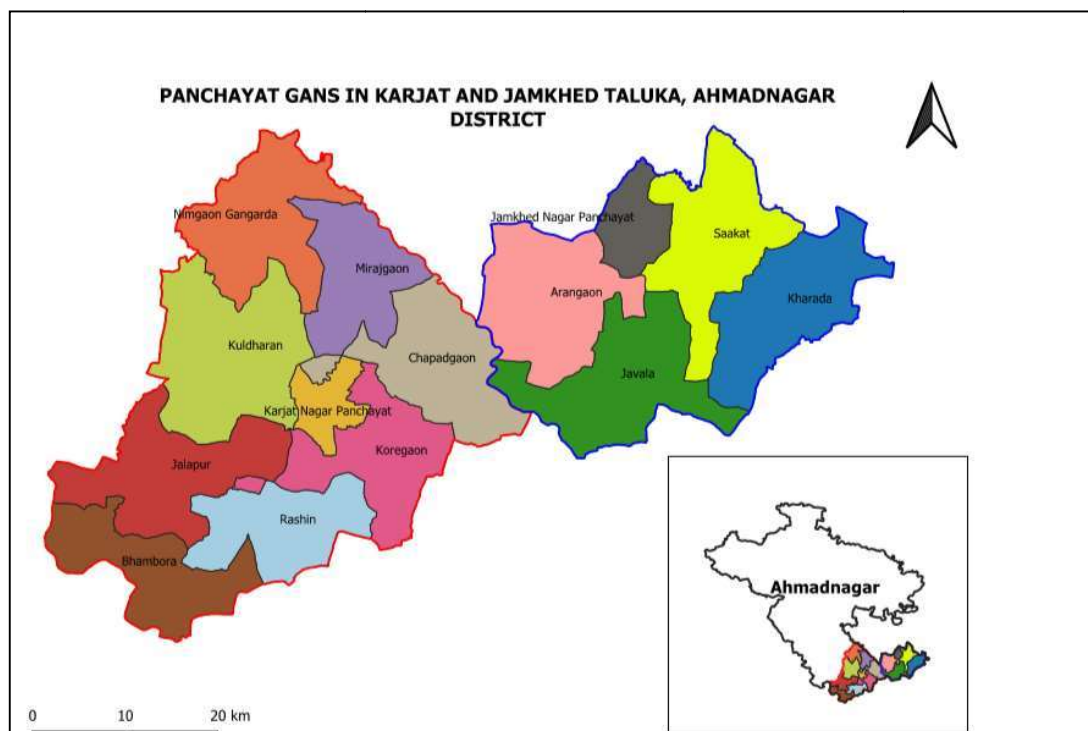
Study area:

The study area includes the entire Karjat and Jamkhed talukas (Figure 2) of Ahmednagar district. Karjat taluka has 120 villages and is divided into 9 clusters (Panchayat Gan²), namely Bhambora, Chapadgaon, Jalapur, Karjat Nagarpanchayat, Koregaon, Kuldharan, Mirajgaon, Nimgaon Gangarda and Rashin. Jamkhed taluka has 86 villages and is divided into 5 clusters, namely Aarangaon, Javala, Kharada, Nagar Panchayat Jamkhed and Sakat.

¹According to the 5th minor irrigation (MI) census, Karjat taluka has 11290 dugwells and 427 borewells, whereas Jamkhed taluka has 6381 dugwells and 86 borewells. However, field observations show that on an average, every household in Karjat and Jamkhed have one dugwell and 2 borewells.

²Panchayat Gan is the Panchayat Samiti constituency.

Figure 2: Study area in Karjat and Jamkhed talukas showing the different clusters



Command and non-command areas

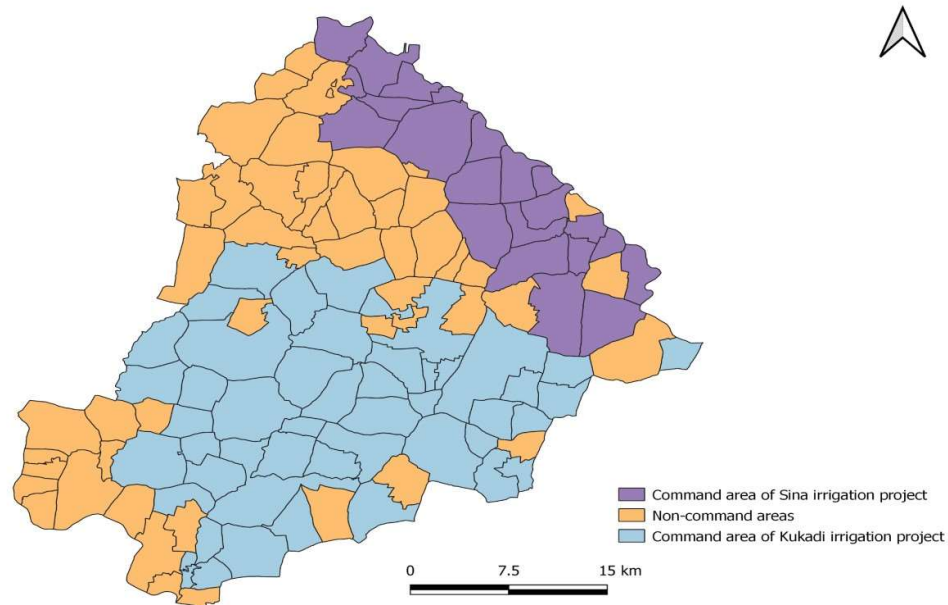
The Karjat taluka receives water from two irrigation projects, 1) Kukadi major irrigation project and 2) Sina medium irrigation project. The Kukadi major irrigation project irrigates about 144,912 ha through the combined storage capacities of 5 dams³ of 1114.7 million cubic metres (MCM) (39.366 thousand million cubic feet (TMC)). Of this, 141.58 MCM (5 TMC) of water is allocated to 54 villages of Karjat taluka to provide water for a culturable command area of 29,990 ha and irrigable command area of 28,028 hectares through the Left Bank Canal (LBC) of the Yedgaon dam. The total length of the LBC is 249 km of which 57 km (166 to 223 km) is in Karjat taluka. However, of the total allocated water, Karjat taluka receives only 42.47 MCM (1.5 TMC) (Executive Engineer, Kolgaon, Karjat).

The Sina dam was constructed in 1984 on the Sina River near NimgaonGangarda village in Karjat under the Sina medium irrigation project. The total storage capacity of the dam is 67.95 MCM (2.4 TMC) and irrigates total command area of 8445 ha. Of this 8445 ha, water is provided to irrigate a command area of 7672 ha in Karjat taluka (21 villages) and 773 ha in Ashti taluka, Beed district. The annual water allocated to Karjat taluka is 51.33 MCM (Sina Irrigation Dept, Mirajgaon). In most of the years the dam fills to only 40% of its capacity. Since the water in the Sina dam is not enough to meet the drinking water needs of the people, especially in the drought areas, the Bhoose Khind tunnel was constructed to transfer water

³The 5 dams constructed under the Kukadi complex are: Yedgaon and Manikdoh dams on the Kukadi river, Vadaj dam on the Meena river, Pimpalgaon Jog on the Aad River and Dimbhe dam on the Ghod river.

from the Kukadi LBC to the backwaters of the Sina dam. About 33.98 MCM (1.2 TMC) water is transferred only when the excess flood water remains in the canal for 36 days.

Figure 3: Map showing the command and non-command areas in Karjat and Jamkhed talukas



Jamkhed taluka is mostly a rainfed region. There is one medium irrigation project, namely, the Khairi Prakalp located near Satephal village and has a provision for irrigating 20,780 ha. However, currently the water is used only for drinking water needs of seven villages in the Kharda Panchayat Gan as only 40% of the dam usually gets filled. The total capacity of the dam is 15.11 MCM (0.53 TMC). Under the minor irrigation scheme, another 42.96 MCM has been created in Jamkhed.

Report structure:

The report is divided into total five chapters. Chapter one is an introductory chapter explaining the rationale and objectives of the study, the study area including the command and non-command areas, overall methodology used to derive the water balance and the hydrogeological assessments in the 4 selected watershed villages.

The second chapter details out the ground situation which is mainly observations and experiences of the people from the field visits. It highlights the issues related to drinking water and agriculture, the situation of the Water User Associations (WUAs) in the command areas, status of the physical structures and the extent of water and soil conservation works done. Chapter three details the hydrogeological watershed assessment done in the selected four villages. These include mapping of recharge and discharge areas, the present status of land use and the physical system in the villages and recommendations for further improvement/ implementation for the conservation of soil and water.

The fourth chapter is the water balance for the Karjat and Jamkhed talukas. It details out the components of the water balance and assumptions made to derive the water balances. Four different scenarios for the water balances are presented in the report. These are: a) Annual water balance for the year 2018-19, b) Water balance for bringing full Kharif and half Rabi area under irrigation, c) Water balance for bringing 30% of the cultivated area under irrigation and d) Biomass based approach.

Chapter five is the way forward which mainly summarizes the major insights from the study and lists the potential activities which could be taken up in the two talukas for ensuring the water security in these two villages.

Methodology

The study is mainly based on secondary data collected at taluka level and field surveys done in selected 10 villages. The objective of the field surveys was to understand the situation of water availability on ground. Field surveys included physical assessment of the watershed projects and the functioning of the irrigation systems, focus group discussions (FGDs) with the villagers to understand issues in the command and non-command areas and functioning of the WUAs if any.

Secondary data related to weather, surface water structures, groundwater, irrigation, cropping pattern were collected at the taluka level. Daily gridded rainfall data was collected from Skymet for 16 years (2003-2018). Similarly, Census 2011 data was used and projected to current year for demographic analysis. Data related to land-use and cropping pattern was collected for the years 2018-19. A more detailed list of the secondary information used for the study is mentioned in Annexure 1. After collection of the secondary data, the information was sorted cluster wise (9 clusters in Karjat taluka and 5 clusters in Jamkhed taluka). A simplified water balance method was used to derive the relationship between supply and demand and thereby assess the surplus/ deficit values for the total water available in the two talukas. The details of the components of the water balance and the assumptions made are explained in the Water balance chapter (Chapter four).

Detailed field visits were carried out in selected 10 villages (6 in Karjat and 4 in Jamkhed). In Karjat, Nimgaon Gangarda and Malthan were selected from the Sina command area, which represent the head and tail villages of the command area, respectively. Apart from understanding the water availability in the region and releases of water from the Sina dam, the other focus was to assess the functioning of the WUAs. Similarly, from the Kukadi irrigation command, Kumbhefal and Yeswadi were selected, which represented the head and the tail areas, respectively. In Jamkhed, Satephal village was selected as the Khairi medium irrigation project is located there and Aghi was selected as a village in the non-command area. Similarly, to make a detailed watershed hydrogeological assessment, Shiur and Sarola villages in Jamkhed and Rehekuri and Walvad in Karjat were selected. During these visits, FGDs with villagers were conducted to understand the water availability in the area for different uses, the existing cropping patterns, water resources in the area (wells, ponds, and tanks), watershed program implemented in the village and the demand of the people for water. Apart from discussions, the existing situation of the canals and field channels of the

irrigation projects were assessed. For the hydrogeological assessments, all the works done for soil and water conservation were assessed and geo-tagged. The field assessments helped to understand the ground situation, which was not reflected easily through secondary data.

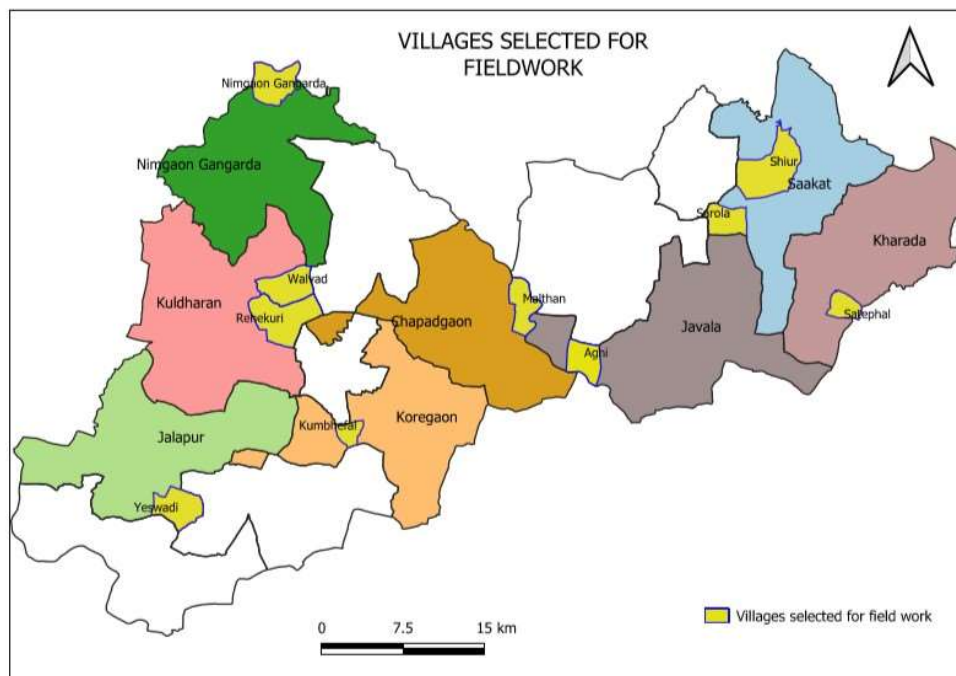
Limitations:

- Rainfall gridded daily data was available only for 16 years and long-term data (30 years) was only available at the taluka level. Although the gridded data was available for limited number of years, we used it as it gives information at the cluster level.
- Data for land use and cropping pattern was available for 2018-19. However, 2018-19 was a drought year and the information need not represent the actual situation during good rainfall years. For example, according to the data provided by the Agriculture department of Karjat taluka, the total area under Kharif cultivation for 2018-19 was only 55% of the cultivable area.
- Discharge data from the irrigation projects were not available. Therefore, water received by every village in the command area through these projects is based on assumptions.

Chapter 2: Issues in the command and non-command areas

As mentioned under methodology, total 10 villages (Figure 4) were visited for detailed assessment of the availability of water on ground, source of water, cropping pattern and to understand people's perspective on water. Some of the important field observations and consensus among the people regarding the availability of water, especially for irrigation are mentioned below.

Figure 4: Map showing the villages selected for the detailed field work



Status of the physical infrastructure of the irrigation systems

Kukadi command area

Karjat taluka receives water from the LBC of the Kukadi irrigation project and the Sina medium irrigation project, covering a total of 54 and 21 villages, respectively⁴. The left bank canal of the Kukadi irrigation project provides irrigation to 28,098 hectares for irrigation. However, as informed by the Executive Engineer of the Kukadi Irrigation project, this year only 30% of the allocated water was received and sometimes, the water provided is even less. Thus, on ground the entire command area receives only one rotation during the Rabi season.

Kumbheshal Panchayat, which falls under the head region of the Kukadi command area, was visited. The villages, Kumbheshal and Netkewadi fall under the jurisdiction of the Kumbheshal Panchayat. The Kukadi left bank canal and the Chilawadi canal passes through the boundaries of the Kumbheshal village. The village situated on a higher elevation does not come under the command area, but people are seen lifting water from the canal and thus

⁴Chapadgaon cluster receives water from both Kukadi and Sina irrigation project.

about 30% of the Kumbhefal village area is indirectly receiving irrigation from the Kukadi command. Netkewadi on the other hand comes under the command area and 80% of the village is under irrigation. Farmers in Kumbhefal lift water from the canals during the Rabi rotation and store them either in wells or large farm ponds (See Box1) through 2.5 to 3inch pipes. They do so to safeguard their Rabi crops and ensure an assured source of resource available for irrigation. Farmers stated that they directly lift water from the canal as they have difficulties in taking permission from the irrigation officials. The main canal passing through the Netkewadi and Kumbhefal villages was lined and in good condition. There were no major leakages reported. The farmers in close proximity of the canal had water in their wells. The main demand of farmers from Kumbhefal village was that they should be included in the command area and should be given permission to lift water.

Yeswadi village is one of the tail end villages of the Kukadi canal and they receive water through 4 minors of Distributary 15. The distributary is lined and the minors need repair. The gates at the minors were fixed by the irrigation department recently. However, the gates were stolen by some villagers. Some farmers got together and had temporarily fixed the gates for three minors. Farmers in Yeswadi usually receive one rotation during Rabi in the month of December. However, this year people were given prior intimation about the rotation period and it is expected that they shall receive one more rotation. The major demand of the farmers was to receive at least three rotations to secure their Rabi crop. The village has one large percolation tank which stores enough water to meet some of the irrigation needs. In Yeswadi, farmers used to earlier pay water taxes for the rotation, but have now stopped paying as water is not received on time. In both these villages, WUAs are neither formed nor proposed, however, farmers showed a keen interest in their formation.

Villages like Rehekuri and Walvad, although located in the Kukadi command area, do not receive water, as they are located slightly on a higher elevation. In these villages about 70% of the area is rainfed. Both these villages are to receive water from the Tukai Chara lift irrigation scheme, however, the works of laying down pipelines has been ongoing for many years now, and villagers informed that they do not see the scheme getting completed soon in the coming years.

Sina command area

The Sina dam is situated at Nimgaon Gangarda and was constructed in 1984. Sina dam lies in the low rainfall zone and therefore does not get filled to its full capacity of 67.95 MCM. In fact data provided by the Irrigation department shows that the Sina dam has filled only 16 times to its full capacity in the last 35 years. As per the Maharashtra Management of Irrigation System by Farmers (MMISF) Act, 2005, water should be distributed from tail region to head region. This is not actually happening on the ground. The dam usually gets filled only to 40% of its capacity, the rotations are very irregular and usually the villages in the head region of the command receive water once during the Rabi season. The last time when the entire command area received water was in 2008-09.

Nimgaon Gangarda, the first village to receive water from Sina dam, was visited by the study team. It was observed that the field channels and the minor canals were in poor condition and

needs immediate repairs. At many places the main concrete lining was missing and weeds were grown in many places. It was also reported that officials from the irrigation department do not come for regular visits to examine the condition of the physical irrigation system. A lot of water is extracted from the Sina reservoir, but there is no account kept on the volume of water extracted. Therefore many farmers have made private investments in pipes to lift water directly from the Sina dam, despite having canals passing through their fields. This year (2019-20) due to good rainfall, water was released from the dam into the main river. Since the village has an old KT weir (which was repaired recently under JSA), water was available for irrigation.

