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Strictly Private & Confidential

Kotak Mahindra Bank Limited
27 BKC, C-27, G Block Bandra Kurla Complex,
Bandra (E), Mumbai, Maharashtra, India- 400051

Date: 18.03.2026

Subject: Draft report for Impact assessment of Sahakara Mitra Samstha Centre For Collective Development Project supported by Kotak Mahindra Bank Limited

Dear Himanshu Nivsarkar,

This refers to our [engagement letter/engagement contract] dated 14th November 2025 with Kotak Mahindra Bank Limited ("you") ('the Contract').

We appreciate the opportunity to assist Kotak Mahindra Bank Limited in providing Impact assessment of 10 CSR projects for FY 25-26.

This is our draft report as described in the Engagement Contract. The performance of our Services and the report issued to you pursuant to the Services are based on and subject to the terms of the Contract.

This report is solely for your benefit and information and is not to be referred to in communications with or distributed or disclosed for any purpose to any third party without our prior written consent. We have been engaged by you for the Services and to the fullest extent permitted by law, we will not accept responsibility or liability to any other party in respect of our Services or the report.

It has been our privilege to work with you, and we look forward to continuing our relationship with you.

Yours sincerely

Full Signature

Thakkar

Jignesh Thakkar
Partner – ESG, KPMG India
KPMG Assurance and Consulting services LLP

Impact Assessment Report

Sahakara Mitra Samstha Centre For Collective Development

Kotak Mahindra Bank Limited

(Project ID -KMBL202324059)

March 2026

Notice to readers:

- Our report shall be prepared solely for Client. KPMG does not accept or assume any liability, responsibility, or duty of care for any use of or reliance on this report by anyone, other than our Client, to the extent agreed in the Agreement.

- Impact assessment is limited to the projects allocated by Client.

- OECD-DAC assessment framework shall be used in preparing the report as detailed herein. No professional assurance standards ex. ISAE, SSAE etc. shall be applied while preparing this report and accordingly the rigors applicable under such standards are not applicable for the scope covered by our report.

- Procedures, analysis and recommendations, if any, shall be advisory in nature basis the information collected from Client's website (https://www.kotak.com/en/home.html) and those provided by the Client.

- Our observations represent our understanding and interpretation of the facts based on reporting of beneficiaries and stakeholders.

- Our report, by its very nature, may involve numerous assumptions, inherent risks, and uncertainties, both general and specific. The conclusions drawn shall be based on the information available with us at the time of preparing the report.

- We shall not perform an audit and shall not express an opinion or any other form of assurance. Further, comments in our report shall not be intended, nor should they be interpreted to be legal advice or opinion. Client shall be fully and solely responsible for applying independent judgment, with respect to the findings included in the report, to make appropriate decisions in relation to future course of action, if any. We shall not take responsibility for the consequences resulting from decisions based on information included in the report.

- While information obtained from the Client's website (https://www.kotak.com/en/home.html) has not been verified for authenticity, accuracy, or completeness, we have obtained information, as far as possible, from sources generally considered to be reliable. However, it must be noted that Client's website may not be updated regularly. We assume no responsibility for the reliability and credibility of such information.

- Our work shall be limited to the specific procedures described in this Engagement Letter and shall be based only on the information and analysis of the data obtained through interviews of beneficiaries supported under the CSR projects, selected as sample respondents and discussions with Client team and stakeholders of the CSR projects. Accordingly, changes in circumstances or information available after the review could affect the findings outlined in our report.

- In no circumstances shall we be liable, for any loss or damage, of whatsoever nature, arising from information material to our work being withheld or concealed from us or misrepresented to us by any person to whom we make information requests.

- In accordance with its policy, KPMG advises that neither it nor any of its partner, director or employee undertakes any responsibility arising in any way whatsoever, to any person other than Client in respect of the matters dealt with in this report, including any errors or omissions therein, arising through negligence or otherwise, howsoever caused.

- In connection with our report or any part thereof, KPMG does not owe duty of care (whether in contract or in tort or under statute or otherwise) to any person or party to whom the report is circulated to and KPMG shall not be liable to any party who uses or relies on this report. KPMG thus disclaims all responsibility or liability for any costs, damages, losses, liabilities, expenses incurred by such third party arising out of or in connection with the report or any part thereof.

- By reading our report, the reader of the report shall be deemed to have accepted the terms mentioned hereinabove.

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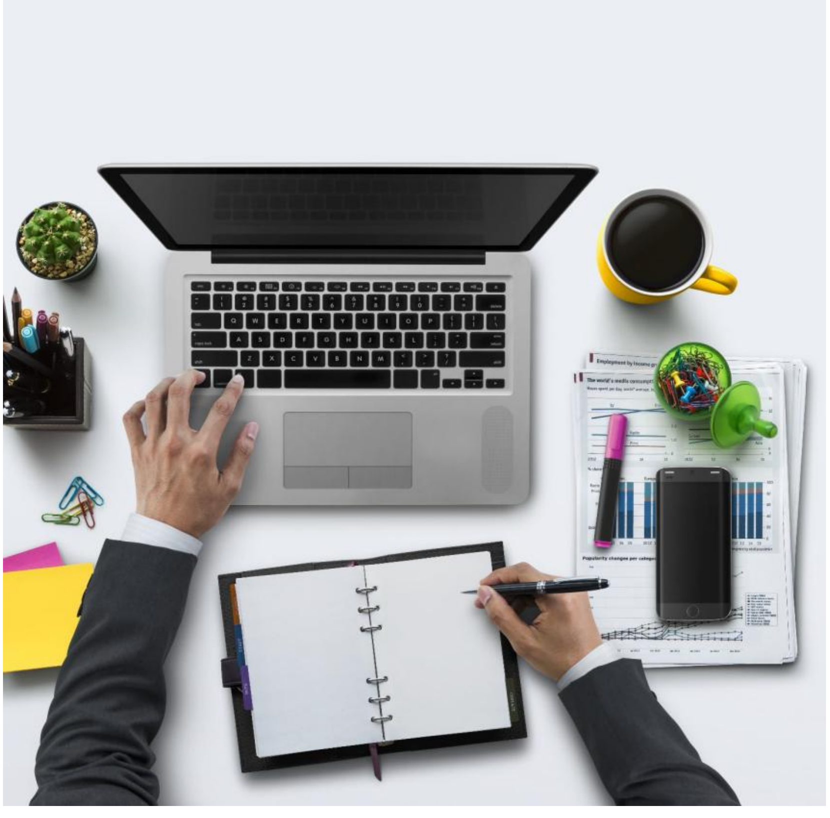


Abbreviations:

Abbreviation	Full form
CCD	Centre for Collective Development
CSR	Corporate Social Responsibility
FGD	Focus Group Discussion
KII	Key Informant Interview
KMBL	Kotak Mahindra Bank Limited
OECD-DAC	Organisation for Economic Co-operation and Development – Development Assistance Committee
QA	Quality Assurance
SDGs	Sustainable Development Goals
NDVI	Normalised Difference Vegetation Index
NDMI	Normalised Difference Moisture Index

Project details:

Program ID	KMBL202324059
Project Implementation Period	01-Jan-2024 to 31-Mar-2024
Partner Organization	Sahakara Mitra Samstha Centre For Collective Development
Location	Karnataka

Executive Summary

This impact assessment of Kotak Mahindra Bank Limited's CSR-supported initiative; Sahakara Mitra Samstha Centre for Collective Development project was conducted using the OECD-DAC evaluation framework, covering six criteria; Relevance, Coherence, Effectiveness, Efficiency, Impact, and Sustainability. The study employed a mixed-method approach, including 107 stakeholder interactions (conducted across Farmers, Program team and PRI members), supported by thematic analysis, technical analysis and performance data review.

Below are the key findings basis the impact assessment from the project:*

KEY FINDINGS

93% Farmers reported increase in water levels in the community water tanks post project implementation

100% Farmers reported that they have diversified their livelihood opportunities through multi-cropping, fisheries, livestock post the project implementation due to increased water levels

78% Farmers reported reduction in water usage per crop cycle, indicating that improved soil structure and moisture retention from silt application.

75% Farmers reported increase in crop yield per acre following the project which highlights the positive impact on productivity

80% Farmers reported that their income has improved due to better crop yields and reduced input costs like labor costs spent in irrigation, reduced fertilizer cost, depreciation cost of machines used for irrigation

9/10 Farmers reported improvement in their income brackets from upto 1-2 lakhs per annum to 3-4 lakhs per annum

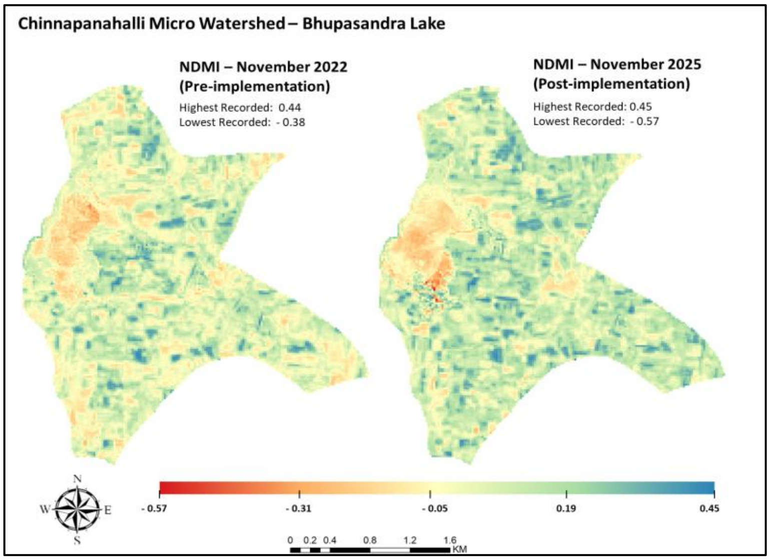
54% Farmers reported reduction in the usage of chemical fertilizer

77% Farmers reported that they consider this project was important to reduce water stress in their village

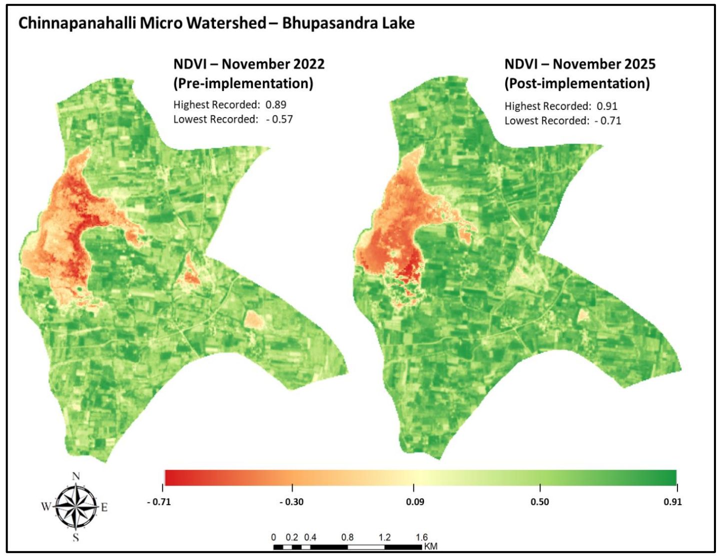
Based on the technical analysis

Key Findings from the Technical Analysis *

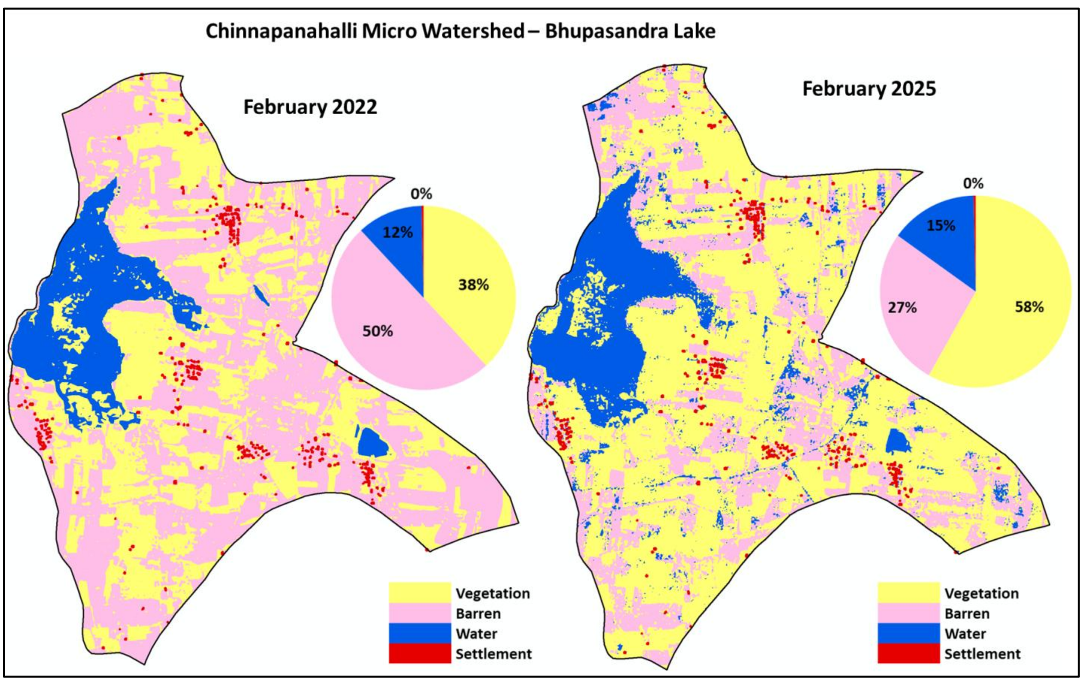
Below are the key findings from the technical analysis across the following parameters for Bhupasandra-



NDMI increased from 0.44 to 0.45, reflecting improved soil-water retention and vegetation moisture across the catchment.



