Dedicated To Life

CSR IMPACT ASSESSMENT REPORT

ZYDUS WATERSHED PROJECT
Zydus Lifesciences Ltd.

Assessment Year
2025-26

CONTENTS

A. SOCIAL ASSESSMENT

ABBREVIATIONS

AFPRO	Action forFood Production
CGWB	Central Ground Water Board
CSR	Corporate Social Responsibility
Cum	Cubic Metre
FGD	Focus Group Discussion
FY	Financial Year
Ha	Hectare
IA	Impact Assessment
KII	Key Informant Interview
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MPCT	Mukesh Patel Charitable Trust
NDW	Nala Deepening and Widening
NITI AAYOG	National Institution for Transforming India
OECD-DAC	Organisation for Economic Co-operation and Development – Development Assistance Committee
PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
SDG	Sustainable Development Goal

CHAPTER 1
EXECUTIVE SUMMARY

PROJECT OVERVIEW

In 2024–25, the Zydus Lifesciences CSR Initiative implemented a watershed programme in Viramgam (Gujarat) through AFPRO and in Shirpur (Maharashtra) through MPCT (Mukesh Patel Charitable Trust) to improve water availability and support rain-fed agriculture in drought-prone regions. In Viramgam, the project covered 11 villages, while in Shirpur, the intervention covered 2 villages, focusing on groundwater recharge and irrigation access.

The programme adopted a multi-component watershed approach, including the restoration of water bodies, farm ponds, recharge structures, and Bandhara-based interventions, supported by community participation.

Before the intervention, limited irrigation access and high dependence on monsoon rainfall constrained agricultural productivity. Post-intervention, improved water availability enabled multi-season cultivation and crop diversification, with ~50% increase in crop yield and income gains exceeding ₹1 lakh annually.

These outcomes are supported by hydrological assessments, indicating ~3.48 lakh cubic metres of groundwater recharge through watershed interventions in Viramgam. In Shirpur, the assessment indicates an overall groundwater recharge potential of ~14.09 lakh cubic metres, primarily driven by rainfall and supported by Bandhara-based interventions, along with improvements in seasonal water availability.

PROJECT ACTIVITIES

Shirpur (Dhule)

5 Bandharas were constructed to enhance surface water storage and support groundwater recharge

VIRAMGAM & MANDAL (AHMEDABAD)

Existing percolation tanks, community ponds, and earthen dams were restored to improve water storage and recharge capacity (5 structures)
Nala deepening and widening works were carried out to improve runoff management and groundwater recharge (2 stretches)
Farm ponds were constructed to enable on-farm water storage and irrigation support (5 units)
Recharge shafts with injection borewells were installed in submergence areas to enhance groundwater recharge (4 units)
Recharge shafts with injection borewells were installed at the farm level to support direct groundwater recharge (17units)

ALIGNMENT WITH SDGs

ALIGNMENT WITH THE GOVERNMENT INITIATIVES

- Jal Shakti Abhiyan
- Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)
- Atal Bhujal Yojana
- MGNREGA

COMMUNITY POND, GUJARAT

Key Findings

COMPONENTA:SHIRPUR-DHULEBANDHARA INTERVENTION

Seasonal drying ofwellsreducedfrom 96.0% to 28.0%, with water availability (>5 months) increasing from 8.0%to100.0%

Irrigation access increased from 20.0% to 100.0% during crop growth stages, 92.0% reported the ability to cultivate multiple seasons.

Shift from 100.0% rainfed to 100.0% irrigated/commercial cropping

Cropping intensity increased from 0.0% to 88.0%, cultivating more than two crops

Fallow land reduced from 96.0% to 12.0%, with 88.0% reporting no fallow land

Crop water stress reduced from 100.0% to 0.0%, with yields increasing from 0.0% to 100.0%

Respondents earning >₹5 lakh increased from 8.0% to 76.0%, while <₹2 lakh declined from 64.0% to 12.0%

COMPONENTB:VIRAMGAM-AHMEDABAD- WATERSHED INTERVENTION

98.3%

ofgroundwaterlevels increased by more than 5 feet.

98.3%

ofthetime,wateravailability in wells extended by more than 3 months.

95.0%

ofwaterstructuresretain water for more than 6 months.

98.3%

of farms receive direct irrigation from structures.

100.0%

ofrespondentsreportedanincreaseincrop yields.

95.0%

oftheyieldincreasemainlyfallsintherange of 25.0%–50.0%.

90.0%

ofagriculturaleffortshaveshiftedtomulti-season cropping.

100.0%

ofrespondentsreportedanincreaseinagricultural income.

58.3%

ofthecostswerereducedduetoirrigation-related improvements.

93.3%

ofthefoddercultivationincreasewasmore than 50.0%.

95.0%

ofrespondentsreportedmilkyieldincrease by over 30% , reflecting significant impact

98.3%

of crops survive better during dry spells.

96.6%

of water is available during irregular rainfall."

98.3%

of the soil moisture improved.

98.3%

of the maintenance systems are in place.

91.7%

of Panchayat involvement was reported.

Key Impacts

COMPONENTA:SHIRPUR-DHULEBANDHARA INTERVENTION

96.0%

reported increased water levels, 80.0% reported longer summer water availability, and 76.0% reported revivalof previously dry wells

88.0%

reportedreducedrainfall dependence, and 88.0% reported irrigation at critical stages

96.0%

adoptedhigh-valuecrops, 92.0% shifted to irrigated crops, and 88.0% introduced new crops

92.0%

reportedmulti-seasoncultivation, and 64.0% reported improved irrigation scheduling

100.0%

cultivatedadditionalseasons, 92.0% increased cultivated area, and 88.0% brought fallow land under cultivation

96.0%

reportedincreasedyields, 92.0% reported higher production, and 80.0% reported improved crop quality

100.0%

reported improved financial security, 92.0% improved financial stability, and 76.0% reported reduced household debt

COMPONENTB:VIRAMGAM-AHMEDABAD- WATERSHED INTERVENTION

98.3%

ofrespondentsreported improved groundwater availability.

98.3%

ofthereportsindicated an extended duration of water availability.

95.0%

ofreportsindicatesustained surface water availability.

98.3%

ofrespondentsreportedimproved irrigation access.

100.0%

increaseinagriculturalproductivity reported.

95.0%

ofthemajorityreportedayieldincrease of 25.0%–50.0%.

90.0%

increase in cropping intensity reported

100.0%

increase in agricultural income reported.

58.3%

reduction in irrigation costs reported.

93.3%

of increased fodder availability reported.

95.0%

ofimprovedlivestockproductivity reported

98.3%

ofcropsreportedlyshowedimproved survival during dry conditions.

96.6%

ofwateravailabilityisreportedduring rainfall variability.

98.3%

ofimprovedsoilmoistureconditions have been reported.

93.3%

ofthemaintenancewasreported as community-led.

91.7%

ofinstitutionalsupportwasreported through Panchayat.

CHAPTER 2
INTRODUCTION

Discussion with SHG group during field visit

BACKGROUND AND NEED OF THE PROGRAMME

Water scarcity and declining groundwater levels continue to pose significant challenges in semi-arid regions of India, particularly in Gujarat and Maharashtra, where agriculture is highly dependent on monsoon rainfall. According to the Central Groundwater Board, groundwater supplies nearly 60.0% of irrigation and 85.0% of rural drinking water, placing increasing pressure on this resource. At the same time, about 52.0% of India's net sown area remains rainfed, making agriculture highly vulnerable to rainfall variability. In comparison, nearly 55.0%–60.0% of the population depends on agriculture and allied activities for their livelihood. India is also the largest user of groundwater globally, accounting for about 25.0% of global extraction, according to the World Bank.

CGWB Reports and Publications

Groundwater depletion and water stress are intensifying due to over-extraction, inadequate recharge, and climate variability. The NITI Aayog Composite Water Management Index (2019) indicates that 21 major cities are at risk of groundwater depletion, and that nearly 40.0% of India's population may face water scarcity by 2030. In rural areas, limited water availability restricts farmers to single-season cropping and low-value agriculture, contributing to reduced productivity, income instability, and seasonal migration. While government initiatives such as Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), Jal Shakti Abhiyan, and Atal Bhujal Yojana promote watershed and groundwater management, there remains a need for localised, community-driven watershed interventions.

In response, the Zydus Lifesciences CSR Initiative, in collaboration with AFPRO & MPCT, implemented a watershed programme during FY 2024–25 across Shirpur (Maharashtra) and Viramgam & Mandal (Gujarat). The programme focused on enhancing groundwater recharge, improving irrigation access, and promoting sustainable water use through interventions such as Bandharas, farm ponds, recharge structures, and watershed development activities. An independent impact assessment was conducted in FY 2025–26 to evaluate the programme’s effectiveness in improving water availability, agricultural productivity, and livelihood outcomes.

OBJECTIVES OF THE PROGRAMME

Viramgam & Mandal (Ahmedabad)

Groundwater augmentation through artificial recharge and rainwater harvesting, with envisaged water storage of more than 16 lakh kilolitres and groundwater recharge potential up to 20 lakh kilolitres

Improving water productivity and water-use efficiency through active community participation

Capacity building of the local community with data, skills, and knowledge for sustainable water resource management

Shirpur (Dhule)

Groundwater recharge and surface water storage enhancement through Bandhara-based watershed interventions

Improving irrigation access and efficient use of available water for agriculture

Strengthening farmer capacity and local participation for sustainable water use and management

ABOUT THE ZYDUS LIFESCIENCES CSR INITIATIVES

Zydus Lifesciences is a prominent Indian pharmaceutical company focused on developing, manufacturing, and marketing healthcare products globally. It aims to enhance health outcomes and support social development through its Corporate Social Responsibility (CSR) initiatives.

Zydus Lifesciences' CSR initiatives prioritize healthcare, education, water conservation, and community development, aiming to enhance life quality for underserved and rural populations. By partnering with implementation agencies, they focus on need-based interventions for sustainable impact. In water management, they support groundwater recharge and sustainable agriculture in water-stressed areas, improving irrigation access and livelihoods for farming communities.

ABOUT THE AFPRO (ACTION FOR FOOD PRODUCTION)

Action for Food Production (AFPRO) is a national development organization focused on sustainable natural resource management and enhancing rural livelihoods. It prioritizes water resource development, agricultural management, watershed management, and capacity building, especially in vulnerable and water-stressed regions.

Under the Zydus Watershed Project (2024–25), AFPRO implemented watershed interventions across Viramgam & Mandal (Gujarat), including farm ponds, recharge structures, and nala development, to improve groundwater availability and irrigation access.

Through its technical expertise and community-based approach, AFPRO facilitated interventions to strengthen water security, agricultural productivity, and livelihood resilience in the intervention areas.

ABOUT THE MUKESH PATEL CHARITABLE TRUST (MPCT)

Mukesh Patel Charitable Trust (MPCT) is a non-profit in Shirpur, Maharashtra, focused on rural development and water resource management. It implements watershed interventions, such as Bandhara construction, groundwater recharge, to enhance water availability and support agriculture in drought-prone areas.

In the Zydus Watershed Programme, MPCT served as the implementing partner for Shirpur, facilitating on-ground execution of interventions and community engagement to enhance water retention and irrigation access.

CHAPTER 3
RESEARCH METHODOLOGY

The programme design study, carried out by SoulAce for the watershed project implemented by AFPRO & MPCT and supported by Zydus Lifesciences, focused on addressing water scarcity and improving irrigation access in Shirpur (Maharashtra) and Viramgam & Mandal (Gujarat). The design aimed to enhance water availability, strengthen agricultural outcomes, and promote sustainable water resource management through integrated watershed interventions.

STUDY OBJECTIVES

- To assess the reach, relevance, and effectiveness of watershed interventions implemented across the project locations
- To evaluate the effectiveness of key interventions such as Bandharas, farm ponds, recharge structures, and watershed development activities
- To examine changes in water availability, irrigation access, and agricultural practices
- To understand stakeholder perspectives on programme implementation, participation, and outcomes
- To identify programme strengths, gaps, and opportunities for improving effectiveness and sustainability

RESEARCH DESIGN

This study employs a mixed-methods approach, integrating quantitative and qualitative methods to provide a comprehensive understanding of the project outcomes.

Quantitative methods involved structured surveys administered to beneficiary households across intervention areas. Qualitative methods

included focus group discussions and key informant interviews with stakeholders, including farmers, community members, and local representatives.

These methods were used to capture changes in water availability, irrigation access, agricultural practices, and livelihoods, and to triangulate findings for a robust assessment. Hydrological analysis was also incorporated to validate groundwater recharge and water availability outcomes.

APPLICATION OF QUANTITATIVE TECHNIQUES

Quantitative methodologies involved structured surveys administered to beneficiary households across the intervention areas, including Shirpur (n=25) and Viramgam (n=60), selected through a defined sampling framework. This approach ensured representative data collection and enabled statistical analysis of key indicators related to water availability, irrigation access, agricultural practices, and livelihood outcomes.

APPLICATION OF QUALITATIVE TECHNIQUES

Qualitative methods included in-depth interviews, focus group discussions (FGDs), and individual interactions with farmers, community members, and local representatives to understand on-ground implementation and experiences. Success stories were also documented to capture individual-level changes.

These interactions complemented quantitative findings by capturing perceptions, challenges, behavioural changes, and practical insights on water availability, irrigation practices, and livelihoods, thereby enabling a comprehensive assessment of programme effectiveness and sustainability.

ENSURING TRIANGULATION

The assessment adopted a triangulation approach to enhance the reliability and validity of findings by integrating multiple data sources and methods. Quantitative data collected through household surveys were complemented with qualitative inputs from Focus Group Discussions (FGDs), Key Informant Interviews (KIIs), and case studies. These findings were further validated using secondary data sources, including project documents, baseline reports, and the hydrological impact assessment, which provided technical evidence on groundwater recharge, water storage, and irrigation improvements. The convergence of evidence from these sources ensured a comprehensive and robust assessment of programme outcomes. Any inconsistencies across data sources were cross-verified through field observations and stakeholder consultations.

DATA SOURCES

The assessment used multiple data sources to ensure triangulation of findings. Primary data was collected through household surveys, FGDs, and stakeholder interviews. Secondary data sources included project documents, baseline reports, and implementation records provided by Zydus Lifesciences CSR, AFPRO & MPCT.

Additionally, a hydrological impact assessment report was used to provide technical evidence on

groundwater recharge potential,
runoff management, and water storage improvements, particularly for interventions implemented in Viramgam and Mandal.

USE OF HYDROLOGICAL ASSESSMENT

The study incorporated findings from a hydrological assessment conducted for the project interventions in Viramgam and Mandal. The analysis provided quantitative estimates of groundwater recharge, runoff reduction, and water storage capacity, which were used to validate field-level findings. This integration strengthened the overall evidence base and enhanced the credibility of the assessment.

PROJECT SNAPSHOT

Project Name

Zydus Watershed Project

Implementation Period

FY 2024–25

Assessment Year

FY 2025–26

Research Design

Mixed-methods, cross-sectional, post-intervention

Sampling Technique

Random and purposive sampling

Qualitative Methods

FGDs, KIIs, semi-structured interviews, and case studies

Study Locations

Shirpur (Maharashtra) and Viramgam & Mandal (Gujarat)

Sample Size

(Shirpur =25) (Viramgam=60)

KEY STAKEHOLDERS

- Farmers and beneficiary households
- Women and community members
- Local community institutions and groups
- Village-level stakeholders and leaders

STUDY TOOLS

Structured questionnaires were used for household surveys conducted through face-to-face interviews. Semi-structured interview guides were used for Key Informant Interviews and stakeholder consultations. Focus Group Discussion guides were used for community-level discussions. Observation checklists were used during field visits to document water structures and their utilisation.

ETHICAL CONSIDERATIONS

Theimpactassessmentwas guidedby astrong ethical framework, ensuring responsible and ethical conduct throughout the study. Informed consent was obtained by clearly explaining the study objectives, procedures, and participant rights.

Confidentiality and privacy were maintained through secure data handling and anonymization of responses. Participation was voluntary and without coercion, and participants were treated with respect, dignity, and fairness at all stages of the assessment.

CHAPTER 4
ANALYSIS OF PROGRAMME DESIGN

PROGRAMME DESIGN OVERVIEW

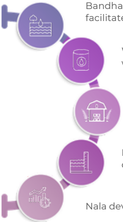
The Zydus WaterShed Project was designed to address water scarcity, limited irrigation access, and dependence on monsoon rainfall in Shirpur (Maharashtra) and Viramgam & Mandal (Gujarat). The programme adopted a multi-component watershed approach combining water storage, groundwater recharge, and community participation to improve water availability and agricultural outcomes.

PROGRAMME LOGIC

Component	Description
Problem	Seasonal water scarcity, rainfed agriculture, and low irrigation access
Intervention	Bandharas, farm ponds, recharge structures, water body restoration, nala development Improved water storage and groundwater recharge
Output	Increased irrigation access and multi-season cultivation
Outcome	Higher crop productivity, increased income, improved livelihood resilience
Impact	

INTERVENTION STRATEGY

The programme combined multiple interventions to address different dimensions of water availability:



Bandhara-based interventions (Shirpur): Designed to enhance surface water storage and facilitate groundwater recharge in basalt aquifer systems

Water body restoration (Viramgam): Strengthened storage capacity and reduced water loss

Farm ponds: Enabled on-farm water storage for irrigation support

Recharge structures: Improved percolation and groundwater recharge through direct and indirect mechanisms

Nala development: Enhanced runoff management and increased infiltration

This integrated approach ensured that both surface and subsurface water systems were addressed simultaneously.

DESIGN STRENGTHS

The programme design demonstrates several key strengths:

COMMUNITY PARTICIPATION
Promoted ownership and improved sustainability of interventions

INTEGRATED WATERSHED APPROACH
Addressed watershed through multiple complementary interventions

ALIGNMENT WITH GOVERNMENT INITIATIVES
Complemented schemes such as PMKSY and Jal Shakti Abhiyan

LOCATION-SPECIFIC DESIGN
Tailored interventions based on local hydrological and geographical conditions

DESIGN GAPS AND CONSIDERATIONS

Despite its strengths, certain gaps and considerations were observed:

GROUNDWATER EXTRACTION RISKS
Particularly in Shirpur, where basalt aquifers exhibit rapid depletion post-recharge

LIMITED BASELINE HYDROLOGICAL DATA
This restricted the ability to quantify pre-intervention groundwater conditions

NEED FOR LONG-TERM MONITORING
Sustained impact requires continued tracking of groundwater and usage patterns

DEPENDENCE ON RAINFALL PATTERNS
Recharge effectiveness remains linked to monsoon variability

RECHARGE SHAFT, GUJARAT

CHAPTER 5
KEY FINDINGS AND IMPACT

Discussion with Vinzuvada village farmers on Recharge shaft and Farm pond

This chapter presents the key findings and the impact of the Zydus–AFPRO & MPCT Watershed Initiative, based on an analysis of primary and secondary data. The findings are derived from structured surveys conducted across two study locations—Ahmedabad (Gujarat) and Shirpur (Maharashtra)—and are triangulated with before–and–after assessments, qualitative insights from FGDs, case studies, and field observations. The analysis is further supported by hydrological assessments that validate changes in groundwater recharge and water availability. The chapter is structured into two subsections, corresponding to each study location, to ensure clarity in presentation and interpretation of the findings.

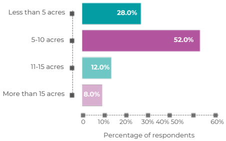
SHIRPUR- BANDHARA INTERVENTION

KEY FINDINGS

The key findings from the beneficiary survey in Shirpur (Maharashtra) among 25 respondents are presented below. The findings are structured across key thematic areas, including water, irrigation, agriculture, productivity, and income. The analysis is further triangulated with qualitative insights from case studies, FGDs, and field observations.

FARM PROFILE OF RESPONDENTS

CHART 1: TOTAL LAND OWNED (N=25)



KEY INFERENCES

The majority are mid-sized farmers

52.0%

of the respondents own 5–10 acres, indicating a strong base of semi-medium landholders.

Substantial smallholder presence

28.0%

of the respondents own less than 5 acres, reflecting notable representation of small and marginal farmers.

Few large landowners

20.0%

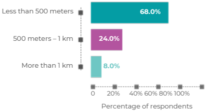
of the respondents own more than 10 acres (12.0% in 11–15 acres and 8.0% above 15 acres), showing a limited presence of large farmers.

Skew toward smaller holdings

80.0%

of the respondents own 10 acres or less, highlighting a predominantly small-to-medium landholding structure.

CHART 2: DISTANCE FROM BANDHARA (N=25)

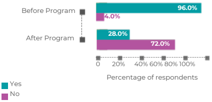


68.0%

of the respondents are located within 500 metres of the Bandhara, indicating strong proximity among beneficiaries, with relatively fewer respondents situated at around 1 km.

GROUNDWATER AVAILABILITY (BEFORE-AFTER)

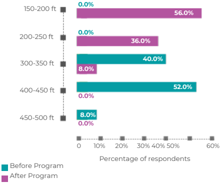
CHART 3: SEASONAL DRYING OF WELLS/ BOREWELLS BEFORE AND AFTER BANDHARA (N=25)



KEY INFERENCES

Seasonal drying of wells and borewells has declined sharply—from 96.0% of respondents reporting earlier drying to just 28.0% post-intervention—indicating a substantial improvement in groundwater availability and reliability. This change can be directly attributed to the construction of Bandharas (check dams), which have enhanced local water retention and recharge mechanisms. By slowing surface runoff, Bandharas allow rainwater to percolate into the ground, increasing groundwater recharge, improving aquifer levels, and prolonging water availability in wells and borewells. As a result, water sources that previously dried up during lean seasons are now more stable, reducing vulnerability to rainfall variability and supporting more consistent access to agricultural and domestic water.

CHART 4: CHANGE IN GROUNDWATER LEVEL DEPTH BEFORE AND AFTER BANDHARA (SUMMER) (N=25)



KEY INFERENCES

Respondents clearly perceive a marked improvement in groundwater availability during summer, with water levels becoming significantly easier to access after the Bandhara intervention. Earlier, most respondents reported having to reach deep water levels (300–450 ft and beyond), indicating stress and difficulty in accessing groundwater. Post-intervention, a majority now experience water availability at

much shallower depths (150–250 ft).

From the community's perspective, this translates into:

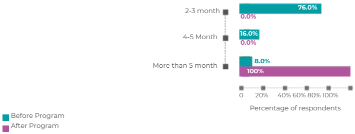
- Reduced effort and cost in drawing water, as wells and borewells no longer need to reach extreme depths
- Greater reliability of water sources during summer, a period previously marked by scarcity
- A sense that water "lasts longer" in wells, even in peak dry months

Overall, respondents experience this change as a visible and practical improvement in everyday water access, directly linked to Bandharas' impact on groundwater recharge and the

stabilisation of local water systems

> Chayabai Santosh Patil, a Gram Panchayat Member from Thalner village, reflected on how water availability has changed over time. She explained that earlier, farmers were completely dependent on rainfall, and even borewells drilled to depths of 500–600 feet often failed to provide sufficient water. During summer, wells would dry up quickly, making irrigation difficult and crop production uncertain. She noted that with the construction of Bandharas, groundwater levels have improved, and water is now accessible at much shallower depths of around 150–200 feet. According to her, water is now available for longer periods, even during summer, and wells that were previously dry are yielding water again. She also observed that rainwater now percolates more effectively, allowing wells to recharge faster and ensuring more reliable water availability for farming. Overall, she highlighted that improved water availability has made farming more stable and predictable for the community.
>
> **- (Chayabai Santosh Patil, Gram Panchayat Member- Thalner, Shirpur, Maharashtra.)**

CHART 5: AVAILABILITY OF WATER IN WELLS THROUGHOUT THE YEAR BEFORE AND AFTER BANDHARA (N=25)



KEY INFERENCES

Beneficiaries report a substantial increase in the duration of water availability, with earlier access limited to just 2–3 months (76.0%) before the intervention, now extending to more than 5 months for all respondents (100.0%) after the intervention. From their perspective, this has reduced the intensity of seasonal water scarcity, especially during the post-monsoon and summer periods.

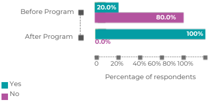
Community members experience this change as:

- Water is available for a longer part of the year, rather than drying up soon after the monsoon
- Improved confidence in planning additional or extended crop cycles, beyond a single season
- A perception that water sources are more dependable and less uncertain, supporting both agriculture and daily needs

Overall, beneficiaries view this as a practical and transformative shift, in which water availability is no longer short-lived but sustained, largely due to improved recharge and storage facilitated by the intervention.

IRRIGATION ACCESS

CHART 6: AVAILABILITY OF IRRIGATION WATER DURING CROP GROWTH STAGES BEFORE AND AFTER THE PROGRAMME (N=25)



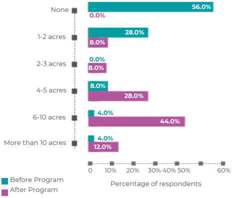
Beneficiaries perceive a clear and tangible increase in water availability, shifting from a short 2–3-month window to yearly availability exceeding 5 months for all households.

This is experienced not just as an increase in duration, but as a reduction in the uncertainty and stress associated with seasonal water shortages, particularly after the monsoon.

From their viewpoint, water is no longer a rapidly depleting resource, but one that sustains through critical agricultural periods, enabling beyond subsistence-level planning. The intervention has thus translated into a more predictable and stable water environment, allowing households to align cropping decisions better, reduce risk, and maintain continuity in both farming and domestic use.