Malthan village (located in the tail end of the command area) receives Distributaries 4, 25 and 26 from the Sina project. It was hard to identify the minors in this village as they were filled with weeds, small bushes and trees. The field channels too were refilled with mud as villagers have not received water for the last ten years. When farmers were questioned about the current state, they informed that since the village has not received water, why should they bother about repairing them. Farmers also reported that people have constructed new wells in the canals in the hope of acquiring groundwater. Vincharna is another small river which passes through the village and here farmers have dug wells in the river bed for extracting groundwater. Interestingly, farmers showed great concerns about the river ecosystem and through agitations they have been able to stop the sand mafia from extracting sand from this river.

Figure 5: Picture showing the minor, which is literally invisible (marked with red arrow) in Malthan village, Karjat taluka



Box 1: Large investments in private lifts to withdraw water for irrigation.

The Yeswadi village in Karjat is located in the Rashin Panchayat gan (cluster). Apart from receiving water from the Kukadi canal, the village is located in close proximity to the Ghod river (~ 4 km away) and the Ujani reservoir (~ 10 km away). Totally 6 farmers from this village (having areas of more than 10 acres) have made large investments in laying 8 inch closed pipelines to lift water directly from the backwater of the Ujani reservoir. All these farmers have taken a loan of 1 to 1.5 crores for lifting water for their farms. These farmers have built large Farm Ponds (40×40 size) to store the lifted water and have taken crops like sugarcane and horticulture. The pumps generally operate for 8 hours when the electricity is available. Farmers in Yeswadi have also hired a pump operator who stays in the adjacent village of the Ujani reservoir for operating the pump. Data received on lifts from the Ujani reservoir confirms that there are about 762 such lifts by famers from seven villages in Karjat taluka.



Water lifted from Ujani reservoir and stored in Farm Ponds in Yeswadi, Karjat

Farmers in Kumbhefal village have constructed large farm ponds (around 40 in number) under the scheme ‘Magel Tyala Shettale’. The main purpose of building these farm ponds is to store and secure water for irrigation. When water is released for rotation during the Rabi season, water is illegally lifted from the canals and stored in farm ponds through pipes. Farmers are willing to pay for the water being lifted if they get it legally from the irrigation department. Creating additional storages like farm ponds have helped the farmers to cultivate cash crops like sugarcane, pomegranate, grapes and lemons. One farmer reported that to fill his farm pond, multiple pumps are operated non-stop for a period of 10 days which can provide assured irrigation to about six hectares of land. The cost for running the pump is about Rs. 1000 to 1500.



Water lifted from the Kukadi main canal and stored in farm ponds in Kumbhefal Panchayat

Big farmers who can afford large investments have found ways for securing water for irrigation through alternative means. Therefore, there is an urgent need to strengthen and manage the local irrigation sources immediately.



A huge farm pond under construction in Kumbhefal village

Command area in Jamkhed taluka

Jamkhed taluka has only one medium irrigation project, namely, the Khairi Prakalp which is located near Satephal village. The irrigation project provides irrigation to about 8-9 villages. Around 80% of its culturable command area receives water for irrigation through privatised lifts from the reservoir. The canal from the Khairi Prakalp is about 21 km long; however the villages located in its command area have not received rotations from the canals for the last 6 years. The reservoir gets filled to its full capacity only during a good rainfall year and permission to lift water is given only when the dam is filled upto 35% of its capacity. The reservoir is used to supply drinking water to the Kharda Panchayat located downstream, through a piped system.

Figure 6: A stream of pipes lifting water for irrigation from the Khairi Prakalp in Jamkhed. The Khairi project this year has enough water due to good rainfall year



Overall, it is observed that there is scope for improving the current physical infrastructure of the irrigation system. Most of the allocated water is not received and only one rotation is given during the Rabi season. With at least two more rotations, the farmers shall be able to get more crop acreage. It was also observed that there is lack of communication with the irrigation department regarding the time for rotation. The water is also distributed from head to tail rather than the other way around.

Status of the Water User Associations (WUAs)

The MMISF Act of 2005 gives the right to farmers to manage the irrigation water they are entitled to through formation of water user association (WUAs). As per the Act, WUA is responsible for the timely distribution of water for crops according to the demand of the farmers and collect appropriate water tax. They are also responsible for the overall management of water resources from the irrigation project. In the Sina medium irrigation project, efforts were made to form the WUAs. In Nimgaon Gangarda, proposals were sent to form WUAs for the minors 3 and 4. However, till date the process did not move forward and the farmers too have lost interest. Through FGD, it was observed that the farmers in Nimgaon Gangarda are neither aware of the rules of the MMISF Act, 2005 nor interested in the formation of the WUAs. On the other hand farmers of the Malthan village were keen in the formation and functioning of the WUAs. They even showed interest in knowing the rules and receiving proper guidance.

There are no WUAs formed in the Kukadi command area. The farmers in the Kukadi command are also not aware of what WUAs constitute of and how it can help to manage water in an efficient manner. Through formation of WUAs, there is scope for better management of the water resources and to bridge the gap between farmers and irrigation department.

Dependence on groundwater for irrigation

Groundwater is the major component for irrigation in the Karjat and Jamkhed talukas. Based on FGD and through field observations, it can be said that on an average every household has about one dugwell and 2-3 borewells. The depth of the borewells varies from 200 ft to 500 ft, especially in the Jamkhed taluka. Lifting water from the borewells and storing them in wells for irrigation is a common occurrence. Villages located in the head region of the command areas and villages in close proximity to the canals, have ample groundwater available for irrigation in a good rainfall year. Villages in the non-command area like Aghi in Karjat and Shiur and Sarola in Jamkhed are completely dependent on groundwater for irrigation.

Cropping pattern

The major crops grown in the Kharif season in Karjat and Jamkhed talukas are bajra, maize, tur, moong, soyabean, cotton and onion, whereas the main crops grown in the Rabi season are jowar and harbhara. Farmers prefer growing sugarcane during a good rainfall year and during the field study, it was observed that in areas close to the canal and dam sugarcane was a predominant crop. This is because many of the wells being in close proximity to these structures had enough groundwater available for irrigation. Farmers also reported that the area under sugarcane has drastically reduced due to continuous drought years. Many farmers, especially those that have larger area under agriculture and the amenities to make provision for storing water for irrigation, generally opt for horticulture crops and sugarcane as they have a higher return. In Sarola 25 farmers are currently spending Rs. 2000 per tanker to provide water for their horticulture crops like lemon, guava and *ber*. When farmers were questioned as to what kind of crops would be grown if they received assured water for irrigation, a majority of them reported that they will go for sugarcane

Drinking water situation in the villages

Drinking water is a major concern in Karjat and Jamkhed talukas. This field visit year (2019-20) although there was relatively good rainfall, wells have already started to dry up. Many villages, even in the command area reported that they are highly dependent on tankers for the drinking water supply. According to the official data, 67 villages in Karjat taluka alone have been dependent on tankers for drinking water for consecutive four years. Tankers usually start from March and continue till the onset of rains in a good rainfall year, whereas in drought years supply of drinking water through tankers starts from December- January. In 2018-19 drought years, tankers which were meant to supply water for cattle were used by the people also to access drinking water.

Villages like Malthan and Satephal have also reported salinity problem in drinking water, even at 150 feet, and hence villagers are dependent on water ATMs and private tankers for drinking water. Rehekuri village has a large percolation tank and water from the tank is pumped and stored in common well. Villagers have reserved this common well only for drinking purpose and hence there is not much scarcity reported. In Aghi, one can see a long queue for drinking water even in the month of January. Here there is a common borewell of the Gram Panchayat which releases water for half an hour after every two days in a common *haudh*. Kumbhefal and Yeswadi have no drinking water system. Sarola village in Jamkhed have already started getting water from tankers thrice a day for drinking water supply.

Figure 7: Drinking water scarcity had already started in Aghi village of Jamkhed taluka in the month of January



Works for water and soil conservation

Many water and soil conservation works were reported to be done under the IWMP and Jalyukt Shivar Abhiyan. For example, a cascade of five cement nala bandhs (CNBs) are built on a small *odha* in Aghi village and two CNBs were built in Yesawdi village. Most of the recently built CNBs are in good condition and were reported to be filled due to good rainfall. Works like CCT and Farm bunding are mostly concentrated in the ridge areas, where forest land is available. Farm ponds were built by many farmers to store water from the canals and groundwater.

Chapter 3: Watershed development: existing work and potential

Jamkhed and Karjat talukas being drought prone often face acute water scarcity and crop losses. While, Karjat receives some water from exogenous sources such as Sina and Kukadi projects, Jamkhed is entirely dependent on the local water – groundwater and local surface impounding- to meet its water requirement for agriculture and domestic needs.

Secondary data shows that local water harvesting through Jalyukt Shivar Abhiyan (JSA) and under various watershed development scheme existed prior to JSA is widely implemented in both the talukas and most of the villages are treated under JSA as the data below suggest

Table 1: Various soil and water conservation work done in Karjat and Jamkhed Talukas under Jalyukt Shivar Abhiyan

Taluka	No. of villages	Villages where JYS implemented	Compartment bunding (ha)	Nala deepening (no of works)	Cement Nala Bund (CNB) no.	Gabion (no)	Earthen Nala Bund (ENB) no.	Continuous contour trenches(ha)
Karjat	120	95	56759	856	75	-	184	354
Jamkhed	87	87	44172	565	261	250	146	880

Source: As per the data collected on Jalyukt Shivar Abhiyan at the taluka level

In order to understand the efficacy of local water harvesting along watershed lines and to what extent it has contributed to meet the water requirements, four villages, two each from both the talukas were selected for field assessment. They were selected from the rainfed areas and not having any access to exogenous water resources.

Table 2: Major land use in the selected villages in Karjat and Jamkhed

Name of the village	Taluka	Cluster (Gan)	Total Geographical area (in ha)	Land not available for cultivation (in ha)	Cultivable land including fallow (in ha)	Area under Kharif (2018-19) (in ha)	Area under Rabi (2018-19) (in ha)
Walvad	Karjat	Kuldharan	1324.32	249.47	1074.85	566.60	802.00
Rehekuri	Karjat	Kuldharan	2073.30	888.17	1185.13	680.00	697.00
Sarola	Jamkhed	Sakat	986.00	49.65	936.35	933.00	394.00
Shiur	Jamkhed	Sakat	2430.00	468.10	1961.90	14390	724.00

Source: Land revenue (Talati) and Dept. of Agriculture, Karjat and Jamkhed (2018-19)

Land use characteristic of a village/watershed is an important component for both planning and implementation of soil and water conservation measures. Except for Rehekuri village, which is part of the Rehekuri black buck sanctuary, three other villages have more than 80% of area under cultivable land. All villages except Sarola have good area under forest and other non-agricultural use. 2018-19 being a drought year not more than 60% of the area was under Kharif or Rabi cultivation in all four villages. This means that there is a need for better water resource conservation and management so that protective irrigation is available at least to overcome the water stress in the initial phase of the Kharif season

Present status of watershed development and potential for additional work

There was substantial water conservation work done in all the four villages under various schemes. Jalyukt Shivar intervention was undertaken in all the villages under which nala deepening and desilting of CNB was done. In few instances new CNBs were constructed and in Rehekuri village, extensive area treatment was undertaken. Now we look into the details of the work done in each village and its current status.

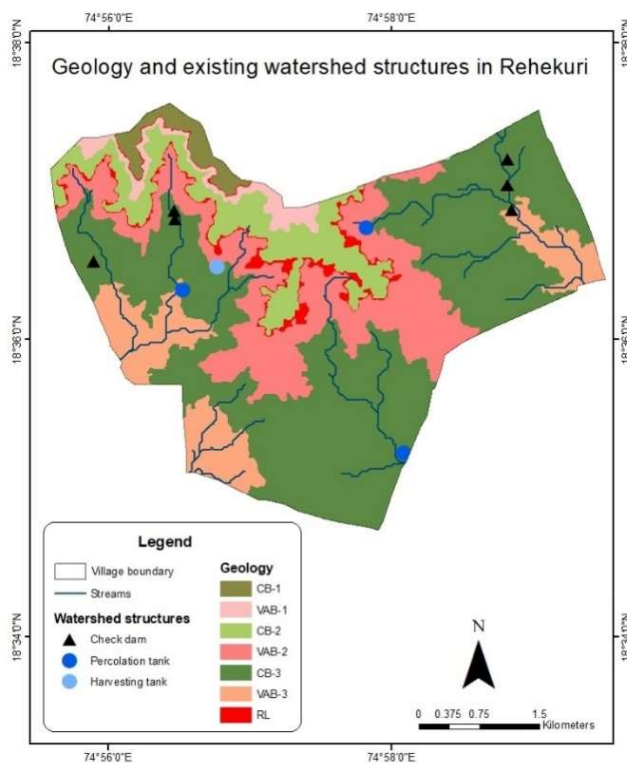
Watershed village 1: Rehekuri

Rehekuri in Karjat Taluka is an upstream village consisting of four different micro watersheds. The total area of the village is 2073 ha of which around 700 ha is forest, which is part of the Rehekuri sanctuary. The forest mostly is covered under sparse vegetation. There are around 200 ha of area which is uncultivable wasteland mainly with rocky terrain.

A total of six geological units were mapped between 661 m and 610 m in Rehekuri (Figure 8). On the hill top to the west a highly fractured and jointed Compact Basalt (CB1) is exposed. This hill top is a southward extension of the ridge in Walvad where the same rock unit is seen exposed. The three CB units are thick and are vertically fractured. Vesicular Amygdaloidal Basalt (VABs) on the other hand is thin and weathered showing the presence of horizontal sheet joints and calcretisation. The two VAB units underlying the red layers are oxidised as compared to VAB3. Units other than CB1 and VAB1 are mapped on the basis of well sections and few weathered surface exposures due to a flat topography and lack of surface rock exposures.

Based on the field observations and flow of groundwater measured in selective wells, there are at least three aquifer systems that underlie Rehekuri. These three aquifers comprising of VAB and fractured CB are accessed by nearly 70 dug wells.

Figure 8: Geology and existing water structures in Rehekuri, Karjat taluka

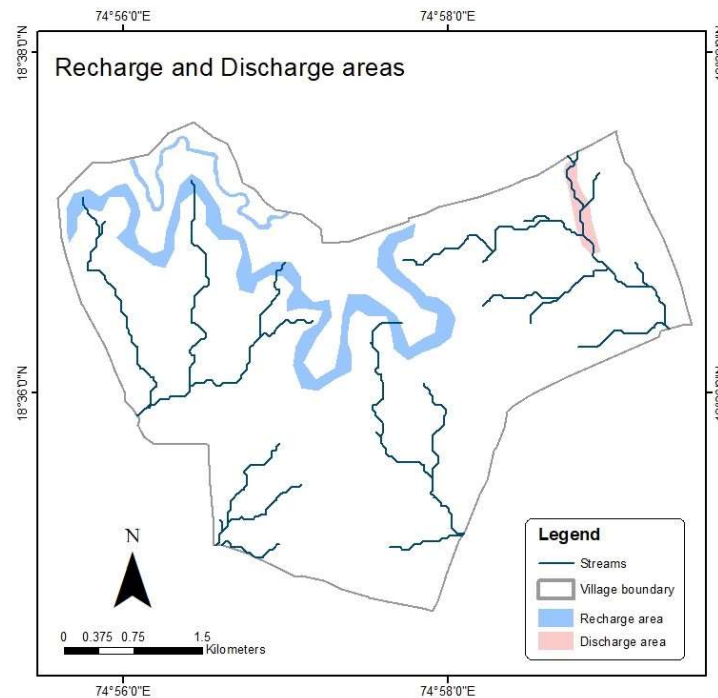


Watershed treatment under JSA is undertaken in the village and two micro watersheds are being treated. The work includes farm bunding in around 500 ha, repair and heightening and desilting of three CNBs (check dams) in one of the micro watersheds.

The CNBs after repair and desiltation has improved the water harvesting potential of the structures. This has benefited in increasing the water availability of the riparian farmers in the micro watershed. Farm bunding undertaken is of good quality with sufficient height and width (1 m³ cross section) in most locations.

Besides these there are three check weirs (one is a KT weir) and four percolation tanks (PT) in the village. All these need repair and desilting while one of the tanks located in the forest area in the sanctuary is desilted but without any water impounded. The PT which is located near the well which supplies drinking water to the village and one adjacent to that still have water and villagers say it needs to be desilted. One of these CNB is repaired under the JSA through a spending of Rs. 227,000 (as per the display board on the site) but has not served any purpose as there is a breach through the nala bank.

Figure 9: Recharge and discharge area in Rehekuri



Based on the geology and water levels, two recharge zones and one discharge zone has been identified. The recharge areas lie on top of the VABs while the main discharge zone is along the river that flow down into the tank located in the downstream village of Bahirobawadi. Overlay of the watershed structures on the geological map shows that two of the three percolation tanks are located on top of VABs. The third one located at the southern boundary of the village is underlain by fractured CB3 and VAB. All the check dams are underlain by CBs.

There is additional scope for work especially for area treatment and gully stabilisation work. There is not much area treatment done of the recharge locations in the micro watersheds. Area treatments like deep CCTs, recharge pits, etc. in waste lands and the forest area, contour bunds/ compartment bunds in the remaining cultivated lands along with gully treatments (both stone and earthen gully plugs) would help in arresting the runoff and recharging the groundwater. The vast area under forest which has partial vegetation and better soil profile needs to be brought under soil and water conservation which can immensely help in recharging the groundwater.

The drainage in the recharge area is not very deep but there is scope for water harvesting through earthen nala bunds (ENB) and gabion structures. Loose boulder structures also have potential in the locations. An integrated planning for soil and water conservation is required taking into consideration the existing works and the potential.

Watershed village 2: Walvad

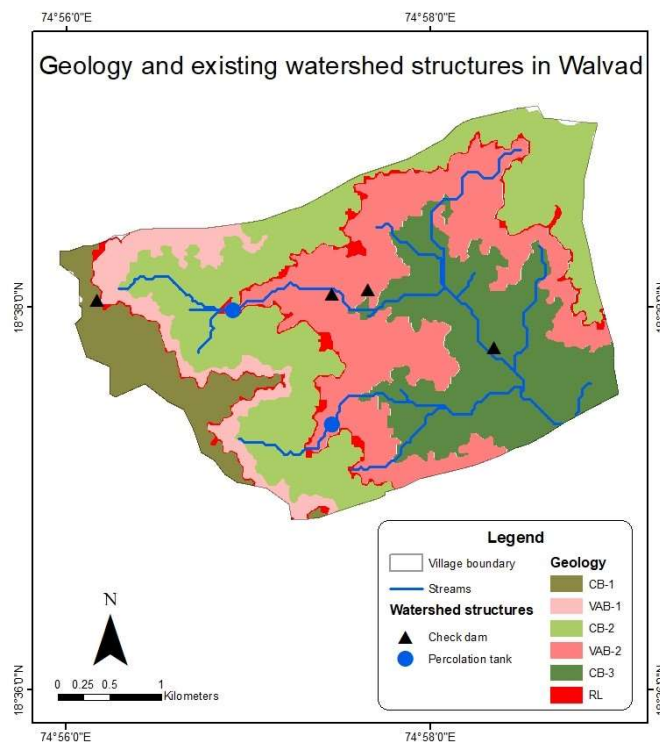
Walvad is also an upstream village near to Rehekuri in Karjat taluka. Walvad village spread over an area of 13 km² is drained by the Kanawala stream. The river originates in the west of

the village at an elevation of 692 m and flows eastward into the Bahirobawadi tank. Walvad has around 135 ha of forest land and another 100 ha of wasteland while the remaining 80% of area is under cultivable land. Walvad is a single outlet watershed where the watershed boundary and village boundary mostly match.