NDVI improved from 0.89 (2022) to 0.91 (2025), indicating healthier riparian vegetation and improved canopy density.

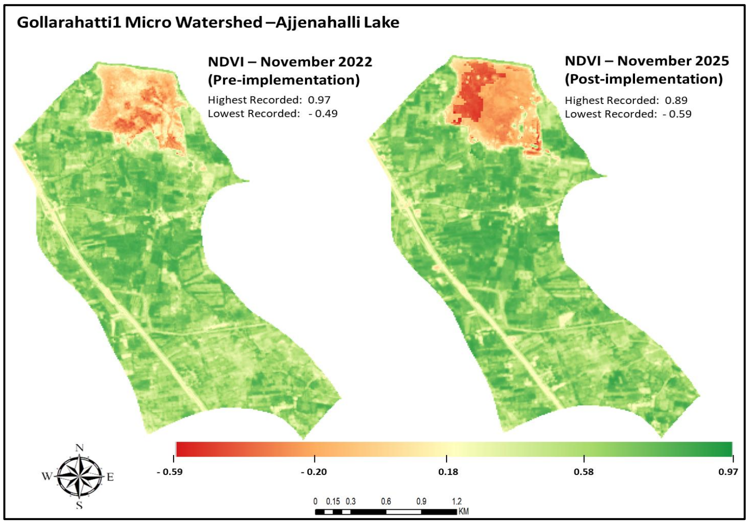


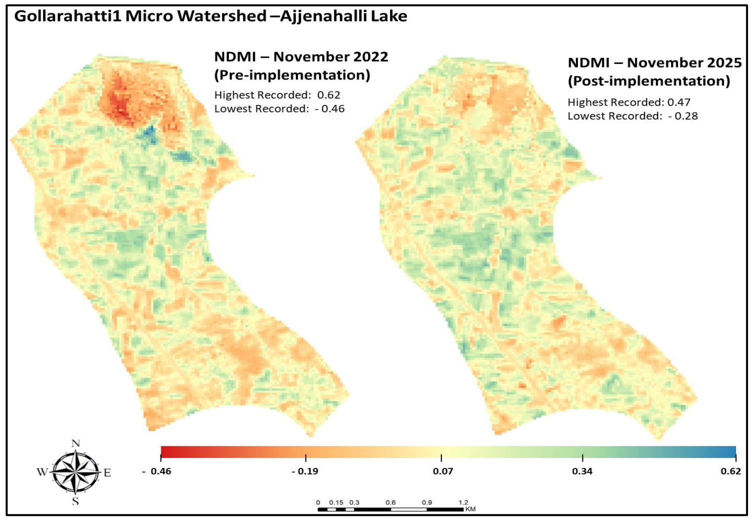
Vegetation cover surged from 38% to 58% (+20%), while barren land reduced from 50% to 27% (-23%), signifying conversion of degraded land into productive green zones.

**Based on the technical analysis*

Key Findings from the Technical Analysis *

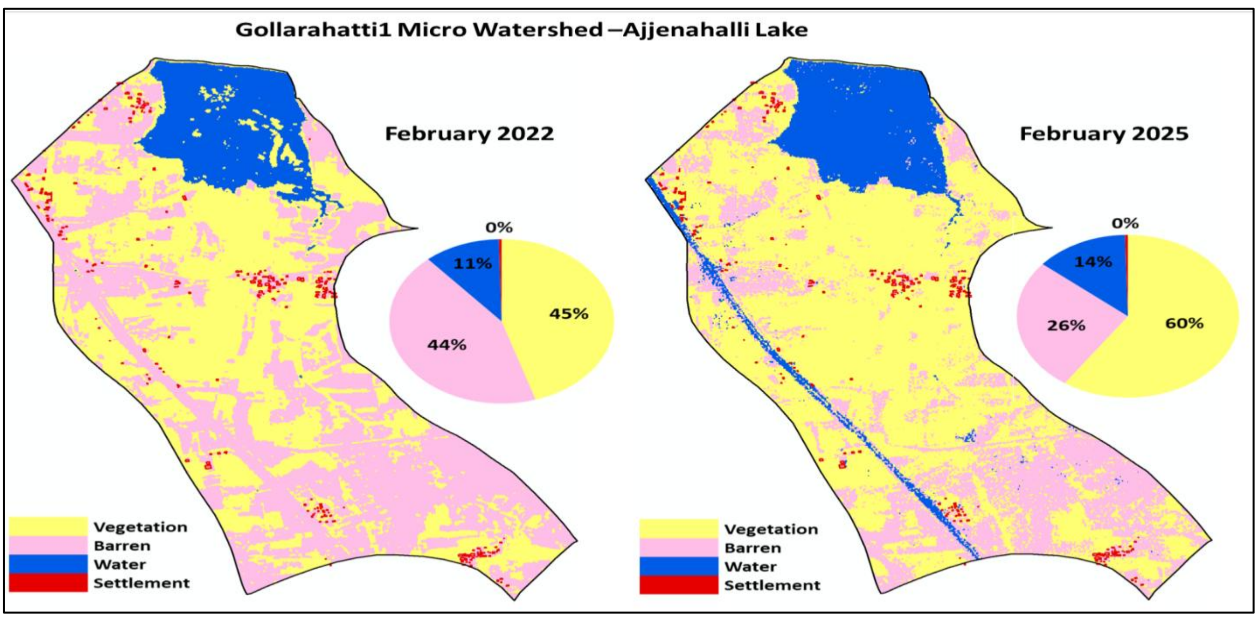
Below are the key findings from the technical analysis across the following parameter for Ajjenahali -





NDVI decreased from 0.97 (2022) to 0.89(2025), indicating decline in riparian vegetation and canopy density which could be attributed to harvesting seasonal fluctuations.

NDMI increased from -0.46 to -0.28, reflecting improved soil-water retention and vegetation moisture across the catchment.

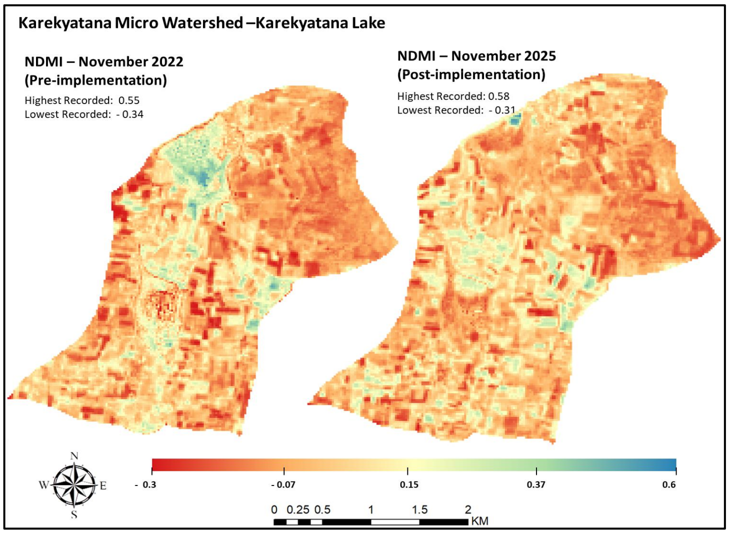


Vegetation cover surged from 45% to 60% (+15%), while barren land reduced from 44% to 26% (-18%), signifying conversion of degraded land into productive green zones.

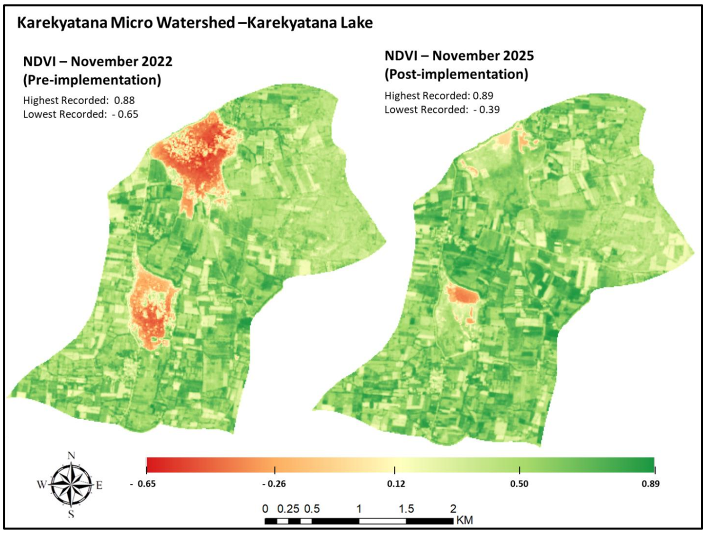
Based on the technical analysis

Key Findings from the Technical Analysis *

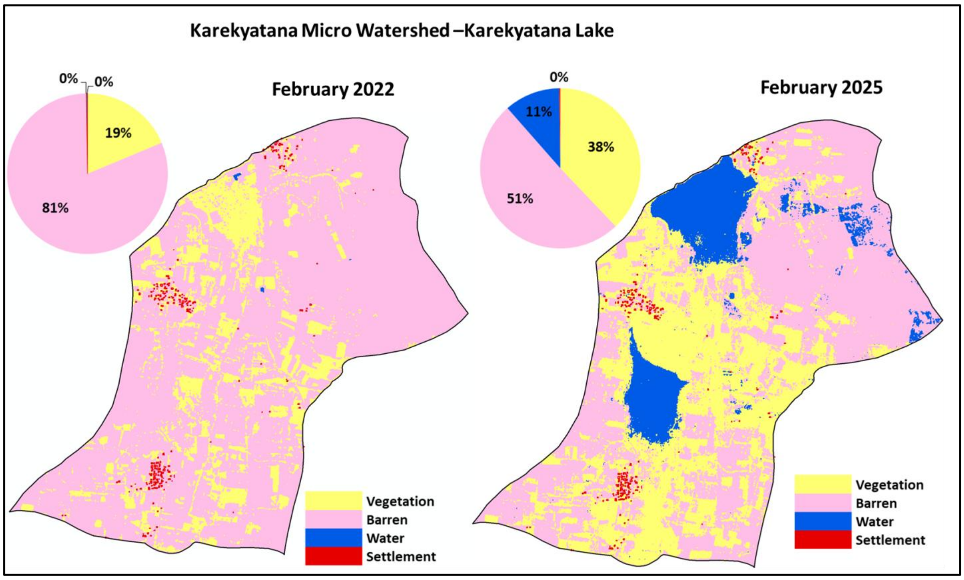
Below are the key findings from the technical analysis across the following parameters Karekyatana-



NDMI increased from 0.55 to 0.58, reflecting improved soil-water retention and vegetation moisture across the catchment.



NDVI improved from 0.88 (2022) to 0.89 (2025), indicating healthier riparian vegetation and improved canopy density.

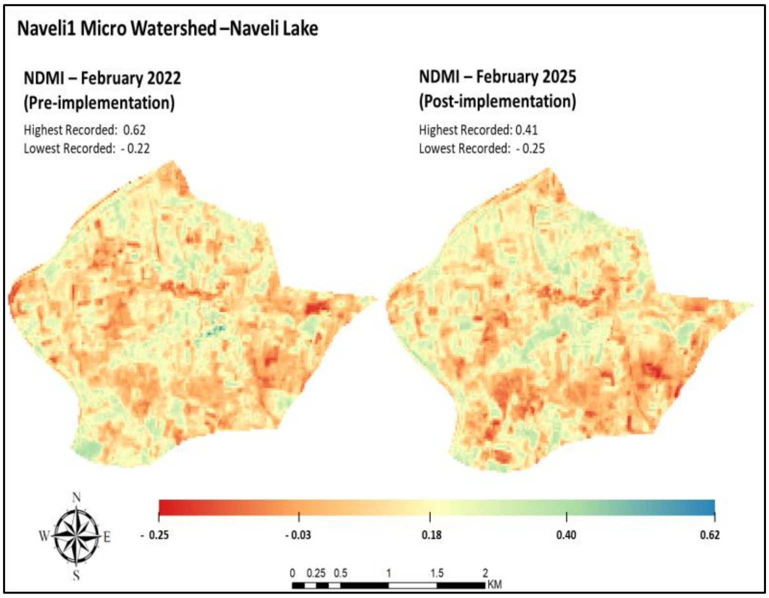


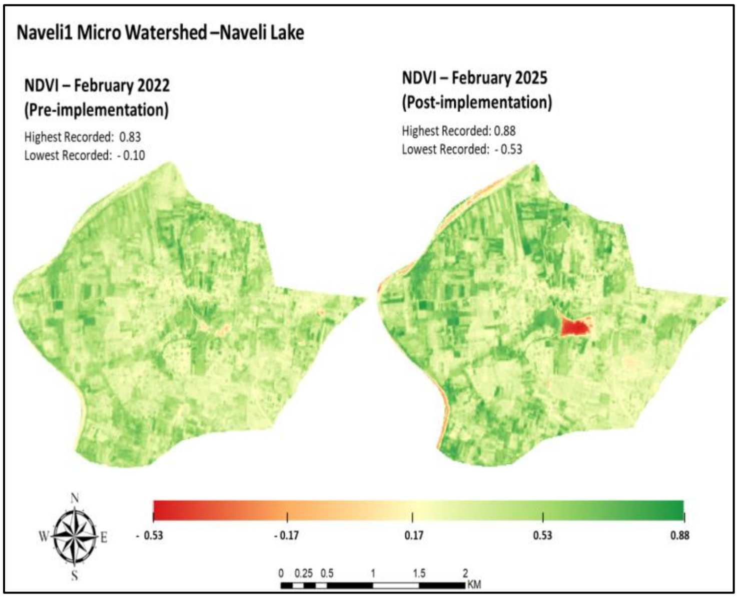
Vegetation cover surged from 19% to 38% (+19%), while barren land reduced from 81% to 51% (-30%), signifying conversion of degraded land into productive green zones.