Overall, beneficiaries interpret this shift as a fundamental improvement in water security, with availability extended, more dependable, and supportive of enhanced livelihood planning.

CHART 7: CHANGE IN AREA UNDER IRRIGATION BEFORE AND AFTER BANDHARA (N=25)



Beneficiaries report a substantial expansion in the average area under irrigation, increasing from approximately 1.8 acres before the intervention to about 6.5 acres after, reflecting

an average gain of nearly 4.7 acres per household.

Overall, beneficiaries view this as a practical and transformative shift, in which water availability is no longer short-lived but sustained, largely due to improved recharge and storage facilitated by the intervention.

Overall, beneficiaries interpret this shift as a fundamental improvement in water security, with availability extended, more dependable, and supportive of enhanced livelihood planning.

The community perceives this change as:

- Expansion from partial to more complete land utilisation, reducing fallow or rain-dependent areas
- Improved ability to diversify and scale up cultivation, rather than restricting to small plots
- A sense that available water now supports productive use of land, not just survival needs

Overall, beneficiaries experience this as a major improvement in agricultural capacity, with increased water availability from Bandharas directly translating into greater cultivated area,

higher potential output, and strengthened livelihoods.

CHART 8: CULTIVATION OF RAINFED CROPS BEFORE BANDHARA INTERVENTION (N=25)

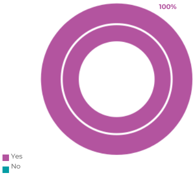
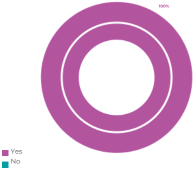


CHART 9: ADOPTION OF IRRIGATED/COMMERCIAL CROPS AFTER BANDHARA INTERVENTION (N=25)

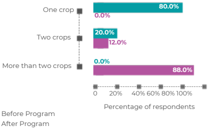


There is a complete shift in cropping patterns, with 100.0% of respondents moving from rainfed cultivation before the intervention to irrigated/commercial crops after the intervention. This indicates a transition towards more stable and potentially higher-value agricultural practices enabled by improved water availability.

> "Mr Vijay Santosh Bagul shared that earlier, much of the farmland could not be irrigated because water availability was limited and farmers largely depended on rainfall. He noted that even where borewells existed, the water was insufficient to cover the entire land. After the Bandharas were constructed, he observed that water availability improved, allowing farmers to bring more of their land under irrigation. According to him, fields that were previously left unirrigated are now being cultivated more consistently, as farmers can extend irrigation across a larger area and manage crops more reliably.
>
> **- (Mr Vijay Santosh Bagul, Deputy Chairman and Panchayat Samiti Member from Shirpur- Maharashtra)** "

> "Sunil Bhagwat Patil shared that earlier, wells and borewells did not provide reliable water, with availability limited to about two months and requiring depths of around 300 ft. He noted that with the construction of Bandharas, water levels have improved significantly, with borewell depth now reduced to around 170 ft and water availability extending throughout the year. According to him, this has made irrigation more reliable, reduced uncertainty in farming, and improved overall water access.
>
> **- (Farmer, Thalner- Shirpur, Maharashtra)** "

CHART 10: CHANGE IN CROPPING INTENSITY BEFORE AND AFTER PROGRAMME (N=25)



Beneficiaries report a dramatic increase in cropping intensity, reflecting a clear shift from single-season to multi-season cultivation. Earlier, 80.0% of respondents were limited to one crop, indicating strong dependence on monsoon rainfall and constrained water availability. Post-intervention, this has transformed significantly, with 88.0% of respondents now cultivating more than two crops annually.

From the community's perspective, this change is experienced as:

- A transition from restricted, rain-fed farming to more continuous and intensive cultivation
- Greater utilisation of land across seasons, including rabi and possibly summer crops
- Increased confidence to experiment with additional or diversified crops, supported by reliable water access

Overall, beneficiaries perceive this as a major shift in agricultural practice, in which improved water availability—driven by the Bandhara intervention—has enabled them to move from subsistence-level single-cropping to more productive, year-round farming systems, enhancing both output and livelihood stability.

CHART 11: CHANGE IN FALLOW LAND BEFORE AND AFTER BANDHARA PROGRAMME (N=25)

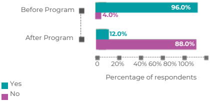
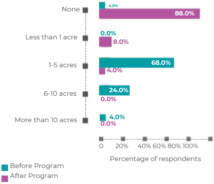


CHART 12: AREA LEFT FALLOW BEFORE AND AFTER BANDHARA (ACRES) (N=25)



A drop in fallow land is observed, declining from 96.0% to 12.0%, with 88.0% reporting no fallow land post-intervention. This is supported by a shift in extent, with 68.0% earlier leaving 1–5 acres and 24.0% leaving 6–10 acres fallow, moving to 88.0% reporting no fallow land. This reflects improved land utilisation.

SOULACE TEAM DURING FIELD VISIT SHIRPUR, DHULE

> Rajendra Balu Pagare shared that earlier, some portions of his land had to be left uncultivated as there was not enough water to support irrigation beyond the rainy season. He explained that even if land was available, it could not be used due to the uncertainty of water, and farmers would avoid taking the risk of sowing crops. With the construction of Bandharas, he noted that water availability has improved, and these previously unused patches are now being brought under cultivation. According to him, farmers are now able to use their land more consistently throughout the seasons, rather than leaving it fallow.
>
> **- (Farmer from Shirpur, Maharashtra)**

CROP PRODUCTIVITY

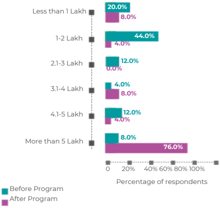
A clear shift is observed from 100.0% of respondents experiencing crop water stress before the intervention to 100.0% reporting increased crop yields after the intervention, indicating a substantial improvement in agricultural productivity driven by improved water availability.

KEY IMPACT

This section examines the impact of the intervention in Shirpur, focusing on changes in agricultural productivity, water availability, income levels, and overall livelihood conditions of the farming community.

INCOME AND ECONOMIC

CHART 13: CHANGE IN ANNUAL FARM INCOME BEFORE AND AFTER BANDHARA (N=25)



Beneficiaries reported a substantial increase in annual farm income, rising from approximately ₹1.9 lakh before the intervention to about ₹4.7 lakh after, reflecting an average gain of nearly ₹2.8 lakh per household.

Beneficiaries reported a substantial increase in annual farm income, rising from approximately ₹1.9 lakh before the intervention to about ₹4.7 lakh after, reflecting an average gain of nearly ₹2.8 lakh per household.

The community perceives this change as:

- A shift from modest, survival-level earnings to more stable and higher income levels
- Improved financial security, with greater ability to manage expenses, invest in farming, and reduce debt dependence
- A sense that enhanced water availability and increased cropping intensity are directly translating into better returns

Overall, beneficiaries experience this as a transformational improvement in their livelihoods, with increased irrigation, multiple cropping, and higher productivity leading to significant and sustained income gains.Top of Form

"Megha Patil shared that earlier, groundwater recharge was limited and uneven, with farmers located far from natural water sources facing greater difficulty accessing water. She explained that water availability varied across locations, affecting cultivation and income opportunities for many farmers. With the construction of Bandharas, she noted that groundwater recharge has improved across a wider area, benefiting both nearby and distant fields. According to her, more consistent water availability has enabled farmers to expand cultivation, leading to improved agricultural income and more stable economic conditions in the village.

- (Sarpanch of Thalner- Shirpur, Maharashtra)"

GROUNDWATER AVAILABILITY (BEFORE- AFTER)

CHART 14: IMPACT OF BANDHARAS ON GROUNDWATER RECHARGE (N=25) (MULTIPLE RESPONSE)

Indicator	% of Respondents	Beneficiary Experience & Interpretation
The water level in the well/borewell has increased	96.0%	Beneficiaries observe that water is now found at much shallower depths, making access easier and reducing the effort, time, and energy required for extraction.
The depth required for digging borewells has reduced	96.0%	Farmers report that new borewells do not need to be drilled as deep as before, lowering installation costs and reflecting improved groundwater levels.
Water remains available in the well for a longer period during the summer	80.0%	Households experience reduced seasonal drying, with wells retaining water deeper into summer, ensuring continuity for irrigation and domestic use.
Earlier dry wells are now yielding water	76.0%	Beneficiaries highlight that previously non-functional wells have been revived, increasing the number of usable water sources and reducing dependence on a single source.
Wells recharge faster after rainfall than before	60.0%	Community members notice that water levels rise quickly after rains, indicating improved percolation and effective recharge due to Bandharas.
Groundwater quality has improved (less salinity / better taste)	52.0%	Respondents perceive better taste and reduced salinity, suggesting dilution of contaminants and improved overall water quality.

CHART 15: IMPACT OF IMPROVED IRRIGATION ON CROP PLANNING AND PRACTICES (MULTIPLE RESPONSES) (N=25) (AS REPORTED BY BENEFICIARIES)

Indicator	% of Respondents	Beneficiary Experience & Interpretation
Able to cultivate crops in more than one season	92.0%	Farmers report a shift to multi-season cropping, utilising land beyond the monsoon and increasing overall productivity.
Able to plan crops with less dependence on rainfall	88.0%	Beneficiaries experience greater control over crop planning, reducing uncertainty linked to erratic rainfall.
Able to irrigate crops at critical growth stages	88.0%	Farmers highlight the ability to provide timely water during key stages, improving crop health and yields.
Increased area under irrigation	84.0%	Respondents observe that more of their land is now irrigated, reducing fallow areas and enhancing cultivation.
Started growing water-intensive or high-value crops	84.0%	Beneficiaries report diversifying into more profitable crops, supported by reliable access to water.
Adopted improved irrigation methods	80.0%	Farmers indicate a shift towards better irrigation practices, improving water use efficiency and management.
Able to schedule irrigation more regularly and efficiently	64.0%	Respondents report better irrigation planning and timing, though some variability remains in full adoption.

OVERALL EXPERIENCE

Beneficiaries perceive improved irrigation as a game-changer in agricultural planning, enabling greater flexibility, higher productivity, and reduced risk, ultimately strengthening farming outcomes and livelihoods.

1 GODI RECHARGE BANDHARA, SHIRPUR

CROPPING PATTERN CHANGES

CHART 16: IMPACT OF BANDHARA ON CROP DIVERSIFICATION AND CROPPING CHOICES

Indicator	% of Respondents	Beneficiary Experience & Interpretation
Started growing vegetables or other high-value crops	96.0%	Farmers report a shift towards more profitable crops, increasing income opportunities and market engagement.
Shifted from only rainfed crops to irrigated crops	92.0%	Beneficiaries transition to assured, irrigation-based farming, reducing dependence on rainfall and improving crop stability.
Able to grow fodder crops for livestock	92.0%	Households highlight improved availability of fodder, which supports livestock health and supplementary income.
Introduced new crops not grown earlier in the village	88.0%	Farmers report crop innovation and diversification, enabled by reliable water availability.
Expanded area under commercial crops	76.0%	Beneficiaries observe greater allocation of land to market-oriented crops, enhancing economic returns.
Able to cultivate crops in multiple seasons (Kharif, Rabi, Summer)	68.0%	Farmers experience increased cropping cycles, though seasonal expansion is still evolving for some households.

Beneficiaries perceive Bandharas as a key driver of agricultural diversification, enabling a shift from traditional, rain-dependent cropping to more diverse, market-oriented, and income-enhancing farming systems.

“

Mr Sandip Shaligram Patil shared that earlier, farming was limited to a single crop during the rainy season, with most land remaining unused for the rest of the year due to a lack of water. Crop choices were restricted to traditional rainfed crops such as cotton, jowar, and bajra, with very little diversification. He explained that with the availability of water after the construction of Bandharas, farmers have started cultivating crops across all three seasons, including rabi and summer crops. According to him, there has been a visible shift towards vegetables, wheat, and horticultural crops, and even previously fallow land is now being cultivated. He noted that land is now used more efficiently throughout the year, with higher cropping intensity and better crop planning based on water availability and market demand.

- (Resident -Thalner village, Shirpur, Maharashtra)

”

LAND USE AND CROPPING INTENSITY

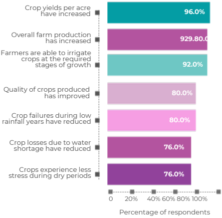
CHART 17: INFLUENCE OF IMPROVED WATER AVAILABILITY ON AGRICULTURAL LAND USE (N=25) (MULTIPLE RESPONSES) (AS REPORTED BY BENEFICIARIES)

Indicator	% of Respondents	Beneficiary Experience & Interpretation
Ability to grow crops in additional seasons on the same land	100.0%	All farmers report year-round or extended cultivation, maximising land use beyond a single season.
The total cultivated area on the farm has increased	92.0%	Beneficiaries observe that more of their land is now actively cultivated, reducing underutilised portions.
Land previously left fallow is now being cultivated	88.0%	Farmers highlight that earlier unused land has been brought into production, improving overall farm output.
Land is being used for new crops (vegetables, fruits, fodder)	88.0%	Respondents experience diversification in land use, shifting towards more productive and high-value crops.
More land has been brought under irrigation	84.0%	Beneficiaries report expanded irrigated areas, enabling consistent, reliable cultivation.
Previously low-productivity land is now used more effectively	84.0%	Farmers perceive improved land productivity, with better yields and utilisation, due to assured water supply.

Beneficiaries perceive improved water availability as a critical enabler of optimal land use, transforming land from seasonally dependent and underutilised to continuously productive and diversified, thereby strengthening both agricultural output and livelihoods.

CROP PRODUCTIVITY

CHART 18: IMPACT OF IMPROVED WATER AVAILABILITY ON CROP PRODUCTIVITY AND OUTPUT (N=25) (MULTIPLE RESPONSES)



Impact of Improved Water Availability on Crop Productivity and Output (as reported by beneficiaries)

INCREASED CROP YIELDS PER ACRE

96.0%

of the beneficiaries widely report that yields per acre have increased, attributing this to consistent water availability throughout the crop cycle. This is experienced as healthier crops and higher yields, directly improving farm returns.

INCREASE IN OVERALL FARM PRODUCTION

92.0%

A large proportion of farmers observe that their total farm output has risen, driven by both increased cropping intensity and improved yields. This is perceived as a visible boost in overall agricultural productivity.

ABILITY TO IRRIGATE AT CRITICAL GROWTH STAGES

92.0%

Farmers report that they can now provide water at key growth stages, such as flowering and grain formation. This has reduced crop stress and ensured better crop development and outcomes.

IMPROVEMENTINCROP QUALITY

80.0%

Respondents report that the quality of produce has improved, including better size, colour, and market value. This is linked to timely and adequate irrigation, which supports uniform crop growth.

REDUCTION IN CROP FAILURES DURING LOW RAINFALL YEARS

80.0%

Beneficiaries experience greater resilience during poor rainfall years, with fewer instances of complete crop failure. Reliable access to water acts as a buffer against climate variability.

REDUCTION IN CROP LOSSES DUE TO WATER SHORTAGE

76.0%

Farmers note that losses caused by water stress have declined, particularly during dry spells. Crops are less likely to wilt or underperform due to improved irrigation support.

REDUCED CROP STRESS DURING DRY PERIODS

76.0%

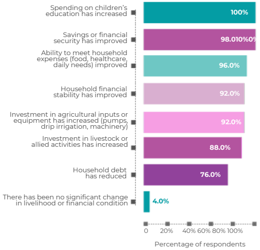
Beneficiaries report that crops now withstand dry conditions better because water is available when needed. This reduces visible signs of stress and contributes to more stable and predictable yields.

Farmers collectively perceive improved water availability as a critical driver of higher yields, better-quality produce, ultimately reduced risk, and strengthening agricultural sustainability and incomes.

2 GODI. RECHARGE BANDHARA SHIRPUR

INCOME AND ECONOMIC OUTCOMES

CHART 19: IMPACT ON HOUSEHOLD ECONOMY AND FINANCIAL WELL-BEING (N=25) (MULTIPLE RESPONSES)



Impact on Household Economy and Financial Well-being (as reported by beneficiaries)

IMPROVED SAVINGS AND FINANCIAL SECURITY

100%

All beneficiaries report that their savings and overall financial security have improved, indicating a shift from uncertain incomes to more stable and surplus-generating livelihoods.

INCREASED SPENDING ON CHILDREN'S EDUCATION

100%

Households highlight a greater ability to invest in children's education, reflecting improved financial confidence and prioritisation of long-term well-being.

ENHANCED ABILITY TO MEET HOUSEHOLD EXPENSES

96.0%

A large majority report that they can now comfortably cover daily expenses, including food, healthcare, and other essential needs, thereby reducing financial stress.

IMPROVED HOUSEHOLD FINANCIAL STABILITY

92.0%

Beneficiaries perceive their overall financial condition as more stable, with better income flows and reduced vulnerability to shocks.

INCREASED INVESTMENT IN AGRICULTURAL INPUTS AND EQUIPMENT

92.0%

Farmers report higher investment in farming inputs and assets such as pumps, drip irrigation, and machinery, indicating reinvestment of increased income into productivity.

INCREASED INVESTMENT IN LIVESTOCK AND ALLIED ACTIVITIES

88.0%

Many households have expanded into livestock and allied activities, diversifying income sources and strengthening resilience.

REDUCTION IN HOUSEHOLD DEBT

76.0%

A significant proportion of respondents note a decline in debt levels, suggesting improved repayment capacity and reduced dependence on borrowing.

MINIMAL REPORTS OF NO CHANGE

4.0%

Only a small fraction of beneficiaries report no significant change in their livelihoods or financial conditions, indicating that the intervention has had a widespread positive economic impact.

Beneficiaries experience these changes as a comprehensive improvement in household economic well-being, with increased agricultural productivity translating into higher incomes, greater investments, reduced debt, and improved quality of life.

"Mr Vilas Tanaji Patil shared that earlier, limited water availability meant most farming was dependent on rainfall, resulting in low yields and high income uncertainty. He noted that after the construction of Bandharas, the situation had changed, with improved water availability allowing farmers to cultivate multiple crops and expand their farming activities. According to him, crop yields have increased, and income has improved by around 40.0%–50.0%, while farmers have also started investing in irrigation systems, equipment, and allied activities. He further mentioned that migration has reduced, as farming and related work are now available locally, contributing to more stable livelihood conditions in the village.

- (Gram Panchayat Member, Thalner-Shirpur, Maharashtra)"

VIRAMGAM AND MANDAL INTERVENTION

KEY FINDINGS

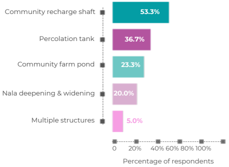
The key findings for Viramgam (Ahmedabad), based on 60 respondents, are presented across the following themes: water availability, irrigation access, agriculture, productivity, and livelihoods. The analysis is triangulated using primary survey data, qualitative insights, and hydrological assessment findings.

DEMOGRAPHIC PROFILE (n=60)

Gender	Age Group	Landholding Size	Farmer Category
Male **96.7%**	Below 30 Years **1.7%**	1–2 Ha **1.7%**	Marginal **16.7%**
Female **3.3%**	31–45 Years **48.3%**	2–5 Ha **10.0%**	Small **23.3%**
-	46–60 Years **43.3%**	Above 5 Ha **88.3%**	Medium **35.0%**
-	60+ Years **6.7%**	-	Large **25.0%**

COMMUNITY WATER STRUCTURE DETAILS

CHART 20: TYPES OF COMMUNITY WATER STRUCTURES AVAILABLE (MULTIPLE RESPONSES) (N=60)



53.3%

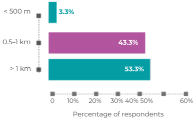
of the findings show that community recharge shafts are the most commonly reported water structures, followed by percolation tanks at 36.7%, along with farm ponds and nala deepening interventions.

"Farmer Ashvinbhai Ramanbhai Jadhav from Vadgas village shared that groundwater levels were previously low, and water was unavailable for long periods. After the intervention, he observed that groundwater levels have increased and that wells and borewells are recharging, allowing water to be available for longer periods.

He reported that water structures, such as the percolation tank, community farm pond, and recharge shaft, provide direct irrigation for his farm and support livestock needs. Being located close to the structure, he benefits from both direct irrigation access and indirect groundwater recharge, reflecting improved availability of both groundwater and surface water.

- Age: 34 years, Landholding: 1–2 ha; Village: Vadgas, Ahmedabad, Gujarat"

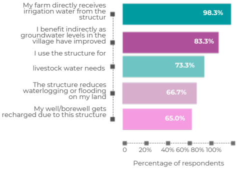
CHART 21: DISTANCE TO COMMUNITY WATER STRUCTURE (N=60)



53.3%

of the respondents are located more than 1 km from the water structures, while the remaining respondents are located within 1 km of them.

CHART 22: HOUSEHOLD/FARM CONNECTION TO WATER STRUCTURE (MULTIPLE RESPONSES) (N=60)



98.3%

of the respondents reported that their farms directly receive irrigation water from the structures, while 83.3%

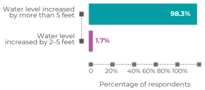
reported indirect benefits through groundwater availability.

In addition, respondents reported using structures for livestock water needs (73.3%), well and borewell recharge (65.0%), and reduction in waterlogging (66.7%).

This indicates that respondents report both direct and indirect use of water structures for multiple purposes.

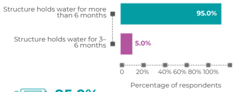
WATER AVAILABILITY & ACCESS

CHART 23: CHANGE IN GROUNDWATER LEVEL AFTER INTERVENTION (N=60)



98.3%
of the respondents reported groundwater levels increased by more than 5 feet after the intervention.

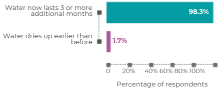
CHART 24: CHANGE IN SURFACE WATER AVAILABILITY (N=60)



95.0%
of the respondents reported that water structures hold water for more than 6 months.

This reflects reported changes in both groundwater levels and the duration of surface water availability.

CHART 25: CHANGE IN DURATION OF WATER AVAILABILITY IN WELLS/BOREWELLS (N=60)



98.3%
of the respondents reported that water in wells and borewells now lasts for 3 or more additional months, while a small proportion (1.7%) reported that water dries up earlier than before.

This reflects reported changes in the duration of water availability among respondents.

FGD NOTE- Thodi Village

FGD Participants from Thodi Village shared that earlier, the nala was shallow and did not retain water for long, limiting irrigation and affecting farming. After the deepening and widening work, they reported that water is now available for longer periods, including into the summer months, and that groundwater levels in wells and borewells have increased.

Farmers also noted that irrigation access has improved, allowing expansion of cultivated area and a shift towards different crops. They reported better crop survival during dry spells

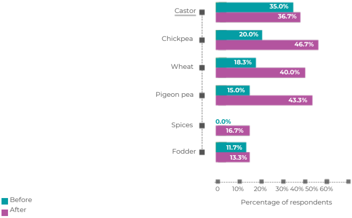
and reduced irrigation-related challenges. Improved water availability was also mentioned in relation to livestock use and

reduced dependence on external water sources.

Participants: Bharatbhai Ganeshbhai; Maheshbhai Mohanbhai; Gugabhai Amrishbhai; Mahadevbhai Arjanbhai; Bhikabhai Haribhai; Jagmalbhai Khoda; Mayankbhai Bhikabhai; Bharatbhai Shankarbhai; Bababhai Madhabhai; Mohanbhai Pashabhai; Laljibhai Jivanbhai; Prabhubhai Mahadevbhai
(Thodi-Viramgam, Ahmedabad-Gujarat)

AGRICULTURAL PRODUCTIVITY

CHART 26: CROPS CULTIVATED BEFORE AND AFTER THE STRUCTURE INTERVENTION (MULTIPLE RESPONSES) (N=60)



Changes in Cropping Patterns as reported by beneficiaries)

Chickpea (20.0% → 46.7%)

Beneficiaries report a sharp increase in chickpea cultivation, as improved water availability has enabled expansion into rabi cropping. Chickpea, being a relatively low-water but high-return crop, is now seen as a reliable option for income enhancement.

Pigeon Pea (15.0% → 43.3%)

Farmers report a significant increase in pigeon pea cultivation, driven by improved soil moisture retention and extended growing seasons. This crop fits well into diversified systems and provides both food security and market value.

Wheat (18.3% → 40.0%)

Respondents report a notable increase in wheat cultivation, which was earlier limited due to water constraints in the rabi season. With improved irrigation, farmers can now adopt wheat as a stable winter crop, thereby enhancing productivity.

Castor (35.0% → 36.7%)

Castor cultivation shows only a marginal increase, as it was already widely grown. Beneficiaries suggest that while water availability has improved, crop preference is gradually shifting toward more profitable or diverse options, limiting major expansion.

Spices (0.0% → 16.7%)

Farmers report the introduction of spices as a new crop category that was not previously cultivated. This reflects increased willingness to experiment with high-value crops, supported by improved water security and market orientation.

Fodder (11.7% → 13.3%)

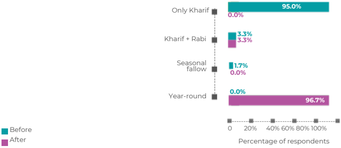
There is a slight increase in fodder cultivation, with beneficiaries noting that improved access to water supports livestock needs. However, the modest growth suggests that fodder remains supplementary rather than a primary focus of cultivation.