Geological mapping in Walvad showed the presence of five flow units over an elevation difference of 74 m (Figure 10). Compact Basalt (CB)1 and CB2 exposed in the higher elevations, are vertically to sub-vertically fractured while CB3 is relatively hard. The average thickness of the CBs varies from 10 m to 20 m. The Vesicular Amygdaloidal Basalt (VABs), on the other hand, shows the presence of sub-horizontal sheet joints and is 5-7 m thick. The alternating sequence of CB and VAB is interrupted by two red layers, which separate CB1 and CB2 from the underlying VAB units.

Based on the subsurface geological units and groundwater flow, at least three aquifer systems can be identified in Walvad. These aquifers comprise of a combination of VAB and fractured CB, which are tapped by more than 100 dug wells and numerous bore wells.

Figure 10: Map showing existing watershed structures in Walvad, Karjat taluka



There is partial treatment of the watershed under different schemes. Farm bunding was done almost 10 years back (most probably under Hariyali) while under the JSA, three CNBs were constructed while some area under CCT is also being taken up. Around one and a half kilometre of the river was also deepened under the JSA

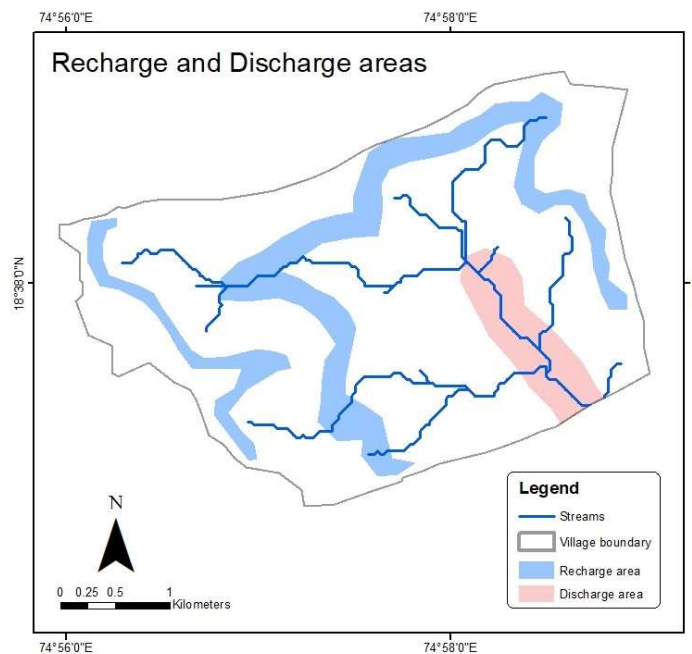
Overall there are four CNBs and two percolation tanks (PT) in the village. Area treatment is very limited, especially compartment bunding on cultivable lands. All the four CNBs including the three new ones under the JSA are of poor quality. The CNBs constructed under

the JSA has leakages as per the villagers and water hardly remains for a month in the structures but some water gets harvested in the deepened nala. Two PTs do harvest some water and help in recharging the nearby wells.

Overlay of the watershed structures on the geological map shows that both the percolation tanks are located on top of VAB2. Community discussions has revealed that dug wells located to the downstream of the percolation tanks dry up a month later, that is, by April than the other wells. Although there has been significant watershed intervention, the village is facing drinking water scarcity, which is met with water tankers for the last decade.

According to the community, the stream in the upper reaches runs dry by the month of November, while in the lower elevations the streams and dug wells dry up by February or March. The percolation tank to the west, similarly, dries in the month of February or March while the other to the south dries up as early as November.

Figure 11: Recharge and discharge areas in Walvad, Karjat taluka



Based on the geology and water levels, two recharge zones and one discharge zone has been identified. The recharge areas lie on top of the VABs while the main discharge zone is along the river that flows down into the tank located in the downstream village of Bahirobawadi.

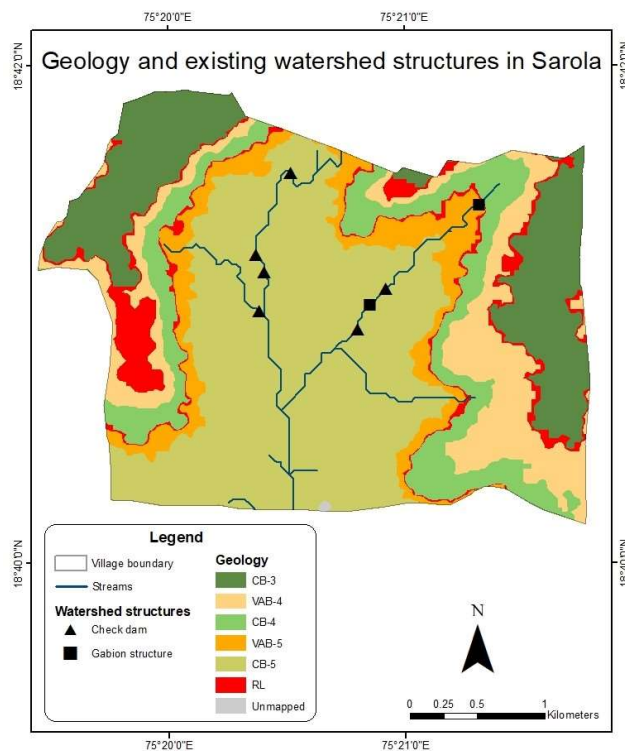
There are some measures both on recharge as well as discharge areas. There is scope for area treatments like deep CCTs and percolation pits on forest and uncultivated wastelands and compartment bunding on farm lands. Around 60% of the cultivated land requires new farm bunds/ compartment bunds or strengthening of the existing bunds. On the first order drainage gully stabilisation works like gully plugs, loose boulder structures could be planned followed by earthen nala bunds, gabion structures etc. There are couple of locations in the discharge areas where CNBs could be planned. Existing structures which are defunct needs to be repaired. PTs could be desilted and silt can be applied in the farm lands

Watershed village 3: Sarola

Sarola is comparatively a small village of around 1000 ha. Most of the land is cultivable while only around 86 ha is classified as non cultivable land. Two main streams drain from Sarola village. One originates in village Katewadi, located to the north of Sarola, while the other stream originates from the north-east of the village. They both converge near the village habitations and flow southwards. Thus it is single outlet watershed.

Five basalt flow units – Three Compact Basalt (CBs) and two Vesicular Amygdaloidal Basalt (VABs), could be mapped in Sarola. CB5 is exposed in the main valley region of the watershed. Apart from the five units, there are two red layers, separating CB3 and VAB4 and another between CB4 and VAB5. Two or three shallow aquifer systems underlie the village, constituted of VABs and fractured CBs. Relatively thick units of CB separate the aquifers from each other.

Figure 12: Geology and existing watershed structures in Sarola, Jamkhed taluka

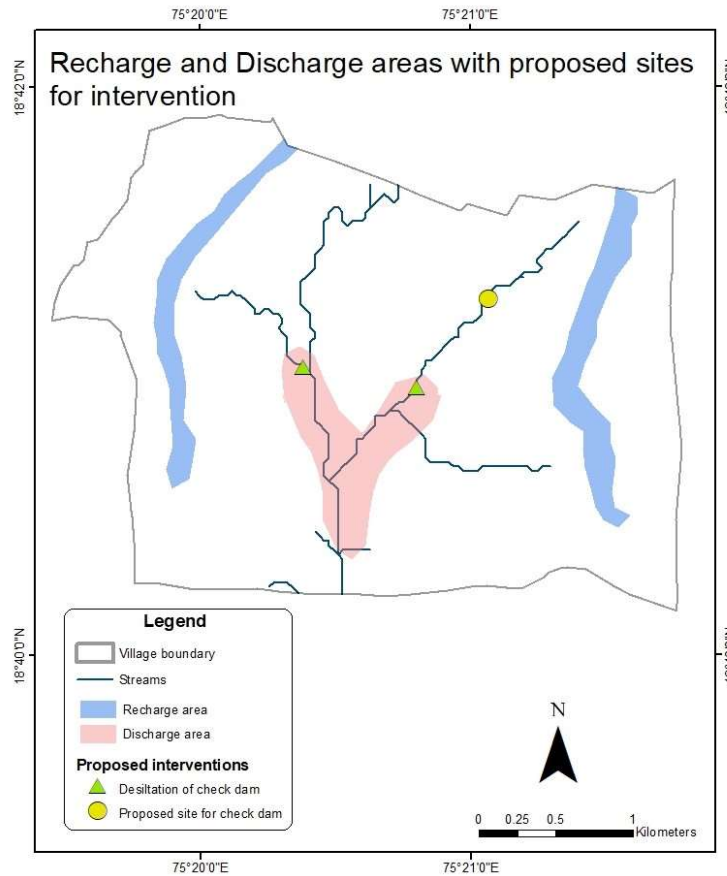


There is partial treatment of the watershed and most of the work is concentrated on the main drainage system that flows from Katewadi village and the other drainage originating from the north-east side of the village where the drinking water source is located. There are six CNBs and two gabion structures on these two drainages

There are four CNBs on the main drainage originating from Katewadi. Three of them are built under the JSA while one is an old masonry cement dam which requires repair. The other three are new and in good condition. Around six km of this drainage has been deepened and desilted. There was still water in this drain which the nearby farmers benefit from. Overall the quality of the work is good.

On the other drainage there are two CNBs and two gabions with core wall for water harvesting. Both the CNBs have very little water column unlike the other ones. Gabion structures are of good quality. The well which supplies drinking water is located in the downstream of the 1st gabion. There was demand that a CNB should be constructed near the well so that it can recharge the well. However the location is on the farm land road which is used by many farmers. This area also has around 70 ha of land owned by the *Devasthanam* and plantation is undertaken there through the gram panchayat.

Figure 13: Recharge and discharge areas for Sarola, Jamkhed taluka



There is hardly any location left for major drainage line structures as it is mostly covered where ever there were appropriate sites available. The location which is marked in the above image is the one mentioned earlier that could help in recharging the drinking water well. But it needs negotiations and consensus as it could block the farm road.

There is scope for area treatment such as CCTs and deep CCTs, gully stabilization work using gully plugs of stone and earthen variety and loose boulder structures. On the recharge areas earthen nala bunds could also be undertaken that could help in groundwater recharge. Farm/compartments bunds of sufficient cross section is required in most cultivable areas and could help in in-situ conservation. What is required is a comprehensive planning for soil and water conservation.

Watershed village 4: Shiur

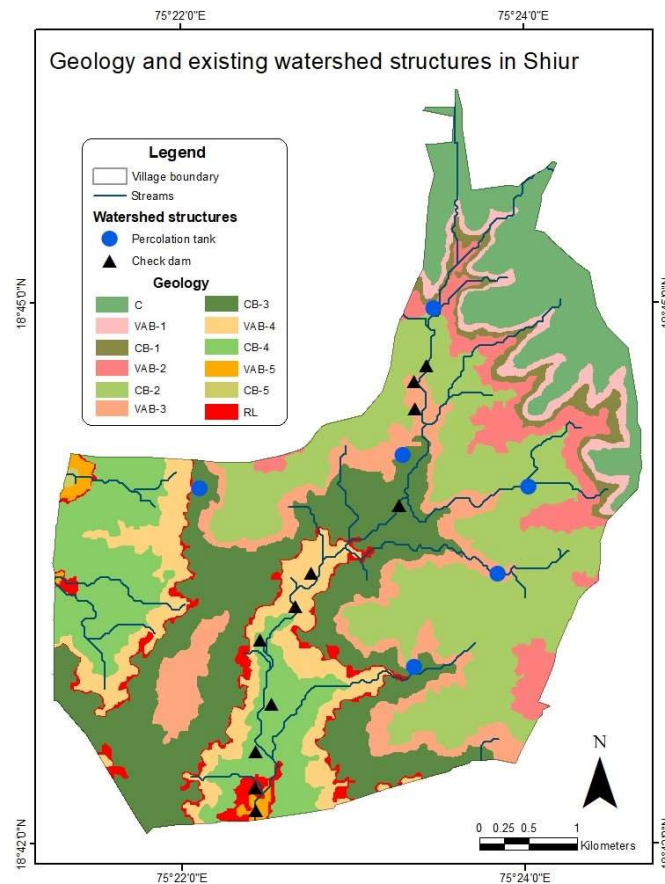
Shiur is located in Jamkhed Taluka. It is large village of around 2400 ha of which around 350 ha is under forest and another 100 ha is wasteland. The geology of the village reflects 11 distinct basaltic rock units. The topmost unit to the north is a compound flow and the remaining constitute of 5 units each of Compact Basalt (CB) and Vesicular Amygdaloidal Basalt (VAB). There are two red layers exposed in the village, one separates CB3 from VAB4 and the other CB4 from VAB5. Most of the VABs show the presence of horizontal sheet joints while the CBs are vertically to sub vertically fractured. The VABs and a small portion of fractured CB together constitute 2-3 main aquifers in Shiur.

Figure 14: Cement nala bandh built under the Jalyukt Shivar Abhiyan in Shiur, which is of poor quality, CNB has no apron and has leakages in the main body



There have been works done under both, IWMP and JSA in Shiur. Watershed works under IWMP were done in 2012. Under IWMP five CNBS were built and deep CCT work was carried out. Under JSA, 3 km of the Kanadi River, that runs through the village was deepened and two CNBs were built by the agriculture department. Altogether there are nine CNBs and two KT weirs on the main Kanadi River. Most of these structures are of poor quality and needs repair. While the old structures like the KT weir are not functioning, the new structures built under IWMP and JSA is also of poor quality.

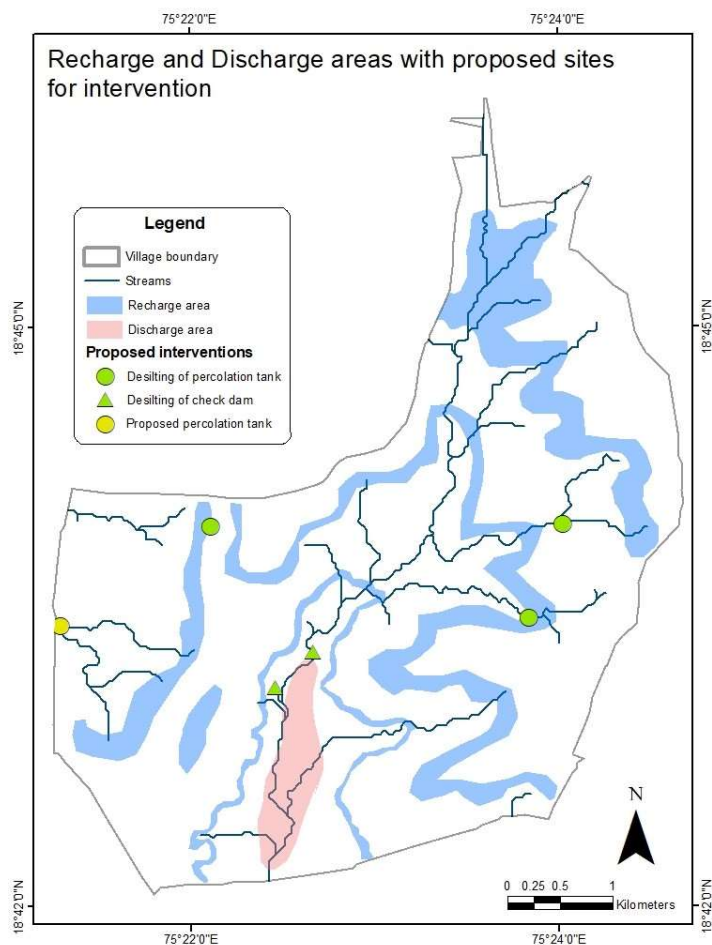
Figure 15: Geology and existing water structures in Shiur, Jamkhed taluka



Besides this there are six percolation tanks and most of them are desilted. The Waghjai tank was desilted through mobilising funds by villagers. Villagers want an additional desilting and deepening of this structure that can help in recharging a large number of wells located downstream. The three main percolation tanks from north to south are Ghatewadi, Basarwadi and Waghjai which are all located on the VABs or fractured CBs, thus recharging the underlying aquifers. Despite the presence of several check dams and percolation tanks, a large proportion of the wells are reported to go dry by the month of March. There is a well on the Basarvadi tank from where water is supplied to the village through pipeline.

The drainage that continues from Waghjai tank and joins the main Kanadi river downstream does not have any water harvesting structures. The villagers are of the opinion that additional work should be done on this drainage for water harvesting and also suggested two appropriate sites.

Figure 16: Recharge and discharge areas in Shiur, Jamkhed taluka



As the drainage is mostly saturated with water harvesting structures and most of the percolation tanks are located in the recharging zones the option for additional work is in terms of area treatment of both forest/wasteland and cultivable lands. Percolation pits and deep CCTs along with gully stabilization work and farm/compartments bunding of high cross section in low class land where no bunding activity is taken could be planned and implemented.

Many of the existing structures have already been desilted to some extent under different government schemes. However, it could be further desilted by a foot or two to enhance infiltration capacity. While doing so, precaution must be observed as it may result in removal of the aquifer itself.

During the field visit, one new site for a percolation tank was proposed by the community. The location of the tank is correct as it is underlain by VAB. However, since this site is located at the boundary of Shiur village, benefits of this tank will accrue the neighbouring village located to the downstream.