Based on the technical analysis

Key Findings from the Technical Analysis *

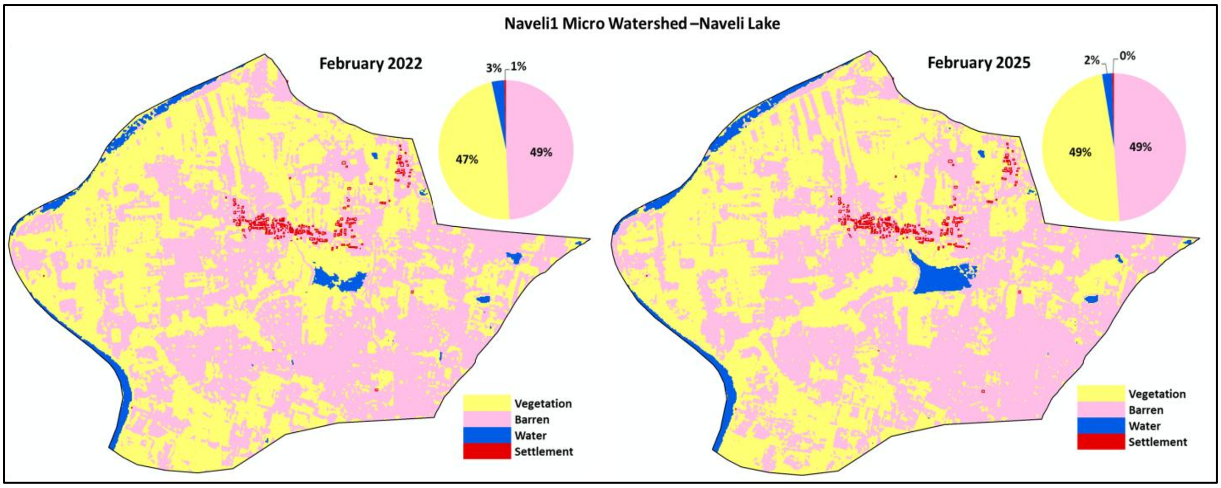
Below are the key findings from the technical analysis across the following parameters for Naveli-





NDMI decreased from 0.62 to 0. 41, which could be due to seasonal variations like harvesting, industrial and domestic use, reflecting slight reduction in soil-water retention and vegetation moisture across the catchment.

NDVI improved from 0.83 (2022) to 0.88 (2025), indicating healthier riparian vegetation and improved canopy density.

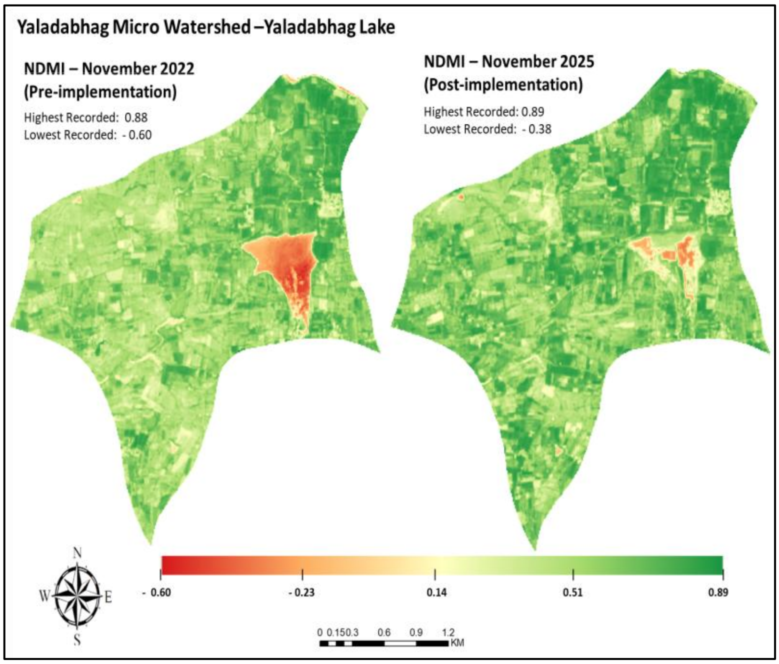


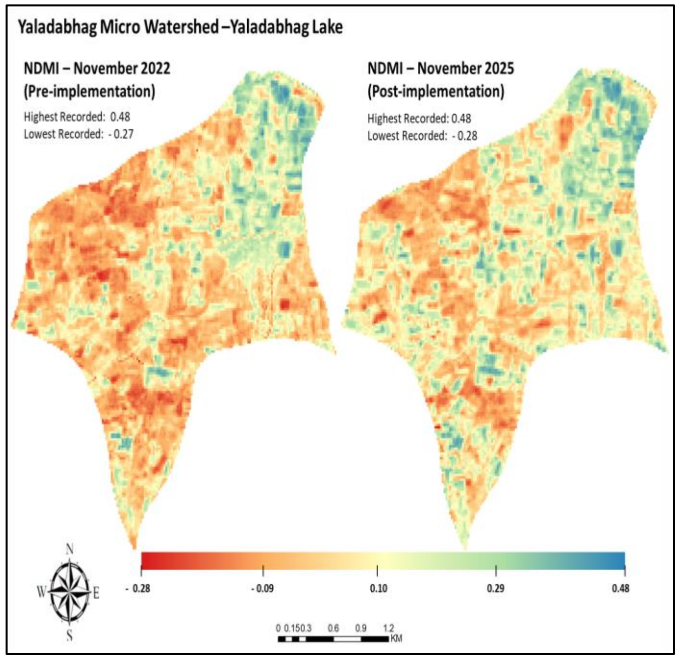
Vegetation cover surged from 47% to 49% (+2%), while no reduction in barren land increased productive green zones.

*Based on the technical analysis

Key Findings from the Technical Analysis *

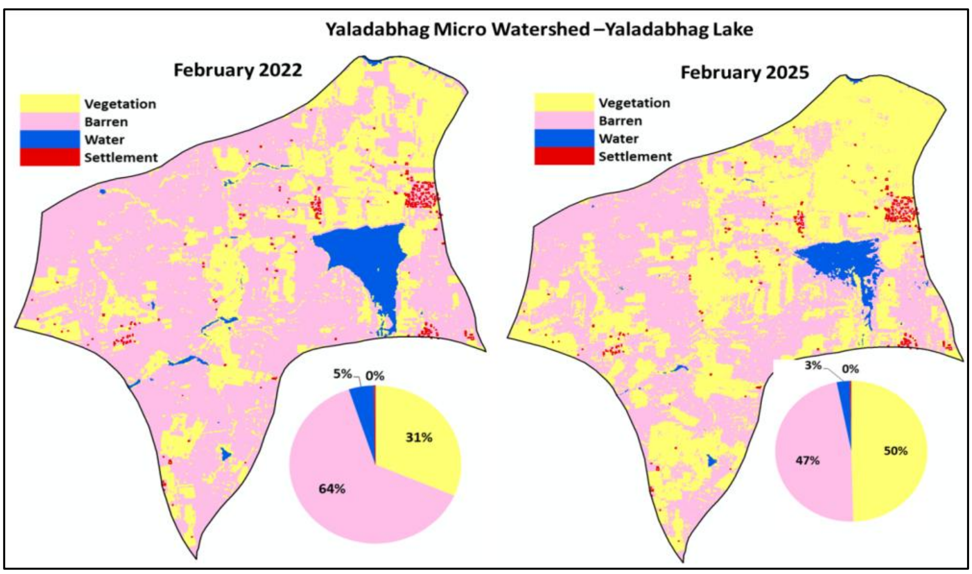
Below are the key findings from the technical analysis across the following parameters for Yaladabhag-





NDVI improved from 0.88(2021) to 0.89 (2025), indicating healthier riparian vegetation and improved canopy density.

There is no change in NDMI value, indicating consistent hydrological conditions despite fluctuations in surface water spread



Vegetation cover surged from 31% to 50% (+19%), while barren land reduced from 64% to 47% (-17%), signifying conversion of degraded land into productive green zones.

Based on the technical analysis

OECD-DAC Evaluation:

The various components/outcomes of the program were evaluated using the OECD DAC criteria, which include relevance, effectiveness, efficiency, impact, and sustainability. The findings of the study are categorized as follows:

OECD-DAC evaluation framework

Relevance

- The project addressed critical community need for water security. About 95% of respondents agreed that water stress had reduced after implementation, and 77% stated the project was important for their village. This highlights that the intervention was highly relevant to local priorities and aligned with the broader goal of improving agricultural resilience.

Effectiveness

- The project effectively achieved its intended outcomes. 93% of farmers observed increased water levels, and 97% reported improved irrigation availability. Additionally, 75% confirmed they could grow more crops than before, indicating that the interventions successfully enhanced agricultural productivity and water access to intended beneficiaries.

Sustainability

- 90% of respondents expressed high confidence in maintaining interventions, and training adoption was widespread. However, technical analysis highlighted groundwater depletion trends in 2024 and mixed soil outcomes, indicating the need for continued governance and adaptive measures to ensure long-term benefits.

Impact

- The project created significant ecological and economic impact. Vegetation cover increased across sites by 15–20%, barren land reduced substantially, and 99% of farmers reported income improvements. These outcomes highlight the project's contribution to environmental restoration and livelihood enhancement.

Efficiency

- Resources were utilized efficiently to achieve intended outcomes in the project. 78% of farmers reduced water usage per crop cycle, and 76% reduced fertilizer use, largely due to silt application improving soil fertility and moisture retention. These changes lowered input costs and improved productivity, demonstrating cost-effectiveness.

Coherence

- The project is coherent with local governance systems and global development goals. 97% of Gram Panchayats actively participated in sustaining interventions, and the project aligns with multiple SDGs, including SDG 2, 6, 8, 13.. This reflects good integration with existing policies and community systems.

Does not meet expectation | Partially meet expectations | Meet expectations

01
Introduction

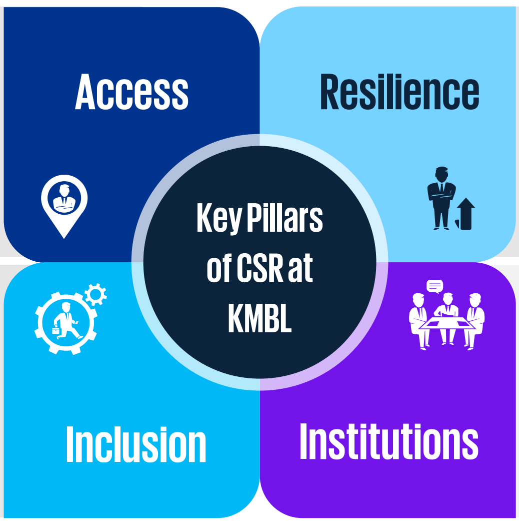
Background

This report aims to assess the impact of Kotak Mahindra Bank Limited's Corporate Social Responsibility (CSR) funding for the restoration and conservation of traditional water tanks in Karnataka and Andhra Pradesh. The initial section provides an overview of Kotak Mahindra Bank Limited, the global and local context of water scarcity, and the urgent need for tank rejuvenation initiatives in semi-arid region in India.

Established in 1985, Kotak Mahindra Group is one of India's leading financial services conglomerates. It aspires to be a trusted partner and contributes towards the economic, environmental, and social growth of the nation and is also committed to contribute towards United Nation's (UN) Sustainable Development Goals (SDGs). The bank has a strong focus on CSR initiatives and believes in giving back to society. This sets out its vision, mission, governance, and CSR focus areas to fulfill its inclusive growth agenda in India. Under its CSR program, Kotak Mahindra Bank has committed significant funding for promoting Environment & Sustainable Development initiatives in India, recognizing its importance for the social and economic development of the country.