OVERALL EXPERIENCE

Beneficiaries perceive these changes as a shift from limited, traditional cropping to a more diversified, opportunity-driven system, where improved water availability has enabled both the expansion of existing crops and the introduction of new, higher-value options

CROPPING INTENSITY AND IRRIGATED AREA

CHART 27: CHANGE IN CROPPING PATTERN BEFORE AND AFTER THE STRUCTURE INTERVENTION (MULTIPLE RESPONSE) (N=60)



Change in Cropping Pattern (as reported by beneficiaries)

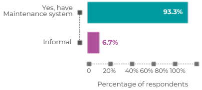
Beneficiaries report a fundamental shift in cropping patterns, moving from predominantly single-season (Kharif-only) farming to near year-round cultivation after the intervention.

- Year-round cultivation (0.0% → 96.7%)
- Nearly all respondents now practice continuous cropping across seasons, reflecting a major transition enabled by reliable water availability. This is experienced as a shift toward full utilisation of land throughout the year.
- Only Kharif cultivation (95.0% → negligible)
- Earlier, the vast majority depended solely on monsoon crops, indicating high vulnerability to rainfall. Post-intervention, this pattern has almost disappeared, showing reduced dependence on rainfed agriculture.
- Kharif + Rabi (3.3% → 3.3%)
- A small segment continues with two-season cropping, suggesting that while most have transitioned to year-round farming, a few still operate within moderate expansion levels, possibly due to resource or capacity constraints.
- Seasonal fallow (minimal presence)
- Very few respondents now leave land fallow, indicating that land is being actively utilised across seasons, supported by improved irrigation.

Beneficiaries perceive this shift as a transformational change in farming practice, in which agriculture has moved from season-bound and uncertain to continuous and productive, significantly enhancing both land-use efficiency and livelihood stability.

COMMUNITY OWNERSHIP & GOVERNANCE

CHART 28: EXISTENCE OF MAINTENANCE SYSTEM (N=60)



93.3%

of the respondents reported having a maintenance system for watershed structures, while 6.7% relied on informal arrangements.

This reflects that maintenance mechanisms are in place across most locations, with a small proportion still following informal practices.

FGD-VADGAS VILLAGE

FGD participants from Vadgas village shared that earlier, there was a severe shortage of water for both agriculture and drinking, with many wells drying up and water being sourced from distant locations, sometimes up to 2 km away. Water for crops during winter and summer was not available on time, leading to reduced yields and income.

After the construction of the percolation tank, they observed that groundwater levels had increased, and wells now remain functional for longer periods. Improved water availability has enabled timely irrigation and cultivation across seasons, along with changes in crop choices and increases in yield and income. Participants also noted reduced irrigation costs, improved water availability for livestock, and continued community involvement in maintenance, supported by the Panchayat.

Participants: Narsinghbhai Jagmalbhai Parmar; Jitendrabhai Ranchhodbhai Parmar; Prakashbhai Narsinghbhai Parmar; Bharatbhai Narsinghbhai Parmar; Alpeshbhai Shankarbhai Rathod; Ashwinbhai Ramnikbhai Jadav; Parshotbhai Ranchhodbhai Jadav; Vikrambhai Bhanvarbhai Parmar; Milanbhai Pravinbhai Patel; Mayurbhai Parshottambhai Jadav; Kanubhai Bhagwanbhai Rathod; Riddiben Kanubhai Rathod

(Vadga-Viramgam, Ahmedabad-Gujarat)

FARM POND, GUJARAT

IMPACT

CHART 29: IMPACT OF WATER STRUCTURE ON HOUSEHOLD/VILLAGE WATER AVAILABILITY (MULTIPLE RESPONSES) (AS REPORTED BY BENEFICIARIES, N=60)

Indicator	% of Respondents	Beneficiary Experience & Interpretation
Water in wells/borewells lasts for more months; increased post-monsoon levels	96.7%	Beneficiaries report that water sources remain functional for longer durations, with visibly higher water levels after the monsoon, reducing seasonal scarcity.
Improved availability of water for drinking and livestock	75.0%	Households experience better access to water for domestic use and livestock, reducing daily stress and ensuring basic needs are met more reliably.
Availability of irrigation water during critical crop stages	66.7%	Farmers report that water is available when crops need it most, supporting better crop growth and reducing the risk of yield loss.

OVERALL EXPERIENCE

Beneficiaries perceive that the water structure has led to multi-dimensional improvements in water availability, supporting household consumption, livestock care, and agricultural needs simultaneously, thereby strengthening overall water security.

CHART 30: INFLUENCE OF WATER STRUCTURE ON GROUNDWATER LEVEL/QUALITY (AS REPORTED BY BENEFICIARIES, N=60)

OVERALL EXPERIENCE

Beneficiaries perceive that the water structure has led to notable improvements in groundwater availability, with a section also experiencing enhanced water quality, contributing to more dependable and usable water resources.

Water salinity was a consistent problem before the intervention, as reported by all respondents. However, all respondents observed a reduction in salinity after the intervention, indicating a clear improvement in water quality.

(Primary Data)

> A Farmer, Prajapati Babubhai Motibhai, from Vinjuvada village, shared that earlier, water availability depended on rainfall and private borewells, leading to crop losses during dry spells, reduced cultivation, and occasional migration. After the construction of the farm pond, water is available for 3–4 months, supporting irrigation during critical crop stages and enabling cultivation across multiple seasons.
>
> The participant reported increases in crop yield (20.0%–40.0%) and income (30.0%–50.0%), along with reduced crop loss during irregular rainfall events. Improved water availability has also supported livestock and fodder cultivation, contributing to more stable income and reduced dependence on external water sources.
>
> **- (Participant Details: Prajapati Babubhai Motibhai, 62 years, Vinjuvada- Mandal, Ahmedabad, Gujarat)**

CHART 31: CHANGE IN CROP YIELD (N=60)

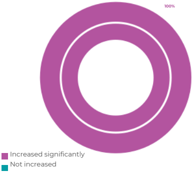
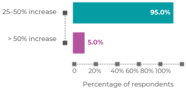


CHART 32: APPROXIMATE YIELD CHANGE IN MAIN CROP (N=60)



KEY INFERENCES

Beneficiaries overwhelmingly report a substantial increase in crop yields, with 95.0% indicating a 25.0%–50.0% improvement in their main crop and a smaller proportion (5.0%) experiencing more than 50.0% gains. From their perspective, this reflects a consistent and widespread enhancement in productivity, rather than isolated or extreme gains. Farmers experience this as:

- More reliable and visibly better harvests, compared to earlier seasons
- Improvements driven by timely irrigation, reduced crop stress, and better crop management
- A sense that yield gains are steady and achievable across most farms, not limited to a few

Overall, beneficiaries perceive this as a strong and uniform productivity boost, with improved water availability translating into significant yet stable increases in agricultural output.

CHART 33: IMPACT OF WATER STRUCTURE ON CROP PRODUCTIVITY AND YIELD (AS REPORTED BY BENEFICIARIES)

Indicator	% of Respondents	Beneficiary Experience & Interpretation
Crop yields have increased significantly due to assured irrigation	46.7%	Nearly half the respondents directly attribute higher yields to reliable irrigation, experiencing better crop growth and improved harvest outcomes.
New or high-value crops have become possible	23.3%	Beneficiaries report that improved water access has enabled crop diversification, allowing the cultivation of more profitable crops such as spices, wheat, and chickpeas.
Earlier low-yield crops now perform better	13.3%	Farmers observe that traditional crops are now yielding better, as consistent water supplies reduce stress and enhance productivity.
Cropping intensity has increased, raising total production	10.0%	Some respondents link improved water availability to multiple cropping cycles, leading to higher overall farm output.
Yields have become more stable with reduced crop loss during dry spells	6.7%	A smaller proportion indicates reduced yield variability, with crops better able to withstand dry periods due to assured irrigation.

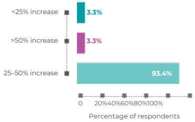
OVERALL EXPERIENCE

Beneficiaries perceive that improved water infrastructure has contributed to both direct and indirect gains in productivity, including higher yields, better crop performance, and diversification, ultimately enhancing agricultural outcomes.

"Farmer Bharatbhai from Thori village (>5 ha) shared that with direct irrigation and improved groundwater availability, he has shifted from seasonal to year-round cultivation. He reported improved crop survival and increased yields, along with reduced waterlogging and support for livestock use.

- (Bharatbhai, 42 yrs old, Thori-Manda, Ahmedabad, Gujarat)"

CHART 34: PERCENTAGE INCREASE IN AGRICULTURAL INCOME (N=60)



Beneficiaries report a clear and widespread increase in agricultural income, with an overwhelming 93.4% experiencing a 25.0%–50.0% rise, while only a small proportion report increases above 50.0% (3.3%) or below 25.0% (3.3%).

From their perspective, this indicates that income gains are:

- Consistent and broadly distributed across households, rather than concentrated among a few.
- Moderate but reliable, suggesting steady improvement rather than volatile or uneven growth.
- Closely linked to enhanced water availability, increased cropping intensity, and improved yields.

Overall, beneficiaries experience this as a stable and meaningful income enhancement, with most households moving to a higher, yet sustainable, earning level, thereby reinforcing livelihood security rather than short-term gains.

FGD-DALOD VILLAGE

FGD participants from Dalod village shared that earlier waterlogging during the monsoon and early drying of borewells affected crop performance and irrigation. After installing recharge shafts, they observed that excess water is now absorbed quickly, groundwater levels have increased, and borewells provide water for longer periods, including during summer.

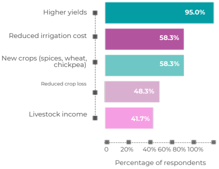
Participants reported more reliable irrigation during critical crop stages, along with improved crop survival and yield increases of around 40.0%–50.0%. They also noted a shift towards crops such as cumin, wheat, and isabgul. Reduction in irrigation costs, including diesel and purchased water, was highlighted, contributing to reported increases in income and improved stability. Farmers maintain the recharge structures themselves, with periodic cleaning, indicating continued use and upkeep.

Participants: Kishorbhai Khodubhai Vagela; Popatbhai Vittalbhai Patel; Ganshyambhai Popatbhai Patel; Mukeshbhai Popatbhai Patel; Maheshbhai Kantibhai Patel; Hashmukhbhai Somabhai Patel; Rajendrakumar Kantilal Patel; Anuriddhsigh Govindsigh Zala; Yashpalsigh Dineshsigh Zala; Ganshyambhai Baldevbhai Patel

(Dalod-Viramgam, Ahmedabad-Gujarat)

LIVELIHOOD & ECONOMIC IMPACT

CHART 35: REASONS FOR CHANGE IN INCOME (MULTIPLE RESPONSES) (N=60)



95.0%
of the respondents reported an increase in household income.

KEY INFERENCES

Beneficiaries attribute the increase in income primarily to higher crop yields (95.0%), indicating that improved water availability has directly translated into greater agricultural output and returns.

Other important contributing factors include:

- Reduced irrigation costs (58.3%), suggesting that improved water access has lowered expenditure on pumping and water sourcing
- Adoption of new crops (53.3%), reflecting diversification into more profitable options such as spices, wheat, and chickpea
- Reduced crop loss (48.3%), indicating better resilience against dry spells and improved crop survival

Additionally, 41.7% report increased income from livestock, suggesting spillover benefits of improved water availability for allied activities.

Overall, beneficiaries perceive income growth as resulting from a combination of productivity gains, cost savings, and diversification, with higher yields as the central driver, supported by multiple reinforcing factors.

Chart 36: Contribution to Income Stability and Livelihood Security (as reported by beneficiaries, n=60)

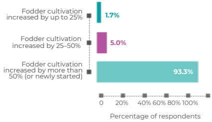
OVERALL EXPERIENCE

Beneficiaries perceive that improved water availability has contributed to both income growth and stability, primarily through enhanced yields and diversification, leading to more secure and resilient livelihoods.

> Farmer Parmar Bhagwanbhai Mahadevbhai from Vinjuvada village (>5 ha) shared that access to water through the community recharge shaft has enabled direct irrigation and supported livestock needs. He reported that improved groundwater availability has increased agricultural income by more than 50.0%.
>
> **- (Parmar Bhagvanbhai Mahadev Bhai, 46 yr, Vinjuvada, Ahmedabad, Gujarat)**

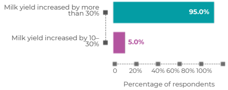
LIVESTOCK & ALLIED ACTIVITIES

CHART 36: CHANGE IN FODDER CULTIVATION (N=60)



Beneficiaries report a strong, direct link between increased fodder availability and improved livestock productivity. With 93.3% observing more than a 50.0% rise in fodder cultivation, households now have more reliable and sufficient feed for livestock throughout the year.

CHART 37: CHANGE IN LIVESTOCK PRODUCTIVITY (MILK YIELD) (N=60)

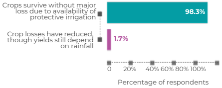


This has translated into significant gains in milk production, with 95.0% reporting yields increased by more than 30.0%, reflecting improved animal health and nutrition. From their perspective, livestock is no longer a secondary activity but an increasingly productive and dependable source of income.

Overall, beneficiaries experience this as a positive spillover effect of improved water availability, where enhanced irrigation supports fodder production, which in turn strengthens livestock output and contributes to diversified, stable livelihoods.

CLIMATE RESILIENCE & RISK REDUCTION

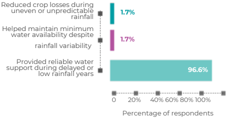
CHART 38: IMPACT ON CROP SURVIVAL DURING DRY SPELLS (N=60)



98.3%
of the respondents reported that crops survive without major loss during dry spells.

Only a small proportion (1.7%) indicated that yields still depend on rainfall. This suggests that crop survival is more stable, even under low rainfall conditions. The responses reflect reduced variability in crop performance during dry periods.

CHART 39: ROLE OF WATER STRUCTURE DURING IRREGULAR RAINFALL (N=60)

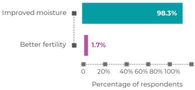


Responses indicate that 96.6% of respondents reported reliable water support during years with delayed or low rainfall. A minimal

proportion (1.7%) reported maintaining minimum water availability or reduced crop losses. This indicates that water availability is reported even during rainfall variability. The findings reflect the role of water structures in supporting farming under uncertain rainfall conditions.

ENVIRONMENTAL IMPACT

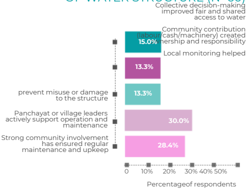
CHART 40: CHANGE IN SOIL CONDITION AFTER INTERVENTION (N=60)



Improved soil moisture was reported by 98.3% of respondents, while 1.7% reported better soil fertility. The responses indicate changes in soil condition primarily related to moisture. This reflects the reported improvement in soil moisture retention.

COMMUNITY OWNERSHIP & GOVERNANCE

CHART 41: INFLUENCE OF COMMUNITY PARTICIPATION ON SUSTAINABILITY OF WATER STRUCTURE (N=60)



OVERALL EXPERIENCE

Beneficiaries perceivethat community participation plays a crucial role in sustaining water structures, with leadership support and collective involvement ensuring better maintenance, equitable use, and long-term functionality.

FGD-DALOD

FGD participants from Dalod village reported that earlier low groundwater levels, drying wells, and saline water limited agriculture, leading to dependence on external sources and seasonal migration. After the introduction of recharge shafts, groundwater availability improved, with wells retaining water for longer periods.

This enabled multi-season cultivation, higher yields, the adoption of high-value crops, reduced irrigation costs, increased income, and fewer crop losses. Benefits were higher for farmers with better irrigation access, while community-led maintenance supported sustainability.

Participants: Vijaybhai Kalubhai; Nikunjbhai Shaileshbhai; Jayrambhai Keshabhai; Vijaybhai Bhikabhai; Jayntibhai Manabhai; Mukeshbhai Popatbhai Patel; Ganshyambhai Popatbhai Patel

(Dalod- Mandal-Viramgam, Ahmedabad, Gujarat)

CHAPTER 6

HYDROLOGICAL IMPACT ASSESSMENT OVERVIEW

HYDROLOGICAL IMPACT ASSESSMENT NOTE (Shirpur)

The observed improvements in water availability and irrigation access in Shirpur are supported by findings from the hydrological assessment. The analysis indicates that the Bandhara-based interventions contributed to enhanced water storage of approximately 81,220 cubic metres and facilitated groundwater recharge of ~1.13 lakh cubic metres. In addition, the overall groundwater recharge potential of the watershed is estimated at ~14.09 lakh cubic metres, primarily driven by rainfall and supported by the interventions. These findings are consistent with field observations indicating improved water retention, reduced runoff losses, and enhanced seasonal water availability, thereby reinforcing the programme's impact.

(Hydrologic Impact Assessment – Shirpur, Dhule, Maharashtra,)

HYDROLOGICAL IMPACT ASSESSMENT NOTE (Viramgam)

The observed improvements in water availability, irrigation access, and agricultural productivity are further supported by findings from the hydrological assessment conducted in Viramgam and Mandal. The analysis indicates that the implemented interventions contributed to significant groundwater recharge and water storage enhancement, including approximately 3.48 lakh cubic metres through recharge structures, 1.12 lakh cubic metres through pond desiltation, and over 38,000 cubic metres through nala development activities. These interventions also improved runoff capture and water retention across the project area. The technical estimates are consistent with beneficiary-reported improvements in irrigation access, multi-season cropping, and reduced water stress, thereby reinforcing the programme's overall impact.

(Hydrologic Impact Assessment-AFPRO-ZYDUS, Viramgam-Mandal-Ahmedabad, March 2026)

WATER RECHARGE AND STORAGE BY WHS ACROSS LOCATIONS(GUJARAT & MAHARASHTRA)

Location	WHS Type	No.	Storage (cum)	Recharge (cum)
Viramgam (Gujarat)	Desilted Ponds	6	56,004	
	Nala Deepening & Widening	3	19,164	
	Farm Ponds	5	8,952	
	Recharge Shafts	75	-	
	Total (Interventions)	-	**84,191**	~7.32 lakh
Shirpur (Maharashtra)	**Bandharas (Godi & Manjrod)**	5	**81,220**	~1.13 lakh
	Overall Recharge Potential	-	**-**	~14.09 lakh

(Note: Recharge values are aggregated estimates based on hydrological assessment)

The hydrological assessment indicates variation in recharge dynamics across the two locations. In Viramgam, groundwater recharge is primarily driven by watershed interventions such as recharge structures, ponds, and nala development. In contrast, Shirpur demonstrates overall recharge potential largely influenced by rainfall, with Bandhara-based interventions contributing to improved water retention and groundwater recharge.

CHAPTER 7
SUCCESS STORIES

FROM RAIN TO RESILIENCE: A FARMER'S JOURNEY WITH FARM POND INNOVATION

GENERAL INFORMATION

Shri Babubhai Motibhai Prajapati, a farmer from Vinzuvada village in Mandal block, owns 6.28 acres of land. Under the Zydus Lifesciences CSR initiative (2024–25), a farm pond measuring 28.00 × 19.00 × 4.06 metres was constructed to support rainwater harvesting and irrigation.

PRE-INTERVENTION

Before the intervention, farming was entirely rainfed with no water storage system in place. Irrigation during critical crop stages was not possible, resulting in frequent crop losses and unstable income. Chickpea production was limited to 3,960 kg, generating an income of ₹1,99,980, and was highly dependent on erratic rainfall.

POST-INTERVENTION

With the construction of the farm pond, rainwater could be stored and used for irrigation during critical crop stages. Improved soil moisture and better crop management practices were observed. Chickpea production increased to 5,940 kg, and income rose to ₹3,11,850.

IMPACT

The intervention resulted in an approximate 50% increase in yield and an income gain of ₹1.11 lakh within one year. It also enabled year-round employment for 3–4 labourers, reduced vulnerability to rainfall variability, and improved livelihood stability.

STRENGTHENING RAIN-FED AGRICULTURE THROUGH WATERSHED INTERVENTIONS

GENERAL INFORMATION

The watershed intervention in Vadgas and the surrounding villages of Ahmedabad district covered 870 hectares and benefited 599 farmers, with 442 hectares directly or indirectly impacting 168 farmers during 2024–25. The intervention included percolation tank development and farm pond construction.

PRE-INTERVENTION

Agriculture in the area was largely rainfed, with limited access to irrigation. Farmers primarily cultivated traditional crops such as castor and pigeon pea with low and uncertain yields. Crop diversification was minimal, and fodder availability was limited, both of which affected livestock productivity.

POST-INTERVENTION

Improved water availability enabled the expansion of irrigated area and the diversification of crops. Significant improvements were observed across major crops, including castor yields increasing from 1,200 to 1,750 kg/ha and pigeon pea from 200–340 to 400–650 kg/ha. Wheat productivity reached 1,600–2,400 kg/ha. New crops, such as chickpea (800–1,500 kg/ha), and spices were introduced, with spices yielding ₹40,000–₹90,000 per hectare.

IMPACT

The intervention enabled a shift from rainfed to diversified and irrigated farming systems, improved fodder availability, and enhanced livestock productivity. It strengthened income opportunities and agricultural stability, particularly for small and marginal farmers.

PRODUCTIVITY ENHANCEMENT THROUGH NALA DEEPENING AND WIDENING (NDW)

GENERAL INFORMATION

The Nala Deepening and Widening (NDW) intervention was implemented across Vadgas, Thori, Dolatpura, and nearby villages, covering 191 hectares and benefiting 46 farmers, with 159 hectares directly or indirectly impacted.

PRE-INTERVENTION

Farmers relied primarily on rainfall because irrigation facilities were unavailable. Crop productivity was low, and cultivation was largely limited to traditional crops with minimal diversification. Water scarcity constrained agricultural expansion and made farming highly vulnerable to rainfall variability.

POST-INTERVENTION

Improved groundwater recharge and water retention enhanced irrigation availability. Farmers were able to expand cultivated area and adopt multi-season cropping. Crop productivity increased, with castor yields improving from approximately 1,200 to 1,750 kg/ha and pigeon pea from 200–340 to 400–650 kg/ha. Wheat productivity reached 1,600–2,400 kg/ha, and high-value crops such as spices were introduced, generating ₹40,000–₹90,000 per hectare.

IMPACT

The intervention supported a transition from single-season to multi-season cultivation, reduced dependence on rainfall, and improved income stability. It also contributed to reduced migration and strengthened resilience to climate variability.

08. IMPACT CREATED AT MULTIPLE-LEVEL

INDIVIDUAL LEVEL

- Improved irrigation access and water availability enabled farmers to cultivate across multiple seasons, reducing dependence on rainfall.
- Increased crop productivity observed, with case evidence showing ~50.0% increase in yield and income gains of over ₹1 lakh per year in some cases.
- The adoption of high-value crops (spices, wheat, chickpeas) improved the potential for farm income.
- Reduced crop loss and water stress contributed to more stable and predictable agricultural outcomes.

COLLECTIVE / COMMUNITY LEVEL

- Improved groundwater availability led to longer water retention in wells and reduced dependence on external water sources.
- Expansion of irrigated area supported multi-season cropping and crop diversification across villages.
- Increased fodder availability improved livestock productivity and secondary income sources.
- Reduced seasonal migration observed due to improved local livelihood opportunities.
- Community participation in the maintenance of structures supported the sustainability of interventions.

REGIONAL / STATE LEVEL

- Demonstrates a replicable watershed and watershed model for water-stressed regions in Gujarat and Maharashtra.
- Interventions contributed to significant groundwater recharge and water storage, supported by hydrological estimates (e.g., ~3.48 lakh cum recharge through structures).
- Improved agricultural outcomes indicate the potential to scale similar interventions in semi-arid regions.
- Aligns with state priorities on water conservation, irrigation enhancement, and climate-resilient agriculture.

NATIONAL LEVEL

- Contributes to strengthening water security and sustainable agriculture systems in drought-prone regions.
- Supports national priorities on groundwater management, rainwater harvesting, and climate resilience.
- Demonstrates an effective CSR-led model integrating watershed and livelihood improvement.
- Reinforces the importance of community-based natural resource management approaches for long-term sustainability.

09. KEY CHALLENGES AND BARRIERS

UNEVEN BENEFIT FROM RECHARGE STRUCTURES
Benefits were higher for farmers located near Bandharas, recharge shafts, and ponds, while those farther away reported limited irrigation gains.

LIMITED INTERVENTION COVERAGE
The number of Bandharas and watershed structures was not sufficient to cover all agricultural land, leaving some farmers dependent on rainfall.

RAINFALL-DEPENDENT PERFORMANCE OF STRUCTURE
The effectiveness of farm ponds and recharge structures depended on rainfall availability, which in turn affected water storage and recharge during low-rainfall periods.

MAINTENANCE OF WATER STRUCTURES
Regular desiltation and upkeep of ponds, nalas, and recharge structures were required, with varying levels of community-led maintenance observed.

PARTIAL ADOPTION OF CROP DIVERSIFICATION
Adoption of high-value crops and multi-season cultivation was limited to a section of farmers, while others continued traditional cropping practices.