Learnings

- All the four villages taken up to understand the watershed development outreach and impacts shows that various programs are implemented including the latest scheme JSA. However, there is far more concentration of drainage line treatment and only in case of Rehekuri there is substantial area-based conservation works
- The quality of work is very mixed. Most of the CNBs constructed are of poor quality while the PTs which are of very old schemes in some cases require maintenance and repair. The drainage deepening and desilting of CNBs and PTs has helped in harvesting some amount of runoff.
- Villagers report that even though the work has helped in groundwater recharge, water in wells remain till the month of February if the rainfall is good. Otherwise by November the wells start drying up. Drinking water shortage is felt in all villages. Some of the villages last year had year round scarcity except for a couple of months after monsoon.
- Water scarcity in these rainfed villages is a result of both over draft and low rainfall. All villages have above 300 dug wells on an average and a large number of borewells also. Horizontal boring is also found to be very common.
- It is important to move away from a drainage centric approach to an integrated approach to soil and water harvesting and vegetation development. A ridge to valley approach, with the consideration of the underlying hydrogeological setup, is required
- Watershed planning based on net plan/resource mapping – both surface and groundwater resources could help in not only optimal conservation but help in building the stakeholder perspective and ownership. It is important to manage the demand side issue of water use. Comprehensive water budgeting and crop planning, technology for water savings and institutional mechanisms of water management could be facilitated among the users.
- At present no institutional mechanism is found in place for maintenance of the assets created. Water user groups around the structures could be thought about. This would mean a different approach and strategy than what is being pursued under JSA

Chapter 4: Water balance as per different scenarios

Concept of water balance

The water balance is based on the hydrological cycle. The main components of the water balance in the non-Himalayan systems in India are rainfall, surface runoff, infiltration, groundwater storage and discharge as base flows, evaporation and evapotranspiration. The water balance is the sum of the total amount of water leaving and entering the system. In the simplest form the water balance equation is expressed as,

$$\text{Inflow} = \text{Outflow} \pm \text{Change in the Storage} \quad \dots\dots \text{Equation 1}$$

However, equation 1 has to be expanded to understand how each of the components of the hydrological water cycle fits within it.

The expanded water balance equation is,

$$\text{Precipitation} + \text{External water coming into the region (Groundwater} + \text{Surface water)} = \text{Evapotranspiration} + \text{Evaporation from surface storages} + \text{Domestic and Livestock water use} + \text{Industrial Water Use} + \text{Runoff} + \text{Change in the surface and groundwater storage}$$

$$\dots\dots\dots \text{Equation 2}$$

Each component of the water balance in Equation 2 is described in Table 3

Table 3: Components of the water balance

Inflow/ Input	Outflow/ Output	Change in storage
<ul style="list-style-type: none"> • Rainfall • External water from surface storages • External water coming from groundwater • Return flow from different uses 	<ul style="list-style-type: none"> • Evaporation from surface storages (reservoirs, ponds, lakes etc) • Evaporation from saturated soil • Evapotranspiration from cultivated land • Evapotranspiration from non-cultivated land (forests, shrub lands, pasture land, grazing land etc) • Drinking water use • Water for Livestock • Industrial water use • Water flowing out from the watershed 	<ul style="list-style-type: none"> • Change in the volume of water stored in surface storages • Change in the volume in the groundwater storage

For this study, the water balance has been derived at;

- Taluka level
- Cluster level (Panchayat Gan)
- Command areas in both the Talukas
- Non command areas

The water balance was derived at the above mentioned scales considering four different scenarios as follows:

- Annual water balance for the year 2018-19 based on the data available for the year.
- Water balance under the scenario where irrigation would be provided for 100% Kharif and 50% Rabi crop above in-situ water as recommended by the Chitale Commission report (1999)
- Water balance under the scenario where assured irrigation would be provided for 30% of the area in both the seasons
- Water requirement for biomass based approach for securing livelihoods.

The following sections will describe how each component of the water balance was determined.

Rainfall analysis

For the rainfall analysis we used gridded data for Karjat and Jamkhed (daily rainfall from 2003- 2018) from Skymet. This is a spatially interpolated rainfall dataset. This data set was used as it takes into consideration the differences in the distribution of the rainfall in different clusters within the talukas. Annual rainfall values were calculated for each cluster in both the talukas from 2003- 2018. The average annual rainfall value was used as basis for deriving the water balance for the first two scenarios. For the biomass based scenario, 75% dependable rainfall values were used while for scenario one the actual rainfall received during 2018-19 was factored

Surface runoff analysis

When a watershed receives a certain amount of rainfall, a part of that rainfall infiltrates into the sub-surface and the remaining water flows over the surface and is termed as surface runoff. Surface runoff is dependent on the geomorphological factors i.e. soil type and depth, land use and slope. A part of this runoff can be captured through either area or drainage treatments in the watershed. There are a number of methods for determining surface runoff. For this study we have used the Strange's method⁵. The rationale for using this method was that after comparison of different empirical methods to estimate runoff, the Strange's method gave us the closest approximation of the runoff estimate for our study area based on our field experience. The Strange's method prescribes a dimensionless runoff coefficient which is a function of the slope, categorized as less than 5%, between 5% and 20% and greater than 20%, depending upon the rainfall. The total volume of the runoff in thousand cubic meters (TCM) can then be determined by multiplying the area in hectares with the runoff coefficient. The detailed calculations for the runoff are given in Annexure 2.

Calculation of the in-situ water utilized for evapotranspiration (ET)

In-situ water component is the water present in the soil as soil moisture that it used by the plants. Of the in-situ water available, most of the water is released as evapotranspiration (ET)

⁵Strange's method is generally used by the Government of Maharashtra for estimation of runoffs.

by the vegetation which is dependent on the climatic conditions like rainfall, temperature, humidity, wind speed and type of vegetation. Since we did not get a reliable evapotranspiration data for the study, we have assumed ET as percentage of the rainfall for different land uses as below:

ET for non-cultivated lands

We have assumed that the in-situ water that gets utilized from non-cultivable land is around 20% of the precipitation. Field experience for this agro-climatic zone shows that in most rurals non-cultivable lands which include built-up or barren land are very small compared to cultivated lands and mostly do not have thick vegetation and hence in-situ moisture from soil mostly gets evaporated.

ET for fallow land

The in-situ water utilized on fallow land has been assumed to be around 30% of the precipitation. Though fallow lands do not have crops growing on them they do have smaller vegetative growth and stocks of crops and hence have slightly higher water utilization compared to non-cultivable lands.

ET for cultivated land

For cultivated areas, ET is the function of the crop taken and water available for growth. The pan India averages for ET is in the range of 40-60% of the total precipitation. For this study we have assumed that 50% of the in-situ water is utilized by the cultivated lands for their growth and ET.

Estimating crop water requirement

Crop water requirement was determined based on the norms prescribed by Water and Land Management Institute (WALMI) (CTARA, IIT, 2018). The WALMI norms prescribe how much water is required by a particular crop for its entire growth period which includes the water for evapotranspiration depending upon the agro-climatic zones in Maharashtra. For this study the minimum crop water requirement value has been used. From the crop data received in Karjat and Jamkhed, the Kharif and Rabi crop water requirements were determined for the major crops in the respective seasons. Since the crop data available was for the year 2018-2019, which was a drought year, we determined the crop water requirement per hectare and used this value to estimate the water demand for agriculture during a year of average rainfall.

Estimation of drinking water and livestock use

The census data was used to determine the total population in both the talukas at cluster level. The 2001 and 2011 census data was used to determine the decadal growth. The decadal growth was used to project the population to the current value i.e. for the year 2020. According to official guidelines by the Central Government of India the minimum drinking water norm for rural areas is 55 litres per capita per day (lpcd). According to World Health Organization, the per capita per day water norm is 50 – 100 lpcd. We have used the higher bound of 100 lpcd for this study.

Similarly, a norm of 35 lpcd was used to determine the total water requirement for livestock as prescribed by the National Commission on urbanization.

Estimation of the water available through local surface storages

From the field work and secondary data it was seen that though there have been local harvesting structures created through different watershed programs, the actual storage of these local structures is only 30% of its capacity. Thus the water available locally was considered as the 30% of the total capacity of the local surface storages.

Estimation of groundwater availability

The groundwater balance for the blocks of Karjat and Jamkhed was estimated using block level data provided by the Groundwater Survey and Development Agency (GSDA, 2017). Based on the data provided by the GSDA, the following formula was applied to arrive at the quantity of annually replenishable groundwater:

$$\text{Annually replenishable groundwater (m}^3\text{)} = \text{Area (m}^2\text{)} \times \text{WL}_f\text{(m)} \times S_y$$

where,

Area was computed using GIS,

WL_f is the annual water level fluctuation as per the GSDA dataset, and

S_y is the specific yield which was arrived at based on the values provided by GSDA, ACWADAM's experience of working in the basaltic aquifer systems spread across the state of Maharashtra and some basic observations during the field visits.

In the case of Jamkhed, a specific yield of 0.005 and for Karjat 0.01 was considered to represent values closest to those commonly observed in such aquifer systems, although the average values by GSDA for the basalts in both the districts is a slightly higher, 0.02. For basalts, values of about 0.02, basalt with high degree of weathering and fracturing – with very productive aquifers – are observed. Most areas in Karjat and Jamkhed are less weathered, fractured and are often of lesser thicknesses than aquifers in more productive regions.

For the groundwater recharge at the cluster level, area of the respective clusters was used, leaving all the other values unchanged.

Similarly, for estimating the total groundwater abstraction at the block and cluster level, a percentage of 90% was applied to the volume of groundwater recharge. According to the GSDA (2017), this is 62.5% and 62.37% for Jamkhed and Karjat respectively. However, based on the significantly high number of groundwater structures, primarily dug wells, which form the main source of irrigation and drinking water, it is estimated that close to 90% of the replenishable groundwater is utilised in the two blocks. The same principle was applied for the clusters.

We have not taken into consideration return flows from different uses, especially agriculture because at taluka level they do not have a significant effect on the overall water balance.

Water Balance for Karjat and Jamkhed taluka:

The following sections will show how the water balances work out under each scenario. Only the summary for the water balances have been presented. The detailed tables and the calculations have been shown in the Annexure 3

Scenario 1: Annual water balance for 2018-19 year based on the data available for that year.

The scenario represents the annual water balance for the year 2018-19. Since 2018-19 was a year of very poor rainfall, the scenario was derived to understand the water availability and use during periods of low rainfall as cropped area reduces during the years of low rainfall compared to the years when the rainfall is average or above average. The assumptions for deriving this scenario are as given below:

Assumptions:

Rainfall: Annual rainfall values for the year 2018-19 for each cluster used from the Skymet data

In-situ water utilization: It is assumed that 20%, 30% and 50% of the total volume of rainfall is utilized for the evapotranspiration from non-cultivated areas, fallows lands and cultivated areas respectively

Total cultivated area: Actual cropped area in Kharif and Rabi season as obtained from the Agricultural Departments in Karjat and Jamkhed taluka.

Cropping pattern: Actual data on crops (including area under each crop) obtained from Agriculture Departments in both the talukas

Water available from local surface storages: It is assumed that volume of water available from local surface storages is only 30% of the total local storage capacity

Water from Kukadi irrigation project and Sina irrigation project: The entire committed water from Sina and Kukadi projects (192.33 MCM) is considered as the exogenous water available to the command areas of the respective projects.

GW abstraction: It is assumed that the amount of groundwater available for use is 90% of the total annual recharge. The total annual recharge has been calculated on the basis of the specific yield in Karjat and Jamkhed district based on the experience of ACWADAM.

Table 4: Scenario1--- Annual water balance for the year 2018-19

Panchayat Gan	Total Volume of rainfall (MCM)	Total demand (MCM)	Total Water Available (surface and groundwater and exogenous sources) (MCM)	Surplus/ Deficit (MCM)
Karjat taluka				
Bhambora	58.20	134.95	19.53	-115.42
Chapadgaon	88.63	50.76	44.62	-6.15
Jalapur	75.96	70.24	39.37	-30.86
Karjat Nagar Panchayat	10.06	21.97	10.02	-11.95
Koregaon	69.66	37.37	38.37	1.01
Kuldharan	98.54	97.52	37.18	-60.34
Mirajgaon	61.84	56.11	27.96	-28.15
Nimgaon	79.84	79.97	19.86	-60.11
Rashin	59.54	22.41	32.90	10.49
Karjat taluka (Total)	602.27	571.30	269.81	-301.49
	21.26 TMC	20.17 TMC	9.42 TMC	-10.64 TMC
Command Area				
Bhambora	22.55	51.51	14.97	-36.54
Chapadgaon	53.82	29.64	40.48	10.84
Jalapur	59.87	54.62	37.23	-17.39
Karjat Nagar Panchayat	8.57	18.33	9.68	-8.65
Koregaon	62.43	33.28	37.52	4.24
Kuldharan	52.67	52.14	31	-21.15
Mirajgaon	43.60	38.59	25.64	-12.95
Nimgaon	24.53	24.68	13.07	-11.6
Rashin	52.32	18.95	31.93	12.98
Command Area (Total)	380.36	321.75	241.52	-80.23
	13.43 TMC	11.36 TMC	8.53 TMC	-2.83 TMC
Non Command Area				
Bhambora	35.65	83.01	4.56	-78.45
Chapadgaon	34.81	20.84	4.09	-16.75
Jalapur	16.09	15.25	2.14	-13.11
Karjat Nagar Panchayat	1.49	3.17	0.35	-2.82
Koregaon	7.23	3.80	0.85	-2.95
Kuldharan	45.87	45.03	6.18	-38.85
Mirajgaon	18.23	17.09	2.32	-14.78
Nimgaon	55.32	54.77	6.78	-47.99
Rashin	7.22	3.10	0.97	-2.12
Non- command Area	221.91	246.05	28.24	-217.81
	7.83 TMC	8.69TMC	0.99 TMC	- 7.69 TMC

Panchayat Gan	Total Volume of rainfall (MCM)	Total demand (MCM)	Total Water Available (surface and groundwater and exogenous sources) (MCM)	Surplus/ Deficit (MCM)
(Total)				
Jamkhed taluka				
Aarangaon	84.06	54.42	16.32	-38.11
Javala	110.45	83.69	11.52	-72.17
Kharada	113.58	53.43	13.51	-39.92
Nagar Panchayat Jamkhed	34.45	27.21	4.21	-22.99
Sakat	108.68	72.22	9.89	-62.34
Jamkhed taluka (total)	451.21	290.99	55.45	-235.55
	15.93 TMC	10.28 TMC	1.96 TMC	-8.31 TMC

Based on the data available for the year 2018-19 and the assumptions listed above, the total deficit water in Karjat is around 10.64 TMC. The deficit in the command areas is about 2.83 TMC and in non-command areas it is about 7.69 TMC. It should be noted that for the water balance calculation in the command area in Karjat taluka, it is assumed that 100% of the committed water is received from Kukadi and Sina irrigation projects. In Jamkhed the water deficit is about 8.31 TMC. The deficits are higher because of deficit rainfall in 2018-19.

Scenario 2: Water balance under the scenario for cropping intensity of 150% as recommended by Chitale Commission report (1999)

This scenario has been developed based on the recommendation of the Chitale Commission report (1999). According to the report, at least 50% of the area in Rabi season should receive irrigation. Thus, this scenario has been built assuming that 100% of the area has been cropped in Kharif season and about 50% of the area in Rabi season will receive water above the in-situ water. Therefore, the overall cropping intensity considered under this scenario is 150%. The assumptions for the scenario are as below.

Assumptions:

Rainfall: Average rainfall values have been used to determine the total volume of water

In-situ water utilization: It is assumed that 20%, 30% and 50% of the total volume of rainfall is utilized for the evapotranspiration from non-cultivated areas, fallows lands and cultivated areas respectively

Water available from local surface storages: It is assumed that the volume of water available from local surface storages is only 30% of the total storage capacity

Water from Kukadi irrigation project and Sina irrigation project: The entire committed water from the Sina and Kukadi projects (192.33 MCM) is assumed as the exogenous water available to the command areas of the respective projects.

Total cultivated area: 100% cultivated area in the Kharif season and 50% of the cultivated area in the Rabi season

Cropping pattern: Cropping pattern data available for 2018-19 has been used to project the total cultivated area under each crop for 100% cropping intensity in Kharif season and 50% cropping intensity in Rabi season.

GW abstraction: It is assumed that amount of groundwater available for use is 90% of the total annual recharge. The total annual recharge has been calculated on the basis of the specific yield in Karjat and Jamkhed district based on the experience of ACWADAM

Table 5: Scenario2--- Water balance for 100% Kharif and 50% of the areas under cultivation

Panchayat Gan	Total Volume of rainfall (MCM)	Total demand (MCM)	Total Water Available (surface and groundwater and exogenous sources) (MCM)	Surplus/ Deficit (MCM)
Karjat taluka				
Bhambora	85.68	47.06	19.70	-27.35
Chapadgaon	109.93	62.74	45.07	-17.66
Jalapur	107.19	59.90	39.89	-20.01
Karjat Nagar Panchayat	24.32	14.69	10.65	-4.05
Koregaon	90.72	55.01	38.64	-16.37
Kuldharan	133.30	76.50	38.05	-38.45
Mirajgaon	92.80	48.32	28.81	-19.51
Nimgaon	124.90	61.48	20.59	-40.88
Rashin	80.88	47.03	33.40	-13.63
Karjat taluka (Total)	849.72	472.72	274.81	-197.91
	30 TMC	16.69 TMC	9.7 TMC	- 6.98 TMC
Command Area				
Bhambora	33.20	19.52	15.04	-4.48
Chapadgaon	66.76	39.80	40.75	0.95
Jalapur	84.48	48.14	37.64	-10.5
Karjat Nagar Panchayat	20.72	12.48	10.21	-2.27
Koregaon	81.31	49.21	37.76	-11.45
Kuldharan	71.25	40.47	31.46	-9.0
Mirajgaon	65.44	35.30	26.24	-9.06
Nimgaon	38.37	18.33	13.3	-5.03
Rashin	71.07	42.16	32.37	-9.79

Panchayat Gan	Total Volume of rainfall (MCM)	Total demand (MCM)	Total Water Available (surface and groundwater and exogenous sources) (MCM)	Surplus/ Deficit (MCM)
Command Area	532.59	305.41	244.77	-60.64
(Total)	18.81 TMC	10.78 TMC	8.64 TMC	-2.14 TMC
Non Command Area				
Bhambora	52.48	27.54	4.67	-22.87
Chapadgaon	43.17	22.90	4.27	-18.64
Jalapur	22.71	11.76	2.25	-9.51
Karjat Nagar Panchayat	3.60	2.22	0.44	-1.78
Koregaon	9.41	5.80	0.88	-4.92
Kuldharan	62.06	36.03	6.59	-29.44
Mirajgaon	27.37	13.02	2.57	-10.45
Nimgaon	86.53	43.14	7.29	-35.85
Rashin	9.81	4.87	1.03	-3.84
Non- command Area	317.13	167.27	29.98	-137.29
(Total)	11.2 TMC	5.91 TMC	1.06 TMC	-4.84 TMC
Jamkhed taluka				
Aarangaon	104.31	36.63	16.32	-20.31
Javala	134.94	48.24	11.52	-36.71
Kharada	123.87	32.50	13.51	-18.99
Nagar Panchayat Jamkhed	40.52	10.66	4.21	-6.45
Sakat	122.21	34.91	9.89	-25.02
Jamkhed taluka	525.85	162.94	55.45	-107.49
(total)	18.57 TMC	5.75 TMC	1.96 TMC	-3.79 TMC

Note: See annexure for details

Under this scenario we have determined the water requirement, both in-situ and applied water for 100% Kharif and 50% of the Rabi crops. According to this scenario, the total deficit water in Karjat taluka is about **6.98 TMC**. The total deficit in the command area is **2.14 TMC** and in the non-command area is around **4.84 TMC**. We have assumed 100% allocation from Kukadi and Sina irrigation projects for the exogenous water component. As of today, from the data received from the irrigation department, the Sina dam has filled up only for 50% of the years and villages in the command are not getting water. Similarly, the villages in the command area of Kukadi are receiving only 1.5 TMC of water against the committed 5 TMC. Therefore, in the present situation this deficit in the command area would be much higher than 1.26 TMC, that is, in the range of **3-5 TMC** and the overall deficit in the Karjat taluka would be around **7-10 TMC**. Thus currently the farmers, both in command and non-command areas, are heavily relying on groundwater for irrigation and are abstracting water from stocks (beyond annual recharge) which cannot be easily replenished.