As part of its commitment to environmental sustainability, Kotak Mahindra Bank partnered with CCD where Bank's CSR support enabled de-siltation of water tanks including activities such as Farmer & community engagement, Desilting of waterbodies, Surface water capacity creation, Waterbody system restoration. These interventions were designed to increase water storage capacity, enhance groundwater recharge, restore native biodiversity, and create climate-resilient ecosystems.

Through this pillar bank attempts to bridge gaps ad ensure that underserved communities have opportunities to grow so that no one is left behind in the journey towards progress.



Focuses on building strength within individuals and communities to withstand any challenge by supporting livelihoods, promoting sustainable practices that let communities thrive amidst the crisis.

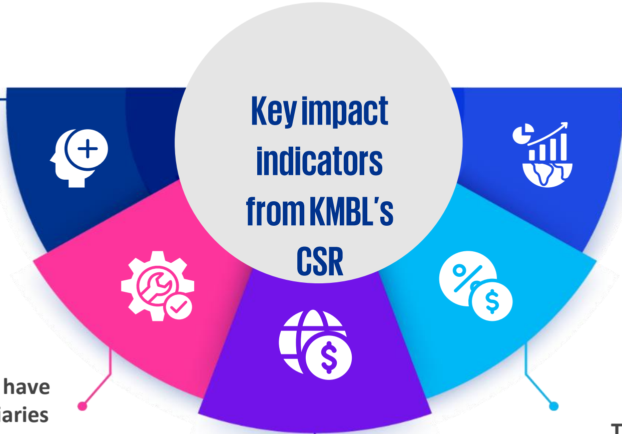
The bank tries to promote diversity and create opportunities for vulnerable communities, ensuring that everyone regardless of background has an equal chance to participate and benefitted from social and economic growth.

Through this pillar the bank emphasizes on benchmarking excellence by strengthening organizations that deliver essential services to ensure long term impact and sustainable development.

Kotak Mahindra Bank's CSR strategy emphasizes creating measurable impact across its core pillars, with environmental conservation as a key focus area. The Bank invests in initiatives that strengthen India's ecological infrastructure, promote sustainable water management, and foster community participation. These efforts integrate environmental restoration with social development, positioning the Bank as a responsible corporate citizen committed to building a sustainable and resilient future.

Source:

1. Kotak Mahindra Annual Action Report, 2025



CSR initiatives are focused in areas such as **Education, Livelihood enhancement, Entrepreneurship and Innovation, Healthcare, Environment and Sustainable Development, Relief and Rehabilitation and Sports.**

Kotak Mahindra Group invested **₹389.3 crore** in CSR initiatives during FY 2024–25, covering education, livelihood, healthcare, environment, relief, rehabilitation, and sports, reflecting strong commitment to community development.

The company's CSR initiatives have benefitted 14.6 lakh+ beneficiaries which reflects the wide reach and effectiveness of its programs.

1.5 lakh+ saplings planted and **16 lakh+ KL water harvesting capacity created**, driving climate resilience and environmental sustainability through Kotak's CSR activities.

The CSR programs focusing on sports has trained 30+ professional athletes who won **80+ medals** at national and international levels, strengthening India's sports ecosystem.

Global Context

Water is the foundation of life and the most critical natural resource for sustaining ecosystems, human health, and economic development. It regulates climate, supports biodiversity, and enables every biological process. Beyond drinking and sanitation, water underpins food security, without it, agriculture collapses, and societies face hunger and poverty. Globally, freshwater availability is under severe stress: the UN warns that by 2030, nearly half the world's population will experience water scarcity.[1] This is not just a resource issue; it is a survival challenge. Water scarcity is intensifying driven by population growth, climate change, and infrastructure decay. Around one-third of the world's population lacks access to safely managed drinking water, and semi-arid regions are especially vulnerable due to irregular rainfall and high evapotranspiration. According to the World Bank, India has 18% of the world's population but only 4% of global water resources.[2] This scarcity also threatens wildlife and natural habitats, disrupting biodiversity and destabilizing ecosystems. When water systems fail, the ecological balance collapses, affecting forests, wetlands, and species survival.

Indian Context

In India, the pressure on water systems is acute. In 2023, 91 million Indians lacked access to safe water. Southern states including Karnataka and Andhra Pradesh are experiencing significantly low reservoir levels only around 17–29% of capacity, far below the decade-average. This situation reflects broader trends in South India where El Niño-driven poor monsoon seasons and rising temperatures have exacerbated drought conditions.

Sources:

1. United Nations World Water Development Report (UNESCO, 2023)

2. World Bank Report 2023

Water tanks have been an integral part of Karnataka's traditional water management system for centuries. Known locally as kere, kalyanis, or pushkarinis, these tanks were ingeniously designed to capture monsoon rainwater, recharge groundwater, and provide irrigation for crops. They also served as community hubs, supporting livestock, fisheries, and even cultural rituals. Historically, these tanks played a critical role in sustaining agriculture in semi-arid regions, where rainfall is erratic and groundwater reserves are limited. However, despite their historical and ecological importance, many of these tanks have fallen into neglect. Siltation, caused by soil erosion and runoff during rains, has drastically reduced their storage capacity. Encroachment for urban development, pollution from agricultural chemicals, and lack of maintenance have further degraded these systems. According to the Central Pollution Control Board, a significant proportion of India's water bodies suffer from siltation and contamination, leading to poor water quality and loss of aquatic biodiversity.[3] This deterioration not only impacts irrigation but also disrupts ecosystems and community livelihoods.

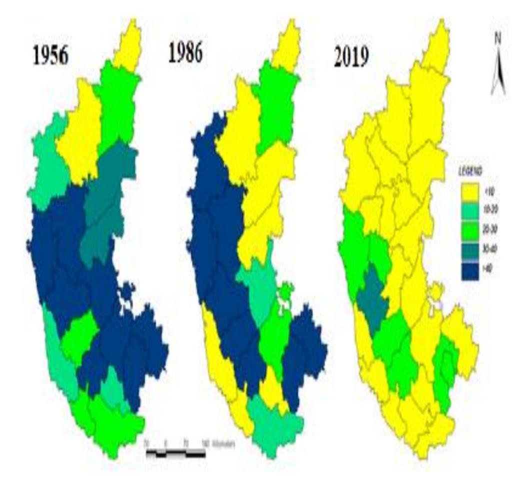


Fig. 4. Spatial distribution of area under tank irrigation (area in percentage)

Historically, most of Karnataka's large tanks were constructed by rulers, chieftains, wealthy merchants, or religious patrons as acts of charity. These tanks, often referred to as sagaras or lakes, were engineering marvels of their time. However, such large tanks are rare; more than 90% of Karnataka's tanks are small units, each serving less than 40 hectares of ayacut, and about 16,400 tanks irrigate less than four hectares each. Tank irrigation once accounted for 44.25% of Karnataka's net irrigated area in 1956–57, but this share has plummeted to just 6.17%. This decline is primarily due to siltation, collapse of old weirs, and inadequate maintenance funding. Government allocations for tank upkeep remain insufficient, and irrigation users rarely contribute to restoration costs, allowing enormous potential to go untapped. Over 70% of the 3,524 minor irrigation tanks in Karnataka have gone dry due to poor monsoon rains, leaving only 1% of tanks with more than 50% storage capacity.[4]

% of area under tank irrigation	1956		1975		2019	
	No. of districts	% of districts	No. of districts	% of districts	No. of districts	% of districts
< 10	2	10.53	7	36.84	20	74.07
10 – 20	3	15.79	2	10.53	-	-
20 – 30	4	21.05	2	10.53	6	22.22
30 – 40	2	10.53	-	-	1	3.70
> 40	8	42.11	8	42.11	-	-
Total	19	100	19	100	27	100

Source: Hand book of Karnataka and Suvarna Karnataka

Thus, tanks are more than water storage structures, they are ecological assets that maintain soil moisture, prevent floods, and sustain biodiversity. Their decline has cascading effects: groundwater depletion, crop failures, and increased vulnerability to drought. In Andhra Pradesh, similar traditional tanks (cheruvus) once sustained agriculture and village life but now face the same challenges. Reviving these tanks is critical because they are cost-effective, decentralized solutions that can mitigate drought, stabilize rural economies, and restore ecological balance. Without them, water scarcity will continue to threaten food security, rural livelihoods, and biodiversity.

Source:

3. Annual report 2021-22, CPCB, Ministry of Environment, Forest and Climate, GoI)

4. Changes in the area under tank irrigation in Karnataka – A spatio-temporal analysis

Importance for Farmers and Agriculture

Water is the single most important input for agriculture, accounting for nearly 70% of global freshwater withdrawals.[5] Without reliable water supply, crop yields decline, soil fertility deteriorates, and rural economies collapse. Alongside water, resources like fertile soil, organic matter, and biodiversity are essential for sustainable farming. Healthy ecosystems regulate water cycles, prevent soil erosion, and maintain nutrient balance all of which are vital for productive agriculture.

For farmers, water is not just a resource—it is the foundation of agricultural productivity. Crops require adequate water for germination, growth, and yield. In semi-arid regions like Karnataka and Andhra Pradesh, where rainfall is unpredictable, tanks provide a lifeline by storing water for irrigation during dry spells. They reduce dependence on groundwater, which is rapidly depleting due to over-extraction.

Tanks also improve soil moisture, reduce fertilizer requirements, and enable multiple cropping cycles, thereby increasing farm income. Beyond irrigation, tanks support livestock and fisheries, creating supplementary income streams for rural households. They help maintain ecological balance by recharging aquifers and sustaining biodiversity, which indirectly benefits agriculture through pollination and pest control. In short, tanks are critical for ensuring agricultural sustainability, food security, and rural resilience thus as climate change intensifies droughts and floods, integrated water management systems like tanks become indispensable for adapting to these challenges.

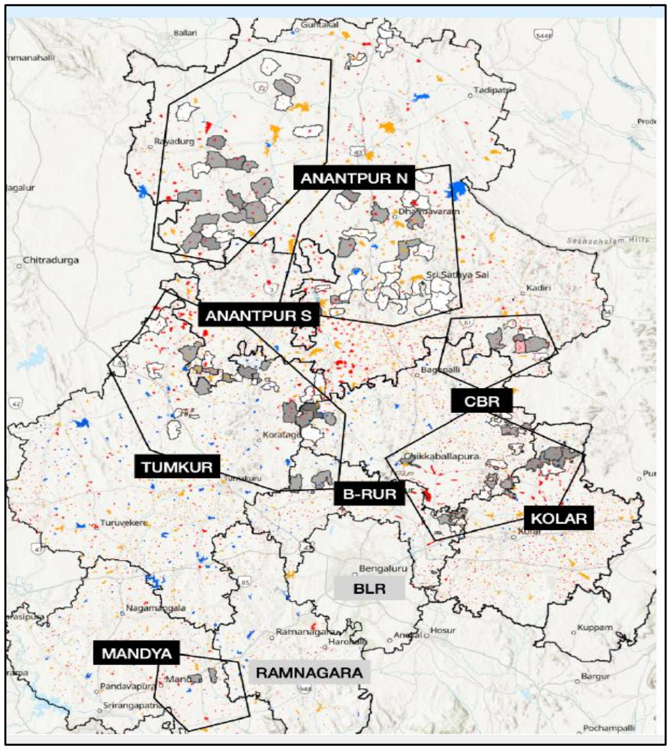
About Sahakara Mitra Samstha - Centre for Collective Development (CCD)

The Sahakara Mitra Samstha - Centre for Collective Development (CCD) is a non-profit organization founded in 2003 with the mission to transform the lives of small and marginal farmers in India. CCD works primarily in the states of Karnataka, Andhra Pradesh, Telangana, and Maharashtra, focusing on building sustainable livelihoods through the establishment of member-owned, member-managed, and member-controlled cooperatives. By educating farmers about the power of collective methods and guiding them in harnessing these techniques, CCD helps reduce systemic inefficiencies in agriculture. The organization supports over 43,000 farmers across 1,200 villages, enabling them to cut down costs, improve yields, receive fair value for their crops, and gain better control over market fluctuations. CCD's initiatives have enhanced agricultural productivity, reduced dependency on chemical fertilizers, and increased farmers' incomes, thereby contributing to the overall socio-economic development of rural communities.

Source:

5. United Nations World Water Development Report (UNESCO, 2023)

About the Project



Kotak Mahindra Bank has initiated a waterbody restoration program focused on rejuvenating traditional tanks and lakes in Karnataka and Andhra Pradesh. The project involves scientific desiltation techniques to remove accumulated silt, improve water storage capacity, enhance groundwater recharge, and support the restoration of ecosystems that encourage biodiversity. Alongside ecological interventions, the initiative emphasizes community engagement through farmer awareness programs and Gram Panchayat participation, ensuring long-term sustainability and stewardship.

Expected Outcomes

The restoration of 5 waterbody is designed to deliver measurable ecological, climatic, and social benefits shown as follows:

ECONOMIC

- Increased agricultural productivity through improved irrigation and soil fertility from nutrient-rich silt.
- Reduced input costs for farmers (lower fertilizer and water expenses).
- Enhanced rural income through fisheries and livestock supported by restored waterbodies.

SOCIAL

- Strengthened community participation and ownership of water resources.
- Improved access to drinking water for rural households and livestock.
- Creation of local employment opportunities during restoration activities.