10. SWOT ANALYSIS

Strengths

St

- Integrated watershed interventions (Bandharas, farm ponds, recharge structures, nala development), improving water storage and recharge
- Significant increase in irrigation access and shift from rainfed to multi-season cropping
- Crop diversification and productivity gains (~50.0% yield increase observed)
- Improved farmer incomes (case evidence of ₹1 lakh+ increase)
- Community participation supporting utilisation and maintenance
- Hydrological evidence of groundwater recharge and improved seasonal availability
- Uneven benefits due to proximity to water structures
- Limited coverage relative to total cultivable land

W

Weakness

- Dependence on wells/borewells to access irrigation benefits
- Variability in maintenance practices across locations
- Limited baseline hydrological data for comparison
- Expansion of interventions to the uncovered farmland and nearby villages

O

Opportunities

- Adoption of water-use efficiency practices (e.g., micro-irrigation)
- Strengthening community-based water management systems
- Convergence with government schemes for scaling and sustainability
- Rainfall variability affecting recharge and water availability

Threats

T

- Risk of groundwater over-extraction, particularly in Shirpur
- Maintenance gaps impacting long-term sustainability
- Potential inequity in water access across beneficiaries

11. OECD FRAMEWORK

Relevance Coherence Effectiveness Efficiency Impact Sustainability

RELEVANCE

The programme addresses critical gaps in water availability, groundwater depletion, and irrigation access in drought-prone regions of Gujarat and Maharashtra. Through interventions such as Bandharas, farm ponds, recharge shafts, and nala development, the programme responds to local needs for water security and sustainable agriculture, covering 11 villages in Viramgam and multiple villages in Shirpur. It directly supports farming communities that depend on rainfed agriculture and have limited access to irrigation.

COHERENCE

The programme aligns with national and state priorities on water conservation, groundwater management, and climate-resilient agriculture.

Alignment with Government Initiatives:

- Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)
- Jal Shakti Abhiyan
- Atal Bhujal Yojana

EFFECTIVENESS

The programme was effective in improving groundwater recharge, irrigation access, and agricultural practices. Beneficiary responses indicate increased water availability, multi-season cropping, and crop diversification, while case evidence shows a ~50.0% increase in yield and income gains exceeding ₹1 lakh annually. Hydrological estimates further support improvements in groundwater recharge and water storage (e.g., ~3.48 lakh cubic metres recharge). However, variation in benefits due to proximity to structures and partial coverage indicates scope for strengthening.

EFFICIENCY

The programme utilised available resources to implement multiple watershed structures across locations, leveraging community participation and existing natural drainage systems. The integrated watershed approach enabled cost-effective improvements in water storage and recharge. However, limited coverage of structures relative to total land area and the need for expanded intervention scale indicate opportunities for improved resource optimisation.

Index : 5 Points - Very High ; 4 Points - High ; 3 Points - Moderate ; 2 Points - Low ; 1 Point - Very Low

IMPACT

The programme has led to significant improvements in water availability, irrigation access, and agricultural productivity. Farmers reported shifts to multi-season cultivation and adoption of higher-value crops, along with reduced water stress and improved income stability. At the community level, improved groundwater recharge contributed to longer water retention in wells and reduced dependence on external sources. Hydrological estimates further validate enhanced recharge and water retention, reinforcing overall programme impact.

SUSTAINABILITY

- Continued maintenance of water structures (desiltation, upkeep) is essential for long-term functionality.
- Strengthening community ownership and water governance mechanisms will support sustainability.
- Expansion of interventions is required to address uneven benefit distribution.
- Integration with efficient irrigation practices can enhance long-term outcomes.
- Continued support and convergence with government programmes can sustain and scale impact.

EVALUATION CRITERIA: Relevance | Coherence | Effectiveness | Efficiency | Impact | Sustainability

Index : 5 Points - Very High ; 4 Points - High ; 3 Points - Moderate ; 2 Points - Low ; 1 Point - Very Low

CHAPTER 12
CONCLUSION

The Zydus Watershed Project significantly strengthened water availability and agricultural outcomes across Shirpur, Viramgam & Mandal through targeted interventions, including Bandharas, farm ponds, recharge structures, and nala development. By improving irrigation access, the programme enabled farmers to shift towards multi-season cultivation and adopt higher-value crops, resulting in enhanced productivity and income gains, with case evidence indicating a ~50.0% increase in yield and an annual income increase of over ₹1 lakh.

The interventions also contributed to improved groundwater recharge, supported by hydrological assessments indicating ~3.48 lakh cubic metres of recharge through watershed interventions in Viramgam. In Shirpur, the assessment indicates an overall groundwater recharge potential of ~14.09 lakh cubic metres, primarily driven by rainfall and supported by Bandhara-based interventions. These findings reinforce observed improvements in water retention and reduced water stress.

While variations in benefits due to coverage and proximity to structures remain, the programme demonstrates an effective and scalable model for watershed development and livelihood enhancement, with strong potential for sustained impact through expanded reach and strengthened community-led management.

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B. ENVIRONMENTAL ASSESSMENT

HYDROLOGIC IMPACT ASSESSMENT

SHIRPUR, DHULE | VIRAMGAM & MANDAL, AHMEDABAD

LIST OF FIGURES

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SUMMARY OF FINDINGS

SHIRPUR

District		Dhule	
Block		Shirpur	
Clusters	Godi	Manjrod	Total
Area of Assessment Watershed (Sq. Km.)	5.584622	13.159432	**18.744054**
Intervention Type	CRB	CRB	**CRB**
Intervention Nos.	4	1	**5**
Capacity (cu. m.)	**92,110**	**22,860**	**1,14,970**
Recharge due to Interventions (cu. m.) (Jan 2025 to Dec 2025)	1,87,735.94	52,406.43	2,40,142.37

Total surface storage created in the intervention area due to the project is 1,14,970 m 3 (92,110 m 3 in Godi + 22,860 m 3 in Manjrod)

The influence of rainfall on the groundwater levels has been significant and is observable after a 90-day delay.

The groundwater levels in the intervention watershed have been stable since 2020 and are presently higher, and are expected to remain high in the coming years. The availability of more recent data will shed further light on the expected trends.

Groundwater recharge directly from rainfall in the intervention area accounts for about 8.6% of the total rainfall received during the intervention period

The volume of surface runoff stored by the intervention measures is 17.65% (31.9% in Godi and 3.41% in Manjrod) of the total runoff generated in the intervention watershed (or) 0.53% (0.92% in Godi and 0.15% in Manjrod) of the total rainfall received during the period of the project intervention and ever since.

The contribution of intervention stored water to ground water recharge is 2,40,142.37 m^3 (1,87,735.94 m^3 in Godi & 52,406.43 m^3 in Manjrod)

SEASONAL CROPPING IMPROVEMENTS

% Change in Cropped Area	Godi	Manjrod	Total
Kharif	19.42%	2.92%	**7.24%**
Rabi	14.23%	-0.35%	**2.16%**
Zaid	21.91%	15.09%	**16.52%**

Analysis of Seasonal Cropping Patterns and Cropping Intensity reveals a significant change in area under cultivation, with notable increases in Zaid crops and in single- and triple-cropping areas. A measurable expansion in cultivated area, with Kharif increasing from 15.38 to 16.49 sq. km (7.24%), Rabi from 12.35 to 12.62 sq. km (2.16%), and Zaid from 4.71 to 5.48 sq. km (16.52%). The higher growth in Zaid cropping, which is highly dependent on assured irrigation, suggests improved groundwater availability during the post-monsoon and summer periods, likely due to the interventions.

CROPPING INTENSITY IMPROVEMENTS

% Change in Cropped Area	Godi	Manjrod	Total
Uncultivated	-58.36%	-35.37%	**-47.66%**
Single Cropping	20.01%	40.01%	**28.40%**
Double Cropping	5.71%	-11.63%	**-8.80%**
Triple Cropping	35.59%	25.11%	**27.15%**

Cropping intensity metrics further corroborate this trend, with uncultivated land decreasing significantly from 2.39 to 1.25 sq. km (−47.66%), alongside increases in single cropping (3.67 to 4.71 sq. km; +28.4%) and triple cropping (3.38 to 4.3 sq. km; +27.15%). The marginal decline in double cropping (9.31 to 8.49 sq. km; −8.79%) indicates a transition toward higher-intensity land use, with areas previously under double cropping shifting to triple cropping.

Overall, there was a 6.65% increase in cropping intensity compared to the pre-intervention scenario (see the table below for details).

% Change in Cropped Area	Net sown area (Sq. Km.)	Gross Cropped (Sq. Km.)	Cropping Intensity
Pre-Intervention	18.76	32.44	172.94
Post-Intervention	18.76	34.60	184.45
% Change			**6.65%**

CARBON STOCK IMPROVEMENTS

% Change	Godi	Manjrod	Total
Tonnes of C	257.78%	-1.67%	**91.81%**
Hectare	201.34%	17.13%	**87.36%**
Tonnes of C/Ha	18.73%	-16.06%	**2.38%**

The overall carbon stock in the intervention area has shown a marked increase, both in total carbon sequestered (91.81%) and in areas with carbon stock (87.36%).

VIRAMGAM & MANDAL

District	Ahmedabad			
Block	Viramgam		Mandal	
Intervention Villages	6 (Vadgas, Vani, Thori, Dumana, Dediyasan, Dolatpura, Goraiya)		4 (Vinzuwada, Varmor, Dalod, Trent)	
Intervention Area (Sq. Km.)	21.73		12.49	
Interventions	**Nos.**	**Capacity (cu. m.)**	**Nos.**	**Capacity (cu. m.)**
Desiltation of Existing Community Pond (PTD)	5	56,003.94	-	-
Nal Deepening & Widening (NDW)	1	19,163.92	-	-
Farm Pond (FP)	2	23,18.34	3	6,633.58
Recharge the shaft with an injection borewell at the farm level	34	NA	34	NA
Recharge Shaft with Injection Borewell in Submergence Area	7	NA	-	-

Intervention Villages	**11**
Intervention Area (Sq. Km.)	**34.21**

Intervention Type	Intervention Nos.	Capacity (cu. m.)	Ground Water Recharge Potential (cu. m.) (2024 -2025)
Desiltation of Existing Community Pond (PTD)	5	56,003.94	1,22,866.19
Nala Deepening & Widening (NDW)	1	19,163.92	42,042.81
Farm Pond (FP)	5	8,951.92	18,161.23
Recharge shaft - Farm Level	68	NA	3,81,966.34
Recharge Shaft - Submergence Area	7	NA	3,67,234.56
Total	86	84,119.78	9,32,271.12

Total surface storage created in the intervention area due to the project is 84,119.77 m3 (77,486.2 m3 in Viramgam and 6633.58 m3 in Mandal)

The influence of rainfall on groundwater levels has been significant, with a 60-90-day delay.

Groundwater levels in Viramgam have been rising since 2020, but have been decreasing in Mandal, where they are presently higher and are expected to remain so in the coming years. The availability of more recent data will shed further light on the expected trends.

Groundwater recharge directly due to rainfall in the intervention area is about 36.75% of the total rainfall received in the intervention period (46.68% in Viramgam and 26.82% in Mandal).

Ground water recharge due to the interventions is equivalent 2.45% of the total rainfall received in the area (3.7% in Viramgam and 1.19% in Mandal).

Volume of surface runoff stored by the intervention measures is 16.36% (21.53% in Viramgam & 11.19% in Mandal) of the total runoff generated in the intervention villages (or) 0.47% (0.8% in Viramgam & 0.13% in Mandal) of the total rainfall received during the project period and ever since.

SEASONAL CROPPING IMPROVEMENTS

% Change in Cropped Area	Viramgam	Mandal	Total
Kharif	14.45%	22.66%	**18.05%**
Rabi	86.39%	66.46%	**77.30%**
Zaid	292.21%	191.57%	**248.35%**

Analysis of Seasonal Cropping Patterns and Cropping Intensity reveals a significant change in area under cultivation, with notable increases in Zaid crops and in single- and triple-cropping areas. Viramgam shows a 14.45% increase in Kharif area, but a much sharper rise in Rabi (86.39%) and Zaid (292.21%), indicating a strong enhancement in irrigation potential beyond the monsoon season. Similarly, Mandal records an increase of 22.66% in Kharif, 66.46% in Rabi, and 191.57% in Zaid. The higher growth in Zaid cropping, which is highly dependent on assured irrigation, suggests improved groundwater availability during the post-monsoon and summer periods, likely due to the interventions.

CROPPING INTENSITY IMPROVEMENTS

% Change in Cropped Area	Viramgam	Mandal	Total
Uncultivated	-52.44%	-58.04%	-54.62%
Single Cropping	-54.62%	-7.18%	-7.67%
Double Cropping	152.84%	120.71%	137.66%
Triple Cropping	170.01%	139.67%	156.43%

Cropping intensity metrics further corroborate this trend, with uncultivated land decreasing significantly from 70.43 to 31.96 sq. km. (-54.32%) in Viramgam & Mandal. Further, single-cropped area decreased slightly (95.95 to 88.59 sq. km; −7.67%), while double cropping increased dramatically (25.05 to 59.53 sq. km; +137.66%) and triple cropping (7.25 to 18.60 sq. km; +156.43%). The marginal decline in single cropping indicates a transition toward higher-intensity land use, with areas previously under single cropping shifting to double cropping and beyond.

Overall, there was a 57.85% increase in cropping intensity compared to the pre-intervention scenario (see the table below for details).

	Net sown area (Sq. Km.)	Gross Cropped (Sq. Km.)	Cropping Intensity
Pre-Intervention	198.68	167.96	84.54
Post-Intervention	198.68	265.14	133.45
% Change			**57.85%**

CARBON STOCK IMPROVEMENTS

% Change in Cropped Area	Viramgam	Mandal	Total
Tonnes of C	18.93%	60.05%	**28.34%**
Hectare	21.00%	64.76%	**31.07%**
Tonnes of C/Ha	-1.71%	-2.86%	**2.08%**

The overall carbon stock in the intervention area has shown a marked increase, both in total carbon sequestered (28.34%) and in areas with carbon stock (31.07%).

SOIL SALINITY IMPROVEMENTS

Location	Sample ID	Lat	Long	Sample Depth	EC (dS/m)	Baseline EC (dS/m)	% Change
Viramgam	Soil Sample 1	23.112135	71.945863	30 cm	0.11	0.91	-87.91%
	Soil Sample 2	23.085175	72.001809	30 cm	0.06	0.4	-85.00%
	Soil Sample 3	23.073341	71.925879	30 cm	0.04	0.28	-85.71%
	Soil Sample 3a	23.07647	71.922243	200 cm	2.08	-	-
	Soil Sample 4	23.07647	71.922243	30 cm	0.04	0.31	-87.10%
	Soil Sample 5	23.090194	71.980425	30 cm	0.27	0.35	-22.86%
	Soil Sample 6	23.138097	71.980452	30 cm	0.01	0.22	-95.45%
	Soil Sample 7	23.108664	71.968291	30 cm	0.09	0.345	-73.91%
	Soil Sample 8	23.098857	71.964272	30 cm	0.19	0.35	-45.71%
	Soil Sample M1	23.359094	71.945918	30 cm	0.06	3.4	-98.24%
Mandal	Soil Sample M2	23.366373	71.934935	30 cm	0.08	0.95	-91.58%
	Soil Sample M3	23.366212	71.915739	30 cm	0.1	0.26	-61.54%
	Soil Sample M3a	23.367174	71.915029	400 cm	0.34	-	-
	Soil Sample M4	23.352199	71.937894	30 cm	0.07	0.28	-75.00%

Significant reductions in soil salinity are also observed in both Viramgam and Mandal, ranging from 22.0% to 98.0%.

The presence of higher EC values at deeper layers (e.g., 2.08 dS/m at 200 cm in Viramgam and 0.34 dS/m at 400 cm in Mandal) further supports the interpretation that salts have been mobilised downward from the surface layers.

Before the interventions, rainfall dissolves surface salts, and run-off carries them towards waterlogged areas. When water evaporates, the salts are left behind, increasing salinity. After the intervention, the recharge shafts act as vertical drainage structures, allowing excess surface water carrying dissolved salts to rapidly percolate into deeper aquifer zones, preventing waterlogging in the fields. Enhanced percolation facilitates the downward movement (leaching) of soluble salts from the topsoil into deeper layers, thereby reducing soil salinity in the active root zone.

OBJECTIVES OF THE ASSESSMENT

Change/ improvement of the groundwater table/ recharge

Change in surface water holding capacity and reduction in Run-off

Change in cropping patterns and intensity, and carbon stock conditions.

PROJECT LOCATIONS

The projects were implemented in the Shirpur Block of Dhule district, and in Viramgam & Mandal Blocks of Ahmedabad District. The details of the measures that were implemented as part of the water conservation efforts are as follows:

DETAILS OF THE INTERVENTIONS - SHIRPUR

District	Dhule	Block	Shirpur
Clusters	Godi	Manjrod	Total
Area of Watershed (Sq. Km.)	5.584622	13.159432	18.744054
Nos.	4	1	5
Capacity (cu. m.)	92110	22860	114970

DETAILS OF THE INTERVENTIONS IN VIRAMGAM & MANDAL

District	Ahmedabad		Block		Viramgam & Mandal	
Intervention Villages	Viramgam		Mandal		Total	
	6 (Vadgas, Vani, Thori, Dumana, Dediyasan, Dolatpura, Goraiya)		4 (Vinzuwada, Varmor, Dalod, Trent)		11	
Intervention Area (Sq. Km.)	21.725042		12.485695		34.210737	
Measures	Nos.	Capacity	Nos.	Capacity	Nos.	Capacity
Desiltation of Existing Community Pond (PTD)	5	56003.94	-	-	6	56003.94
Nal Deepening & Widening (NDW)	1	19163.92	-	-	3	19163.92
Farm Pond (FP)	2	2318.34	3	6633.58	5	8951.92
Recharge the shaft with an injection borewell at the farm level	34	NA	34	NA	68	NA
Recharge Shaft with Injection Borewell in Submergence Area	7	NA			7	NA

The maps below show the locations of the intervention watersheds and all available intervention locations within these watersheds for this project.

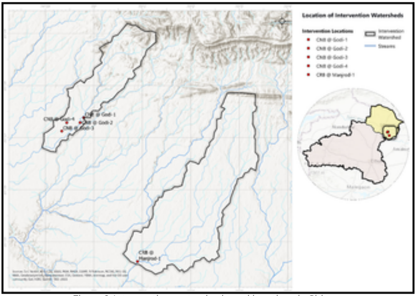


Figure 1: Intervention watersheds and locations in Shirpur

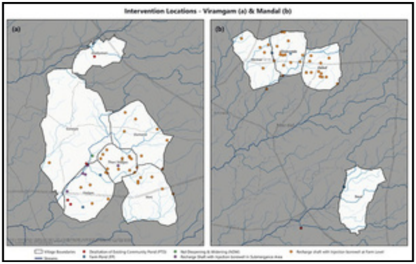


Figure 2: Intervention Villages and Locations in Viramgam & Mandal

The detailed locations of all interventions covered in the evaluations are provided in Annexure 1. The additional parameters considered are geology, hydrogeology, and soil types, and the information on the same is provided in Annexure 2.

While some of the assessments, such as the run-off estimation and the contribution of the interventions to the groundwater levels, were done only considering the intervention area, some assessments, such as the rainfall and the groundwater depth assessments, had to be done considering a larger area, such as the entire block or the district, due to the constraints faced with data availability. Care was taken to ensure that the results were correctly represented across varying assessment units for this condition.[1]

ASSESSMENT APPROACH

The assessment approach consists of various steps for each objective, as shown below:

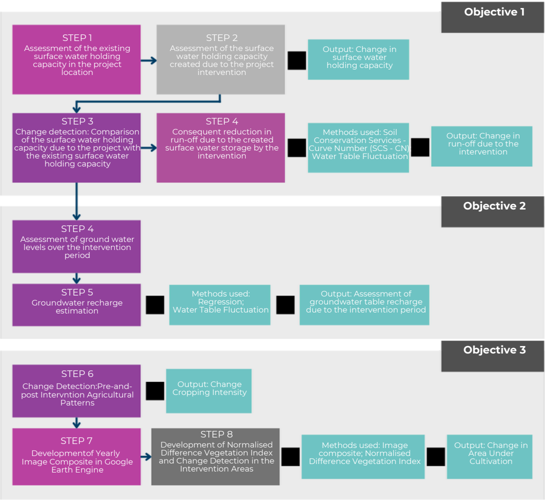


Figure 4: Approach of the Assessment

[1] The rainfall and the ground water depth assessments were done based on the closest observation point as the unit of assessment as these parameters, i.e., rainfall and ground water are not bound on the surface by any constraints and can be reasonably generalised for the project area.

DATA COLLECTION

The following datasets have been collected from the field to facilitate the objectives of the study:

- Intervention dimensions (Annexure 1)
- Photos from the field survey (Annexure 5)

In addition to the above datasets, data were collected from various sources to fill data gaps encountered during the assessment. These are as follows:

- In addition to the above datasets, data were collected from various sources to fill data gaps encountered during the assessment. These are as follows:
- Depth to water level from the Central Ground Water Board (CGWB) (Annexure 3)
- Rainfall data from the Indian Meteorological Department (IMD) (Annexure 4)

Other datasets that were used in the assessment are as follows:

- Soil types from the National Remote Sensing Centre[1]
- Aquifer system from the Central Ground Water Board (CGWB)
- Specific Yield from Central Ground Water Board (CGWB)
- Global Hydrologic Soil Groups for Run-off Estimation
- Sentinel 2 Earth Observation Imagery
- World Conservation Monitoring Centre's (WCMC) Above and Below Ground Biomass Carbon Density

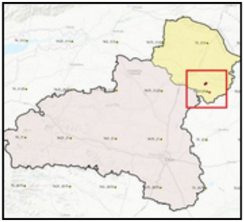
[1] Soil and Land Resources Assessment Division, National Remote Sensing Centre, ISRO
[1] Ross, C.W., L. Prihodko, J.Y. Anchang, S.S. Kumar, W. Ji, and N.P. Hanan. 2018. Global Hydrologic Soil Groups (HYSOGs250m) for Curve Number-Based Run-off Modeling. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1566
[1] Soto-Navarro C., Ravilious C., Arnell A., de Lamo X., Harfoot M., Hill S. L. L., Wearn O. R., Santoro M., Bouvet A., Mermoz S., Le Toan T., Xia J., Liu S., Yuan W., Spawn S. A., Gibbs H. K., Ferrier S., Harwood T., Alkemade R., Schipper A. M., Schmidt-Traub G., Strassburg B., Miles L., Burgess N. D. and Kapos V. (2020) Mapping co-benefits for carbon storage and biodiversity to inform conservation policy and action. Philosophical Transactions of the Royal Society B. 375 https://doi.org/10.1098/rstb.2019.0128

RESULTS

The results of the assessment of the interventions' impacts on water conservation are presented in the sections below. It includes assessment of rainfall and water-level trends; estimation of recharge from rainfall; assessment of surface water holding capacity and the associated reduction in run-off; estimation of recharge from the interventions; and assessment of changes in land use/land cover and vegetation levels over the course of the intervention period.

ANALYSIS OF RAINFALL TRENDS - SHIRPUR

The rainfall analysis for the coordinates 21.25°N, 75°E in Dhule district, based on data from 2020 to 2025, reveals a highly seasonal pattern dominated by monsoon rainfall from June to September. The months of July and August account for the largest share of annual rainfall, while the period from October to May remains largely dry, with only occasional pre-monsoon showers in April and May. Spatial variations are evident across the district, with certain locations receiving almost twice as much rainfall as others, likely due to differences in topography and local climatic influences. The graph below shows the monthly variation in rainfall over the intervention area. The section highlighted in orange shows rainfall variation during the intervention period and since then.



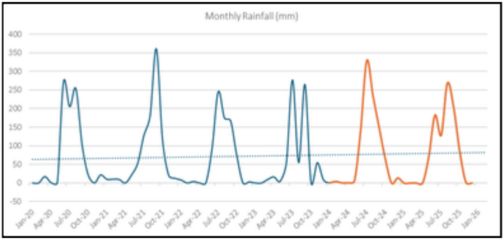


Figure 3: Monthly rainfall over the intervention area - Shirpur

The rainfall pattern in the intervention area shows a strongly seasonal, monsoon-dominated climate with high interannual variability. Most of the annual rainfall is concentrated between June and September, with frequent peaks exceeding 200–350 mm in individual months (notably mid-2021, mid-2022, and mid-2024), indicating intense southwest monsoon activity.

Outside the monsoon window, rainfall is minimal to near zero for most months, highlighting a long dry season typical of semi-arid regions of northern Maharashtra. The data also reveals significant year-to-year fluctuations in both onset and intensity—for example, 2023 shows erratic spikes, while 2024–2025 includes sharp, isolated heavy events rather than evenly distributed rainfall. The slight upward trendline suggests a marginal increase in average monthly rainfall over time, but variability remains the dominant feature. Overall, the region experiences short periods of very high rainfall interspersed with prolonged dry periods, posing challenges for water storage, agricultural planning, and drought resilience.

ANALYSIS OF RAINFALL TRENDS – VIRAMGAM & MANDAL

The rainfall analysis for the coordinates 23.25°N, 73°E in Ahmedabad district, based on data from 2020 to 2025, reveals a highly seasonal pattern dominated by monsoon rainfall from June to September. The months of July and August account for the largest share of annual rainfall, while the period from October to May remains largely dry, with only occasional pre-monsoon showers in April and May. The graph below shows the monthly variation of rainfall over the intervention area. The section highlighted in orange shows rainfall variation during the intervention period and since then.