For Jamkhed taluka, the total deficit under Scenario2 is about **3.79 TMC**. Compared to Karjat taluka, Jamkhed receives 100 mm more rainfall and the total geographic area is also less. Though Jamkhed has higher rainfall than Karjat, especially in the last decade, they have had continuous four years of poor rainfall, leading to heavy reliance on groundwater. Also, unlike Karjat taluka they are not receiving additional water from any irrigation projects.

Scenario 3: Water balance under the scenario where 30% of the cultivated area receives water for irrigation (or applied water)

Under the Chairmanship of S.G. Barve, the first Irrigation Commission of Maharashtra was set up. The Commission submitted its report in 1962 after assessing the water resources in the state. According to the report, only 30% of the area in the state can be brought under irrigation even when full efficiency is met. In fact the current average irrigated area in Maharashtra is about 17% (Directorate of Economics and Statistics, 2016). Therefore, this scenario has been derived based on the findings of the Barve Commission Report. The scenario considers that around 30% of the Kharif area will receive protective irrigation and only 30% of the cultivated area in the Rabi season will be irrigated. The assumptions made for deriving this scenario are as below.

Assumptions:

Rainfall: Average rainfall values have been used to determine the total volume of water

In-situ water utilization: Here we have assumed that 20%, 30% and 50% of the total volume of rainfall is utilized for the evapotranspiration from non-cultivated areas, fallows lands and cultivated areas respectively

Water available from local surface storages: It is assumed that the volume of water available from local surface storages is only 30% of the total storage capacity

Water from Kukadi irrigation project and Sina irrigation project: The entire committed water from the Sina and Kukadi projects (192.33 MCM) is assumed as the exogenous water available to the command areas of the respective projects.

Cropping pattern: Cropping pattern data available for 2018-19 has been used to project the total cultivated area under each crop.

Applied water available: It is assumed that irrigation will be provided for 30% of the cultivated area in Kharif season for protective irrigation and 30% of cultivated area will be irrigated in the Rabi season.

GW abstraction: It is assumed that amount of groundwater available for use is 90% of the total annual recharge. The total annual recharge has been calculated on the basis of the specific yield in Karjat and Jamkhed district based on the experience of ACWADAM

Table 6: Scenario3--- Water balance where 30% of the cultivated area is under irrigation

Panchayat Gan	Total Volume of rainfall (MCM)	Total demand (MCM)	Total Water Available (surface and groundwater and exogenous sources) (MCM)	Surplus/ Deficit (MCM)
Karjat taluka				
Bhambora	85.68	53.88	19.70	-34.18
Chapadgaon	109.93	30.06	45.07	15.01
Jalapur	107.19	37.79	40.19	2.40
Karjat Nagar Panchayat	24.32	7.34	10.64	3.30
Koregaon	90.72	27.22	38.64	11.41
Kuldharan	133.30	45.41	38.05	-7.36
Mirajgaon	92.80	25.82	28.72	2.89
Nimgaon	124.90	32.47	20.70	-11.78
Rashin	80.88	29.87	33.40	3.54
Karjat taluka (Total)	849.72	289.88	275.11	-14.76
	30 TMC	10.24 TMC	9.71 TMC	-0.52 TMC
Command Area				
Bhambora	33.20	22.29	15.03	-7.25
Chapadgaon	66.76	18.95	40.75	21.80
Jalapur	84.48	30.22	37.94	7.72
Karjat Nagar Panchayat	20.72	6.20	10.21	4.01
Koregaon	81.31	24.20	37.76	13.56
Kuldharan	71.25	23.92	31.46	7.54
Mirajgaon	65.44	18.77	26.15	7.38
Nimgaon	38.37	9.61	13.40	3.80
Rashin	71.07	26.61	32.37	5.76
Command Area (Total)	532.59	180.76	245.07	64.31
	18.81 TMC	6.38 TMC	8.65 TMC	2.27 TMC
Non Command Area				
Bhambora	52.48	31.42	4.67	-26.75
Chapadgaon	43.17	10.93	4.27	-6.66
Jalapur	22.71	7.39	2.25	-5.14
Karjat Nagar Panchayat	3.60	1.10	0.44	-0.66
Koregaon	9.41	2.85	0.88	-1.97
Kuldharan	62.06	21.29	6.59	-14.71
Mirajgaon	27.37	6.94	2.57	-4.37
Nimgaon	86.53	22.59	7.29	-15.30
Rashin	9.81	3.08	1.03	-2.05
Non- command Area	317.13	107.59	29.98	-77.61
	11.2 TMC	3.8 TMC	1.06 TMC	-2.74 TMC

Panchayat Gan	Total Volume of rainfall (MCM)	Total demand (MCM)	Total Water Available (surface and groundwater and exogenous sources) (MCM)	Surplus/ Deficit (MCM)
(Total)				
Jamkhed taluka				
Aarangaon	104.30	19.38	16.32	-3.06
Javala	134.93	24.48	11.52	-12.95
Kharada	123.87	18.78	13.51	-5.27
Nagar Panchayat Jamkhed	40.52	7.17	4.21	-2.96
Sakat	122.20	18.94	9.89	-9.05
Jamkhed taluka (total)	525.84	88.77	55.45	-33.32
	18.57 TMC	3.13 TMC	1.96 TMC	-1.17 TMC

Note: See annexure for details

For Karjat taluka under scenario 3 there is an overall deficit is **0.52 TMC**. In the command areas of Karjat taluka there is a surplus of **2.27 TMC**. But there is a deficit of **2.74 TMC** in the non command areas of Karjat taluka. The total deficit in Jamkhed is only about **1.17 TMC**.

Scenario 4: Biomass Based Scenario⁶

Since the inception, in fact even prior to it, SOPPECOM has been advocating an alternative approach to rural development as compared to the green revolution type of approach based on large amounts of external inputs like agro-chemicals, hybrid seeds and water from large dams. There are many distinctive features of this alternative approach and it is difficult to capture them in a single descriptive term, though we often call it a biomass based approach. These distinctive features include: the way it approaches equity issues and access to resources, its approach to agriculture and allied production as biomass production, the way it approaches the problem of the large and the small and of the local and the exogenous resources, the way it approaches the problem of combining judiciously renewable and non-renewable sources of energy and materials, the way it sees the issue of people's participation and empowerment including knowledge and lastly the problem of dispersed industry and non-farm incomes (Paranjape and Joy, 1995, Datye, 1997).

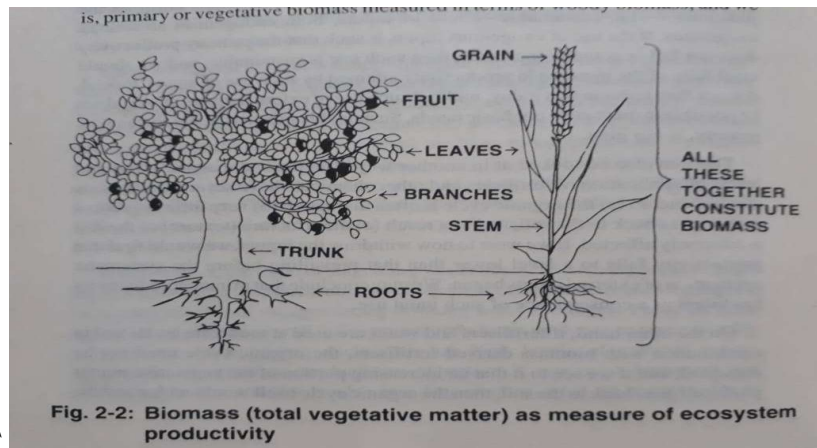
⁶The description on the biomass based approach is based in the following sources: i) Joy K. J. (2017), "Biomass-based Rural Revitalization in Future India", in Ashish Kothari and K. J. Joy (ed), *Alternative Futures: India Unshackled*, Authors Upfront, Delhi; ii) Datye K. R. (assisted by Suhas Paranjape and K. J. Joy), 1997, *Banking on Biomass: A New Strategy for Sustainable Prosperity Based on Renewable Energy and Dispersed Industrialisation*, Centre for Environment Education, Ahmedabad, iii).Paranjape, Suhas and K. J. Joy, 1995, *Sustainable Technology: Making the Sardar Sarovar Project Viable -- A Comprehensive Proposal to Modify the Project for Greater Equity and Ecological Sustainability*, Centre for Environment Education, Ahmedabad.

The biomass based approach can tie together the livelihood and ecosystem needs, thus paving the way for rural revitalisation – both its economy and ecology.

What is biomass?

Biomass refers to the total mass of all living beings/things within an ecosystem. Here we use the term biomass to mean the sum total of all vegetative matter (meaning photosynthetic biomass) produced in the ecosystem. All parts of a plant (or crop) are biomass and not merely the harvestable portion (Figure 17)

Figure 17: Biomass and its various components



Biomass production and ecosystem productivity in relation to human needs have two distinct but related aspects: one, potential biomass productivity and, two, its partitioning. Potential biomass productivity represents the total photosynthetic biomass produced within the system while partitioning of this biomass into different products gives us different use values. Potential biomass productivity depends on the sum total of ecosystem relationships and is determined by factors like soil conditions and moisture holding capacity, the total water regime within the ecosystem, and the amount of biomass and nutrients that flow and re-circulate through the ecosystem. The realization of this potential biomass productivity and its partitioning into different use values is a much more individual matter, depending on species selection, crop and water management, nutrient management, etc. (Paranjape and Joy, 1995; Datye *et al.*, 1997; Joy, 1999).

Biomass weight is always given as “dry biomass” in the sense that all water content is removed so that it is easy to compare across different types of biomass. Different types of biomass have different proportions of water content. For example, tomato may have, say, 90% as water whereas grain may have much less water content. Once the water is taken out complete through drying (dry biomass) then we can compare different types of biomass with each other.

Biomass: the main provider of our needs

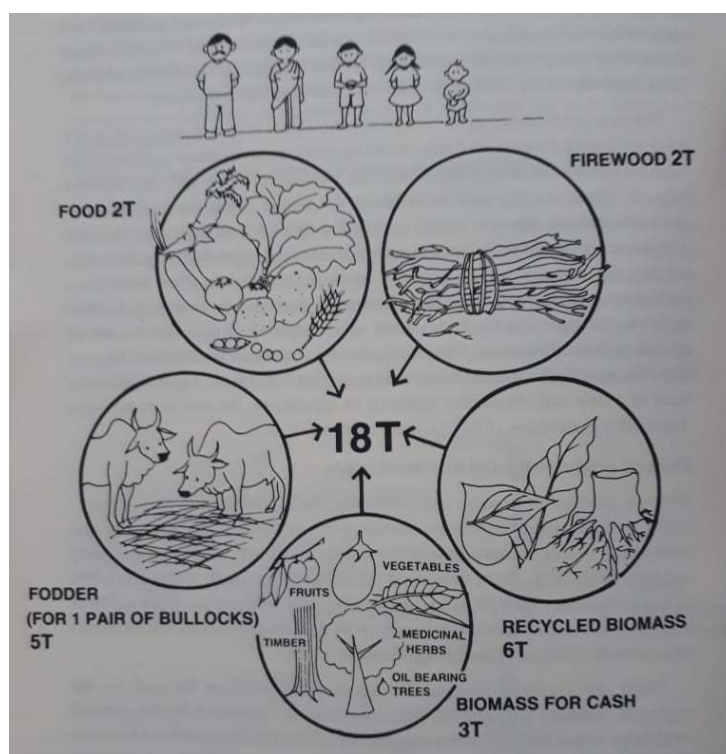
We know that biomass, in one form or the other, has been the main provider of human societies: some biomass is consumed directly in the form of food, some used indirectly (as

fuel, fodder), some biomass is sold in the market to meet cash income needs (or also processed for value addition) and some biomass goes back into the soil in the form of green manure, compost, cow dung and so on to provide the required nutrients and also to improve the water holding capacity of the soil.

Biomass and livelihood needs

Studies as well as experience show that a typical farmer family of five members can meet all its needs – food, fodder, fuel, recyclable biomass for the agriculture system and some surplus biomass for cash income – if it can either produce or get access to about 18 tonne (T) of biomass (dry weight) in a year: food and allied needs 2 T, firewood 2 T, fodder 5 T, recyclable biomass 6 T and biomass for cash income 3 T (Figure 18).

Figure 18: Biomass needs for a family of five members



The above estimate is in line with a reasonable upper bound approach (keeping higher values than actually required) with ample scope for optimisation. For example, 5 T fodder requirement is estimated assuming the family owns a pair of bullocks. If the cattle herd is rationalised and two families share one pair of bullocks, about 2.5 T in fodder can be saved⁷. Similarly, if the families can shift to fuel efficient devices and methods then part of the biomass earmarked for fuel could be saved; part of it can go back to the soil as throughput

⁷In fact, with advances in the cattle/goat management techniques such as the Mukta Sanchar Gotha (controlled open grazing) with hydroponics and azola to produce green fodder, even five farmers can come together to set up a unit of 10 animals and 20 poultry birds (**Source:** Notes from Vilas Gore).

and the remaining can be added to the surplus biomass of 3 T. Thus, we can safely say that each family can produce a surplus biomass of the order of 3 to 5 T.

This surplus biomass can be handled in a variety of ways. The conventional way is to produce this as perishable commodities like vegetables, fruits or other forms of high value agriculture produce and sell these to meet cash requirements. Efforts are also made to process and turn them into consumer products (like jams, pickles and so on). However, if this surplus biomass is produced in the form of small dimension timber, bamboo, fibre, oils, medicinal plants, then an additional variety of marketable products become possible. This option has great significance for value addition, thus generating significant non-farm incomes to rural communities. The surplus biomass in the form of small dimension timber, bamboo, different types of fibers, etc., can be used in various infrastructure applications to replace/reduce the use of steel, plastics, etc. (fossil, non-renewable materials). SOPPECOM and allied organisations have developed technologies using these types of biomass in infrastructure areas like buildings, roads and water harvesting/storage structures. It can be the main input into a dispersed rural industrialization. It also has relevance as a climate adaption strategy.

Thus, the biomass based approach has two components. The first is the primary production sector in which agriculture would be seen as part of a wider biomass production system, as described earlier. Here the emphasis is to meet all the basic needs like food, fodder and fuel in kind without going through the market at the scale of a micro-watershed/village or at the most at the level of a cluster of villages. The second part of the vision is the decentralised agro-industrial production system in which the surplus biomass, other local materials like stone, clay, sand and renewable energy (wind, solar, small hydro) are brought together in the form of integrated production cum energy generation units (IPEUs). IPEUs would provide goods, income and electricity.

Water requirement

From the 18 T/HH/year requirements we can also estimate the water required to produce this 18 T biomass. Very often we only talk about land productivity. For example, we often say how much Jowar is produced per acre. We seldom say how much Jowar is produced per unit of water. Water productivity is not often considered. Biomass based approach considers water productivity very important. It considers access to water required to produce 18 T of biomass per family as an important pre-requisite.

Now let us turn to the question of how much water is required to produce 18 T of biomass per family per year. In production systems based on intensive use of external inputs, for example the green revolution agriculture, the water productivity is often much less as compared to sustainable and regenerative agriculture. Water intensive crops like sugarcane and summer paddy show a productivity as less as 7 kg/ha-mm and 7.5 kg/ha-mm respectively (ha-mm = 10,000 liters = 10 m³). However, analysis shows that with judicious and sustainable use of limited inputs, productivity of about 30 to 40 kg/ha-mm could be realised for almost all common types of vegetation fairly well adapted to the ecosystem. In fact, in good rainfall years, most rainfed species show this level of productivity. Hence the role of water

(especially applied water) is to create “good rainfall conditions” for all especially in areas where water is a scarce resource.

Water productivity norm of 18 kg/ha-mm shows that to produce 18 T of biomass the water requirement would be 6000 m³ in a year.

Land use

In drought prone regions, water is going to be scarce and it would not be possible to bring all agriculture land under irrigation (or applied water). In fact, long back the Barve Commission had said that even if Maharashtra harvests all its water, the state cannot irrigate more than 30% of its cropped area. There is a tendency among farmers in drought prone regions to bring lands which may not be suitable for seasonal and shallow rooted crop production. For farmers this is one way of risk management. However, our experiments and also literature show that if assured water can be provided to stabilise crops on good quality lands, then the farmers do not have the compulsion to bring low quality lands under crop production. If farmers are assured of getting better productivity and also production, then they would be willing to release the low quality lands for a multi-year biomass production system which has the ability to internalise rainfall variations in its stride. Plants with multi-year life cycles are better equipped to face dry spells: once these plants are established (for the first 2-3 years and during the establishment phase it would require some applied water) then even with long dry spells the plants do not die. The incremental biomass may be less, but this is more than made up in good rainfall years. Some of the plants also have the ability to overcome water stress through various means including stomata closure. Assurance of certain minimum access to water is one of the preconditions for this strategy. Variable water available (discussed below) in the water cycle can be utilized for this.

Estimating the water balance for Karjat and Jamkhed

Assumptions: estimating water availability

Rainfall: We have used 75% dependable rainfall. It means, out of 100 years, for 75 years we would get this rainfall. There would be many years where we would also get more rainfall than this. We think that water planning needs to be done at a higher dependability because we are talking of basic needs. This would mean that out of four years, three years would go well and only one year there may be some shortage. The surplus generated during the three good rainfall years can see the family through one bad year. However, in the case of planning based on average rainfall, one out of two years would be a bad year.

Assured and variable components of water: The water available in an area at 75% or more dependability is known as the assured component of water. The water that is available over and above this, but available only for certain years is the variable component of the water in an area. The assured and variable water need to be handled differently: assured water to be provided on a priority basis and equitably to all households for domestic needs, livestock needs and for the production of 18 T of biomass. The variable water can be used for bulk biomass production (trees, shrubs, creepers, fibers, etc.) on low quality lands (degraded, sloppy, with less soil cover, etc.), or it can be made available at a higher cost to more

industrious/progressive farmers on a first come first served basis. There could be many such options.