ECOLOGICAL

- Revival of biodiversity in and around tanks, supporting aquatic life and natural habitats.
- Prevention of soil erosion and restoration of watershed health.
- Increased surface water storage and groundwater recharge to mitigate drought impacts.

Project Objectives

The overarching goal of the initiative is to rejuvenate degraded water bodies across India and transform them into sustainable freshwater ecosystems that enhance ecological health and community engagement. The specific goals are as follows:

Increase Water Storage Capacity:

Enhance the capacity of water across waterbodies to hold more surface water and improve groundwater recharge based on standard guidelines.

Expand Agricultural Coverage

Increase the coverage of land (in acres) where silt application will benefit farms, improving soil fertility and crop productivity.

Promote Sustainable Practices

Encourage environmentally friendly and sustainable agricultural practices through the use of natural resources like tank silt.

Boost Crop Yield and Farmer Income

Improve crop yield and farmer income by reducing fertilizer and water usage, thereby lowering input costs.

Reduce Rural Migration

Minimize migration from villages to cities by creating livelihood opportunities through improved agricultural conditions.

Strengthen Community Engagement

Increase community participation and awareness, making local stakeholders responsible for maintaining and preserving waterbodies.

02

Methodology

Objective of the study:

This impact assessment study employed the OECD-DAC evaluation framework, a globally recognized approach for evaluating social impact initiatives. The framework facilitates a qualitative analysis of the effectiveness, relevance, and sustainability of development interventions. The assessment was guided by six core criteria: relevance, coherence, effectiveness, efficiency, impact, and sustainability. The following overview outlines how each of these criteria was applied within the context of the project.

Stakeholder interaction with farmers

OECD-DAC evaluation framework

Relevance

Asks: Is the project addressing the right needs?

Assesses: It examines how well the project addresses the actual needs, the local context, and broader development goals, ensuring it is meaningful and responsive to the community and stakeholders.

Effectiveness

Asks: Is the project achieving its intended results?

Assesses: It measures the extent to which the project has achieved its intended objectives and delivered its expected outcomes.

Sustainability

Asks: Will the benefits last over time?

Assesses: It assesses whether the benefits of the project are likely to continue after external support of funding ends.

Impact

Asks: What difference has the project made?

Assesses: It examines the broader, long- term effects of the project, both positive and negative on individuals, communities, and the ecosystem.

Efficiency

Asks: Are resources being used wisely?

Assesses: It evaluates how economically resources such as time, funds, and materials were converted into results, emphasizing cost effectiveness and optimal use of inputs.

Coherence

Asks: How well does the project fit within the larger system?

Assesses: It analyses how well the project complements or aligns with other policies, interventions, SDGs and programs within the same context or sector.

The project evaluation based on OECD-DAC parameters effectively communicates the project's strengths and areas for improvement, providing a comprehensive overview for stakeholders and decision-makers.

This section details the approach, methodology, and sampling techniques employed to conduct an in-depth evaluation of the CCD; water tank de-siltation project. The study was designed to capture both qualitative and quantitative insights ensuring a comprehensive assessment of the project's impact and effectiveness.

- **Literature review:** A thorough review of existing literature was conducted, utilizing academic and industry sources. This involved a systematic search across relevant databases, publications, and publicly available industry documents to establish a foundational understanding of the research context and identify gaps addressed by the project.
- **Survey Design:** A survey tool was developed, grounded in the research questions and objectives of the study. It was designed to capture qualitative data and complemented by a detailed technical analysis plan to evaluate the impact of the environmental conservation and restoration activities.
- **Survey Distribution:** KPMG India resource personnel conducted the surveys in person by visiting the project location. Data collection was facilitated through a survey tool for efficiency and accuracy. A robust sampling method was employed to ensure a structured, representative sample reflective of the target population.
- **Interviews:** Structured, semi-structured interviews and Focus Group Discussions (FGDs) were conducted with key stakeholders, offering rich quantitative and qualitative insights. These stakeholders included- maintenance team and NFS team. The interviews served to explore the conditions, challenges, and changes seen after the project implementation, which were further analyzed thematically.
- **Data Analysis:** Thematic analysis was applied to data gathered through interviews and surveys, identifying recurring patterns and overarching themes.

- **Technical Analysis:** Few detailed Technical analysis were conducted for this project to provide scientific validation and strengthen the evidence base for the environmental interventions undertaken under this project and triangulating with our thematic analysis. Some of those are:

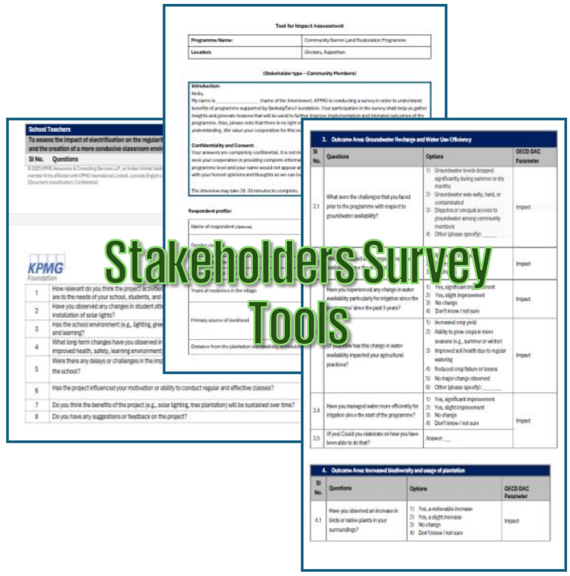
1. **Soil Analysis:** This assessment will evaluate soil health to measure moisture, infiltration and nutrient dynamics utilizing using satellite datasets (Sentinel and Landsat) which helps to understand the ecological baseline and improvements, of afforestation or restoration efforts.
2. **Normal Difference Vegetation Index:** This assessment will evaluate vegetation health and density by analyzing spectral reflectance in the red and near-infrared bands using satellite datasets (Sentinel and Landsat). NDVI helps establish an ecological baseline and monitor improvements in vegetation cover resulting from afforestation or restoration efforts.
3. **Normal Difference Moisture Index:** This assessment will measure vegetation moisture content and drought stress by utilizing shortwave infrared and near-infrared bands from satellite datasets (Sentinel and Landsat). NDMI provides insights into water availability and plant stress, supporting evaluation of ecosystem resilience and restoration progress.
4. **Land Cover and Land Use Analysis:** This assessment will analyze changes in land use and land cover patterns to understand the spatial dynamics of vegetation, built-up areas, and water bodies. Using high-resolution satellite datasets (Sentinel and Landsat) and GIS tools, the study will establish a baseline and monitor shifts resulting from restoration interventions. This helps evaluate ecological improvements, identify encroachment risks, and guide future planning for sustainable lake and catchment management.
5. **Groundwater Assessment:** Through remote sensing indices and piezometric observations, this will help to quantify recharge efficiency, water availability, and seasonal resilience which helps to understand how restoration interventions have contributed to water conservation and improved hydrological balance.

- **Synthesis and Reporting:** The findings from the literature review and interviews were synthesized to develop a comprehensive understanding of the project’s impact. The synthesis process identified key themes, trends, and potential gaps, providing actionable insights for enhancing the project outcomes. The results of the study are compiled in this report, encompassing key findings and actionable recommendations for improving future study and practices.

Tools for the study

A combination of tools was utilized to ensure accurate and reliable data collection during the study:

- **Focused Group Discussions (FGDs):** Conducted with farmers to capture collective perceptions and the broader impact of the Project.
- **Key Informant Interviews (KIIs):** Conducted with project team, Gram panchayat to gain insights into the Project implemented by CCD. These interviews aimed to understand the broader impact of the project from the perspective of observers rather than direct beneficiaries.
- **In depth Interviews:** In depth interviews were conducted with farmers for the understanding of the project outcomes and broader impact.



Sampling methodology and sample size

The sample size for the study was determined using the purposive sampling ensuring a structured and representative sample population to engage secondary stakeholders such as program team, maintenance workers selected for their relevance and ability to provide informed insights.

A total of 107 interviews were conducted, capturing diverse stakeholder perspectives. This included:

- 4 key informant interviews were conducted with program team.
- 3 key informant interviews with the Gram Panchayat Members were conducted to understand the condition of their village post project implementation and their participation levels in sustaining the project.
- 3 focused group discussion was conducted with the farmers to understand their current situation and challenges faced to better understand project's broader impact.
- 85 in depth interviews were conducted with farmers to understand their pre post situation and the current set of challenges and development they have seen.

Identified Stakeholders	Tools Utilized	Sample Covered
Program Team	Key informant interviews	4
Gram Panchayat	Key informant Interviews	3
Farmers	In depth interviews	85
	Focused Group Discussions	15
Total		**107**

Ethical considerations for data privacy

On 4th -5th November, KPMG resource personnel visited the project site in Karnataka. During the visit, the following ethical principles were carefully observed and adhered to.

- Informed consent: The interviews were done after the respondents gave their consent. Even after the interviews were completed, their permission was sought to proceed with their responses.

- Confidentiality: The information provided by participants has been kept private. At no point were their data or identities disclosed. The research findings have been quoted in a way that does not expose the respondents' identities.

- Comfort: The interviews were performed following the respondents' preferences. In addition, the interview time was chosen in consultation with them. At each level, respondents' convenience and comfort were considered.

- Right to reject or withdraw: Respondents were guaranteed safety and allowed to refuse to answer questions or withdraw during the study.

Theory of change: Sahakara Mitra Samstha Centre For Collective Development (KMBL202324059)

Input	Activities	Output	Outcome	Impact
Financial resources from Kotak Mahindra Bank Limited Human resources IIT-IIT WebApp & scientific tools NGO partners & community anchors Farmer participation & GP permission Waterbody data across 6 districts	Farmer & community engagement Desilting of waterbodies Surface water capacity creation Waterbody system restoration Cluster GP model implementation Surveys and data collection Capacity building and training	56 modules of silt removed 56 Crore Liters water capacity created 31 GPs saw improved water access, better crop yields 771 farmers benefitted across 5 districts from improved water access supporting their livelihood 8 clusters formed, with 1 reaching 10+ modules of silt removal	Improved Water flows better across villages reducing water stress. Sustained engagement and ownership of waterbody systems by GPs Economic upliftment in farmer incomes due to better crop yields and reduced input costs. Enhanced surface water availability for irrigation and domestic use Increased farm productivity, reduced input costs, and better crop yield Improved soil fertility Potential for fisheries, plantations, and agri-linked livelihoods created	Improved local water availability and reduce water stress Enhanced soil quality and water retention leading to sustainable farming practices Improved watershed ecosystems and ecological balance Strengthened data-driven governance and community ownership

03
Findings

Findings:

This chapter presents the findings from the impact assessment of the integrated waterbody restoration initiative implemented across Andhra Pradesh and Karnataka under the Kotak Mahindra Bank-supported program. The evaluation examines how interventions such as desilting, embankment strengthening, inlet and outlet regulation, and biodiversity enhancement have contributed to improving water storage capacity, ecological health, and climate resilience. Outcomes are analyzed against defined indicators and aligned with recognized evaluation principles. The review also explores the project's potential to establish sustainable freshwater ecosystems and create a holistic conservation model that delivers long-term ecological, economic, and social benefits for the communities and regions involved.

Improved Local Water Availability and Reduced Water Stress

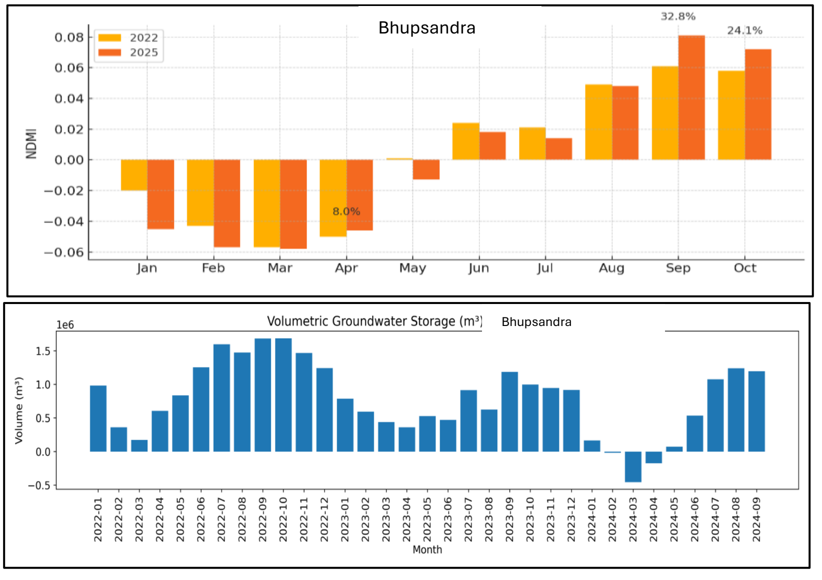
Local water availability is a critical lifeline for agricultural areas, as it directly influences crop productivity, farmer livelihoods, and overall food security. In regions dependent on groundwater and seasonal rainfall, any decline in water resources can lead to severe stress on both ecosystems and communities. Ensuring sustainable water availability is therefore essential for maintaining agricultural resilience and reducing vulnerability to droughts.