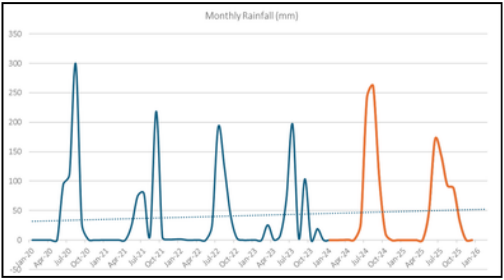


Figure 4: Monthly rainfall over the intervention area – Viramgam & Mandal

The rainfall pattern in Viramgam is highly seasonal and variable, dominated by the monsoon months. Most precipitation occurs between June and September each year, with sharp peaks—particularly in July and August—indicating intense but short-lived rainfall events.

The highest recorded monthly rainfall occurs around mid-2020 (approximately 300 mm), with similarly strong but slightly lower peaks in subsequent years (generally between 180 and 260 mm). Outside the monsoon period, rainfall remains minimal to near zero, highlighting a prolonged dry season. While there is noticeable year-to-year fluctuation in peak intensity, the dotted trendline suggests a slight overall increase in average monthly rainfall. The projection for 2024–2025 continues this pattern, with significant monsoon spikes but no clear evidence of drastic long-term change, indicating persistent reliance on seasonal rains with potential variability in intensity.

CHANGE IN GROUNDWATER LEVEL - SHIRPUR

Groundwater monitoring is generally conducted at the district level by combining observations from monitoring wells spread across the district. In the case of the intervention villages, the closest monitoring well present and relevant to the intervention area is highlighted on the map shown. However, a continuous dataset for this well was not available. Thus, given the large-scale nature of aquifers, establishing a groundwater-level baseline has relied on observed levels from nearby monitoring stations. The depth-to-water-level data were obtained from the annual Ground Water Year Books for Maharashtra, published by the Central Ground Water Board (CGWB), for the years 2020 to 2024.

However, a complete dataset for the period from 2020 to the present was not available, so statistical methods were used to impute the missing data. The chart below shows the groundwater monitoring wells and the fluctuations in pre- and post-monsoon groundwater levels in the vicinity of the intervention villages in the intervention area.

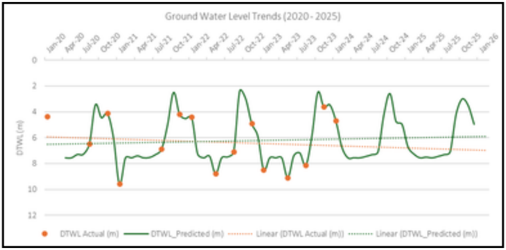


Figure 5: Ground Water Level Trends (2014 - 2024) - Shirpur

The groundwater level trends at Saver village in Shirpur from 2020 to 2025 exhibit a pronounced seasonal pattern strongly influenced by monsoonal rainfall and the hydrogeological characteristics of the Deccan basalt terrain of Maharashtra. The depth to water level (DTWL) consistently becomes deepest during the pre-monsoon months (April–June), often reaching 7–10 m, and recovers significantly after the monsoon (August–October), rising to shallower levels of around 2–5 m. This reflects a typical “flash recharge–rapid depletion” system, where groundwater levels respond quickly to rainfall but decline steadily due to limited aquifer storage and ongoing extraction. The groundwater level trends at Saver village in Shirpur from 2020 to 2025 exhibit a pronounced seasonal pattern strongly influenced by monsoonal rainfall and the hydrogeological characteristics of the Deccan basalt terrain of Maharashtra.

The depth to water level (DTWL) consistently becomes deepest during the pre-monsoon months (April–June), often reaching 7–10 m, and recovers significantly after the monsoon (August–October), rising to shallower levels of around 2–5 m. This reflects a typical “flash recharge–rapid depletion” system, where groundwater levels respond quickly to rainfall but decline steadily due to limited aquifer storage and ongoing extraction.

Note: The last available groundwater depth data is from January 2024. The data from May 2024 to the present has not been published yet. Thus, in the absence of the necessary data, statistical methods (a lagged regression model) were used to predict values for this period. These predicted data may not reflect the true groundwater levels, and the derived estimates are likely to change as official groundwater depth measurements become available for 2024 and 2025.

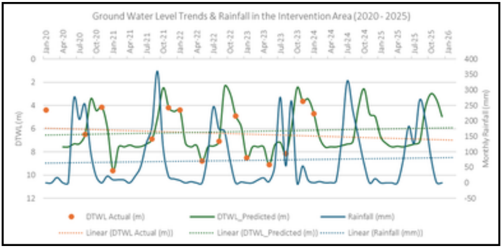


Figure 6: Groundwater levels & cumulative rainfall in the intervention area - Shirpur

A 3-month lagged regression analysis was conducted to assess the relationship between rainfall and groundwater levels and to predict groundwater levels for the missing months. Based on the obtained Goodness-of-Fit R^2 values of 0.363, this model explains 36.3% of the variance in the water table. In environmental data, this is considered a strong correlation, especially when using only a single variable (rainfall). Furthermore, the obtained p-value of 0.023 is below the standard 0.05 threshold, indicating the result is statistically significant. We can say with 97.7% confidence that this relationship is real and not due to random chance. The negative slope of -0.0152 means that as rainfall increases (3 months ago), the depth to the water level decreases (meaning the water table rises). This is as expected in a natural hydrological system. The obtained intercept of 7.56m suggests the "equilibrium" depth of the water table when there has been no significant rainfall in the preceding months. Comparing groundwater depth measurements in the intervention area before and after the intervention will confirm the change in water level due to the intervention.

CHANGE IN GROUNDWATER LEVEL – VIRAMGAM & MANDAL

Groundwater monitoring is generally conducted at the district level by combining observations from monitoring wells across the district. In the case of the intervention villages, the closest monitoring well present and relevant to the intervention area is highlighted on the map shown. However, a continuous dataset for this well was not available. Thus, given the large-scale nature of aquifers, establishing a groundwater- level baseline has relied on observed levels from nearby monitoring stations. The depth-to-water- level data were obtained from the annual Ground Water Year Books for Gujarat, published by the Central Ground Water Board (CGWB), for the years 2020 to 2024. However, a complete dataset for the period from 2020 to the present was not available, so statistical methods were used to impute the missing data. Additional well-monitoring data collected by the implementing partner were also used to fill in the missing data wherever appropriate. The chart below shows the groundwater monitoring wells and the fluctuations in pre- and post-monsoon groundwater levels in the vicinity of the intervention villages in the intervention area.

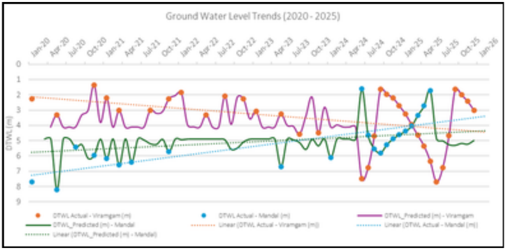


Figure 7: Ground Water Level Trends (2014 - 2024) – Viramgam & Mandal

The integrated analysis of rainfall, groundwater trends, and regression-based modelling (2020–2025) for Viramgam and Mandal highlights both the seasonal dependence on monsoon recharge and emerging concerns of groundwater sustainability.

Groundwater levels in both locations respond to monsoon rainfall with a clear lag, confirming recharge-driven dynamics; however, the strength and reliability of this relationship vary significantly. In Viramgam, a statistically significant 3-month lag model shows a moderate correlation between rainfall and groundwater levels, providing a reasonably robust basis for estimating missing data and indicating delayed recharge through subsurface layers.

In contrast, Mandal shows a weak and statistically insignificant relationship, suggesting that groundwater fluctuations are influenced more by local factors such as extraction and surface conditions than by rainfall alone, thereby increasing uncertainty in predicted values. Despite seasonal recovery during monsoon periods, long-term trends indicate gradual groundwater depletion, particularly in Mandal. Overall, the findings emphasise that while rainfall remains a key driver of recharge, sustainable groundwater management—especially the regulation of extraction and the enhancement of recharge—is critical to address the region's increasing variability and declining trends.

Note: The last available groundwater depth data is from January 2024. The data from May 2024 to the present has not been published yet. Additionally, sufficient historical data were not available to reliably assess groundwater trends. Thus, in the absence of the necessary data, statistical methods (a lagged regression model) were used to predict values for the missing periods. These predicted data may not reflect the true groundwater levels, and the derived estimates are likely to change as official groundwater depth measurements become available for 2024 and 2025.

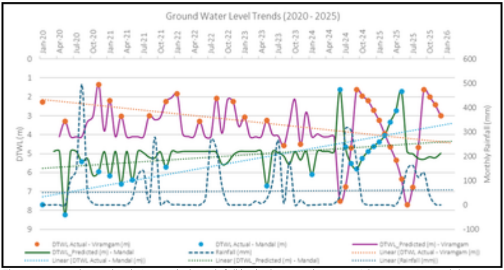


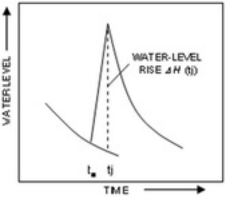
Figure 8: Groundwater levels & cumulative rainfall in the intervention area – Viramgam & Mandal

Lagged regression analyses were conducted to assess the relationship between rainfall and groundwater levels and to predict groundwater levels for the missing months. For Viramgam, the best-fit model with a 3-month lag (DTWL = −0.00737 × $Rain_{t-3}$ + 4.1018) shows a moderate but statistically significant relationship (R^2 = 0.2383, p = 0.0029), indicating that nearly 24.0% of groundwater level variation can be explained by rainfall. The negative slope confirms that higher rainfall leads to higher groundwater levels (a shallower depth), and the lag reflects delayed recharge due to percolation through relatively thick vadose-zone materials such as clay or silt. This makes the model reasonably reliable for estimating missing values and capturing seasonal recharge behaviour in Viramgam.

In contrast, Mandal exhibits a much weaker and statistically insignificant relationship with a 2-month lag (DTWL = 0.00258 × $Rain_{t-2}$ + 4.8782; R^2 = 0.0284, p = 0.465). The very low explanatory power suggests that rainfall alone does not adequately predict groundwater fluctuations at this site, likely due to the stronger influence of local factors such as pumping, surface run-off, or shallow aquifer dynamics. As a result, while the model was used to estimate missing data, its predictive reliability for Mandal is limited and should be interpreted with caution. Overall, the modelling approach reinforces earlier observations: Viramgam shows
a clearer, delayed rainfall–recharge linkage suitable for gap-filling, whereas Mandal's groundwater system is more complex and less directly controlled by rainfall, leading to higher uncertainty in predicted values.

ESTIMATION OF GROUNDWATER RECHARGE DUE TO RAINFALL

The Water Table Fluctuation (WTF) method estimates groundwater recharge by analysing water-level fluctuations in observation wells. The water-table fluctuation method assumes that rises in groundwater levels in unconfined aquifers are due to recharge reaching the water table. Recharge is calculated as the change in water level over time multiplied by specific yield.



$R(t_j) = Sy^* \Delta H(t_j)$

where $R(t_j)$ (m) is recharge occurring between times t_0 and t_j, Sy is specific yield (dimensionless), and $\Delta H(t_j)$ is the peak water level rise attributed to the recharge period (cm).

The specific yield values were obtained from the Groundwater Estimation Commission's report on groundwater resource estimation methodology[1][2]. The specific yield values identified for the different types of aquifers found across the intervention areas identified from the GEC reports are given below:

Location	Dhule	Viramgam & Mandal
Major Aquifer System	Basalt	Coastal Alluvium
Sy Range	0.01 – 0.03	0.08 – 0.12
Sy Chosen	0.02	0.1
RIF Range	0.12 – 0.14	0.08 – 0.12
RIF Chosen	0.13	0.1

Based on this method, in Shirpur, about 9.7% of the rainfall has recharged directly to the ground in the intervention sites during the intervention period, and the 6-year average is 13.2%; in Viramgam, about 50.2% of the rainfall has recharged directly to the ground in the intervention sites, and 28.85% in Mandal during the intervention period. The results and calculations are presented below:

https://cgwb.gov.in/Documents/GEC97.pdf
Detailed Guidelines (cgwb.gov.in)

WATER TABLE FLUCTUATION METHOD RESULTS - SHIRPUR

Major Aquifer System	Basalt						
Year	**Precipitation (mm)**	**ΔH annual**	**Sy**	**R_m**	**R_{mm}**	**as % of P**	**Volume of recharge (in cu. m.)**
2020	895.0872117	4.111	0.02	0.082226562	82.22656225	9.2%	1543725.755
2021	924.3592055	7.112	0.02	0.142243166	142.2431658	15.4%	2670480.591
2022	767.5867696	6.418	0.02	0.128365142	128.3651416	16.7%	2409933.843
2023	744.4315693	6.614	0.02	0.132276511	132.2765111	17.8%	2483366.098
2024	940.4444946	4.985	0.02	0.099696486	99.69648587	10.6%	1871707.01
2025	939.6985983	4.564	0.02	0.091286186	91.28618636	9.7%	1713811.61
						13.2%	**12693024.91**
Average Recharge directly due to Rainfall received since 2020							

WATER TABLE FLUCTUATION METHOD RESULTS - VIRAMGAM

Location		Viramgam					
Major Aquifer System		Coastal Alluvium					
Year	Precipitation (mm)	ΔH annual	Sy	R_m	R_{mm}	as % of P	Volume of recharge (in cu. m.)
2020	574.7068615	2.752	0.1	0.275179629	275.1796288	47.9%	5978288.993
2021	649.6560217	2.054	0.1	0.205442725	205.4427248	31.6%	4463251.825
2022	425.6654956	2.262	0.1	0.226179629	226.1796288	53.1%	4913761.935
2023	387.7667015	2.430	0.1	0.243001628	243.0016284	62.7%	5279220.583
2024	411.8442862	2.500	0.1	0.2532	253.2	61.5%	5500780.634
2025	535.0451111	2.350	0.1	0.2356	235.6	44.0%	5118419.895
						50.1%	**5208953.98**
Average Recharge directly due to Rainfall received since 2020							

WATER TABLE FLUCTUATION METHOD RESULTS - MANDAL

Location		Mandal					
Major Aquifer System		Coastal Alluvium					
Year	Precipitation (mm)	ΔH annual	Sy	R_m	R_{mm}	as % of P	Volume of recharge (in cu. m.)
2020	574.7068615	3.342	0.1	0.334176518	334.1765184	58.1%	4172426.085
2021	649.6560217	1.722	0.1	0.172176518	172.1765184	26.5%	2149743.495
2022	425.6654956	0.686	0.1	0.068601467	68.60146665	16.1%	856536.9892
2023	387.7667015	1.822	0.1	0.182176518	182.1765184	47.0%	2274600.445
2024	411.8442862	1.488	0.1	0.14875	148.75	36.1%	1857247.131
2025	535.0451111	1.887	0.1	0.188661713	188.6617127	35.3%	2355572.603
Average Recharge directly due to Rainfall received since 2020						**36.5%**	**2277687.79**

Further, the groundwater recharge from the Rainfall Infiltration Method (RIF) can be obtained from the following relation:

Groundwater Recharge = Geographical Area x Actual Rainfall x Infiltration Factor

RAINFALL INFILTRATION METHOD - SHIRPUR

Area of intervention watersheds (in sq. m.)	18774052.00

Year	P (m)	RIF (m)	Volume of recharge (in cu. m.)
2020	0.895087212	0.11636134	2184573.801
2021	0.924359206	0.05546155	1041238.067
2022	0.76758677	0.04605521	864642.8356
2023	0.744431569	0.04466589	838559.8196
2024	0.940444495	0.05642667	1059357.231
2025	0.939698598	0.05638192	1058517.021
			7046888.776
Total			

RAINFALL INFILTRATION METHOD - VIRAMGAM

Area of intervention watersheds (in sq. m.)	21725042.00

Year	P (m)	RIF (m)	Volume of recharge (in cu. m.)
2020	0.574706861	0.05747069	1248553.07
2021	0.649656022	0.0649656	1411380.436
2022	0.425665496	0.04256655	924760.0769
2023	0.387766701	0.03877667	842424.7875
2024	0.411844286	0.04118443	894733.4415
2025	0.535045111	0.05350451	1162387.751
			1080706.594
Total			

RAINFALL INFILTRATION METHOD - MANDAL

Area of intervention watersheds (in sq. m.)	12485695.00

Year	P (m)	RIF (m)	Volume of recharge (in cu. m.)
2020	0.574706861	0.05747069	717561.4586
2021	0.649656022	0.0649656	811140.6942
2022	0.425665496	0.04256655	531472.955
2023	0.387766701	0.03877667	484153.6766
2024	0.411844286	0.04118443	514216.2145
2025	0.535045111	0.05350451	668041.0069
			621097.6676
Total			

ESTIMATION OF THE PERCENTAGE OF RAINFALL CONVERTED INTO GROUNDWATER RECHARGE

As per GEC-1997 norms, the rainfall recharge computed by the WTF method has been compared with that from the RIF method, and the final recharge is assigned a value based on set criteria to avoid unreasonably high or low estimates.

A quantity called percentage difference (PD), which is the difference between the rainfall recharge computed by the water table method (A) and the recharge by the rainfall infiltration method (B), and expressed as a percentage of the rainfall recharge by the rainfall infiltration method, is computed as follows:

$$PD = \frac{(A - B)}{B} \times 100$$

where 'A' is the rainfall recharge by the WTF method and 'B' is the rainfall recharge by the RIF method.

The set criteria (GEC 1997) to be adopted are as follows:

- If PD ≥ − 20.0% and < + 20.0%, then the value of the water table fluctuation method is adopted.
- If PD ≤ − 20.0%, then the value of 0.8 × rainfall infiltration factor method is adopted.
- If PD ≥ + 20.0%, then the value of 1.2 × rainfall infiltration factor method is adopted.

By following the above criteria, groundwater recharge is estimated.

Location	Period	WTF Model	Rainfall Infiltration Method	Percentage Difference	Criteria	Volume of recharge due to rainfall (Cu. m.)
		Volume of recharge (in cu. m.)	Volume of recharge (in cu. m.)			
Shirpur	Intervention Period	1713811.61	1058517.021	61.9	A	1270220.425
	6 Year Average	2115504.15	1174481.463	80.12	A	1409377.76
Viramgam	Intervention Period	1162387.751	5118419.895	340.33	C	1394865.301
	6 Year Average	1080706.594	5208953.98	381.99	C	1296847.91
Mandal	Intervention Period	1080706.594	2355572.603	252.61	C	801649.2083
	6 Year Average	621097.6676	2277687.79	266.71	C	745317.2

GROUND WATER RECHARGE DUE TO RAINFALL - SHIRPUR

Over the 6 years from 2020 to 2025, covering the interventions and their operations to the present, the amount of groundwater recharge directly due to rainfall stands at 14,09,377.76 Cu. m. across the intervention watershed, which is about 8.64% of the annual average rainfall, and the amount of groundwater recharge directly due to rainfall during the intervention period stands at 12,70,220.42 Cu. m. across the intervention watershed, which is about 7.79% of the total rainfall received over the intervention area during the intervention period.

GROUND WATER RECHARGE DUE TO RAINFALL – VIRAMGAM & MANDAL

Over the 6 years from 2020 to 2025, covering the interventions and their operations to the present, the amount of groundwater recharge directly due to rainfall stands at 21,96,514.509 Cu. m. (13,94,865.301 Cu. m. in Viramgam and 8,01,649.2083 Cu. m. in Mandal) across the intervention villages, which is about 46.68% of the annual average rainfall in Viramgam and 26.82% of the rainfall in Mandal.

In addition, groundwater recharge occurs naturally from surface storage measures and is also promoted by recharge shafts at both farm and submergence levels. This amounts to 10,36,951.707 Cu. m. (7,32,648.61 Cu. m. in Viramgam and 3,04,303.0945 Cu. m. in Mandal), which accounts for 3.3% of the total rainfall received in the area (3.6% in Viramgam and 2.7% in Mandal).

CHANGE IN SURFACE WATER HOLDING CAPACITY AND RUN-OFF REDUCTION

SHIRPUR

The intervention area spans two watersheds in the district's Shirpur block. On-site verification and satellite imagery indicate that the major land uses in the intervention area are agriculture, followed by rangeland. Based on the information available from the field survey and the organisation, the volume of storage created is estimated.

The change in surface storage in the intervention area was net positive; no surface storage existed in the pre-intervention period. A surface storage volume of 1,14,970 cubic metres is being considered for the assessment, comprising the storage volumes available through the CRBs at both watersheds. The detailed dimensions of the interventions are provided in Annexure 1.

VIRAMGAM & MANDAL

The intervention area is spread over eleven villages in the Viramgam and Mandal blocks of the district. On-site verification and satellite imagery show that the major land use in the intervention area is agriculture followed by built up. Based on the information available from the field survey and the organization, the volume of storage created is estimated.

The change in surface storage in the intervention area was net positive, i.e., no existing surface storage was considered in the pre-intervention period9. A surface storage volume of 84,119.77 cubic meters (77,486.2 Cu. m. in Viramgam and 6,633.58 Cu. m. in Mandal) is being considered for the assessment, which is a combination of the storage volume available through the all the interventions. The detailed dimensions of the interventions are provided in Annexure 1.

ESTIMATION OF GROUNDWATER RECHARGE DUE TO THE INTERVENTIONS

Groundwater recharge due to interventions occurs mainly from the capture and storage of surface run-off through Cement Nala Bunds, PTDs, Farm Ponds, and Borewells, as well as from natural recharge.

Run-off is defined as the portion of precipitation that reaches rivers or oceans as surface or subsurface flow. After infiltration and other losses from precipitation (rainfall), excess rainfall flows through small natural channels on the land surface to the main drainage channels. Such flows are called surface flows. A portion of the infiltrated rainwater moves parallel to the land surface as subsurface flow and reappears elsewhere on the surface. Such flows are called interflows. Another part of the infiltrated water percolates downward into the groundwater, then moves laterally to emerge in depressions and rivers, joining the surface flow. This type of flow is called the subsurface flow or groundwater flow.

While interventions such as the Cement Nala Bunds capture surface flows, these structures also contribute to groundwater recharge at the intervention sites.

Run-off estimates can indicate the amount of water captured by the intervention structures as surface storage and thus the potential amount available for groundwater recharge. Run-off can be estimated by various methods, such as:

- Empirical formulae and tables
- Rational Method
- Run-off Estimation based on Land Use and Treatment
- Empirical formulae for flood peak

In this assessment, we are using empirical formulae and tables, along with run-off estimation based on land use and treatment, as these have proven to be the most reliable methods for conducting the assessment in the absence of reliable groundwater-level data and on-the-ground access to the intervention sites.

BINNIE'S PERCENTAGES

It provides therelationship between rainfall and run-off, expressed as rainfall as a percentage of run-off. The percentages mentioned below are based on observations on two rivers in Madhya Pradesh.

RUN-OFF OF THE RAINFALL RECEIVED

Annual Rainfall (mm)	Run
500	15
600	21
700	25
800	29
900	34
1000	38
1100	40

COEFFICIENTS

The run-off coefficient (run-off cm) and rainfall 'P' (cm) can be correlated as R = KP, where 'K' is the run-off coefficient. The run-off coefficient depends on factors that affect run-off. The run-off method applies only to small projects, such as those implemented as part of this project. The usual values of K are as given below.

USUAL VALUES OF RUN-OFF COEFFICIENTS (K)

Type of Area	K
Urban Residential	0.3 - 0.5
Forests	0.05 - 0.2
Commercial & Industrial	0.9
Parks, farms, Pastures	0.05 - 0.3
Asphalt or concrete pavement	0.85

BARLOW'S TABLES

Thefollowing values ofK(in percentage) for various types of catchments were developed by T.G. Barlow based on the studies of catchments mostly under 130 sq. km. in Uttar Pradesh.

BARLOW'S PERCENTAGE RUN-OFF COEFFICIENTS

Class	Description of Catchment	Percentage run
A	Flat, cultivated and black cotton soils	10
B	Flat, partly cultivated, various soils	15
C	Average	20
D	Hills and plains with little cultivation	35
E	Very hilly and steep, with hardly any cultivation	45

These percentages are for the typical monsoon and should be adjusted using the following coefficients, based on the season, as shown.

BARLOW'S RUN-OFF COEFFICIENTS FOR DIFFERENT NATURES OF SEASON

Nature of Season	Class of catchments				
	A	B	C	D	E
Light rain, no heavy downpour	0.7	0.8	0.8	0.8	0.8
Average or varying rainfall, no continuous downpour	1	1	1	1	1
Continuous downpour	1.5	1.5	1.6	1.7	1.8

As part of this method, the special tropical rainfall was divided into the following four classes:

- **Negligible falls:** All rainfalls under 12 mm a day unless continuous for several days; also rainfalls 12 to 40 mm a day, when there is no rain.
- **Light falls:** All rainfalls up to 25 mm a day followed by similar or heavier falls. Steady pours of 25 to 40 mm a day, when there is no rain of a similar or greater amount before or after that.
- **Medium falls:** Rainfalls from 25 to 40 mm a day when preceded or followed by any but light falls.
- **Heavy Falls:**
    - All rainfalls over 75 mm a day or continuous falls at 50 mm a day.
    - All rainfalls of an intensity of 50 mm or more per hour.

The run-off percentages, as shown in the following table, were developed by combining the type of catchment and the nature of the season.