In situ water use (green water) as per land use classes: We have estimated in situ water use as per three land use classes, namely, non-cultivable land, fallow land and cultivated land. We have not taken into account forest land for two reasons: one, the forest land in Karjat and Jamkhed is not significant and two, the biomass produced through the in situ use of water in the forest area very often is not available to people. For the cultivated area, we have used a norm of 50% of the rainfall being used as in situ water (through evapotranspiration). Very often 60% is used, but we have taken a more conservative approach here. The norms for in situ water use assumed for non-cultivable land and fallow land are 20% and 30% (of the rainfall) respectively.

Local applied water: We have taken 15% of the total water available (and this is a function of total geographical area x 75% dependable rainfall) in the form of groundwater (through annual re-charge) and local surface storages (like minor irrigation tanks). We have used an efficiency norm of 70% to estimate the local applied water available at the field level.

Exogenous water: The entire committed water from the Sina and Kukadi projects (192.33 MCM) is assumed as the exogenous water available to the command areas of the respective projects in Karjat taluka.

Assumptions: estimating water demand/use

Domestic water: Domestic water requirement per family (of five members) is taken as 200 m³ of water per year (100 liters/person/year – 100 lpcd). This is the World Health Organisation (WHO) norm.

Water for livestock: We have used a norm of 200 m³ per family per year as the livestock requirement (same as domestic water norm).

Water form biomass production: 6000 m³ to produce 18 T of biomass (per family per year)

Water for industries/commercial use: This is taken at 5% of the total local water available

Water for environmental flows: This is taken at 20% of the total local water available

Table 7: Scenario4--- Water balance using the biomass based approach

Panchayat Gan	Total Volume of rainfall (MCM)	Total demand (MCM)	Total Water Available (surface and groundwater and exogenous sources) (MCM)	Surplus/ Deficit (MCM)
Karjat taluka				
Bhambora	58.22	44.73	43.01	-1.72
Chapadgaon	78.69	47.63	75.73	28.10
Jalapur	74.87	42.41	67.80	25.39
Karjat Nagar	14.73	27.37	14.92	-12.45

Panchayat Gan	Total Volume of rainfall (MCM)	Total demand (MCM)	Total Water Available (surface and groundwater and exogenous sources) (MCM)	Surplus/ Deficit (MCM)
Panchayat				
Koregaon	62.30	41.11	63.33	22.22
Kuldharan	97.56	47.74	74.35	26.61
Mirajgaon	62.63	45.68	53.01	7.34
Nimgaon	84.30	47.28	52.80	5.52
Rashin	53.29	45.40	51.61	6.21
Karjat taluka (Total)	586.58	389.35	496.57	107.22
	20.78 TMC	13.75 TMC	17.53 TMC	3.78 TMC
Command Area				
Bhambora	22.56	15.53	24.45	8.92
Chapadgaon	47.79	30.46	59.81	29.35
Jalapur	59.01	33.82	59.94	26.12
Karjat Nagar Panchayat	12.55	24.15	13.81	-10.35
Koregaon	55.83	36.43	59.89	23.46
Kuldharan	52.14	26.53	50.66	24.13
Mirajgaon	44.16	36.30	43.55	7.25
Nimgaon	25.90	17.29	22.86	5.57
Rashin	46.82	41.98	48.51	6.52
Command Area (Total)	366.76	262.05	383.47	120.97
	12.95 TMC	9.25 TMC	13.54 TMC	4.29 TMC
Non Command Area				
Bhambora	35.66	29.25	18.56	-10.69
Chapadgaon	30.90	15.77	15.99	0.22
Jalapur	15.86	10.29	7.78	-2.51
Karjat Nagar Panchayat	2.18	4.06	1.08	-2.99
Koregaon	6.46	5.72	3.40	-2.32
Kuldharan	45.42	20.01	23.74	3.73
Mirajgaon	18.47	9.56	9.45	-0.11
Nimgaon	58.40	28.68	29.99	1.31
Rashin	6.46	3.50	3.10	-0.40
Non- command Area (Total)	219.82	125.99	113.10	-13.74
	7.76 TMC	4.45 TMC	3.99 TMC	-0.48 TMC
Jamkhed taluka				
Aarangaon	80.90	49.91	41.89	-8.03
Javala	102.23	50.53	52.48	1.96
Kharada	90.23	55.71	45.34	-10.37
Nagar Panchayat	32.69	62.52	14.88	-47.65

Panchayat Gan	Total Volume of rainfall (MCM)	Total demand (MCM)	Total Water Available (surface and groundwater and exogenous sources) (MCM)	Surplus/ Deficit (MCM)
Jamkhed				
Sakat	93.87	48.83	46.47	-2.36
Jamkhed taluka (total)	404.48	267.72	201.54	-66.44
	14.28 TMC	9.45 TMC	7.12 TMC	-2.34 TMC

Note: See annexure for details

Under the biomass based scenario there is an overall surplus of **3.78 TMC** in Karjat taluka. In the command areas of Karjat taluka there is an overall surplus of **4.29 TMC**. Considering the losses, the command area may not receive the entire 100% of the committed water. However, even if they were to receive exogenous water at about 60% efficiency, considering the conveyance losses there still would be a surplus of about **1 TMC** in the command area. The non-command area of Karjat has a deficit of about **0.46 TMC**. In the non-command area the total local water, including the in-situ water available is about 113 MCM. Subtracting from the total rainfall volume in the non-command area about 106 MCM of water can potentially be harvested. Owing to the topographical and geological limitations in some regions even if 25% of this water were to be tapped, i.e. 26.5 MCM then the deficit in the non-command areas can be met and there would still be some water above the demands remaining for ecological needs

Under this scenario, there is an overall deficit of **2.34 TMC** in Jamkhed taluka. The total rainfall volume available is about 488 MCM. The total local water available, including the in-situ water is about 201.54 MCM. Therefore about 288.54 MCM of water is available for harvesting. Assuming topographical and geological disadvantages in certain regions, again even if 25 % of this water is were to be harvested the demands of the people in the Jamkhed taluka can be met.

For both the talukas we recommend that 20% of the local water available should be reserved for environmental flows. This amounts to about 56.4 MCM in Karjat and 35 MCM in Jamkhed taluka

Table 8: Summary of the water balance under all the four scenarios in Karjat and Jamkhed talukas

Name of Taluka	Details	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Karjat	Total volume of rainfall (TMC)	21.26	30	30	20.78
	Total water required for all demands (TMC)	20.17	16.69	10.24	13.75
	Total water available (surface and groundwater (TMC) and exogenous sources	9.42	9.7	9.71	17.53
	Surplus/ Deficit (TMC)	-10.64	-6.98	-0.52	3.78
Jamkhed	Total volume of rainfall (TMC)	15.93	18.57	18.57	14.28
	Total water required for all demands (TMC)	10.28	5.75	3.13	9.45
	Total water available (surface and groundwater (TMC) and exogenous sources	1.96	1.96	1.96	7.12
	Surplus/ Deficit (TMC)	-8.31	-3.79	-1.17	-2.34

Chapter 5: Way Forward

In drought prone areas like Karjat and Jamkhed, water availability and water resource management is a complex issue and there are natural limitations to the extent of irrigation that is possible. This is mainly due to agro-climatic conditions and frequent droughts these areas experience. Given this context it is important to manage the available water resources in a sustainable, productive and equitable manner. It is very crucial to take up demand management, technological innovations in both cropping pattern and water savings and above all putting in place governance mechanisms and institutional innovations to the fore front along with managing supply. This would also mean incorporating certain normative principles in the water resource management like prioritizing the water needs, given the fact that access to drinking water is a major concern as expressed in villages, mainly by women⁸. Based on our derived experience and viewing it in relation to the field realities we propose the following critical issues as strategies for sustainable management of the water resources.

Water use prioritization

The following hierarchy of principles should be followed for evolving allocation principles across states and sectors.

- First, *water for life*: providing adequate water of acceptable quality for meeting the drinking, cooking and sanitation needs of all the people and animals in the basin,
- Second, *water for the ecosystem*: ensuring adequate water flows and water in the river system for aquatic life and other ecological functions,
- Third, *water for sustaining livelihoods*: enabling productive activities while ensuring equitable use and protecting public health, and
- Fourth, *water for adaptation to change*: keeping reserves and margins for ongoing and future demographic, economic and land use changes and climate change.

Ensuring the access to current committed water

The command areas of the Kukadi and Sina irrigation projects in Karjat taluka must get their committed share of water. The study shows that there is a deficit even after the command areas receive their full quota of water from these projects. Along with getting access to the full committed quota from both Kukadi and Sina projects, the strategy should be to enhance the local water availability as there is limit for bringing exogenous water as most of the basin/sub basins are in scarcity category and closed basins. At present lot of work is undertaken for local water harvesting but most of this work is drainage and water harvesting centric.

⁸During our interaction in the field many of them were of the opinion that if drinking water problem is resolved and access is ensured of both quality and quantity, throughout the year that itself would be a great contribution. This needs to be seen in the face of the enormous economic cost involved in providing tanker waters every year during summer and scarcity months.

The strategy must be to improve the in-situ conservation (green water) through area treatment, soil fertility management and agronomical practices. While the existing water harvesting structures are abundant and, in many villages saturated, its quality and functionality need attention. Our rough estimate shows that not more than 30% are in good condition and working up to its full potential while the rest needs total overhauling to repairs, desilting, etc. The exogenous water must be used to strengthen and supplement the local water and not substitute it. For this, an integrated conjunctive water resources management strategy taking into consideration both the exogenous and local water is required.

A rapid technical survey along with participative resource mapping could give an idea about the watershed development potential at a village/micro watershed level, taking into account the existing work, its audit and requirement of new work and the broad plans to execute it in a participative manner.

Managing the demand

While hard options for improving the water availability are important, it is equally important that soft options are sought to manage the demand side to improve efficiency of water use. Technological innovation in irrigation is one of them. While proven technologies like sprinkler for field crops and drip for crops like horticulture, sugarcane, cotton etc. are slowly gaining ground, it is important to search for other alternatives also. There may be local innovations by farmers that can be incentivized and promoted. Agronomical practices like mulching, inter-cropping; improving the bio soil fertility, etc. could also be promoted. Sustainable sugarcane initiative (SSI) is seen as one of the options to reduce the water footprint in sugarcane cultivation. 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% 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% of water (Gujja et al, 2012). Apart from these, since groundwater forms a major source of both domestic and irrigation requirements in these regions, there is a need to manage the groundwater abstraction, in the form of pump regulation, distance regulation between drinking and irrigation sources, change in cropping pattern among others.

Governance and institutional arrangements

While supply and demand management are very important it is crucial to have appropriate and effective governance and institutional mechanisms at village and cluster levels. This would mean promoting and nurturing institutions in both command and non-command areas.

WUA, as envisaged under MMISF Act, needs to be promoted and strengthened in all command areas. In the Sina command area, proposal for forming the WUAs was sent to the irrigation department; however, it has not moved beyond that stage to form legally registered WUAs under the MMISF Act. In the Kukadi command there are no WUAs at all. From field interviews and discussions with the farmers it was seen that the farmers are keen on managing the water resources in the command area through WUAs. Farmers should be provided with all the rights existing under the provisions of this act. This may help them in

negotiating with the authority to get their full quota of water. The WUAs could also be federated at a larger level so that they are better positioned vis-a-vis irrigation department. Capacity building of the WUAs about the MMISF Act and their roles and responsibilities is also important besides regular hand-holding to ensure institutional strengthening. The physical system needs to be rehabilitated prior to handing over it to the WUA.

In the same manner, in the non command and dry land areas, Watershed Development Institutions need to be promoted. With the advent of Jalyukt Shivar Abhiyan institutional vacuum is felt in watershed development. Institutions are crucial for not only improving the implementation of work but ensuring some sort of sustainability of the assets created. User Groups (UGs) around local water and other resource groups, Self Help Groups (SHGs), farmers groups, etc. needs to be promoted. However, it is important that all the institutions are complementary in its functions with the objective of resource management, production enhancement, innovations and liaisoning with financial and technical institutions. Farmers Producer Companies (FPOs) can be thought about at cluster levels and with the expertise and experience available with Baramati Agro Limited successful interventions are possible in many areas with FPOs.

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Annexes:

Annexure 1: Secondary data used for the study

Sr. No.	Data Used	Year	Source
1.	Demography	2011	Census
2.	Livestock	2017	Livestock Census
3.	Land use	2018-19	Revenue department, Karjat and Jamkhed
4.	Cropping Pattern (both Kharif and Rabi)	2018-19	Agriculture Department, Karjat and Jamkhed
5.	Daily rainfall data at taluka level	1989-2018	Indian Meteorological Department
6.	Daily rainfall gridded data	2003 to 2018	Skymet data for Karjat and Jamkhed
7.	Digital Elevation Model 30×30 meter resolution	-	Downloaded from Shuttle Radar Topography Mission, NASA.
8.	Groundwater recharge and extraction	2017	Groundwater Survey and Development Agency (GSDA) and 5 th Minor Irrigation census
9.	Kukadi irrigation project	-	Irrigation Department, Subdivision Mohadi, Karjat
10.	Sina irrigation project	-	Irrigation Department, Sina division, Nimgaon Gangarda
11.	Local surface water harvesting structures	-	Integrated Watershed Management Programme (IWMP), Jalyukt Shivar Abhiyan, Minor Irrigation Dept. (Karjat and Jamkhed)

Annexure 2: Runoff calculated using Strange's method

Karjat taluka

Panchayat Gan	Slope categories	Area in GIS (ha)	Actual geographic area (ha)	Ratio of GIS Area to actual area	Corrected Area (ha)	Runoff coefficient	Runoff (TCM)	Runoff in MCM
Bhambora	<5	11355.01		1.04	11841.97	0.4555	5394.02	
	5 < slope < 20	3976.56			4147.10	0.6853	2842.01	
	>20	3.77			3.93	0.9131	3.59	
	Total Area	15335.35	15993.00			Total	8239.61	8.24
Chapadgaon	<5	12853.85		1.08	13900.33	0.5377	7474.21	
	5 < slope < 20	5456.50			5900.73	0.8065	4758.94	
	>20	28.61			30.94	1.0535	32.59	
	Total Area	18338.95	19832.00			Total	12265.74	12.27
Jalalpur	<5	14984.12		1.01	15204.24	0.4555	6925.53	
	5 < slope < 20	4744.56			4814.26	0.6853	3299.21	
	Total Area	19728.68	20018.50			Total	10224.74	10.22
Karjat NP	<5	3467.65		0.88	3051.68	0.5377	1640.89	
	5 < slope < 20	1397.08			1229.49	0.8065	991.58	
	Total Area	4864.73	4281.17			Total	2632.47	2.63
Koregaon	<5	11782.63		1.02	11974.94	0.4835	5789.88	
	5 < slope < 20	4476.69			4549.75	0.7263	3304.49	
	Total Area	16259.32	16524.69			Total	9094.37	9.09
Kuldharan	<5	16614.24		1.01	16737.02	0.4835	8092.35	
	5 < slope < 20	7417.37			7472.19	0.7263	5427.05	
	>20	180.15			181.48	0.9671	175.51	

Panchayat Gan	Slope categories	Area in GIS (ha)	Actual geographic area (ha)	Ratio of GIS Area to actual area	Corrected Area (ha)	Runoff coefficient	Runoff (TCM)	Runoff in MCM
	Total Area	24211.76	24390.69			Total	13694.91	13.69
Mirajgaon	<5	13507.38		0.99	13318.72	0.7528	10026.33	
	5 < slope < 20	607.23			598.75	1.1019	659.77	
	Total Area	14114.61	13917.47			Total	10686.10	10.69
NimgaonGangarda	<5	12345.20		1.02	12611.55	0.7209	9091.67	
	5 < slope < 20	6087.79			6219.13	1.0802	6717.91	
	>20	321.78			328.72	1.4403	473.46	
	Total Area	18754.77	19159.41			Total	16283.04	16.28
Rashin	<5	10301.31		1.01	10449.90	0.4835	5052.53	
	5 < slope < 20	4372.00			4435.06	0.7236	3209.21	
	Total Area	14673.31	14884.96			Total	8261.74	8.26

Jamkhed taluka

Panchayat Gan	Slope categories	Area in GIS (ha)	Actual geographic area (ha)	Ratio of GIS Area to actual area	Corrected Area (ha)	Runoff coefficient	Runoff (TCM)	Runoff in MCM
Aarangaon	<5	14770.98	1	0.84	12351.58	0.5946	7344.25	
	5 < slope < 20	5218.11	0		4363.42	0.8918	3891.29	
	Total Area	19989.09	16715				11235.55	11.24
Jamkhed NP	<5	4146.79	1	0.97	4031.17	0.7201	2902.85	
	5 < slope < 20	2263.24	0		2200.14	1.0802	2376.59	
	>20	32.60	0		31.69	1.4403	45.64	
	Total Area	6442.63	6263				5325.08	5.33
Javala	<5	15375.89	1	1.01	15565.01	0.5946	9254.95	

	5< slope<20	5883.70	0		5956.07	0.8918	5311.62	
	Total Area	21259.59	21521		21521.08		14566.58	14.57
Kharda	<5	11447.10	1	0.99	11305.30	0.7201	8140.95	
	5< slope<20	6982.89	0		6896.39	1.0802	7449.48	
	>20	886.12	0		875.14	1.4403	1260.46	
	Total Area	19316.11	19077				16850.89	16.85
Sakat	<5	10573.72	1	0.99	10496.22	0.7201	7558.33	
	5< slope<20	7615.89	0		7560.06	1.0802	8166.38	
	>20	1227.71	0		1218.71	1.4403	1755.31	
	Total Area	19417.32	19275				17480.02	17.48

Annexure 3: Detailed calculation for water balances

Scenario 1: Annual Water Balance for 2018-2019 rainfall scenario and cropping patterns in Karjat taluka

- All units of volume are in MCM unless specified
 - All units of areas are in hectares unless specified

	Bhambora	Chapadgaon	Jalalpur	Karjat Nagar Panchayat	Koregaon	Kuldharan	Mirajgaon	Ningaoon Gangarda	Rashin	Karjat taluka
Volume of water available through rainfall (MCM)										
Total geographic area	15993.68	19333.86	20018.5	4281.17	16524.69	24390.69	13917.47	19159.41	14884.96	148504.43
Average rainfall (mm)	363.92	458.41	379.46	235	421.53	404	444.315	416.733	400	391.49
Volume of rainfall available	58.2	88.63	75.96	10.06	69.66	98.54	61.84	79.84	59.54	602.27
Surface runoff volume	5.59	9.88	7.24	1.09	6.98	10.12	7.12	10.41	6.08	64.51
In-situ water utilization (MCM)										
Total non-cultivable area	3972	3531.35	4960	538	2568.85	5698.25	2345.86	4935.35	3412.06	31962.41
Volume of in-situ water utilized in non-cultivable areas	2.89	3.24	3.76	0.25	2.17	4.6	2.08	4.11	2.73	25.84
Total fallow land area	1719	154.78	425.41	53.53	9.2	105.46	29.46	97.4	5.88	2600.12
Volume of in-situ water utilized in fallow lands	1.88	0.21	0.48	0.04	0.01	0.13	0.04	0.12	0.01	2.92
Total non cropped land	4780.76	7616.73	7455.197	1116.64	6860.97	6402.73	3573.58	21.88.85	8878.81	48874.27