Under this project, targeted interventions such as desilting of tanks, construction of recharge structures, and restoration of natural drainage pathways were implemented to enhance water storage and infiltration. To assess improvements, two complementary indicators were analyzed:

NDMI (Normalized Difference Moisture Index) – derived from Sentinel-2 satellite imagery using NIR and SWIR bands. NDMI reflects vegetation moisture, helping us understand surface and canopy water stress.

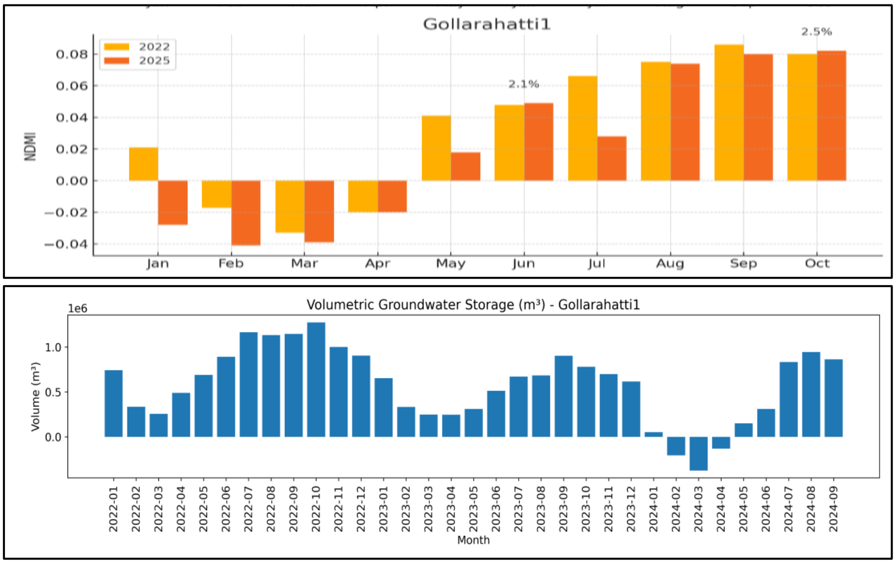
Groundwater Storage Anomaly (GWSA) – downscaled from GRACE satellite data to 100 m resolution using rainfall, NDVI, temperature, and terrain predictors. This metric reveals deep aquifer storage changes, indicating long-term water security.

Firstly, at Bhupsandra the NDMI analysis shows early-season dryness in 2025, but a strong recovery during monsoon months, indicating improved surface moisture availability. Groundwater peaked at 1.6 × 10^6 m^3 (≈ 25 cm) in 2022, reflecting robust recharge after monsoon interventions like desilting and check dams. However, by early 2024, storage dropped to –0.4 × 10^6 m^3 (≈ –6 cm), signaling severe aquifer depletion despite surface moisture gains.



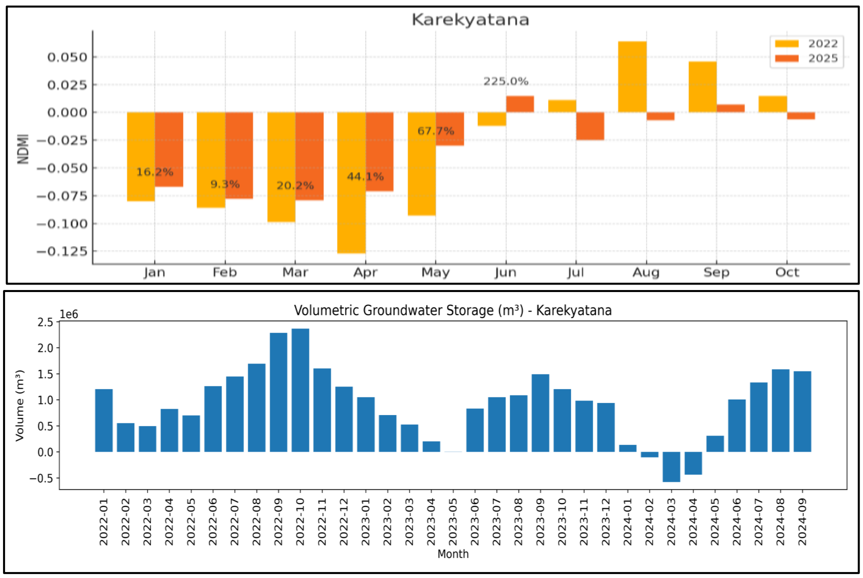
Volumetric Groundwater and NDMI analysis for Bhupsandra

At Ajjenhali the NDMI trends show modest improvement during monsoon, suggesting better soil moisture retention. Yet groundwater decreases from 1.2 × 10^6 m^3 (≈ 20 cm) in 2022 to –0.3 × 10^6 m^3 (≈ –5 cm) in 2024. The gap between vegetation moisture and aquifer recharge underscores over-extraction and low infiltration efficiency.



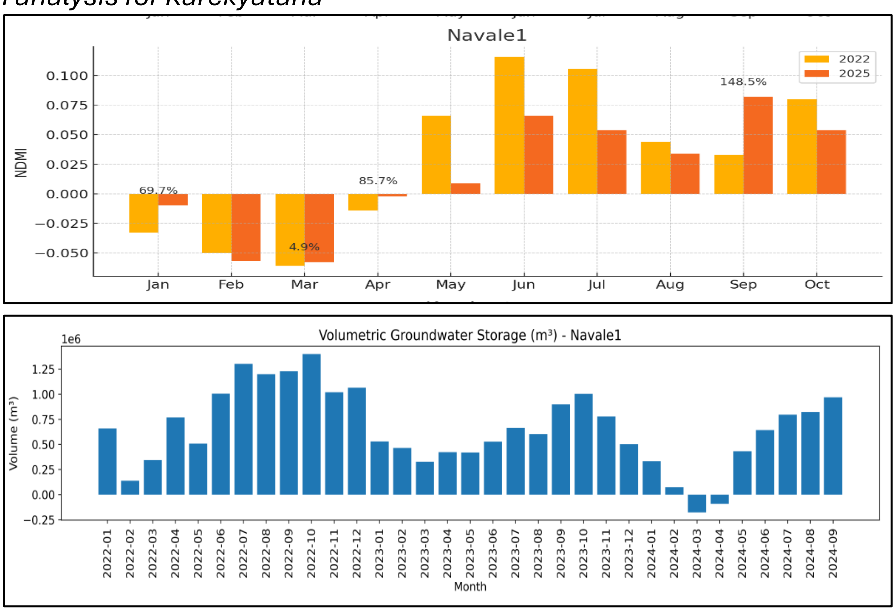
Volumetric Groundwater and NDMI analysis for Ajjenhali

Karekyatana shows highest increase in NDMI surge in 2025, with a 225% increase in June, reflecting good crop moisture and soil water retention. Groundwater mirrored this strength initially, peaking at 2.3–2.4 × 10^6 m^3 (≈ 35–37 cm) in late 2022. However, by early 2024, storage collapsed to –0.5 × 10^6 m^3 (≈ –8 cm), indicating severe aquifer stress despite surface gains.



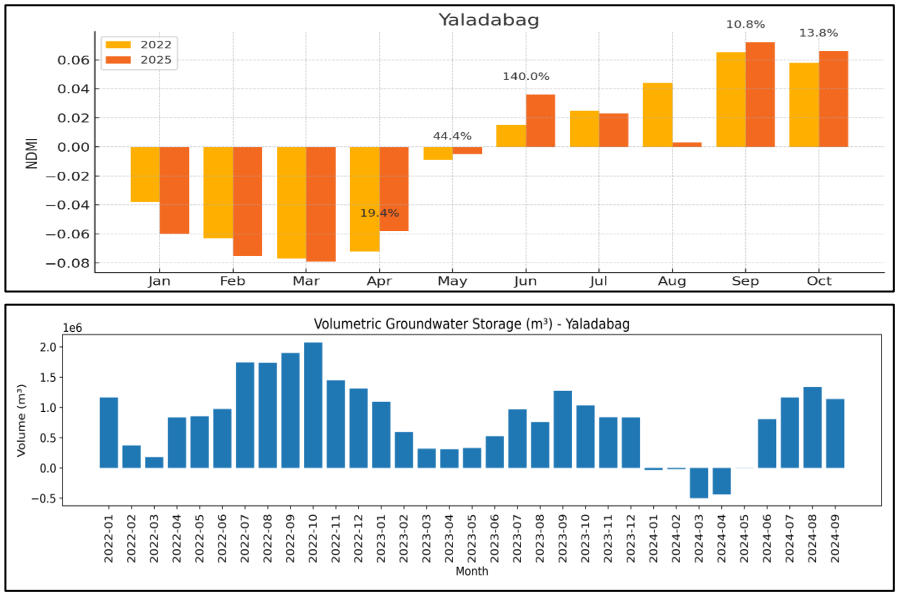
Volumetric Groundwater and NDMI analysis for Karekyatana

At Naveli NDMI improved steadily during monsoon months, with a 70% rise in May 2025, signaling better soil moisture conditions. Groundwater peaked at 1.3 × 10^6 m^3 (≈ 25 cm) in 2022 but declined to –0.2 × 10^6 m^3 (≈ –4 cm) in 2024. Although partial recovery occurred mid-2024, levels remained well below baseline, indicating moderate vulnerability.



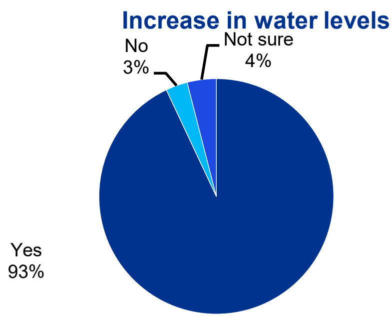
Volumetric Groundwater and NDMI analysis for Naveli

Yaladabag recorded the highest groundwater availability in 2022, with storage peaking at approximately 2.0×10^6 m^3 (≈ 29 cm) during September–October. By 2024, storage collapsed to about -0.5×10^6 m^3 (≈ −7 cm), reflecting excessive extraction and reduced rainfall. Seasonal peaks weakened each successive year, confirming the need for aggressive recharge strategies.



Volumetric Groundwater and NDMI analysis for Yaladbhag

Increased water levels

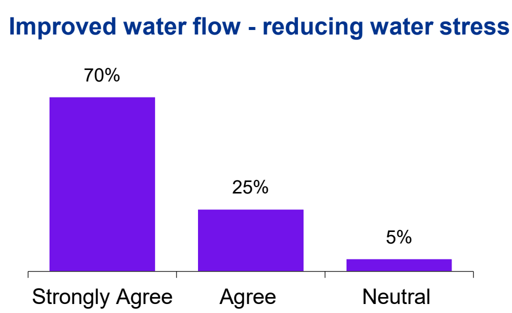


Basis the sampled interactions, it was observed that majority of respondents acknowledged positive changes in water availability following project interventions. About 93% reported experiencing increased water levels in wells, tanks, or farm ponds after activities such as desilting and construction of recharge structures. In contrast, 3% stated they did not notice any improvement and 4% were unsure, highlighting the need for continued awareness and monitoring to validate and communicate the benefits of these interventions effectively.

“Earlier, we had to dig borewells up to 900 feet to find water. Now, water is available at 600–700 feet. This improvement in the water cycle has made farming less stressful and more sustainable.
— Farmer at Karekyatna Lake

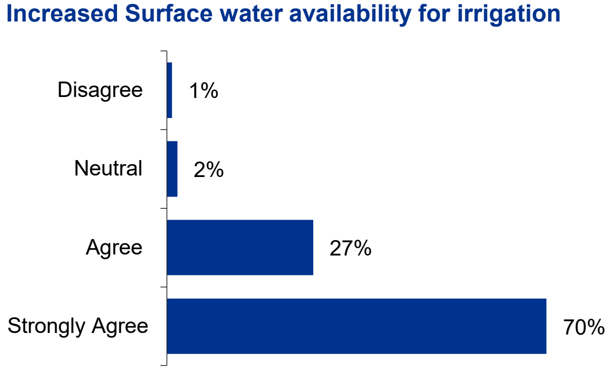
“Failed borewells have been recharged, and water is now available at 10–15 feet instead of 25 feet. This improvement in water availability has made farming more sustainable and less dependent on deep drilling.”
— Farmer at Yaladbag Lake

Reduced water stress post improved water flow



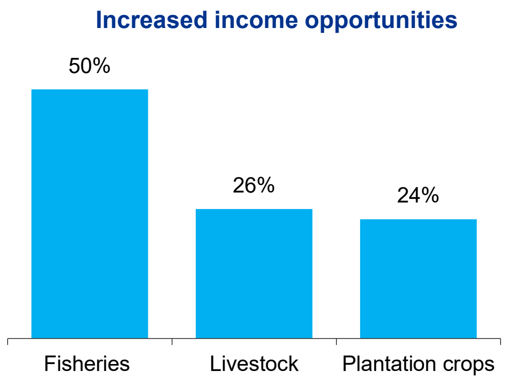
Basis the interaction with the sampled beneficiaries it was observed that there are positive response to project interventions aimed at improving water availability. A substantial 70% of respondents strongly agree that there has been an increase in water flow and a reduction in water stress, while 25% agree, reinforcing the perception of significant improvement. Only 5% remained neutral. This overwhelming consensus (95% positive responses) demonstrates that the project has effectively addressed water scarcity concerns, leading to benefits for agricultural activities and household water security. Such strong community endorsement underscores the success of interventions like desilting, recharge structures, and water conservation measures, and highlights the importance of sustaining these efforts for long-term resilience.