BARLOW'S RUN-OFF PERCENTAGES

Nature of Rainfall	Percentage of Flow in Catchments of Different Types				
	A	B	C	D	E
Negligible falls	-	-	-	-	-
Light falls	1	3	5	10	15
Medium falls	10	15	20	25	33
Heavy falls	20	33	40	55	70

ESTIMATION OF DIRECT RUN-OFF FROM RAINFALL

In this run-off estimation method, the effects of surface conditions within a watershed are evaluated using land-use and treatment classes. Land use is the watershed cover, including all vegetation, litter and mulch, fallow areas, and non-agricultural uses such as water surfaces (lakes, swamps, etc.) and impervious surfaces (roads, roofs, etc.). Land treatment applies mainly to agricultural land uses and includes mechanical practices, such as contouring or terracing, and management practices, such as grazing control or crop rotation. The classes consist of combinations of use and treatment found in watersheds. Land use and treatment classes are readily obtained either by observation or by measuring plant and litter density and extent in sample areas.

HYDROLOGICAL SOIL GROUPS

There are four soil groups used to determine the hydrological soil cover complexes, which are part of a method for estimating rainfall run-off. Major characteristics of these groups are described below. The respective infiltration rates and soil permeabilities for the different groups are also shown below. Infiltration rate is the rate at which water enters the soil at the surface, and is controlled by surface conditions. Permeability rate is the rate at which water moves in the soil, which is controlled by the nature and characteristics of soil horizons.

Hydrologic soil (HSG)	Soil textures	Run-off potential	Water transmission
Group A	Soils having high infiltration rates, even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.	Low	High rate
Group B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well-drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.	Moderate	Moderate rate
Group C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.	Moderate	Moderate rate
Group D	Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high-water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious material.	High	Low rate

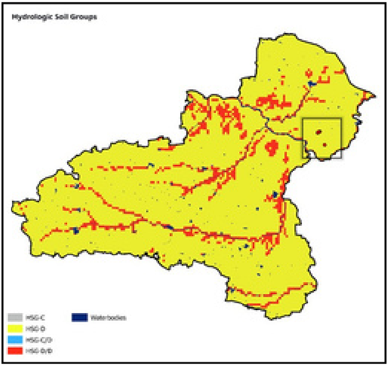


Figure 9: Hydrologic Soil Groups of the Project Watersheds – Shirpur

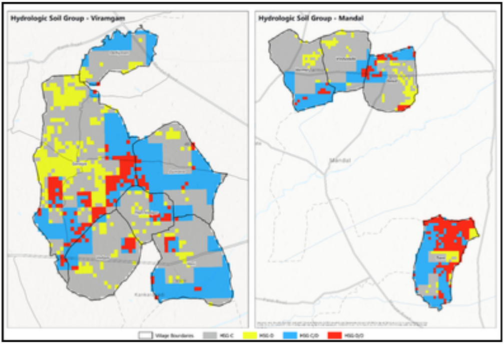


Figure 10: Hydrologic Soil Groups of the Project Villages – Viramgam & Mandal

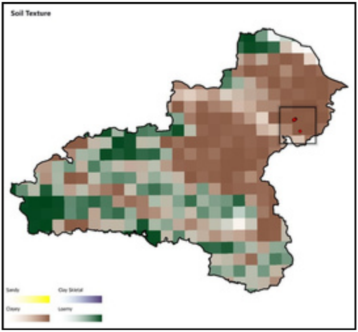


Figure 11: Soil Characteristics in the Project Watersheds

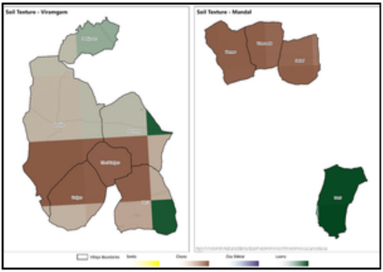


Figure 12: Soil Characteristics in the Project Villages

INFILTRATION RATES

Class	Rates/hr in		Remarks
	Inches	Millimetres	
Very Low	Below 0.1	Below 2.5	Highly clayey soils
Low	0.1 - 0.5	2.5 - 12.5	Shallow soils, clay soils, and soils low in organic matter
Medium	0.5 - 1.0	12.5 - 25.0	Sandy loams, silt loams
High	Above 1.0	Above 25.0	Deep sands, well-aggregated soils

RELATIVE CLASSES OF SOIL PERMEABILITY

Class	Permeability	
	Inches/ hr	mm/ hr
Slow		
Very Slow	Less than 0.05	1.3
Slow	0.05 to 0.20	1.31 to 5.00
Moderate		
Moderately Slow	0.20 to 0.30	5.01 to 20.00
Moderate	0.80 to 2.50	20.01 to 50.00
Moderately Rapid	2.50 to 5.00	50.01 to 130.00
Rapid		
Rapid	5.00 to 10.00	130.01 to 250.00
Very Rapid	Over 10.00	Over 250.00

LAND USE AND TREATMENT CLASSES

Common landuseand treatmentclassesarebrieflydescribedbelow. These classes are used to determine hydrologic soil-coverage complexes, which are part of a method for estimating rainfall run-off.

- **Cultivated lands:** These include all field crops such as maize, sugarcane, paddy and wheat.
- **Fallow lands:** These are lands taken up for cultivation, but are temporarily out of cultivation for a period of not less than one year, and not more than 5 years. Current fallow lands are cropped areas left fallow this year.
- **Uncultivated lands include:**
    - Permanent pastures and other grazing lands.
    - Cultivable waste, which is land available for cultivation, whether or not taken up for cultivation or abandoned after a few years for one reason or another. Land once cultivated but uncultivated for 5 years in succession shall also be included in this category.

  Forest area includes all lands classed as forest under any legal enactment dealing with forest or administered as forest, whether State-owned or private, and whether wooded or maintained as potential forest land.
- Tree crops include woody perennial plants that reach a mature height of at least 8 feet and have well-defined stems and a definite crown shape.
- Lands put to non-agricultural uses are areas occupied by buildings, roads, railroads, etc.
- Barren and uncultivable lands include areas covered by mountains, deserts, and other inhospitable terrain.

Based on these assessments, the following were estimated:

SURFACE STORAGE

The volume of surface storage created by the intervention = 1,14,970 m 3 (92,110 m 3 in Godi + 22,860 m 3 in Manjrod)

The volume of surface storage created by the intervention = 84,119.77 m3 (77,486.2 m3 in Viramgam and 6633.58 m3 in Mandal)

Total volume of surface storage created = 1,99,089.77 m3

RAINFALL & RUNOFF

- Total rainfall received over the intervention period and since in Shirpur = 8,66,62,573.71 m^3
- Total rainfall received over the intervention period and since in Viramgam & Mandal = 3,11,38,476.14 m^3 (2,02,24,842.43 m^3 in Viramgam and 1,09,13,633.7 m^3 in Mandal)

Total rainfall received over the intervention period and since = 11,78,01,049.85 m^3

RUNOFF REDUCTION

- Total run-off generated over the intervention area in Shirpur = 32,71,016.42 m^3
- Total runoff generated over the intervention area = 8,82,637.33 m3 (7,52,517.85 m3 in Viramgam and 1,30,119.48 m3 in Mandal)

Total runoff generated over the intervention area = 41,53,653.75 m3

Percentage of rainfall that is converted to run-off in Shirpur = 3.77%

Percentage of rainfall that is converted to runoff in Viramgam & Mandal = 2.46 % (3.72% in Viramgam & 1.19% in Mandal

The intervention area received enough rainfall for all the CRBs to be filled to capacity 3.33 times in Shirpur, 2.09 times in Viramgam, and 2.19 times in Mandal on average throughout the period and since as a part of and due to the project interventions.

RUN-OFF REDUCTION - SHIRPUR

Volume of surface run-off stored by the intervention measures after considering 40.0% evaporation loss = 3,69,449.80 m^3 (2,88,824.52 m^3 in Godi and 80,625.28 m^3 in Manjrod)

Which is,

- 17.65% of the total runoff generated as a part of and due to the water conservation efforts of this project (or)
- 0.53 % of the total rainfall received during the project period and ever since

This means that the interventions that were created as a part of this project has contributed to a combined reduction in surface runoff by about 17.65% in the intervention area. Although this number is a conservative estimation and however, is bound to increase over the years. Care must be taken to ensure the effective functioning of these water harvesting structures. Regular desilting and clearing of overgrowth along with any structural repairs are required across all the structures to ensure that their storage capacity is maintained and the structural integrity is preserved.

Thus, in total, 7.79% of the rainfall is converted into direct recharge, about 0.53% of the rainfall is stored in the intervention created surface storage, 40% is lost as evaporation, and the remaining runoff volume accounts for factors such as runoff that is stored in other water bodies present, runoff that is not captured, evapotranspiration, and other losses.

RUN-OFF REDUCTION – VIRAMGAM & MANDAL

Volume of surface runoff stored by the intervention measures after considering evaporation loss of 0.00448m/day = 1,76,580.47 m3 (1,62,024.71 m3 in Viramgam and 14,555.76 m3 in Mandal)

Which is,

16.36% (21.53% in Viramgam & 11.19% in Mandal) of the total runoff generated which is conserved as a part of and due to the water conservation efforts of this project (or)

0.47% (0.8% in Viramgam & 0.13% in Mandal) of the total rainfall received during the project period and ever since

This means that the interventions that were created as a part of this project has contributed to a combined reduction in surface runoff by about 16.36% in the intervention area. Although this number is a conservative estimation and however, is bound to increase over the years. Care must be taken to ensure the effective functioning of these water harvesting structures. Regular desilting and clearing of overgrowth along with any structural repairs are required across all the structures to ensure that their storage capacity is maintained and the structural integrity is preserved.

Thus, in total, 46.68% of the rainfall in Viramgam and 26.82% of the rainfall in Mandal is converted into direct recharge, about 0.8% of the rainfall in Viramgam and 0.13% of rainfall in Mandal is stored in the intervention created surface storage, 3.72% is recharged due to the interventions directly in Viramgam and 0.12% in Mandal, and the remaining runoff volume accounts for factors such as runoff that is stored in other water bodies present, runoff that is not captured, evaporation and evapotranspiration, and other losses.

SEASONAL CROPPING PATTERNS & CROPPING INTENSITY

The analysis of the cropping pattern could be considered in terms of increased cropping intensity and maintaining the same area under cultivation despite reduced rainfall. In terms of cropping intensity, an increase in the cropped area in the post-implementation period relative to the pre-implementation period may indicate the availability of additional groundwater resources, either from increased well yields or from the sustainability of wells during dry months. The increase in cropping intensity can be taken as a positive impact. In terms of maintaining the same area under cultivation, in the post-implementation period, the area may receive less rainfall than the pre-implementation period or may be reeling under drought. In such cases, if the cropped area/cropping intensity remains unchanged despite lower rainfall, it again indicates a positive impact.

In the current intervention areas, given the implementation period and the time lag between implementation and impact assessment, the main focus will be on seasonal changes in cropping patterns and changes in cropping intensity.

Assessing this is based on the analysis of vegetation indices, primarily NDVI. Vegetation Indices are combinations of surface reflectance at two or more wavelengths designed to highlight a particular property of vegetation. They are derived using the reflectance properties of vegetation. For this assessment, the Normalised Difference Vegetation Index (NDVI) is used. NDVI is an indicator of vegetation greenness, density, and health at each pixel in a satellite image. The index detects and quantifies the presence of living green vegetation using this reflected light in the visible and near-infrared bands.

The standard formula for calculating NDVI is:
NDVI = (NIR – red) / (NIR + red)

Using the near-infrared band 8 and red band 4 of Sentinel-2 imagery, composite Images for 2022 and 2024/2025 were developed in Google Earth Engine, and the resulting images were used for this assessment to understand changes between the pre-intervention and post-intervention states.

The NDVI value ranges from -1 to 1 and shows the vigour of the crop:

- Values close to 1: the more intense the green, the more vigorous the vegetation and vegetation cover. Considerations for the type of farming, bare soil, etc., must be made. The index also measures the vigour of the underbrush.
- Values close to 0: areas with very little vegetation, early stages of cultivation, bare soil, or non-productive areas.
- Negative values: usually associated with areas of water, snow, or clouds.

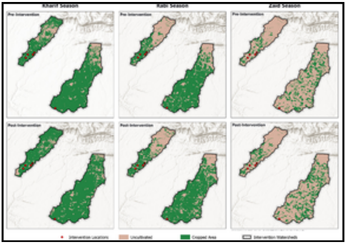


Figure 13: Pre-Intervention & Post-Intervention Seasonal Cropping Patterns

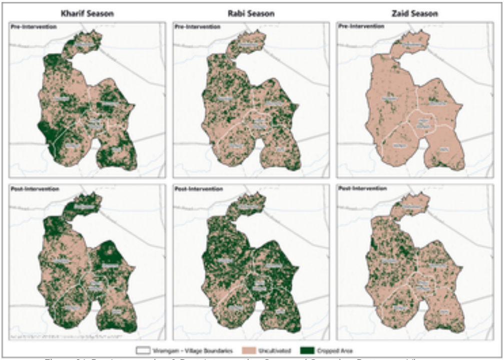


Figure 14: Pre-Intervention & Post-Intervention Seasonal Cropping Patterns – Viramgam

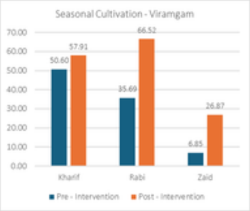
Figure 15: Pre-Intervention & Post-Intervention Seasonal Cropping Patterns – Mandal

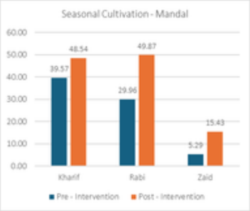
ZONAL STATISTICS VALUES OF THE SEASONAL CROPPING PATTERNS - SHIRPUR

Pre/Post	Location	Kharif – Sq. Km	Rabi - Sq. Km	Zaid - Sq. Km
Pre - Intervention		15.38	12.35	4.71
Post - Intervention	Shirpur	16.49	12.62	5.48
% Change		+7.24	+2.16	+16.52

ZONAL STATISTICS VALUES OF THE SEASONAL CROPPING PATTERNS – VIRAMGAM & MANDAL

Pre/Post	Location	Kharif – Sq. Km	Rabi - Sq. Km	Zaid - Sq. Km
Pre - Intervention	Viramgam	50.602313	35.686199	6.852052
	Mandal	39.568946	29.957797	5.292255
	Total	**90.171259**	**65.643996**	**65.643996**
Post - Intervention	Viramgam	57.912463	66.516219	26.874116
	Mandal	48.535204	49.868007	15.430661
	Total	**106.447667**	**116.384226**	**42.304777**
% Change	Viramgam	14.4462764	86.39199709	292.2053715
	Mandal	22.65983532	66.46086159	191.5706254
	Total	**18.05054979**	**77.29607137**	**248.3506881**





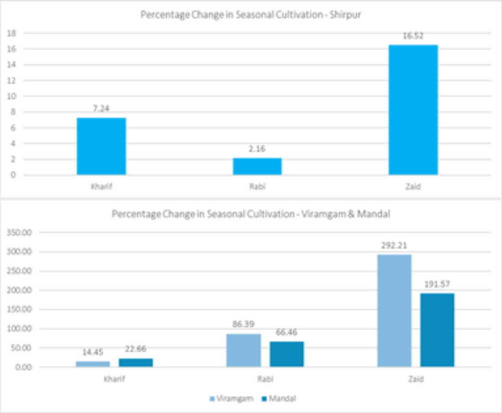


Figure 16: Pre and Post Intervention Seasonal Cropping Pattern Change across the Intervention Watersheds

The analysis, change detection and calculation of the vegetation index reveal substantial shifts in the seasonal cropping pattern in the intervention watersheds. The data indicate a substantial overall expansion in the area under cultivation across all three cropping seasons, suggesting enhanced water security through increased groundwater availability.

In Shirpur, the Kharif season shows an increase from 15.38 to 16.49 sq. km (7.24%), which, although moderate, indicates improved early-season soil moisture and better recharge conditions at the onset of the monsoon. More notably, the Rabi season—highly dependent on stored soil moisture and groundwater— increases from 12.35 to 12.62 sq. km (2.16%), reflecting improved groundwater retention and availability during the dry months. The most significant change is observed in the Zaid season, which increases from 4.71 to 5.48 sq. km (16.52%), highlighting a substantial expansion in summer cropping. This sharp rise strongly indicates that the post-monsoon groundwater levels remained sufficiently high to support irrigation beyond the traditional cropping cycle.

In Viramgam & Mandal, at an aggregate level, the total cultivated area increased from 90.17 to 106.45 sq. km in Kharif (18.05%), from 65.64 to 116.38 sq. km in Rabi (77.30%), and from 12.14 to 42.30 sq. km in Zaid (248.35%). While the Kharif increase is moderate—reflecting improved soil moisture conditions at the onset of the monsoon—the significantly higher growth in the Rabi and, especially, the Zaid seasons highlights a marked improvement in groundwater storage and availability during the post-monsoon and dry periods.

At the location level, Viramgam shows a 14.45% increase in Kharif area, but a much sharper rise in Rabi (86.39%) and Zaid (292.21%), indicating a strong enhancement in irrigation potential beyond the monsoon season. Similarly, Mandal records an increase of 22.66% in Kharif, 66.46% in Rabi, and 191.57% in Zaid, further supporting the trend of improved dry-season water availability. The disproportionately large increase in Zaid cropping in both locations is particularly significant, as this season is entirely dependent on assured irrigation and is highly sensitive to groundwater availability.

These changes align well with the projected rise in groundwater levels in the Shirpur region, where enhanced recharge from cement nala bunds has improved aquifer storage and prolonged water availability. In basaltic terrains like Shirpur, where groundwater storage is typically limited and rapidly depleted, such structures play a crucial role in increasing infiltration and sustaining water levels. Further, these patterns also strongly suggest that the recharge shafts in Viramgam & Mandal have enhanced aquifer replenishment by facilitating rapid infiltration of surface water into deeper aquifers, thereby increasing groundwater storage and extending its availability into the Rabi and Zaid seasons. In semi-arid regions like Viramgam and Mandal, where groundwater depletion and rainfall variability are critical constraints, such interventions improve water retention and reduce seasonal water stress. Overall, the shift toward intensified and multi- season agriculture, and the expansion of water-intensive or summer crops (Zaid), indicate that the interventions have played a key role in stabilising and augmenting water availability, thereby enabling increased cropping intensity and agricultural productivity, as can be noted by improved access to groundwater during the most water-scarce period of the year.

CROPPING INTENSITY

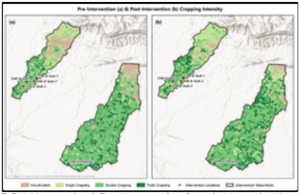


Figure 17: Pre-Intervention & Post-Intervention Cropping Intensity Map - Shirpur

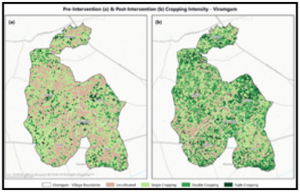


Figure 18: Pre-Intervention & Post-Intervention Cropping Intensity Map - Viramgam

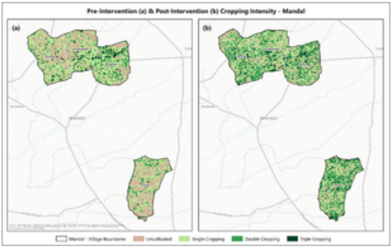


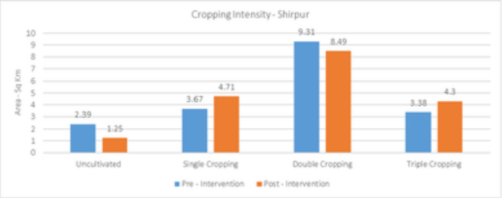
Figure 19: Pre-Intervention & Post-Intervention Cropping Intensity Map - Mandal

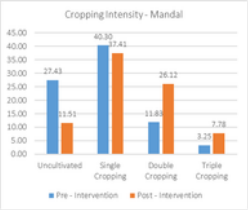
ZONAL STATISTICS VALUES OF THE CROPPING INTENSITY

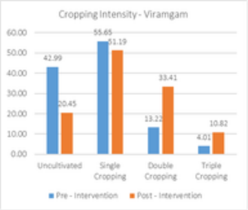
Pre/Post	Location	Uncultivated – Sq. Km.	Uncultivated – Sq. Km.	Double Cropping – Sq. Km.	Triple Cropping – Sq. Km.
Pre - Intervention	Shirpur	2.39	3.67	9.31	3.38
Post - Intervention		1.25	4.71	8.49	4.3
% Change		-47.66	28.4	-8.79	27.15

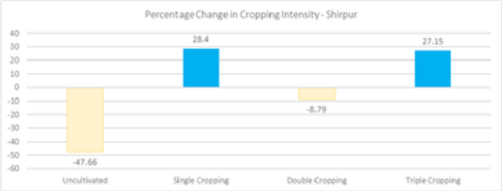
ZONAL STATISTICS VALUES OF THE CROPPING INTENSITY

Pre/Post	Location	Uncultivated – Sq. Km.	Single Cropping – Sq. Km.	Double Cropping – Sq. Km.	Triple Cropping – Sq. Km.
Pre - Intervention	Viramgam	42.993023	55.651035	13.215617	4.007648
	Mandal	27.434646	40.302409	11.833433	3.245261
	Total	**70.427669**	**95.953444**	**25.04905**	**7.252909**
Post - Intervention	Viramgam	20.445389	51.186529	33.414468	10.820937
	Mandal	11.512255	37.407546	26.118052	26.118052
	Total	**31.957644**	**88.594075**	**59.53252**	**18.598833**
% Change	Viramgam	-52.44	-8.02	152.84	170.01
	Mandal	-58.04	-7.18	120.71	139.67
	Total	**-54.62**	**-7.67**	**137.66**	**156.43**


Cropping Intensity - Shirpur
Area - Sq Km
2.39
1.25
3.67
4.71
9.31
8.49
3.38
4.3
Uncultivated
Single Cropping
Double Cropping
Triple Cropping
Pre - Intervention
Post - Intervention


Cropping Intensity - Mandal
27.43
11.51
40.30
37.41
11.83
26.12
3.25
7.78
Uncultivated
Single Cropping
Double Cropping
Triple Cropping
Pre - Intervention
Post - Intervention


Cropping Intensity - Viramgam
42.99
20.45
55.65
51.19
13.22
33.41
4.01
10.82
Uncultivated
Single Cropping
Double Cropping
Triple Cropping
Pre - Intervention
Post - Intervention


Percentage Change in Cropping Intensity - Shirpur
-47.66
28.4
-8.79
27.15
Uncultivated
Single Cropping
Double Cropping
Triple Cropping

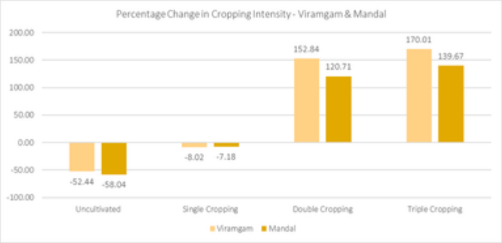


Figure 20: Pre and Post Intervention Cropping Intensity Change across the Intervention Watersheds

The cropping intensity shows clear evidence of improvement in agricultural activity, which can be strongly linked to improved groundwater availability. In Shirpur, a significant reduction in uncultivated land—from 2.39 sq. km to 1.25 sq. km (−47.66%)—indicates that previously fallow or water-scarce areas have been brought under cultivation, reflecting improved water availability and recharge. In Viramgam & Mandal, at an aggregate level, uncultivated land decreased significantly from 70.43 to 31.96 sq. km (−54.62%), indicating that a large proportion of previously fallow or water-scarce land has been brought under cultivation. This reflects enhanced water security and improved access to irrigation, particularly during post-monsoon and extended dry periods, consistent with the observed expansion of cropped area across all seasons, particularly the sharp increases in Rabi and Zaid cultivation.

The increase in single-cropping area in Shirpur (by 28.4%) suggests that more land is now at least seasonally viable for cultivation, likely due to improved soil moisture conditions during the Kharif season, as also indicated by the moderate increase in Kharif-cropped area. More importantly, the rise in triple cropping (from 3.38 to 4.3 sq. km, +27.15%) highlights a substantial improvement in year-round water availability, enabling farmers to cultivate across all three seasons—Kharif, Rabi, and Zaid. This trend strongly correlates with the earlier observation of a significant increase in Zaid cropping (16.52%), which is highly dependent on sustained groundwater availability during the summer months.

A notable transition is observed from low- to high-intensity cropping systems in Viramgam & Mandal. Single-cropped area decreased slightly from 95.95 to 88.59 sq. km (−7.67%), while double cropping increased dramatically from 25.05 to 59.53 sq. km (+137.66%) and triple cropping from 7.25 to 18.60 sq. km (+156.43%).

This indicates that land previously under single cropping has shifted toward multiple cropping cycles, supported by improved year-round water availability. At the individual level, Viramgam recorded a 152.84% increase in double cropping and a 170.01% increase in triple cropping, while Mandal showed corresponding increases of 120.71% and 139.67%. These changes align closely with the earlier seasonal analysis, which showed substantial increases in Rabi and, especially, Zaid cropping—both of which are highly dependent on sustained groundwater availability beyond the monsoon period.

The decline in double cropping (–8.79%) in Shirpur and in single cropping (- 7.76%) in Viramgam & Mandal suggests a transition rather than a reduction in agricultural intensity, with some areas previously under double cropping shifting toward triple cropping due to improved irrigation reliability. This shift indicates a qualitative enhancement in cropping intensity rather than a decline. Overall, the data reflect a clear movement toward higher cropping intensity and better land utilisation, driven by improved groundwater recharge from cement nala bunds and recharge shafts. In the basaltic aquifer setting of Shirpur, and the semi-arid climate of Viramgam & Mandal, where water availability typically limits multi-season agriculture, such changes demonstrate the effectiveness of recharge interventions in stabilising and extending groundwater availability, thereby supporting more intensive and diversified agricultural practices.