	Bhambora	Chapadgaon	Jalalpur	Karjat Nagar Panchayat	Koregaon	Kuldharan	Mirajgaon	Nimgaon Gangarda	Rashin	Karjat taluka
2018-19										
Volume of in-situ water utilized in non cropped land 2018-19	5.22	10.74	8.48	0.78	8.67	7.76	4.76	2.73	10.65	59.56
Cultivable area	12021.31	15802.51	15,057.8	3743.17	13955.8	18692.44	11571.61	14224.05	11472.9	116541.67
Volume of in-situ water utilized in cultivated areas	21.87	36.22	28.57	4.4	29.41	37.76	25.71	29.64	22.95	236.53
Water required for various demands										
Gross cultivated area	12284	18663	14468.2	5712	14264.7	22654.25	15185.57	19991.8	8002.21	131225.88
Total volume of water required for gross cultivated area	155.48	85.64	97.54	25.56	65.53	133.93	80.53	108.16	43.99	796.41
Applied water required for gross cultivated area	133.61	49.42	68.97	21.16	36.12	96.17	54.83	78.52	21.04	559.89
Volume of water for domestic use	1.14	1.16	1.05	0.76	1.05	1.12	1.16	1.13	1.16	9.74
Volume of water for livestock	0.2	0.18	0.21	0.05	0.19	0.22	0.13	0.31	0.2	1.67
Total volume of water required for all demands	134.95	50.76	70.24	21.97	37.37	97.52	56.11	79.97	22.41	571.3
Volume of water available from local sources										

	Bhambora	Chapadgaon	Jalalpur	Karjat Nagar Panchayat	Koregaon	Kuldharan	Mirajgaon	Nimgaon Gangarda	Rashin	Karjat taluka
Volume of water available from local surface storages	0.37	1.91	1.24	0.44	0.87	2.48	1.7	1.31	1.41	11.72
Volume of groundwater	7.08	8.56	8.86	1.90	7.32	10.8	6.16	8.48	6.59	65.76
Total water available from exogenous sources										
Volume of water from Kukadi irrigation project	12.08	12.92	29.27	7.68	30.18	23.90	0	0	24.90	140.93
Volume of water from Sina irrigation project	0	21.23	0	0	0	0	20.1	10.17	0	51.4
Total volume of water from local and exogenous sources	19.53	44.62	39.37	10.02	38.37	37.18	27.96	19.86	32.90	269.81
Surplus/ Deficit = Total volume available – Total Demand	-115.42	-6.15	-30.86	-11.95	1.01	-60.34	-28.15	-60.11	10.49	-301.49

Water Balance under Scenario 1 for Command area in Karjat taluka

	- All units of volume are in MCM unless specified	- All units of areas are in hectares unless specified
	Command Areas (Sina and Kukadi irrigation projects)	
Total geographic area		93989.39
Average rainfall (mm)		391.49
Volume of rainfall available		380.36
Surface runoff volume		39.88
Total non-cultivable area		18305
Volume of in-situ water utilized in non-cultivable areas		14.75
Total fallow land area		1138.55
Volume of in-situ water utilized in fallow lands		1.26
Non-cropped land in 2018-19		33870.62
Volume of in-situ water utilized in non-cropped lands		41.23
Total cultivable area		75683.48
Volume of in-situ water utilized in cultivated areas		153.30
Gross cultivated area in 2018-19		81137.65
Volume of water required for gross cultivated area		469.92
Applied water required for gross cultivated area		316.62
Volume of water for domestic use		4.39
Volume of water for livestock		0.73
Total Volume of water required for all demands		321.75
Volume of water available from local surface storages		7.57
Volume of groundwater		41.62
Total water allocated from exogenous irrigation projects		192.33
Total Water Available for application from local and exogenous sources		241.52
Surplus/ Deficit = Total volume available – Total Demand		-80.23

Water Balance under Scenario 1 for Non-command areas in Karjat taluka

	- All units of volume are in MCM unless specified	- All units of areas are in hectares unless specified
	Non Command Areas	
Total geographic area		54515
Average rainfall (mm)		391.49
Volume of rainfall available		221.90
Surface runoff volume		24.4
Total non-cultivable area		13657
Volume of in-situ water utilized in non-cultivable areas		11.1
Total fallow land area		1460.93
Volume of in-situ water utilized in fallow lands		1.66
Non-cropped land in 2018-19		15003.64
Volume of in-situ water utilized in non-cropped lands		18.33
Total cultivable area		40857.99
Volume of in-situ water utilized in cultivated areas		83.22
Gross cultivated area in 2018-19		50088.21
Volume of water required for gross cultivated area		326.48
Applied water required for gross cultivated area		243.27
Volume of water for domestic use		2.34
Volume of water for livestock		0.44
Total Volume of water required for all demands		246.05
Volume of water available from local surface storages		4.1
Volume of groundwater		24.14
Total water allocated from exogenous irrigation projects		0
Total Water Available for application from local and exogenous sources		28.24
Surplus/ Deficit = Total volume available – Total Demand		-217.81

Scenario 1: Annual Water Balance for 2018-2019 rainfall scenario and cropping patterns in Jamkhed Taluka

- All units of volume are in MCM unless specified
 - All units of areas are in hectares unless specified

	Aarangaon	Javala	Kharada	Nagar Panchayat Jamkhed	Sakat	Jamkhed Taluka
Volume of water available through rainfall						
Total geographic area	16715.67	21521.08	19076.83	6263	19275.36	82851.93
Rainfall in 2018-19 (mm)	502.89	513.21	595.36	550	563.82	545.1
Volume of rainfall available	84.06	110.45	113.58	34.45	108.68	451.21
Surface runoff volume	9.05	11.92	15.45	4.52	15.55	56.48
In-situ water utilization						
Total non-cultivable area	1444.01	2662.7	2768.68	684.3	3659.83	11219.52
Volume of in-situ water utilized in non-cultivable areas	1.45	2.73	3.29	0.75	4.12	12.36
Total fallow land area	3054.33	3771.67	3261.62	1115.74	3123.10	14326.48
Volume of in-situ water utilized in fallow lands	4.6	5.8	5.82	1.84	5.28	23.36
Total cultivated area	12217.32	15086.70	13046.51	4462.96	12492.42	57305.92
Volume of in-situ water utilized in cultivated areas	30.71	38.71	38.83	12.27	35.21	155.76
Water required for various demands						
Gross cultivated area	20923	23920.83	17135	7328.87	22912.55	92221.24
Total volume of water required for gross cultivated area	83.74	121.05	90.68	37.73	106.10	439.32
Applied water required for gross cultivated area	53.02	82.34	51.84	25.45	70.88	283.56
Volume of water for domestic use	1.21	1.18	1.40	1.74	1.19	6.72
Volume of water for livestock	0.19	0.18	0.18	0.016	0.15	0.72
Total volume of water required for all demands	54.42	83.69	53.43	27.21	72.22	291
Volume of water available from local sources						
Volume of water available from local surface storages	11.63	5.494	8.16	2.46	4.48	32.23
Volume of groundwater	4.68	6.03	5.34	1.75	5.4	23.23
Total volume from local sources	16.31	11.52	13.51	4.21	9.87	55.45
Surplus/ Deficit = Total volume available – Total Demand	-38.1	-72.17	-39.92	-23	-62.34	-235.54

Scenario 2: Water balance under 100% of the cultivated area under Kharif and 50% of the cultivated area Rabi crop in Karjat taluka

- All units of volume are in MCM unless specified
- All units of areas are in hectares unless specified

	Bhambora	Chapadgaon	Jalalpur	Karjat Nagar Panchayat	Koregaon	Kuldharan	Mirajgaon	Nimgaon Gangarda	Rashin	Karjat taluka
Volume of water available through rainfall										
Total geographic area	15993.68	19333.86	20018.5	4281.17	16524.69	24390.69	13917.47	19159.41	14884.96	148504.43
Average rainfall (mm)	535.72	568.60	535.45	568.00	549.00	546.53	666.80	651.80	543.35	573.926
Volume of rainfall available	85.68	109.93	107.19	24.32	90.72	113.30	92.80	124.90	80.88	849.72
Surface runoff volume	8.23	12.26	10.22	2.63	9.09	13.69	10.68	16.28	8.26	91.34
In-situ water utilization										
Total non-cultivable area	3972	3531.35	4960	538	2568.85	5698.25	2345.86	4935.35	3412.06	31962.41
Volume of in-situ water utilized in non-cultivable areas	4.26	4.02	5.31	0.61	2.82	6.23	3.13	6.43	3.71	36.52
Total fallow land area	1719	154.78	425.41	53.53	9.2	105.46	29.46	97.4	5.88	2600.12
Volume of in-situ water utilized in fallow lands	2.76	0.26	0.68	0.09	0.02	0.17	0.06	0.19	0.01	4.25
Total cultivated area	12021.31	15802.51	15057.8	3743.17	13955.8	18692.44	11571.61	14224.05	11472.9	116541.67
Volume of in-situ water utilized in cultivated areas	32.20	44.93	40.31	10.63	38.31	51.08	38.58	46.36	31.17	333.57

	Bhambora	Chapadgaon	Jalalpur	Karjat Nagar Panchayat	Koregaon	Kuldharan	Mirajgaon	Nimgaon Gangarda	Rashin	Karjat taluka
Water required for various demands										
Gross cultivated area at 150% cropping intensity	18031.96	23703.76	22586.71	5614.75	20933.81	28038.6	17357.41	21336.07	17209.35	174812.5
Volume of water required for gross cultivated	77.91	106.33	98.95	24.51	92.06	126.23	85.61	106.39	76.84	794.88
Applied water required for gross cultivated area	45.71	61.40	58.63	13.88	53.76	75.15	47.03	60.03	45.67	461.31
Volume of water for domestic use	1.14	1.16	1.05	0.76	1.05	1.12	1.16	1.13	1.16	9.74
Volume of water for livestock	0.2	0.18	0.21	0.05	0.19	0.22	0.13	0.31	0.2	1.67
Total volume of water required for all demands	47.06	62.74	59.90	14.69	55.01	76.5	48.32	61.48	47.01	472.72
Volume of water available from local sources										
Volume of water available from local surface storages	0.54	2.36	1.76	1.07	1.14	3.35	2.55	2.04	1.91	16.72
Volume of groundwater	7.08	8.56	8.86	1.90	7.32	10.8	6.16	8.48	6.59	65.76
Total water available from exogenous sources										
Volume of water from Kukadi irrigation project	12.08	12.92	29.27	7.68	30.18	23.90	0	0	24.90	140.93
Volume of water from Sina irrigation project	0	21.23	0	0	0	0	20.1	10.17	0	51.4

	Bhambora	Chapadgaon	Jalalpur	Karjat Nagar Panchayat	Koregaon	Kuldharan	Mirajgaon	Nimgaon Gangarda	Rashin	Karjat taluka
Total volume of water from local and exogenous sources	19.7	45.07	39.89	10.65	38.64	38.05	28.81	20.59	33.40	274.81
Surplus/ Deficit = Total volume available – Total Demand	-27.35	-17.66	-20.01	-4.05	-16.37	-38.45	-19.51	-40.88	-13.63	-197.91

Water Balance under Scenario 2 for Command areas in Karjat taluka

- All units of volume are in MCM unless specified
- All units of areas are in hectares unless specified

	Command area (Sina and Kukadi irrigation project)
Total geographic area	93989.39
Average rainfall (mm)	573.92
Volume of rainfall available	532.59
Surface runoff volume	55.99
Total non-cultivable area	18305.713
Volume of in-situ water utilized in non-cultivable areas	20.66
Total fallow land area	1139.55
Volume of in-situ water utilized in fallow lands	1.85
Total cultivatable area	75683
Volume of in-situ water utilized in cultivated areas	214.64
Gross cultivated area at 150% cropping intensity	113525
Volume of water required for gross cultivated area	512.68
Applied water required for gross cultivated area	298.05
Volume of water for domestic use	6.33

	Command area (Sina and Kukadi irrigation project)
Volume of water for livestock	1.03
Total volume of water required for all demands	305.41
Volume of water available from local surface storages	10.82
Volume of groundwater	41.62
Total water allocated from exogenous irrigation projects	192.33
Total water available for application from local and exogenous sources	244.77
Surplus/ Deficit = Total volume available – Total Demand	-60.64

Water Balance under Scenario 2 for Non-command areas in Karjat taluka

	- All units of volume are in MCM unless specified
	- All units of areas are in hectares unless specified
	Non-command area
Total geographic area	54515.03
Average rainfall (mm)	573.92
Volume of rainfall available	317.128
Surface runoff volume	35.03
Total non-cultivable area	13657.04
Volume of in-situ water utilized in non-cultivable areas	15.85
Total fallow land area	1460.93
Volume of in-situ water utilized in fallow lands	2.4
Total cultivated area	40857.99
Volume of in-situ water utilized in cultivated areas	118.93
Gross cultivated area at 150% cropping intensity	61286.98
Volume of water required for gross cultivated area	282.19
Applied water required for gross cultivated area	163.26
Volume of water for domestic use	3.38
Volume of water for livestock	0.64
Total volume of water required for all demands	167.27
Volume of water available from local surface storages	5.84

	Non-command area
Volume of groundwater	24.14
Total water allocated from exogenous irrigation projects	0
Total water available for application from local and exogenous sources	29.98
Surplus/ Deficit = Total volume available – Total Demand	-137.29

Scenario 2: Water balance under 100% Kharif and 50% Rabi crop in Jamkhed taluka

- All units of volume are in MCM unless specified
- All units of areas are in hectares unless specified

	Aarangaon	Javala	Kharada	Nagar Panchayat Jamkhed	Sakat	Jamkhed Taluka
Volume of water available through rainfall						
Total geographic area	16715.67	21521.08	19076.83	6263	19275.36	82851.93
Average rainfall (mm)	624	627	649	647	634	636.3
Volume of rainfall available	104.31	134.94	123.88	40.52	122.21	525.84
Surface runoff volume	11.23	14.56	16.85	5.32	17.48	65.44
In-situ water utilization						
Total non-cultivable area	1444.01	2662.7	2768.68	684.3	3659.83	11219.52
Volume of in-situ water utilized in non-cultivable areas	1.80	3.33	3.59	0.88	4.64	14.26
Total fallow land area	3054.33	3771.67	3261.62	1115.74	3123.10	14326.48
Volume of in-situ water utilized in fallow lands	5.711	7.094	6.35	2.16	5.94	27.27
Total cultivated area	12217.32	15086.70	13046.51	4462.96	12492.42	57305.92
Volume of in-situ water utilized in cultivated areas	38.12	47.29	42.36	14.44	39.60	181.81
Water required for various demands						
Gross cultivated area at 150% cropping intensity	18325.99	22630.05	19569.76	6694.44	18738.63	85958.89
Volume of water required for gross cultivated area	73.35	94.17	73.27	23.35	73.16	337.32
Applied water required for gross cultivated area	35.23	46.88	30.91	8.91	33.56	155.51
Volume of water for domestic use	1.21	1.18	1.40	1.74	1.19	6.72
Volume of water for livestock	0.19	0.18	0.18	0.016	0.15	0.715
Total volume of water required for all demands	36.63	48.23	32.50	10.66	34.90	162.94

	Aarangaon	Javala	Kharada	Nagar Panchayat Jamkhed	Sakat	Jamkhed Taluka
Volume of water available from local sources						
Volume of water available from local surface storages	11.63	5.494	8.16	2.46	4.48	32.23
Volume of groundwater	4.68	6.03	5.34	1.75	5.4	23.23
Total volume from local sources	16.31	11.52	13.5	4.21	9.88	55.45
Surplus/ Deficit = Total volume available – Total Demand	-20.31	-36.71	-19	-6.45	-25.02	-107.49

Scenario 3: Water balance to provide irrigation for 30% of cultivated area in Kharif and 30% cultivated area in Rabi season in Karjat Taluka

- All units of volume are in MCM unless specified
- All units of areas are in hectares unless specified

	Bhambora	Chapadgaon	Jalalpur	Karjat Nagar Panchayat	Koregaon	Kuldharan	Mirajgaon	Nimgaon Gangarda	Rashin	Karjat taluka
Volume of water available through rainfall										
Total geographic area	15993.68	19333.86	20018.5	4281.17	16524.69	24390.69	13917.47	19159.41	14884.96	148504.43
Average rainfall (mm)	535.72	568.60	535.45	568.00	549.00	546.53	666.80	651.80	543.35	573.926
Volume of rainfall available	85.68	109.93	107.19	24.32	90.72	113.30	92.80	124.90	80.88	849.72
Surface runoff volume	8.23	12.26	10.22	2.63	9.09	13.69	10.68	16.28	8.26	91.34
In-situ water utilization										
Total non-cultivable area	3972	3531.35	4960	538	2568.85	5698.25	2345.86	4935.35	3412.06	31962.41
Volume of in-situ water utilized in non-cultivable	4.26	4.02	5.31	0.61	2.82	6.23	3.13	6.43	3.71	36.52

	Bhambora	Chapadgaon	Jalalpur	Karjat Nagar Panchayat	Koregaon	Kuldharan	Mirajgaon	Nimgaon Gangarda	Rashin	Karjat taluka
areas										
Total fallow land area	1719	154.78	425.41	53.53	9.2	105.46	29.46	97.4	5.88	2600.12
Volume of in-situ water utilized in fallow lands	2.76	0.26	0.68	0.09	0.02	0.17	0.06	0.19	0.01	4.25
Total cultivated area	12021.31	15802.51	15057.8	3743.17	13955.8	18692.44	11571.61	14224.05	11472.9	116541.67
Volume of in-situ water utilized in cultivated areas	32.20	44.93	40.31	10.63	38.31	51.08	38.58	46.36	31.17	333.57
Water required for various demands										
Per hectare water requirement for Kharif crop (MCM/ha)	0.1262	0.0042	0.0059	0.0039	0.0042	0.0058	0.0056	0.00589	0.0062	0.05
Volume of water required for Kharif area assuming 30% is under protective irrigation	45.51	19.899	26.772	4.423	17.866	32.509	19.584	25.133	21.366	213.07
Volume of in-situ water utilized for 30% Kharif area	9.66	13.47	12.09	3.18	11.49	15.32	11.57	13.90	9.35	100.07
Volume of applied water required for 30% Kharif area	35.85	6.4	14.6	1.23	6.37	17.1	8.01	11.22	12.01	113
Total area under Rabi irrigation (30% of cultivated	3606.39	4740.75	4517.342	1122.95	4186.76	5607.73	3471.48	4267.21	3441.87	34962.5