Increased surface water availability for irrigation



Basis the sampled interactions, it was observed that a there is improved surface water availability for irrigation. A dominant 70% of respondents strongly agree with this statement, while an additional 27% agree, bringing the total positive response to an overwhelming 97%. Only 2% remained neutral, and a negligible 1% disagreed, suggesting that skepticism is minimal. This near-unanimous agreement reflects the success of measures such as desilting, tank restoration, and construction of recharge structures, which have enhanced water storage and accessibility for agricultural use. The findings underscore the positive impact of the project on irrigation potential, contributing to improved crop productivity and farmer confidence.

Diversified Livelihood Opportunities due to water availability

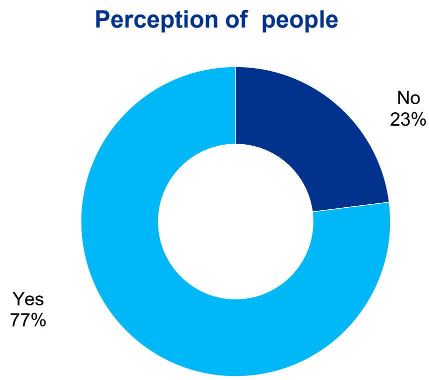


Basis the interaction with the sampled beneficiaries it was observed that the improved water availability has not only reduced water stress but also opened up new livelihood opportunities for communities as 50% of respondents have engaged in fisheries, leveraging restored tanks and ponds to rear fish and sell them in nearby markets, creating a steady income stream. Additionally, 26% have invested in livestock, with milk being sold to local dairies such as the state-run Nandini, providing regular cash flow. Furthermore, 24% have shifted to plantation crops like coconut and areca nut, medicinal plants, marigold and other flowers which offer higher economic returns compared to traditional crops. These changes indicate that water interventions have catalyzed diversified income sources, enhancing household resilience and contributing to broader socio-economic development.

"Now with the increased water availability I have started planting Marigold and Areca Nut and thinking of planting some medicinal plants as they give much better yield & income."
— Farmer at Karekyatana Lake

Community Perception on Project Importance

It was observed that majority of respondents—77%—felt that this project was important to reduce water stress in their village, highlighting widespread recognition of its relevance and impact. Only 23% did not agree, which may reflect localized challenges or differing priorities. This high level of agreement underscores the project's success in addressing a critical community need and reinforces the importance of continuing such interventions to ensure sustainable water management and resilience against future scarcity.



Thus, it can be concluded that although NDMI shows improvement in certain months for all the locations indicates better surface and soil moisture, but this does not automatically translate into groundwater recharge as NDMI only reflects upper soil moisture, not deep aquifer replenishment. The combination of high NDMI and low GWSA signals that water is retained in shallow layers due to:

- Higher evapotranspiration during hot months
- Soil saturation without deep percolation, especially in areas with hard lateritic layers
- Impermeable surfaces from urbanization, reducing infiltration

Thus, this reflects the common theme for all the locations that the human extraction exceeds natural replenishment, and this imbalance is driven by following reasons as per the technical analysis:

Domestic Use: Increased borewell dependency, multi-story apartment consumption, and limited municipal supply

Agricultural Use: Intensive irrigation during Rabi and summer seasons; shallow wells drying up, forcing deeper borewell drilling

Industrial Use: Small-scale industries in peri-urban areas relying on continuous borewell pumping

Reduced Rainfall: Rainfall declined in 2023-2024 as reflected by the CHIRPS data, weakening soil moisture recharge, aquifer replenishment, baseflow contributions.

Further, interactions with sampled beneficiaries and field observations also revealed that farmers have started diversifying crops shifting from traditional staples to marigold, coconut, areca nut, and other high-value crops. NDMI improvements during monsoon months reflect this change, as these crops maintain canopy moisture longer. While income diversification through livestock, fishing, and plantation crops like marigold, coconut, and areca nut has boosted livelihoods, it has also increased water demand—particularly for perennial crops that require sustained irrigation. Farmers in locations such as Yaladabag, Karekyatana, and Bhupsandra have even initiated fish farming in restored tanks, signaling improved surface water availability but has accelerated groundwater depletion, as water is diverted for multiple uses. As per ICAR guidelines, optimized irrigation systems like drip irrigation require approximately 20 liters[1] per areca palm per day and 24 liters[2] per coconut palm per day. In practice, manual irrigation often uses significantly more water, which can be attributed to the depletion levels observed.

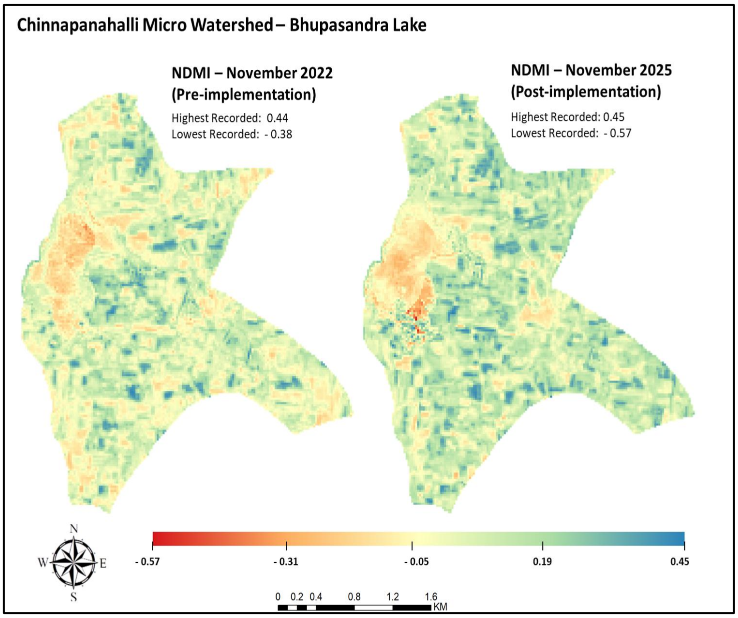
Thus, the current condition demands better cooperation and governance to set water use thresholds and promote integrated water management. If these are managed well this can led to some social and economic benefits as well like higher farm incomes through crop diversification and allied activities like aquaculture, can help in reducing migration and debt cycles, strengthening rural livelihoods. Better health and nutrition, as water stress declines. Community empowerment, through participatory water governance and transparent data sharing.

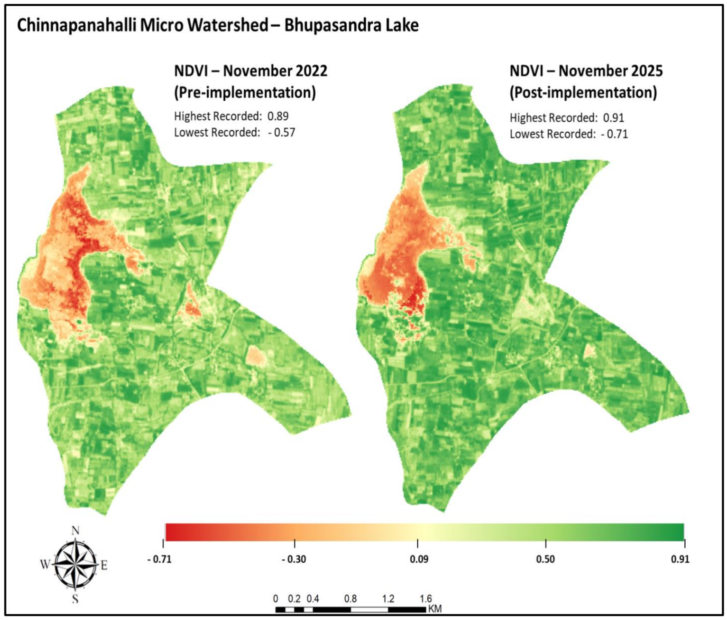
Source: *1. Central Plantation Crops Research Institute. (n.d.). Farmers corner: Crop advice – Arecanut. CPCRI.*

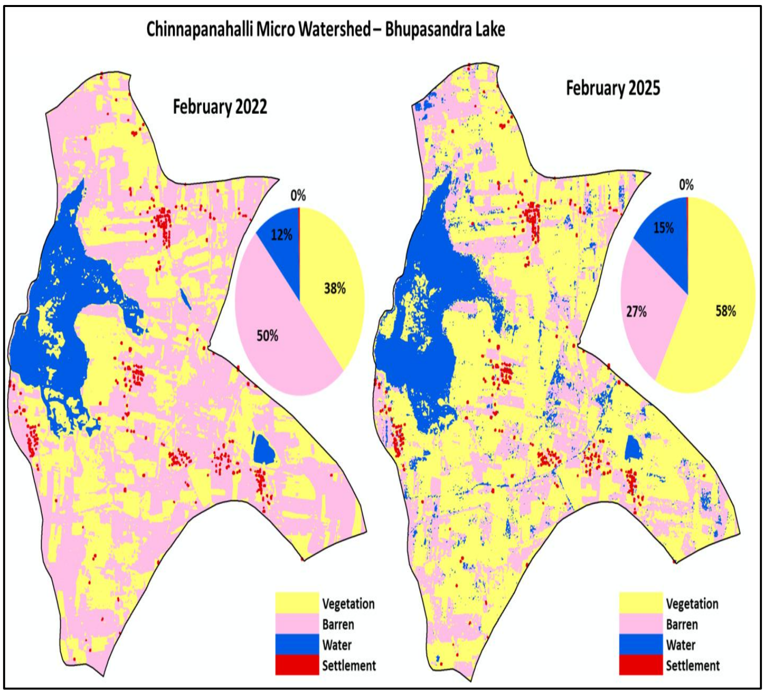
2. Central Plantation Crops Research Institute. (n.d.). Coconut cultivation practices. CPCRI.

Improved watershed ecosystems and ecological balance

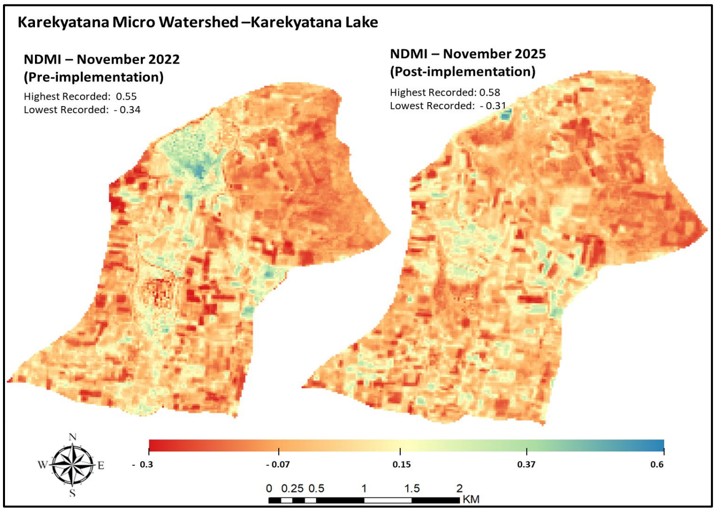
Restoring watershed ecosystems is fundamental to achieving long-term hydrological stability, preserving biodiversity, and ensuring sustainable livelihoods for communities that depend on these resources. Healthy watersheds act as natural sponges, capturing rainfall, recharging groundwater, and maintaining stream flows, which are essential for agriculture, drinking water, and ecological balance. However, years of silt accumulation, unchecked runoff, and land degradation can severely compromise these functions. Thus, this project, through targeted interventions such as lake desiltation, channel restoration, and construction of water retention structures tries to revive these critical ecosystems. This transformation is validated through Land Use Land Cover (LULC) changes, Normalized Difference Vegetation Index (NDVI), and Normalized Difference Moisture Index (NDMI) analysis as follows for each of the site.