CARBON STOCK

Carbon stockestimation isthe process of measuring the amount of carbon stored in a given area. This is being done because measures to conserve water and improve soil moisture can increase carbon storage, thereby reducing carbon emissions.

In the case of this assessment, the carbon stock estimation is done by considering the above- and below-ground terrestrial carbon storage in tonnes (t) of carbon per hectare (ha). The biomass and vegetation cover present over the period from 2023 to 2024 were estimated to establish a pre-intervention baseline.

The assessment is based on the above and below-ground biomass carbon density data from the UN Environment Programme - World Conservation Monitoring Centre. The dataset was available only for 2010; thus, for this assessment, a linear regression analysis was performed using the above dataset as the base data and NDVI and land cover under trees for the assessment year as predictors. The assessment provided an RMSE[2] of 3.6134 for Shirpur and 0.11 for Viramgam & Mandal, which is quite low; thus, the model derived for 2025-2026 is quite accurate.

The carbon stock estimates for the intervention watersheds in Shirpur are about 733.19 tonnes of carbon over an area of 33.04 hectares, which works out to 22.18 tonnes of carbon per hectare for the year 2023-24 and 1406.33 tonnes of carbon over an area of 61.91 hectares, which works out to 22.71 tonnes of carbon per hectare for the year 2025-26 (91.81% increase in tonnes of carbon and 87.36% increase in area containing the carbon stock). In the case of Viramgam & Mandal, the carbon stock estimates are about 1667.61 tonnes of carbon (1285.95 in Viramgam and 381.66 in Mandal) over an area of 82 hectares (63.14 Ha in Viramgam and 18.86 Ha in Mandal), which works out to 20.34 tonnes of carbon per hectare (20.37 in Viramgam and 20.23 in Mandal) for the year 2023-24 and 2140.19 tonnes of carbon (1529.36 in Viramgam and 610.83 in Mandal) over an area of 107.48 hectares (76.4 in Viramgam and 31.8 in Mandal), which works out to 19.91 tonnes of carbon per hectare (20.02 in Viramgam and 19.65 in Mandal) for the year 2025- 26 (28.34% increase in tonnes of carbon and 31.07% increase in area containing the carbon stock).

[2] Linear regression model: Base data - WCMC Above and Below Ground Biomass Carbon Density; predictors - NDVI, Trees from the dynamic world

The data above show the intensification of permanent vegetation in the intervention area. As shown in the maps below, carbon stock is present in areas with year-round vegetation and varies by vegetation type. Increasing the area under permanent vegetation is one way to increase the carbon stock in the area.

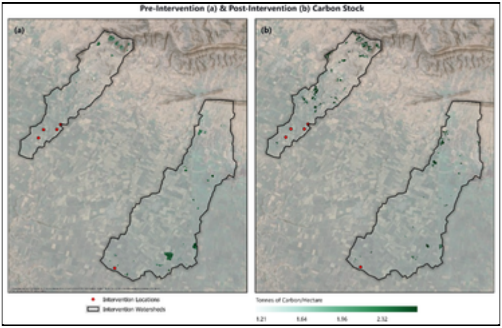


Figure 21: Carbon Stock - Shirpur

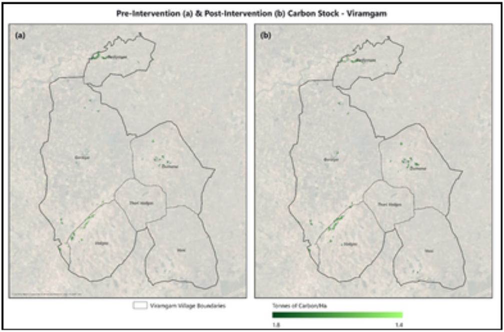


Figure 22: Carbon Stock - Viramgam

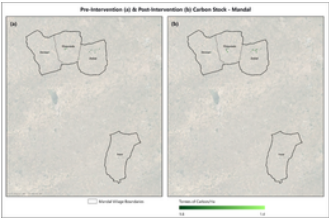


Figure 23: Carbon Stock – Mandal

SOIL SALINITY – VIRAMGAM & MANDAL

Soil salinity is estimated by measuring the soil electrical conductivity (EC), which is the ability of soil water to carry an electrical current. Electrical conductivity is an electrolytic process that occurs primarily through water-filled pores. Cations (Ca2+, Mg2+, K+, Na+, and NH4+) and anions (SO42-, Cl-, NO3-, and HCO3-) from salts dissolved in soil water carry electrical charges and conduct the electrical current. Consequently, ion concentration determines the EC of soils. In agriculture, EC has been used primarily as a measure of soil salinity (Table 1); however, in non-saline soils, EC can be used as an estimate of other soil properties, such as soil moisture and depth. EC is expressed in deciSiemens per metre (dS/m).

Factors influencing the electrical conductivity of soils include:

- The amount and type of soluble salts in solution, porosity, soil texture (especially clay content and mineralogy), soil moisture, and soil temperature.
- High levels of precipitation can flush soluble salts out of the soil and reduce EC.
- Conversely, in arid soils (with low levels of precipitation), soluble salts are more likely to accumulate in soil profiles, resulting in high EC.
- In general, EC increases as clay content increases.
- In soils where the water table is high and saline, water will rise by capillarity and increase salt concentration and EC in the soil surface layers. It is generally accepted that the higher the porosity (i.e., the higher the soil moisture content), the greater the soil's ability to conduct electrical current; that is, other properties being similar, the wetter the soil, the higher the EC.
- Soil parent materials contribute to EC variability. Granites have lower EC than marine shales, and clayey lacustrine deposits have higher EC than sandy outwash or alluvial deposits.
- Microtopographic depressions in agricultural fields typically are wetter and accumulate organic matter and nutrients, and therefore have higher EC than surrounding higher-lying, better-drained areas.

High EC can indicate salinity (EC > 4 dS/m) problems that impede crop growth (inability to absorb water even when present) and microbial activity. Soils with high EC, resulting from high sodium concentrations, generally have poor structure and drainage, and sodium becomes toxic to plants.

The assessment area, despite being a very flat location prone to waterlogging in the fields, with coastal alluvial geology and high clay content, contributes to elevated EC values. However, with the top 90cm of the soil being clayey and with high alluvium present, the EC values can be expected to be lower than if it were of a different origin. The samples were collected from the field and analysed by preparing a saturated paste extract at a 1:5 soil-water ratio. The details of the samples collected and the EC values measured are given below. The measured EC values were compared with baseline values measured by the implementing partner before the intervention to identify changes attributable to the intervention.

OBSERVED EC VALUES AND PERCENTAGE CHANGE POST-INTERVENTION

Location	Sample ID	Lat	Long	Sample Depth	EC (dS/m)	Baseline EC (dS/m)	% Change
Viramgam	Soil Sample 1	23.112135	71.945863	30 cm	0.11	0.91	-87.91%
	Soil Sample 2	23.085175	72.001809	30 cm	0.06	0.4	-85.00%
	Soil Sample 3	23.073341	71.925879	30 cm	0.04	0.28	-85.71%
	Soil Sample 3a	23.07647	71.922243	200 cm	2.08	-	-
	Soil Sample 4	23.07647	71.922243	30 cm	0.04	0.31	-87.10%
	Soil Sample 5	23.090194	71.980425	30 cm	0.27	0.35	-22.86%
	Soil Sample 6	23.138097	71.980452	30 cm	0.01	0.22	-95.45%
	Soil Sample 7	23.108664	71.968291	30 cm	0.09	0.345	-73.91%
	Soil Sample 8	23.098857	71.964272	30 cm	0.19	0.35	-45.71%
	Soil Sample M1	23.359094	71.945918	30 cm	0.06	3.4	-98.24%
Mandal	Soil Sample M2	23.366373	71.934935	30 cm	0.08	0.95	-91.58%
	Soil Sample M3	23.366212	71.915739	30 cm	0.1	0.26	-61.54%
	Soil Sample M3a						
	Soil Sample M4	23.367174	71.915029	400 cm	0.34	-	-
		23.352199	71.937894	30 cm	0.07	0.28	-75.00%

The soil electrical conductivity (EC) data from Viramgam and Mandal indicate a substantial reduction in soil salinity levels following the implementation of groundwater recharge shafts during 2024–25. Across the sampled locations at 30 cm depth, EC values show a consistent and significant decline when compared to baseline conditions. In Viramgam, EC reductions range from −22.86% to −95.45%, with most samples exhibiting reductions greater than 70.0%, indicating effective leaching of salts from the root zone. Similarly, in Mandal, the reductions are even more pronounced, ranging from −61.54% to −98.24%, suggesting a great improvement in soil quality. The presence of higher EC values at deeper layers (e.g., 2.08 dS/m at 200 cm in Viramgam and 0.34 dS/m at 400 cm in Mandal) further supports the interpretation that salts have been mobilised downward from the surface layers.

These improvements can be directly linked to the construction of farm-level groundwater recharge shafts, which play a dual role in such semi-arid, poorly drained regions. Firstly, during monsoon periods, when waterlogging is common, these shafts act as vertical drainage structures, allowing excess surface water to percolate into deeper aquifer zones rapidly. This reduces surface ponding and prevents prolonged saturation of agricultural fields, thereby mitigating waterlogging stress on crops. Secondly, enhanced percolation facilitates the downward movement (leaching) of soluble salts from the topsoil into deeper layers, thereby reducing soil salinity in the active root zone. This is particularly important in areas like Viramgam and Mandal, where evapotranspiration-driven salt accumulation is a persistent problem.

The observed reduction in surface EC, coupled with increased cropping intensity and expansion of Rabi and Zaid cultivation, suggests that recharge shafts have improved both soil health and water availability. By simultaneously addressing waterlogging and salinity—two interlinked constraints—the intervention has enhanced the overall productivity and sustainability of agricultural systems in the region.

CONCLUSIONS

This section summarises the assessment's key findings and the limitations encountered during the process. For more accurate quantification, further studies will need to be conducted using higher-detail datasets and corroboration from the field.

KEY FINDINGS

Insummation, thekey findings from the above assessments are as follows:

- Total surface storage created in the intervention area due to the project is 1,99,161.85 m3 (Shirpur - 1,14,970 m3 = 92,110 m3 in Godi + 22,860 m3 in Manjrod; 77,486.2 m3 in Viramgam and 6,633.58 m3 in Mandal)
- The influence of rainfall on the groundwater levels has been significant and is observable after a 90- day delay in Shirpur and a 60 to 90-day delay in Viramgam & Mandal.
- The groundwater levels in the intervention watersheds of Shirpur have been stable since 2020 and are presently at higher values and are expected to remain high in the coming years. Whereas groundwater levels in Viramgam have been rising since 2020, they have been declining in Mandal and are presently at higher values, and are expected to remain high in the coming years. The availability of more recent data will shed further light on the expected trends.
- Groundwater recharge directly due to rainfall in the intervention area is about 8.6% of the total rainfall received in the intervention period in Shirpur, and 36.75% of the total rainfall received in the intervention period in Viramgam & Mandal (46.68% in Viramgam and 26.82% in Mandal).
- The volume of surface runoff stored by the intervention measures is 17.65% (31.9% in Godi and 3.41% in Manjrod) of the total runoff generated in the intervention watershed (or) 0.53% (0.92% in Godi and 0.15% in Manjrod) of the total rainfall received during the period of the project intervention and ever since.
- The contribution of intervention stored water to ground water recharge is 2,40,142.37 m^3 (1,87,735.94 m3 in Godi & 52,406.43 m^3 in Manjrod)
- Volume of surface runoff stored by the intervention measures is 16.36% (21.53% in Viramgam & 11.19% in Mandal) of the total runoff generated in the intervention villages (or) 0.47% (0.8% in Viramgam & 0.13% in Mandal) of the total rainfall received during the project period and ever since.
- Analysis of Seasonal Cropping Patterns and Cropping Intensity reveals that there has been a significant change in area under cultivation, with a notable increase in the Zaid crops and area under single and triple cropping. A measurable expansion in cultivated area is observed in Shirpur, with Kharif increasing from 15.38 to 16.49 sq. km (7.24%), Rabi from 12.35 to 12.62 sq. km (2.16%), and Zaid from 4.71 to 5.48 sq. km (16.52%). Viramgam shows a 14.45% increase in Kharif area, but a much sharper rise in Rabi (86.39%) and Zaid (292.21%), indicating a strong enhancement in irrigation potential beyond the monsoon season. Similarly, Mandal records an increase of 22.66% in Kharif, 66.46% in Rabi, and 191.57% in Zaid. The higher growth in Zaid cropping, which is highly dependent on assured irrigation, suggests improved groundwater availability during the post-monsoon and summer periods, likely due to the interventions.
- Cropping intensity metrics further corroborate this trend, with uncultivated land decreasing significantly from 2.39 to 1.25 sq. km (−47.66%) in Shirpur, alongside increases in single cropping (3.67 to 4.71 sq. km; +28.4%) and triple cropping (3.38 to 4.3 sq. km; +27.15%). The marginal decline in double cropping (9.31 to 8.49 sq. km; −8.79%) indicates a transition toward higher-intensity land use, with areas previously under double cropping shifting to triple cropping.
- Cropping intensity metrics for Viramgam & Mandal show the uncultivated land decreasing significantly from 70.43 to 31.96 sq. km. (-54.32%) in Viramgam & Mandal. Further, single-cropped area decreased slightly (95.95 to 88.59 sq. km; −7.67%), while double cropping increased dramatically (25.05 to 59.53 sq. km; +137.66%) and triple cropping (7.25 to 18.60 sq. km; +156.43%). The marginal decline in single cropping indicates a transition toward higher-intensity land use, with areas previously under single cropping shifting to double cropping and beyond.
- The overall carbon stock present in the intervention area has shown a marked increase both in terms of the total carbon sequestered (+91.81% in Shirpur; +28.34% in Viramgam & Mandal) and the areas with carbon stock (+87.36% in Shirpur; +31.07% in Viramgam & Mandal).
- Significant reduction in soil salinity can also be observed in both Viramgam and Mandal, with reduction varying between 22.0% and 98.0%.

SUMMARY OF FINDINGS

Location		Shirpur			Viramgam & Mandal		
Intervention Type		Godi	Manjrod	Total	Viramgam	Mandal	Total
Total Area of Watershed (Sq. Km.)		5.584622	13.159432	18.744054	21.725042	12.485695	34.210737
Soil Group		D			C & D		
Volume of Storage Created (Cu. m.)		92110	22860	114970	77.486.20	6,633.58	84,119.77
Total rainfall over the intervention area (Cu. m.)		31487168.79	74195398.83	105682567.6	20224842.43	10913633.7	31138476.14
Q - Total run-off over intervention area (Cu. m.)		905529.9756	4396377.969	5301907.945	752517.85	130119.48	882637.33
Run-off volume stored in interventions	Pre-evaporation Loss	2,88,825.86	80,626.61	3,69,452.47	162024.71	14555.76	176580.47
	Post Evaporation Loss	2,88,824.52	80,625.28	3,69,449.80	41391.45146	8547.816263	49939.26772
% of run-off stored by interventions	Pre-evaporation Loss	31.90	3.41	17.65	21.53	11.19	16.36
	Post Evaporation Loss	31.90	3.41	17.65	21.53	11.19	16.36
% of rainfall stored by interventions	Pre-evaporation Loss	0.92	0.15	0.53	0.8	0.13	0.47
	Post Evaporation Loss	0.92	0.15	0.53	0.8	0.13	0.47
Surface water contribution to ground water recharge (40.0%) (Cu. m.)		1,87,735.94	52,406.43	2,40,142.37	752516.89	13075.97	765592.87
Recharge only due to the interventions (as a percentage of the total rainfall received over the intervention area)	%	0.60	0.09	0.28	3.72	0.12	2.46
Recharge only due to rainfall - 5-year average (2020-2025)	Cu. m.	419240.45	990137.3	1409377.76	1296847.91	745317.2012	2042165.11
(as a percentage of the total rainfall received over the intervention area)	%	8.64268963	8.64268963	8.64268963	46.68185313	26.82873434	36.75529373

Total run-off capacity expressed as multiples of intervention volume	Times	3.14	3.53	3.33	2.09	2.19	2.14

LIMITATIONS

Theassessmentissubject to several limitations, particularly due to the short time frame of the analysis, which was conducted only 1 year after the interventions were implemented. Such a limited post-intervention period makes it challenging to conclusively attribute observed changes in groundwater levels, cropping patterns, and vegetation dynamics solely to the recent construction of cement nala bunds, as hydrological responses in basaltic aquifer systems often manifest over longer time scales. Additionally, the presence of multiple similar water conservation and recharge interventions across the broader region—outside the scope of this specific assessment—can introduce cumulative effects that may influence groundwater levels and agricultural patterns, complicating the isolation of impacts attributable solely to the studied structures.

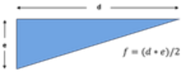
Further constraints arise from the limited availability of continuous, up-to-date groundwater data, particularly for recent years, which limits the ability to perform detailed temporal trend analysis and to validate short-term changes. Although statistical methods, such as interpolation and regression-based approaches, were employed to address data gaps wherever possible, these techniques have inherent limitations. They may not fully capture local variability, extreme events, or sudden changes in groundwater behaviour. Consequently, the reliability of derived trends is uncertain. These limitations highlight the need for long-term, continuous monitoring and more comprehensive datasets to accurately evaluate the effectiveness of such interventions and distinguish their impacts from broader regional hydrological influences.

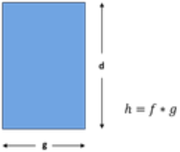
ANNEXURES
ANNEXURE 1 – INTERVENTIONS

Shirpur

Sr. No.	Name of Bandhara-24-25	Lat	Long
1	CRB @ Godi-1	21.289755	74.996509
2	CRB @ Godi-2	21.288158	74.995241
3	CRB @ Godi-3	21.285434	74.988959
4	CRB @ Godi-4	21.288135	74.99068
5	CRB @ Manjrod-1	21.243677	75.01499

Name	Max Elevation (m above msl)	Min Elevation (m above msl)	Backwater Distance (m)	Height of the Structure (m)	Area (sq. m.)	Width/ Length of the Structure (m)	Calc. Volume (cu.m.)	Calc. Volume (Tcm)	Given Total Volume (Tcm)	Given Utilisation Volume (Tcm)
a	b	c	d	e	f	g	h	i	j	k
CRB @ Godi-1	204	199	400	4	800	20	16000	16	25.05	14.84
CRB @ Godi-2	202	197	300	4	600	20	12000	12	22.92	13.52
CRB @ Godi-3	196	192	350	4	700	17	11900	11.9	22.22	12.56
CRB @ Godi-4	198	196	320	4	640	20	12800	12.8	21.92	11.86
CRB @ Manjrod-1	186	184	370	4	740	17.5	12950	12.95	22.86	12.86
Total							65650	65.65	114.97	65.64



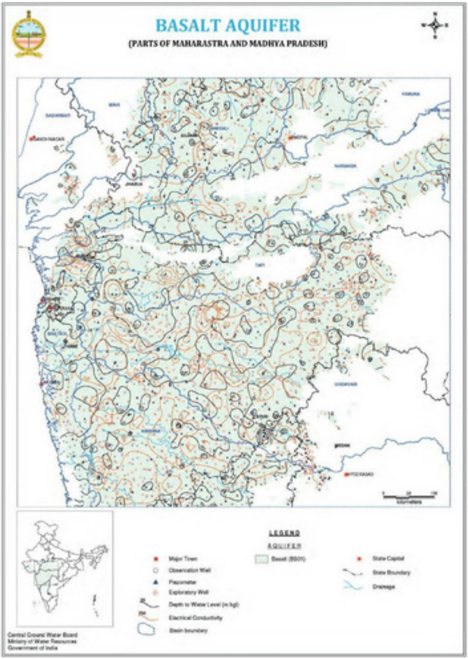


Measurement	Source
d = Backwater Distance (in m)	Remotely Sensed Measurement
e = Height of Structure (in m)	Field Observation & Design Documents
f = Area of Water Column (in sq. m.)	Calculated
g = Width/Length of Structure (in m)	Remotely Sensed Measurement, Field Observation & Design Documents
h = Volume of Water Stored (in cu. m.)	Calculated

Viramgam & Mandal

ANNEXURE 2 – AQUIFER CHARACTERISTICS

Aquifer Type/Geology - Shirpur



Aquifer Type/Geology – Viramgam & Mandal

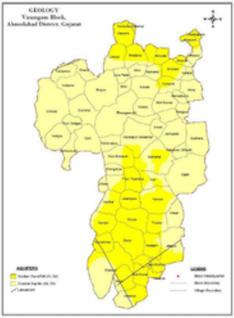


Fig.2: Major Aquifer

Fig.2: Major Aquifer

Specific Yield - Basalt

Table 19 : State wise Distribution and Characteristics of Basalt Aquifer System

STATE NAME	Major Aquifers (Area in sq km)		Aquifer Properties								
	Basic Basalt	Ultra Basic	Aquifer System	Type of Aquifer	Thickness of Weathered Zone	DTW (Decadal Avg)	Fractures Encountered	Transmissivity	Yield	Specific Yield	Quality (EC in Micromhos/cm)
	BS01	BS02			m	m bgl	m bgl	m²/day	m³/day	%	
Andhra Pradesh	9066	-	Single/Multiple	Unconfined to semiconfined	5 -20	10-20	40-80	6 - 740	90 - 180	1-1.5	1500-2000
Arunachal Pradesh	1397	-	Not Explored								
Bihar	34	-	Single	Unconfined	40	5-10	60-130	10-300	100-200	1-1.5	500-1000
Chhattisgarh	836	-	Single	Unconfined	10 - 20	5-10	upto 150	5 - 50	360 - 480	1-2	500-750
Goa	35	-	Single	Unconfined	60	5-10	70-120	10-200	100-200	2-3	3500-5000
Gujarat	74297	-	Single	Unconfined Semi-confined	20-40	5-10	100 - 280	20-250	1 - 30	1-2	1500-8000
Jammu & Kashmir	6173	-	Not Explored								
Jharkhand	3085	7	Single/Multiple	Unconfined Semi-confined	10-35	5-10	100 - 130	26 - 176	12 -240	2-3	500-750
Karnataka	34892	-	-	Unconfined	10-45	5-10	60-125	20-180	80-175	1-2	2000-3500
Madhya Pradesh	135433	-	Single/Multiple	Unconfined to semi confined	15 - 25	10-20	60 - 175	100 - 250	70 - 350	1.5-2	500-2000
Maharashtra	235903	-	Single/Multiple	Unconfined Semi-confined to Confined	15-30	5-10	20-200	20-200	45 - 90	2-3	500-2500
Rajasthan	9794	5	-	-	29-45	10-20	60-120	18-180	50-150	1-2	2500-3000
Uttar Pradesh	572	-	Single	Unconfined	5-30	10-20	30-150	-	-	-	500-1000
West Bengal	244	-	Single	-	10-25	5-10	35-90	-	-	-	500-750
Total Area	512290	12									

DTW : Depth to water level
m bgl: Meter below ground level

Specific Yield - Alluvium

Table 18 : State wise Distribution and Characteristics of Alluvium Aquifer System