	Bhambora	Chapadgaon	Jalalpur	Karjat Nagar Panchayat	Koregaon	Kuldharan	Mirajgaon	Nimgaon Gangarda	Rashin	Karjat taluka
area)										
Volume of water required for Rabi irrigation	16.68	22.30	21.85	5.3	19.60	26.88	16.53	19.80	16.49	165.47
Volume of water for domestic use	1.14	1.16	1.05	0.76	1.05	1.12	1.16	1.13	1.16	9.74
Volume of water for livestock	0.2	0.18	0.21	0.05	0.19	0.22	0.13	0.31	0.2	1.67
Total volume of water required for all demands	53.88	30.06	37.79	7.34	27.22	45.41	25.82	32.47	29.87	289.88
Volume of water available from local sources										
Volume of water available from local surface storages	0.54	2.36	1.76	1.07	1.14	3.35	2.55	2.04	1.91	16.72
Volume of groundwater	7.08	8.56	8.86	1.90	7.32	10.8	6.16	8.48	6.59	65.76
Total water available from exogenous sources										
Volume of water from Kukadi irrigation project	12.08	12.92	29.27	7.68	30.18	23.90	0	0	24.90	140.93
Volume of water from Sina irrigation project	0	21.23	0	0	0	0	20.1	10.17	0	51.4
Total volume of water from local and exogenous sources	19.7	45.07	39.89	10.65	38.64	38.05	28.81	20.59	33.40	274.81
Surplus/ Deficit = Total volume	-34.18	15.01	2.40	3.30	11.41	-7.36	2.89	-11.78	3.54	-14.76

	Bhambora	Chapadgaon	Jalalpur	Karjat Nagar Panchayat	Koregaon	Kuldharan	Mirajgaon	Nimgaon Gangarda	Rashin	Karjat taluka
available – Total Demand										

Water Balance under Scenario 3 for Command areas of Karjat Taluka

	Command area (Sina and Kukadi irrigation projects)
Total geographic area	93989.39
Average rainfall (mm)	573.926
Volume of rainfall available	532.59
Surface runoff volume	56
Total non-cultivable area	18305.71
Volume of in-situ water utilized in non-cultivable areas	20.66
Total fallow land area	1139.55
Volume of in-situ water utilized in fallow lands	1.85
Total cultivated area	75683.48
Volume of in-situ water utilized in cultivated areas	214.64
Water requirement for 30% of area under Kharif as protective irrigation	130.9
In-situ water requirement for 30% of Kharif Area	64.39
Applied water requirement for 30% of Kharif area	66.6
30% of cultivated area for Rabi	22705.04
Applied water required for Rabi area	107.72
Volume of water for domestic use	6.33
Volume of water for livestock	0.11
Total Volume of water required for all demands	180.76
Volume of water available from local surface storages	10.82
Volume of groundwater	41.62
Total water allocated from exogenous irrigation projects	192.64
Total Water Available for application from local and exogenous sources	245.07

Surplus/ Deficit = Total volume available – Total Demand	Command area (Sina and Kukadi irrigation projects)
	64.31

Water Balance under Scenario 3 for Non-command areas of Karjat Taluka

Total geographic area	Command area (Sina and Kukadi irrigation projects)
Average rainfall (mm)	54515.03
Volume of rainfall available	573.926
Surface runoff volume	317.13
Total non-cultivable area	35.03
Volume of in-situ water utilized in non-cultivable areas	13657.04
Total fallow land area	15.85
Volume of in-situ water utilized in fallow lands	1460.93
Total cultivated area	2.4
Volume of in-situ water utilized in cultivated areas	40857.99
Water requirement for 30% of area under Kharif as protective irrigation	118.93
In-situ water requirement for 30% of Kharif Area	82.08
Applied water requirement for 30% of Kharif area	35.68
30% of cultivated area for Rabi	46.40
Applied water required for Rabi area	12257
Volume of water for domestic use	57.75
Volume of water for livestock	3.38
Total Volume of water required for all demands	0.07
Volume of water available from local surface storages	107.59
Volume of groundwater	5.84
Total water allocated from exogenous irrigation projects	24.14
Total Water Available for application from local and exogenous sources	0
Surplus/ Deficit = Total volume available – Total Demand	29.98
	-77.61

Scenario 3: Water balance under the scenario where irrigation for 30% of cultivated area in Kharif season and 30% of cultivated area in Rabi season in Jamkhed taluka

- All units of volume are in MCM unless specified
- All units of areas are in hectares unless specified

	Aarangaon	Javala	Kharada	Nagar Panchayat Jamkhed	Sakat	Jamkhed Taluka
Volume of water available through rainfall						
Total geographic area	16715.67	21521.08	19076.83	6263	19275.36	82851.93
Average rainfall (mm)	624	627	649	647	634	636.3
Volume of rainfall available	104.31	134.94	123.88	40.52	122.21	525.84
Surface runoff volume	11.23	14.56	16.85	5.32	17.48	65.44
In-situ water utilization						
Total non-cultivable area	1444.01	2662.7	2768.68	684.3	3659.83	11219.52
Volume of in-situ water utilized in non-cultivable areas	1.80	3.33	3.59	0.88	4.64	14.26
Total fallow land area	3054.33	3771.67	3261.62	1115.74	3123.10	14326.48
Volume of in-situ water utilized in fallow lands	5.711	7.094	6.35	2.16	5.94	27.27
Total cultivated area	12217.32	15086.70	13046.51	4462.96	12492.42	57305.92
Volume of in-situ water utilized in cultivated areas	38.12	47.30	42.36	14.44	39.60	181.81
Water required for various demands						
Per hectare water requirement for Kharif crop (MCM/ha)	0.0039	0.0042	0.0036	0.0031	0.0038	0.019
Volume of water required for Kharif area assuming 30% is under protective irrigation	14.607	19.146	14.179	4.279	14.369	66.58
Volume of In-situ water utilized for 30% Kharif area	11.43	14.19	12.71	4.33	11.88	54.54
Volume of applied water required for 30% Kharif area	3.17	4.96	1.47	-0.05	2.49	12.04
Total Area under Rabi irrigation (30% of cultivated area)	3665.2	4526.01	3913.95	1338.9	3747.73	17191.78
Volume of applied water required for Rabi irrigation	14.82	18.17	15.72	5.48	15.11	69.30
Volume of water for domestic use	1.21	1.18	1.40	1.74	1.19	6.72
Volume of water for livestock	0.19	0.18	0.18	0.016	0.15	0.715
Total Volume of water required for all demands	19.38	24.48	18.78	7.17	18.94	88.77
Volume of water available from local sources						
Volume of water available from local surface storages	11.63	5.494	8.16	2.46	4.48	32.23
Volume of groundwater	4.68	6.03	5.34	1.75	5.4	23.23

	Aarangaon	Javala	Kharada	Nagar Panchayat Jamkhed	Sakat	Jamkhed Taluka
Total volume from local sources	16.31	11.52	13.5	4.21	9.88	55.45
Surplus/ Deficit = Total volume available – Total Demand	-3.06	-12.96	-5.27	-2.96	-9.05	-33.32

Scenario 4: Water Balance under biomass scenario for Karjat taluka

- All units of volume are in MCM unless specified
- All units of areas are in hectares unless specified

	Bhambora	Chapadgaon	Jalapur	Karjat Nagar Panchayat	Koregaon	Kuldharan	Mirajgaon	Nimgaon Gangarda	Rashin	Karjat taluka
Total geographic area	15993.68	19333.86	20018.5	4281.17	16524.69	24390.69	13917.47	19159.41	14884.96	148504.43
75% dependable rainfall (mm)	364	407	374	344	377	400	450	440	358	390
Volume of rainfall available at 75% dependable rainfall	58.21	78.69	74.87	14.73	62.30	97.56	62.63	84.30	53.29	586.58
Total non-cultivable area	3972	3531.35	4960	538	2568.85	5698.25	2345.86	4935.35	3412.06	31962.41
Volume of in-situ water utilized in non-cultivable areas	2.89	2.87	3.71	0.37	1.94	4.56	2.11	4.34	2.44	25.24
Total fallow land area	1719	154.78	425.41	53.53	9.2	105.46	29.46	97.4	5.88	2600.12
Volume of in-situ water utilized in fallow lands	1.88	0.19	0.48	0.06	0.01	0.13	0.04	0.13	0.01	2.91
Total cultivatable area	12021.31	15802.31	15057.81	3743.17	13955.87	18692.44	11571.61	14224.05	11472.9	116541.67
Volume of in-situ water utilized in cultivated areas	21.88	32.16	28.16	6.44	26.31	37.38	26.04	31.29	20.54	230.19
Total volume of in-situ water utilized	26.65	35.22	32.35	6.86	28.25	42.07	28.19	35.76	22.99	258.34

	Bhambora	Chapadgaon	Jalalpur	Karjat Nagar Panchayat	Koregaon	Kuldharan	Mirajgaon	Nimgaon Gangarda	Rashin	Karjat taluka
Total number of households (projected for 2020)	6534	6828	6041	4162	5937	6697	6648	6729	6677	56253
Biomass required @18 T per family (tons)	117614	122902	108741	74920	106871	120537	119657	121122	120190	1012555
Domestic water requirement @200 m ³ /HH	1.31	1.37	1.21	0.83	1.19	1.34	1.33	1.35	1.34	11.25
Livestock water requirement @ 200 m ³ /HH	1.31	1.37	1.21	0.83	1.19	1.34	1.33	1.35	1.34	11.25
Water required for biomass production based on a productivity norm of 3kg/m ³ of water	39.20	40.97	36.25	24.97	35.62	40.18	39.89	40.37	40.06	337.52
Water required for industrial and commercial use taken at 5% of the available rainfall	2.91	4.04	3.74	0.74	3.11	4.88	3.13	4.22	2.66	29.33
Total water requirement	44.73	47.73	42.41	27.37	41.11	47.74	45.68	47.28	45.40	389.35
Local water available for applied water at 15% of 75% dependable volume of water	8.73	11.8	11.23	2.21	9.34	14.63	9.39	12.65	7.99	87.99
Exogenous water: Allocated water from Sina project	0.00	21.24	0.00	0.00	0.00	0.00	20.11	10.07	0.00	51.42

	Bhambora	Chapadgaon	Jalalpur	Karjat Nagar Panchayat	Koregaon	Kuldharan	Mirajgaon	Nimgaon Gangarda	Rashin	Karjat taluka
Exogenous water: Allocated water from Kukadi project	12.08	12.92	29.28	7.68	30.20	23.91	0.00	0.00	24.90	140.97
Total committed exogenous water	12.08	34.16	29.28	7.68	30.20	23.91	20.11	10.07	24.90	192.39
Local applied water available for biomass production	6.12	9.38	8.81	0.54	6.97	11.96	6.74	9.95	5.32	65.79
Local applied water for biomass production with 70% efficiency	4.28	6.35	6.17	0.38	4.88	8.37	4.71	6.97	3.73	45.84
Total potential local water use for biomass production (in-situ use and applied)	30.93	41.57	38.52	7.24	33.13	50.44	32.90	42.73	26.71	304.18
Exogenous water for biomass production	12.08	34.16	29.28	7.68	30.20	23.91	20.11	10.07	24.90	192.39
Total water (local water [consisting of insitu + local applied water] +exogenous water) available for biomass production + industrial/commercial use	43.01	75.73	67.80	14.92	63.33	74.35	53.01	52.80	51.61	496.57
Total water (local water [consisting of insitu + local applied water] + exogenous water) available for biomass production	40.10	71.80	64.05	14.19	60.22	69.47	49.88	48.59	48.95	467.24

	Bhambora	Chapadgaon	Jalalpur	Karjat Nagar Panchayat	Koregaon	Kuldharan	Mirajgaon	Nimgaon Gangarda	Rashin	Karjat taluka
after deducting water required for industrial/commercial use										
Surplus/deficit for biomass production	-1.72	28.1	25.39	-12.45	22.22	26.61	7.34	5.52	6.21	107.22

Water Balance under Scenario 4 in the Command Area of Karjat Taluka

- All units of volume are in MCM unless specified
All units of areas are in hectares unless specified

	Command area (Sina and Kukadi irrigation projects)
Total geographic Area	93989.39
75% dependable rainfall (mm)	390
Volume of rainfall available	366.76
Total non-cultivable area	18305.71
Volume of in-situ water utilized in non-cultivable areas	14.26
Total fallow land area	1139.55
Volume of in-situ water utilized in fallow lands	1.27
Total cultivatable area	75683.48
Volume of in-situ water utilized in cultivated areas	147.72
Total volume of in-situ water utilized	163.25
Total number of households (projected for 2020)	38151
Biomass required @18 T per family (tons)	686718
Domestic water requirement @200 m ³ /HH (MCM)	7.63
Livestock water requirement @ 200 m ³ /HH (MCM)	7.18
Water required for biomass production based on a productivity norm of 3kg/m ³ of water (MCM)	228.91
Water required for industrial and commercial use taken at 5% of the available rainfall	18.34

	Command area (Sina and Kukadi irrigation projects)
Total water requirement (MCM)	262.05
Local water available for applied water at 15% of 75% dependable volume of water	55.01
Exogenous water: Allocated water from Sina project	51.42
Exogenous water: Allocated water from Kukadi project	140.97
Total committed exogenous water	192.64
Local applied water available for biomass production	39.75
Local applied water for biomass production with 70% efficiency	27.83
Total potential local water use for biomass production (in-situ use and applied)	191.08
Exogenous water for biomass production at 60% efficiency column	192.39
Total water (local water [consisting of in situ + local applied water] + exogenous water) available for biomass production + industrial/commercial use	383.47
Total water (local water [consisting of in situ + local applied water] + exogenous water) available for biomass production after deducting water required for industrial/commercial use	365.13
Surplus/deficit for biomass production	120.97

Water Balance under Scenario 4 for Non-command areas of Karjat taluka

All units of volume are in MCM unless specified
All units of areas are in hectares unless specified

	Non- Command area
Total geographic area	54515
75% dependable rainfall (mm)	390
Volume of rainfall available	219.82
Total non-cultivable area	13657
Volume of in-situ water utilized in non-cultivable areas	10.98
Total fallow land area	1460.93
Volume of in-situ water utilized in fallow lands	1.64
Total cultivated area	40857.99
Volume of in-situ water utilized in cultivated areas	82.47
Total volume of in-situ water utilized	95.09

	Non-Command area
Total number of households (projected for 2020)	18102
Biomass required @18 T per family (tons)	325836
Domestic water requirement @200 m ³ /HH (MCM)	3.62
Livestock water requirement @ 200 m ³ /HH (MCM)	2.76
Water required for biomass production based on a productivity norm of 3kg/m ³ of water (MCM)	108.61
Water required for industrial and commercial use taken at 5% of the available rainfall	10.99
Total water requirement	125.99
Local water available for applied water at 15% of 75% dependable volume of water	32.97
Exogenous water: Allocated water from Sina project	0
Exogenous water: Allocated water from Kukadi project	0
Total committed exogenous water	0
Local applied water available for biomass production	25.73
Local applied water for biomass production with 70% efficiency	18.01
Total potential local water use for biomass production (in-situ use and applied)	113.01
Exogenous water for biomass production at 60% efficiency column	0
Total water (local water [consisting of in situ + local applied water] + exogenous water) available for biomass production + industrial/commercial use	113.10
Total water (local water [consisting of in situ + local applied water] + exogenous water) available for biomass production after deducting water required for industrial/commercial use	102.11
Surplus/deficit for biomass production	-13.74

Scenario4: Water Balance under biomass scenario for Jamkhed Taluka

- All units of volume are in MCM unless specified
- All units of areas are in hectares unless specified

	Aarangaon	Javala	Kharda	Nagar Panchayat Jamkhed	Sakat	Jamkhed taluka
Total geographic area	16715.67	21521.08	19076.83	6263.00	19,275.36	82851.94
Average rainfall at 75% dependability (mm)	484	475.00	473.00	522.00	487.00	488.20

	Aarangaon	Javala	Kharda	Nagar Panchayat Jamkhed	Sakat	Jamkhed taluka
Volume of rainfall available at 75% dependability						
Total non-cultivable area	80.904	102.23	90.23	32.69	93.87	404.48
Volume of in-situ water utilized in non-cultivable areas	1444	2,662.70	2,768.68	684.30	3,659.83	11219.52
Total fallow land area	1.4	2.53	2.62	0.71	3.56	10.83
Volume of in-situ water utilized in fallow lands	3054.33	3,771.68	3,261.63	1,115.74	3,123.11	14326.49
Total cultivated area	4.43	5.37	4.63	1.75	4.56	20.75
Volume of in-situ water utilized in cultivated areas	12217.33	15086.70	13046.51	4462.96	12492.42	57305.92
Total volume of in-situ water utilized	29.57	35.83	30.85	11.65	30.42	138.32
Total number of households (projected for 2020)	35.40	43.74	38.10	14.11	38.55	169.89
Biomass required @18 T per family (tons)	7167	7,096	7,999	9,514	6,896	38,671
Domestic water requirement @200 m ³ /HH (MCM)	129006	127728	143982	171252	124128	696080
Livestock water requirement @ 200 m ³ /HH (MCM)	1.43	1.42	1.60	1.90	1.38	7.73
Water required for biomass production based on a productivity norm of 3kg/ m ³ of water (MCM)	1.43	1.42	1.60	1.90	1.38	7.73
Water required for industrial and commercial use taken at 5% of the available rainfall	43	42.58	47.99	57.08	41.38	232.03
Total water requirement	4.05	5.11	4.51	1.63	4.69	20.22
Local water available for applied water at 15% of 75% dependable volume of water	49.91	50.53	55.71	62.52	48.83	267.72
Total committed exogenous water	12.14	15.33	13.54	4.90	14.08	60.67
Local applied water available for biomass production	0.0	0.0	0.0	0.0	0.0	0.0
Local applied water for biomass production with 70% efficiency	9.27	12.50	10.34	1.10	11.32	45.20
Total potential local water use for biomass production (in-situ use and applied)	6.49	8.75	7.23	0.77	7.93	31.64
Total water (local water [consisting of in situ + local applied water] + exogenous water) available for biomass production after deducting water required for industrial/commercial use	41.89	52.48	45.34	14.88	46.47	201.54
Surplus/deficit for biomass production	37.84	47.37	40.83	13.24	41.78	181.31
	-8.03	1.96	-10.37	-47.65	-2.36	-66.44