STATE NAME	Major Aquifers (Area in sq. km)						Aquifer Properties								
	Younger Alluvium	Pebble/Gravel	Older Alluvium	Aeolian Alluvium	Coastal Alluvium	Valley Fills	Aquifer System	Type of Aquifer	Thickness	Zones Tapped	DTW (Decadal Avg)	Transmissivity	Yield	Specific Yield	Quality (EC in Micromhos /cm)
	AL01	AL02	AL03	AL04	AL05	AL06			m	m bgl	m bgl	m²/day	m³/day	%	
Andhra Pradesh	15204	-	-	-	6820	-	Multiple	Unconfined	50-80	60-80	2-5	300 to 2000	180 to 264	6 - 10	500-3000
Arunachal Pradesh	68	-	4423	-	-	-	Multiple	Semi-confined Confined	upto 200	50-80	2-5	467 to 3111	1488 to 2400	8 - 16	500-1000
Assam	52381	-	4678	-	-	-	Multiple	Semi-confined Confined	30-200	50 - 166	2-5	upto 9000	2160 to 4752	8 - 15	500-750
Bihar	73971	-	7833	-	-	-	Multiple	Semi-confined to Confined	50-650	50 - 248	5-10	3000-12000	200 to 1500	8 - 12	500-1000
Chhattisgarh	130	-	-	-	-	-	Multiple	Unconfined	Not explored						
Delhi	194	-	1056	68	-	-	Multiple	Semi Confined to confined	20-400	50-200	5-10	500-1200	800-2000	8 - 15	2000-3000
Goa	8	-	-	-	35	-	Single	Unconfined	2 - 10	-	-	2 to 2408	50 - 500	4 - 8	-
Gujarat	7036	-	25136	8948	19048	1309	Multiple	Semi-confined to Confined	10-475	50 - 435	10-20	200-800	200-2000	6 - 10	2000-3500
Haryana	2751	460	25851	12798	-	-	Multiple	Semi-confined to Confined	20-400	50-200	5-10	500-1200	800-2000	6 - 12	1000-4500
Himachal Pradesh	967	-	386	-	-	650	Multiple	Semi-confined to Confined	10 - 335	50 - 108	5-10	31 - 3606	104 - 5152	6 - 16	500-750
Jammu & Kashmir	21025	-	-	2816	-	-	Multiple	Semi-confined to Confined	40-160	50-120	5-10	100-600	200-1200	6 - 15	500-750
Jharkhand	2927	313	2286	-	-	-	Multiple	Semi-confined to confined	40- 130	50-70	5-10	20.8-570	12 - 960	6 - 10	500-1000
Karnataka	703	-	-	-	-	-	Multiple	Unconfined	20-60	30-60	5-10	2-48	50 -500	8	500-2000
Kerala	3145	-	-	-	-	-	Multiple	Unconfined	30-350	100-350	2-5	3 - 275	25.92 - 86.4	8 - 16	-
Madhya Pradesh	27714	-	13094	-	-	-	Multiple	Unconfined	40 - 300	70-250	5-10	500 - 6700	864 - 2592	8 - 12	500-1000
Maharashtra	12427	434	-	-	1236	-	Multiple	Semi-confined to confined	50 - 400	80-300	10-20	63 - 136	13 - 56	6 - 10	500-1500
Manipur	1897	-	-	-	2018	-	Multiple	Semi-confined to confined	50- 130	50-80	5-10	200-800	240 - 720	8 - 15	1500
Meghalaya	1032	-	-	-	-	-	Not Explored								
Nagaland	537	-	-	-	-	-	Multiple	Unconfined Semi-confined	40- 100	40 - 75	5-10	100 - 9000	864 - 3888	8 - 15	500-1500
Orissa	6775	-	24941	593	5426	-	Multiple	Semi-confined to confined	20-400	70 - 350	2-5	15 - 8000	75 - 6480	8 - 15	500-2000
Puducherry	310	-	-	-	112	-	-	-	-	-	2-5	-	-	8 - 14	1000-3000
Punjab	5592	460	33094	8967	-	305	Multiple	Semi-confined to Confined	20 - 600	70 - 450	10-20	100 - 7720	432 - 5184	8 - 15	500-2000
Rajasthan	3300	6	80114	114989	-	-	Multiple	Semi-confined to Confined	40-700	50-400	10-40	200-400	500-1200	8 - 10	-
Tamil Nadu	16915	78	-	56	5845	-	Multiple	Confined	40-400	70 - 350	2-5	50 - 5000	10 - 690	6 - 8	1000-3000
Tripura	602	-	-	-	-	-	Multiple	Semi-confined to Confined	10 - 15	-	-	-	240	-	500-1000
Uttarakhand	670	1247	6277	-	-	-	Multiple	-	30-200	50-100	5-10	30-3000	100-2000	8 - 15	500-750
Uttar Pradesh	37407	1960	172526	-	-	-	Multiple	Confined	100-650	100 - 650	5-10	upto 16000	1500 - 4000	8 - 18	500-3000
West Bengal	51464	8	3943	-	-	371	Multiple	Semi-confined to Confined	50-700	50 - 400	5-10	600-4000	200-1500	8 - 20	500-2000
Total Area	555298	5203	407490	145028	40560	3864									

DTW : Depth to water level
m bgl: Water below ground level

Table 2.1: Norms Recommended for Specific Yield

Sl. No.	Principal Aquifer	Major Aquifers Code	Major Aquifers Name	Age	Recommended (%)	Minimum (%)	Maximum (%)
1	Alluvium	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	Quaternary	10	8	12
2	Alluvium	AL02	Pebble / Gravel/ Bazada/ Kandi	Quaternary	16	12	20
3	Alluvium	AL03	Older Alluvium (Silt/Sand/Gravel/Lithomargic clay)	Quaternary	6	4	8
4	Alluvium	AL04	Aeolian Alluvium (Silt/ Sand)	Quaternary	16	12	20
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay)	Quaternary	10	8	12
6	Alluvium	AL06	Valley Fills	Quaternary	16	12	20
7	Alluvium	AL07	Glacial Deposits	Quaternary	16	12	20
8	Laterite	LT01	Laterite / Ferruginous concretions	Quaternary	2.5	2	3
9	Basalt	BS01	Basic Rocks (Basalt) - Weathered, Vesicular or Jointed	Mesozoic to Cenozoic	2	1	3
10	Basalt	BS01	Basic Rocks (Basalt) - Massive Poorly Jointed	Mesozoic to Cenozoic	0.35	0.2	0.5
11	Basalt	BS02	Ultra Basic - Weathered, Vesicular or Jointed	Mesozoic to Cenozoic	2	1	3
12	Basalt	BS02	Ultra Basic - Massive Poorly Jointed	Mesozoic to Cenozoic	0.35	0.2	0.5
13	Sandstone	ST01	Sandstone/Conglomerate	Upper Palaeozoic to Cenozoic	3	1	5
14	Sandstone	ST02	Sandstone with Shale	Upper Palaeozoic to Cenozoic	3	1	5
15	Sandstone	ST03	Sandstone with shale/ coal beds	Upper Palaeozoic to Cenozoic	3	1	5
16	Sandstone	ST04	Sandstone with Clay	Upper Palaeozoic to Cenozoic	3	1	5
17	Sandstone	ST05	Sandstone/Conglomerate	Proterozoic to Cenozoic	3	1	5
18	Sandstone	ST06	Sandstone with Shale	Proterozoic to Cenozoic	3	1	5
19	Shale	SH01	Shale with limestone	Upper Palaeozoic to Cenozoic	1.5	1	2
20	Shale	SH02	Shale with Sandstone	Upper Palaeozoic to Cenozoic	1.5	1	2
21	Shale	SH03	Shale, limestone and sandstone	Upper Palaeozoic to Cenozoic	1.5	1	2
22	Shale	SH04	Shale	Upper Palaeozoic to Cenozoic	1.5	1	2
23	Shale	SH05	Shale/Shale with Sandstone	Proterozoic to	1.5	1	2

Rainfall Infiltration Factor

Table 2.2: Norms Recommended for Rainfall Infiltration Factor

SL. No.	Principal Aquifer	Major Aquifers Code	Major Aquifers Name	Age	Recommended (%)	Minimum (%)	Maximum (%)
1	Alluvium	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	Quaternary	22	20	24
2	Alluvium	AL02	Pebble / Gravel/ Bazada/ Kandi	Quaternary	22	20	24
3	Alluvium	AL03	Older Alluvium (Silt/Sand/Gravel/Lithomargic clay)	Quaternary	22	20	24
4	Alluvium	AL04	Aeolian Alluvium (Silt/ Sand)	Quaternary	22	20	24
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay) -East Coast	Quaternary	16	14	18
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay) - West Coast	Quaternary	10	8	12
6	Alluvium	AL06	Valley Fills	Quaternary	22	20	24
7	Alluvium	AL07	Glacial Deposits	Quaternary	22	20	24
8	Laterite	LT01	Laterite / Ferruginous concretions	Quaternary	7	6	8
9	Basalt	BS01	Basic Rocks (Basalt) - Vesicular or Jointed	Mesozoic to Cenozoic	13	12	14
9	Basalt	BS01	Basic Rocks (Basalt) - Weathered	Mesozoic to Cenozoic	7	6	8
10	Basalt	BS01	Basic Rocks (Basalt) - Massive Poorly Jointed	Mesozoic to Cenozoic	2	1	3
11	Basalt	BS02	Ultra Basic - Vesicular or Jointed	Mesozoic to Cenozoic	13	12	14
11	Basalt	BS02	Ultra Basic - Weathered	Mesozoic to Cenozoic	7	6	8
12	Basalt	BS02	Ultra Basic - Massive Poorly Jointed	Mesozoic to Cenozoic	2	1	3
13	Sandstone	ST01	Sandstone/Conglomerate	Upper Palaeozoic to Cenozoic	12	10	14
14	Sandstone	ST02	Sandstone with Shale	Upper Palaeozoic to Cenozoic	12	10	14
15	Sandstone	ST03	Sandstone with shale/ coal beds	Upper Palaeozoic to Cenozoic	12	10	14
16	Sandstone	ST04	Sandstone with Clay	Upper Palaeozoic to Cenozoic	12	10	14
17	Sandstone	ST05	Sandstone/Conglomerate	Proterozoic to Cenozoic	6	5	7
18	Sandstone	ST06	Sandstone with Shale	Proterozoic to Cenozoic	6	5	7
19	Shale	SH01	Shale with limestone	Upper Palaeozoic to Cenozoic	4	3	5
20	Shale	SH02	Shale with Sandstone	Upper Palaeozoic to Cenozoic	4	3	5

ANNEXURE 3 – GROUND WATER DATA

SHIRPUR

Month	Rainfall (mm)	DTWL Actual (m)	DTWL Predicted (m)
Jan-20	0	4.37	4.37
Feb-20	0		
Mar-20	17.202		
Apr-20	0.691858		7.560728
May-20	0		7.560728
Jun-20	271.2535		7.500028
Jul-20	209.8249		7.280478
Aug-20	253.6928	6.47565	6.47
Sep-20	103.6481		3.4484
Oct-20	31.33791		4.448099
Nov-20	0	4.13154	4.13
Dec-20	11.71638		3.969708
Jan-21	10.11813	9.6	9.6
Feb-21	10.28033		7.560728
Mar-21	9.502781		7.560728
Apr-21	0		7.407339
May-21	21.63999		7.560728
Jun-21	33.25818		7.312981

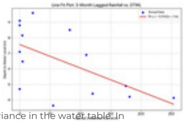
Month	Rainfall (mm)	DTWL Actual (m)	DTWL Predicted (m)
Jul-21	128.2391		7.310486
Aug-21	150.9975	6.9	6.9
Sep-21	360.8201		5.024209
Oct-21	116.4008		2.487542
Nov-21	20.38317	4.2	4.2
Dec-21	12.7588		4.518421
Jan-22	8.011492	4.4	4.4
Feb-22	0		7.251829
Mar-22	3.897828		7.560728
Apr-22	0		7.439321
May-22	0	8.8	8.8
Jun-22	91.75549		7.560728
Jul-22	245.3743		7.488004
Aug-22	174.8083	7.1	7.1
Sep-22	167.2848		2.581743
Oct-22	73.52674		2.985475
Nov-22	0	4.9	4.9
Dec-22	2.860147		5.884883

Month	Rainfall (mm)	DTWL Actual (m)	DTWL Predicted (m)
Jan-23	0	8.3	8.3
Feb-23	0		7.560728
Mar-23	9.455808		7.560728
Apr-23	16.26867		7.560728
May-23	4.407877	8.1	8.1
Jun-23	52.82507		7.401428
Jul-23	277.0233		7.180288
Aug-23	54.85051	8.15	8.15
Sep-23	265.1065		5.891491
Oct-23	1.086893		2.488174
Nov-23	34.64877	3.63	3.63
Dec-23	8.642318		3.452583
Jan-24	0.544087	4.7	4.7
Feb-24	4.211158		6.7324
Mar-24	0.331814		7.558151
Apr-24	0.886091		7.552562
May-24	3.549268		7.560728
Jun-24	139.5843		7.448794

Month	Rainfall (mm)	DTWL Actual (m)	DTWL Predicted (m)
Jul-24	328.8769		7.314314
Aug-24	254.2462		7.109848
Sep-24	148.5309		4.188711
Oct-24	65.68241		2.575954
Nov-24	0		4.733238
Dec-24	13.54795		4.958544
Jan-25	0		6.711448
Feb-25	0		7.276421
Mar-25	0		7.560084
Apr-25	0		7.354132
May-25	71.20484		7.560728
Jun-25	182.3939		7.448794
Jul-25	128.781		7.314314
Aug-25	288.3909		7.109848
Sep-25	203.8787		4.188711
Oct-25	83.60139		2.898428
Nov-25	1.647805		3.492749
Dec-25	0		4.958544

**The values in the cells marked in red were derived through statistical methods.*

Regression Model



- 3month laggedregression equation - DTWL = -0.0152 x Rainfall$_{(t-3)}$ + 7.56
- Negative Correlation: The negative slope (-0.0152) means that as rainfall increases (3 months ago), the depth to the water level decreases (meaning the water table rises). This is exactly what we expect in a natural hydrological system.
Recharge Baseline: The intercept (7.56m) suggests the "equilibrium" depth of the water table when there has been no significant rainfall in the preceding months.

Goodness of fit - R^2 = 0.363: This model explains 36.3% of the variance in the water table. In environmental data, this is considered a strong correlation, especially when using only a single variable (rainfall).

p-value = 0.023: This is less than the standard 0.05 threshold, meaning the result is statistically significant. We can say with 97.7% confidence that this relationship is real and not due to random chance.

VIRAMGAM & MANDAL

Month	Rainfall (mm)	DTW Actual - Viramgam (m)	DTW Actual - Mandal (m)	DTW Predicted (m) - Viramgam	DTW Predicted (m) - Mandal
Jan-20	0	2.27	7.7	2.27	7.7
Feb-20	0				
Mar-20	0.617341145				4.878234816
Apr-20	0			4.101796288	4.878234816
May-20	0	3.5	8.22	3.5	8.22
Jun-20	107.6792012			4.097097912	4.878234816
Jul-20	145.8088946			4.101796288	4.878234816
Aug-20	494.9143934		5.43	4.101796288	5.43
Sep-20	41.00515365			3.309480545	5.254174607
Oct-20	5.974948842			3.029492234	6.254175033
Nov-20	0	1.35	5.95	1.35	5.95
Dec-20	0.142899401			3.799514205	4.893640056
Jan-21	0	2.2	6.18	2.2	6.18
Feb-21	0			4.101796288	4.878031294
Mar-21	0	3.02	6.6	3.02	6.6
Apr-21	0			4.101796288	4.878234816
May-21	30.08489554		6.4	4.101796288	6.4
Jun-21	120.8833131			4.101796288	4.878234816
Jul-21	138.6413025			4.101796288	4.957371739
Aug-21	11.84592903	3		3	5.292487262
Sep-21	278.4870577			3.203296008	5.235178708
Oct-21	2.907260142			3.081131703	4.908777233
Nov-21	18.31294009	2.25	5.72	2.25	5.72
Dec-21	1.789133722			2.04758804	4.885730679
Jan-22	3.644692089	1.84		1.84	4.925448581
Feb-22	0			3.966804196	4.882847748
Mar-22	0			4.088607139	4.882475335
Apr-22	0			4.089471931	4.878234816
May-22	0	3.3		3.3	4.878234816
Jun-22	28.51679982			4.101796288	4.878234816
Jul-22	266.0719684			4.101796288	4.878234816
Aug-22	227.8977568	2.08		2.08	4.943446471
Sep-22	70.62823431			3.921063539	5.564149482
Oct-22	4.992061441			2.140365046	5.46582475
Nov-22	0	2.26		2.26	5.068070855
Dec-22	0			3.559021143	4.891205872
Jan-23	0.711493172	3.05		3.05	4.878234816
Feb-23	0			4.101796288	4.878234816
Mar-23	15.45625149			4.101796288	4.880069263
Apr-23	6.271978997			4.096551295	4.878234816
May-23	26.26342186	3.24	6.7	3.24	6.7
Jun-23	95.71350468			3.987855775	4.894405089
Jul-23	266.1256965			4.055560468	4.945949524
Aug-23	7.709474043	4.57		4.57	5.125021626
Sep-23	176.0944082			3.396224789	5.564182853
Oct-23	0.759982347			2.139983716	4.898511239
Nov-23	19.63427544	4.5		4.5	5.332156895
Dec-23	0.043217061			2.803662268	4.880294282
Jan-24	0		6.1	4.096193845	6.1
Feb-24	0			3.917056196	4.878346296
Mar-24	2.298584643			4.100477547	4.878234816
Apr-24	1.719457055			4.101796288	4.878234816
May-24	5.992843479			4.101796288	4.884161268
Jun-24	39.34577363	7.5	1.6125	7.5	1.6125
Jul-24	313.4028437	6.75	4.6375	6.75	4.6375
Aug-24	306.8949081	4.7	5.525	4.7	5.525
Sep-24	177.6512195	1.625	5.8125	1.625	5.8125
Oct-24	15.11724337	1.95	5.2625	1.95	5.2625
Nov-24	0	2.2	4.883333333	2.2	4.883333333
Dec-24	0	2.7	4.6125	2.7	4.6125
Jan-25	0	3.25	4.375	3.25	4.375
Feb-25	0	3.95	4.05	3.95	4.05
Mar-25	0	4.65	3.333333333	4.65	3.333333333
Apr-25	0	5.35	2.725	5.35	2.725
May-25	49.48897687	6.35	1.725	6.35	1.725
Jun-25	146.9676459	7.71		7.71	4.878234816
Jul-25	162.6513441	6.77		6.77	5.00585827
Aug-25	113.2055492	4.67		4.67	5.257162221
Sep-25	132.5350005	1.62		1.62	5.297599577
Oct-25	40.62347839	2		2	5.170113240
Nov-25	1.507497743	2.415		2.415	5.21995046
Dec-25	0	3		3	4.98297453
Jan-26	0	3.8		3.8	4.887278214
Feb-26	0	3.675		3.675	4.878234816

The values in the cells marked in red were derived through statistical methods.

Regression Model

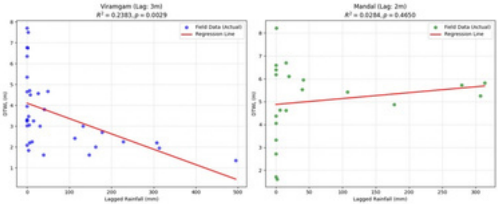
Location	Lag - Best fit	Regression Equation	R^2	p-value
Viramgam	3 Months	DTWL = (-0.00737 x Rain_t-3) + 4.1018	0.2383	0.0029
Mandal	2 Months	DTWL = (0.00258 x Rain_t-2) + 4.8782	0.0284	0.465

Viramgam

- Lag: 3 Months
- Correlation (R^2 = 0.2386): 23.8% of the water level changes are now explained by rainfall from three months prior.
- Significance (p = 0.0029): This value is extremely low (p < 0.001), meaning this relationship is highly statistically significant and not due to chance.
- The 3-month delay at Viramgam suggests a thicker "vadose zone" (the dry soil above the water table). The water must slowly percolate through clay or silt layers before it reaches the monitoring depth.

Mandal

- Lag: 2 Months
- Correlation (R^2 = 0.0284): While the fit appears lower than Viramgam's, it is because Mandal is highly reactive to individual events rather than a long-term average.
- Significance (p = 0.465): The high p-value indicates that while there is a pattern, Mandal is likely affected by other immediate factors (like surface run-off or shallow pumping) that introduce noise into the data.



ANNEXURE 4 – RAINFALL

SHIRPUR

VIRAMGAM & MANDAL

Date	Rainfall (mm)
01-07-25	0.13188453
02-07-25	3.990098132
03-07-25	4.680532932
04-07-25	15.91046753
05-07-25	4.877527905
06-07-25	24.50481006
07-07-25	8.738539689
08-07-25	5.897615716
09-07-25	8.627281189
10-07-25	0.291329817
11-07-25	0.291329817
12-07-25	6.272645473
13-07-25	9.535549545
14-07-25	0
15-07-25	0
16-07-25	0
17-07-25	0
18-07-25	0
19-07-25	0
20-07-25	0.543011868
21-07-25	3.678576328
22-07-25	0
23-07-25	0
24-07-25	0
25-07-25	3.495837688
26-07-25	0.810654296
27-07-25	15.38451195
28-07-25	25.89027136
29-07-25	1.795489908
30-07-25	1.101984143
31-07-25	0
01-08-25	1.577988982
02-08-25	0
03-08-25	0.21989755
04-08-25	5.937546158

Date	Rainfall (mm)
01-01-25	0
02-01-25	0
03-01-25	0
04-01-25	0
05-01-25	0
06-01-25	0
07-01-25	0
08-01-25	0
09-01-25	0
10-01-25	0
11-01-25	0
12-01-25	0
13-01-25	0
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23-01-25	0
24-01-25	0
25-01-25	0
26-01-25	0
27-01-25	0
28-01-25	0
29-01-25	0
30-01-25	0
31-01-25	0
01-02-25	0
02-02-25	0
03-02-25	0
04-02-25	0

Date	Rainfall (mm)
01-07-24	10.77477551
02-07-24	33.58319082
03-07-24	0.395653376
04-07-24	27.38050612
05-07-24	17.95571346
06-07-24	4.543972492
07-07-24	0
08-07-24	0
09-07-24	10.24525752
10-07-24	0
11-07-24	0
12-07-24	2.431992799
13-07-24	3.512676656
14-07-24	3.551651453
15-07-24	0
16-07-24	0
17-07-24	12.15246964
18-07-24	6.162914276
19-07-24	2.161771297
20-07-24	0
21-07-24	0
22-07-24	0
23-07-24	0
24-07-24	0
25-07-24	10.24340153
26-07-24	29.98434448
27-07-24	0.17584604
28-07-24	0.278221412
29-07-24	0
30-07-24	0.335261342
31-07-24	50.02673993
01-08-24	35.41453924
02-08-24	1.298828618
03-08-24	6.307759556
04-08-24	3.958922625

Date	Rainfall (mm)
01-01-24	0
02-01-24	0
03-01-24	0
04-01-24	0
05-01-24	0
06-01-24	0
07-01-24	0
08-01-24	0
09-01-24	0
10-01-24	0
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25-01-24	0
26-01-24	0
27-01-24	0
28-01-24	0
29-01-24	0
30-01-24	0
31-01-24	0
01-02-24	0
02-02-24	0
03-02-24	0
04-02-24	0

Date	Rainfall (mm)
01-07-23	33.96369934
02-07-23	38.595047
03-07-23	0
04-07-23	0
05-07-23	0
06-07-23	6.788920879
07-07-23	12.3082819
08-07-23	1.865525343
09-07-23	11.60189903
10-07-23	12.50696278
11-07-23	0
12-07-23	0
13-07-23	0
14-07-23	0
15-07-23	0
16-07-23	0
17-07-23	0
18-07-23	0
19-07-23	14.59430027
20-07-23	4.252057552
21-07-23	8.759544783
22-07-23	0
23-07-23	31.30983543
24-07-23	1.841737894
25-07-23	7.873578347
26-07-23	0
27-07-23	2.505600469
28-07-23	0.291329817
29-07-23	0
30-07-23	6.167941779
31-07-23	1.969491324
01-08-23	0.278221412
02-08-23	0.934331725
03-08-23	0.840996151
04-08-23	0

Date	Rainfall (mm)
01-01-23	0
02-01-23	0
03-01-23	0
04-01-23	0
05-01-23	0
06-01-23	0
07-01-23	0
08-01-23	0
09-01-23	0
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23-01-23	0
24-01-23	0
25-01-23	0
26-01-23	0
27-01-23	0
28-01-23	0
29-01-23	0.13188453
30-01-23	0
31-01-23	0
01-02-23	0
02-02-23	0
03-02-23	0
04-02-23	0

Date	Rainfall (mm)
01-07-22	0
02-07-22	0
03-07-22	0.546442824
04-07-22	0.673959422
05-07-22	0
06-07-22	2.02286315
07-07-22	0
08-07-22	7.11313629
09-07-22	17.89441299
10-07-22	0
11-07-22	18.55484282
12-07-22	17.88178261
13-07-22	1.652444976
14-07-22	14.00675842
15-07-22	17.13898087
16-07-22	8.758485675
17-07-22	1.271377882
18-07-22	2.066190958
19-07-22	0
20-07-22	7.648578789
21-07-22	0.291329817
22-07-22	1.24206235
23-07-22	0
24-07-22	28.69946289
25-07-22	5.124275684
26-07-22	28.43144798
27-07-22	14.41752311
28-07-22	3.284282684
29-07-22	0.670562685
30-07-22	0
31-07-22	0.278221412
01-08-22	0
02-08-22	0
03-08-22	0
04-08-22	0.17584604

Date	Rainfall (mm)
01-01-22	0
02-01-22	0
03-01-22	0
04-01-22	0
05-01-22	0
06-01-22	0
07-01-22	1.481226821
08-01-22	0
09-01-22	0
10-01-22	0
11-01-22	0
12-01-22	0
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30-03-22	0
31-03-22	0
01-04-22	0
02-04-22	0
03-04-22	0
04-04-22	0

05-08-22	3.865293219
06-08-22	29.81059532
07-08-22	0
08-08-22	0
09-08-22	0
10-08-22	4.734500685
11-08-22	0
12-08-22	0.335281342
13-08-22	20.43677711
14-08-22	1.625100837
15-08-22	1.756460402
16-08-22	2.625407896
17-08-22	8.341732025
18-08-22	12.09798516
19-08-22	0.810664296
20-08-22	0.307730506
21-08-22	0
22-08-22	0
23-08-22	0
24-08-22	27.97060689
25-08-22	9.900388718
26-08-22	0.747945686
27-08-22	0
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11-09-22	10.21444798
12-09-22	7.63932966
13-09-22	8.866497231
14-09-22	9.387124138
15-09-22	2.587947369
16-09-22	1.747918844
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18-09-22	0
19-09-22	0
20-09-22	0
21-09-22	0
22-09-22	0
23-09-22	0
24-09-22	0
25-09-22	0
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27-09-22	0
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30-09-22	0
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02-10-22	0

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27-06-22	9.77359581
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29-06-22	0
30-06-22	0

ANNEXURE 5 – PHOTOS

SHIRPUR


Zydus Watershed Project
Under CSR Initiatives

VIRAMGAM






MANDAL