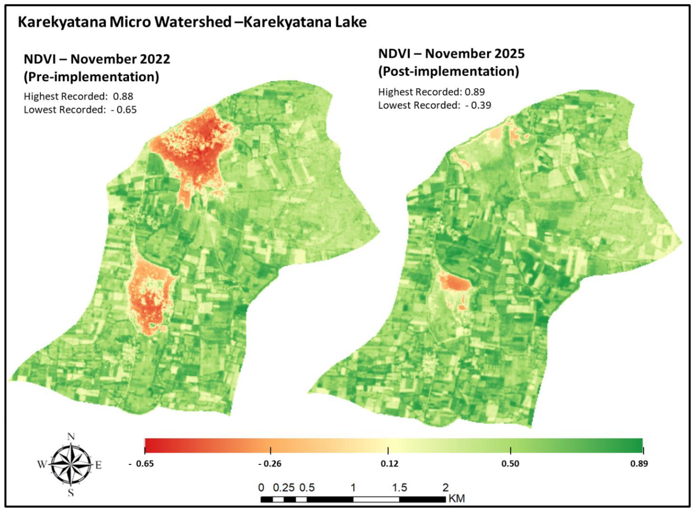


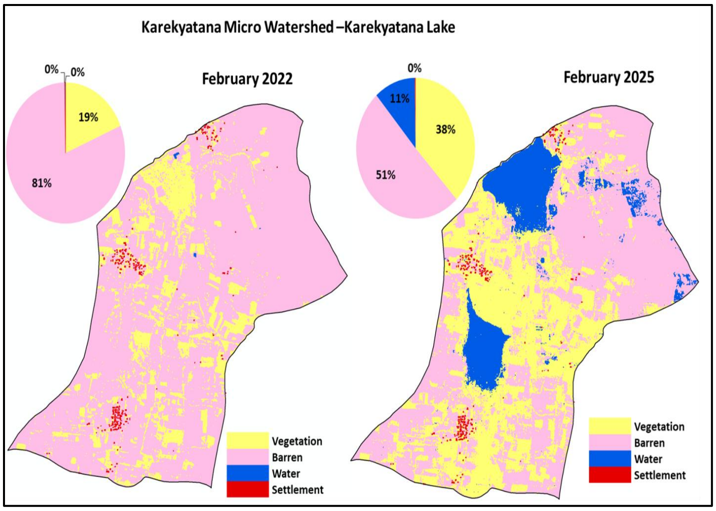




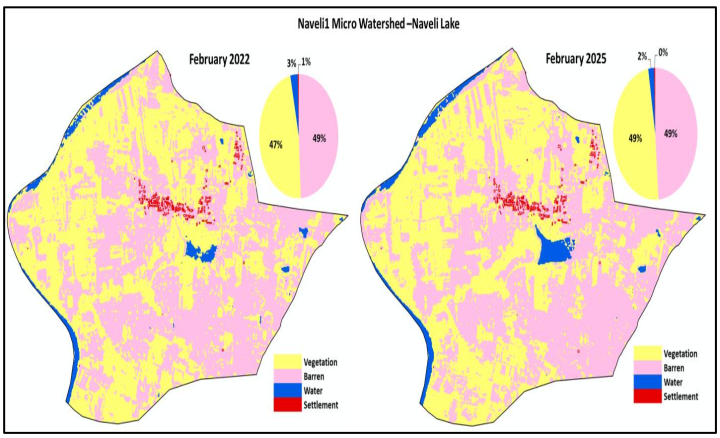
Between 2022 and 2025, Bhupasandra witnessed a 3% (12% to 15%) increase in water spread, a 20% rise in vegetation cover, and a 23% reduction in barren land. This indicates successful ecological restoration driven by lake desiltation and improved water retention. Further Vegetation health improved slightly, with peak NDVI increasing from 0.89 to 0.91, confirming better plant vigor and density. Visual maps show deeper green tones replacing barren patches, validating the LULC greening trend. NDMI: Moisture conditions remained stable, with peak NDMI moving from 0.44 to 0.45. While the improvement is marginal, the expanded water body and consistent moisture signature indicate enhanced hydrological stability.

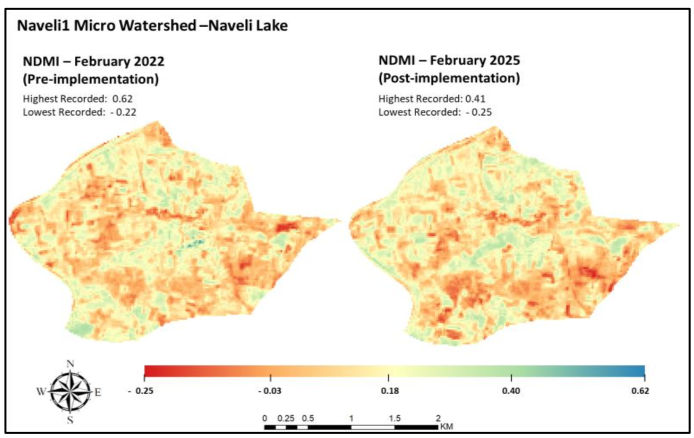




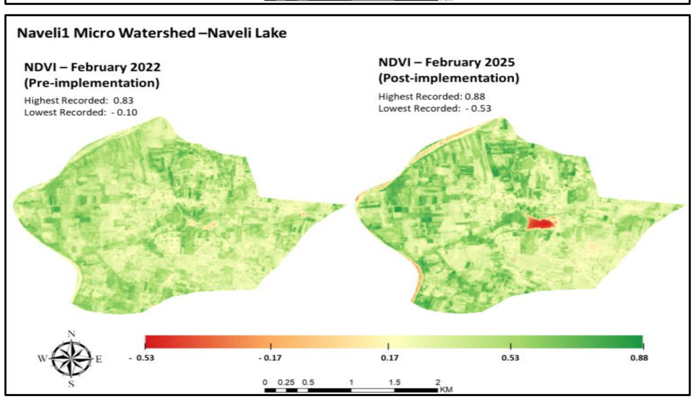


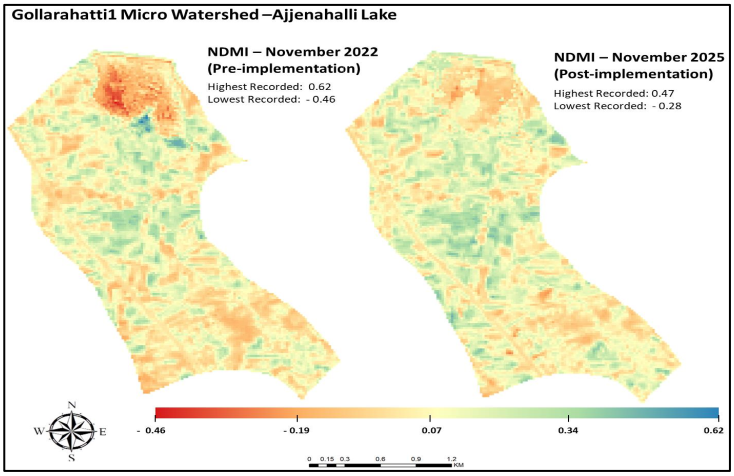
Between 2022 and 2025, at Karekyatana Lake there was the highest increase in water spread from 0% to 11%, vegetation doubled (19%), and barren land reduced by 30%, confirming complete lake revival and ecosystem restoration. Peak NDVI improved slightly from 0.88 to 0.89, while maps show widespread greening replacing barren land. Even moisture conditions improved significantly, with peak NDMI rising from 0.55 to 0.58 and dry extremes improving from -0.34 to -0.31, confirming better soil-water retention and hydrological health leading to better ecological health.

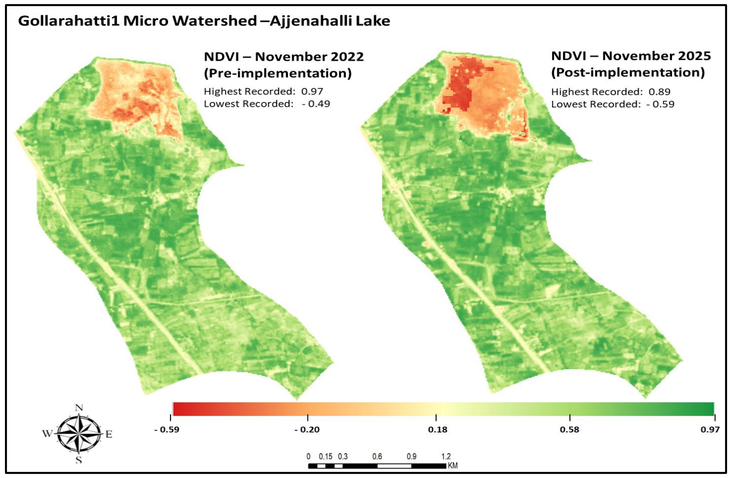




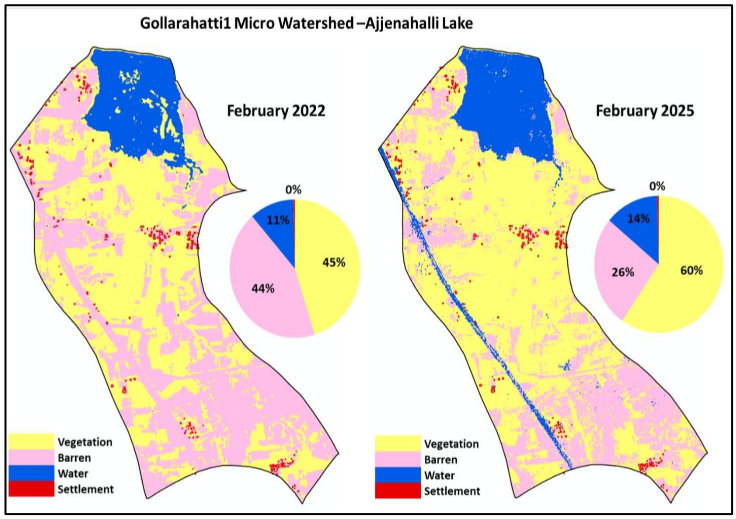
At Naveli vegetation increased by 2%, settlement cleared, but water spread decreased slightly (1%), suggesting localized improvement but limited overall impact. Peak NDVI improved from 0.83 to 0.88, indicating healthier vegetation despite minimal LULC change. However moisture declined, with peak NDMI dropping from 0.62 to 0.41, and dry extremes worsening slightly (-0.22 → -0.25) likely due to seasonal factors like harvesting.

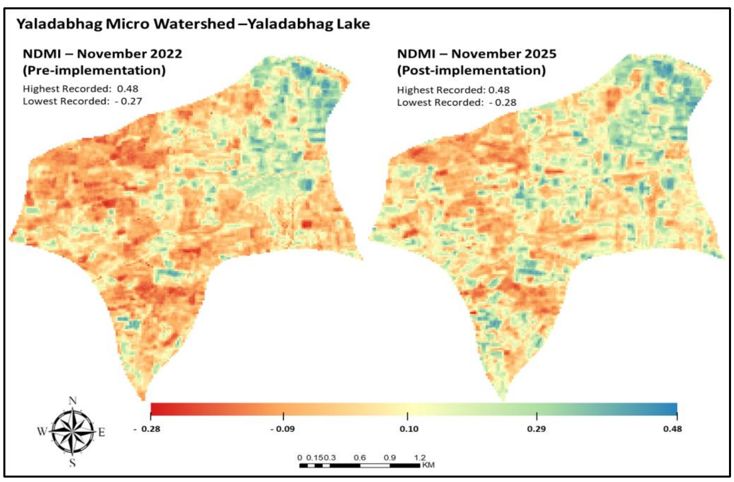


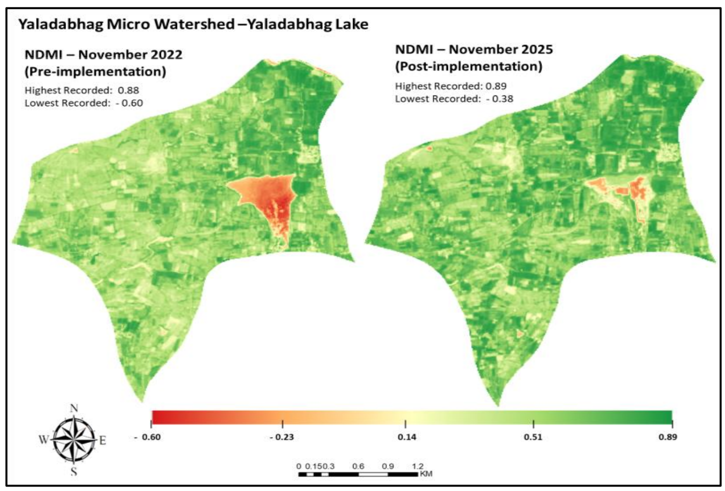




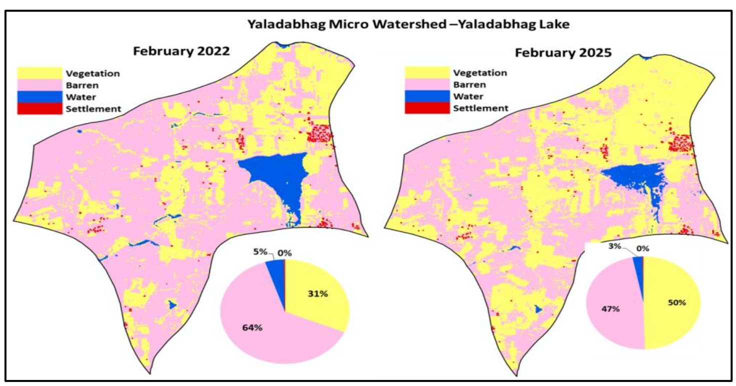
Between 2022 and 2025, the watershed recorded a 3% (11% to 14%) increase in water area, 15% rise in vegetation, and 18% reduction in barren land, signaling improved water availability and ecological recovery. Peak NDVI decreased slightly from 0.97 to 0.89, likely due to seasonal factors like harvesting, but overall green cover expanded significantly, as confirmed by visual maps. Moisture improved in dry zones, with the lowest NDMI rising from -0.46 to -0.28, reducing extreme dryness. Peak NDMI stabilized (0.62 → 0.47), indicating balanced moisture distribution across the watershed.

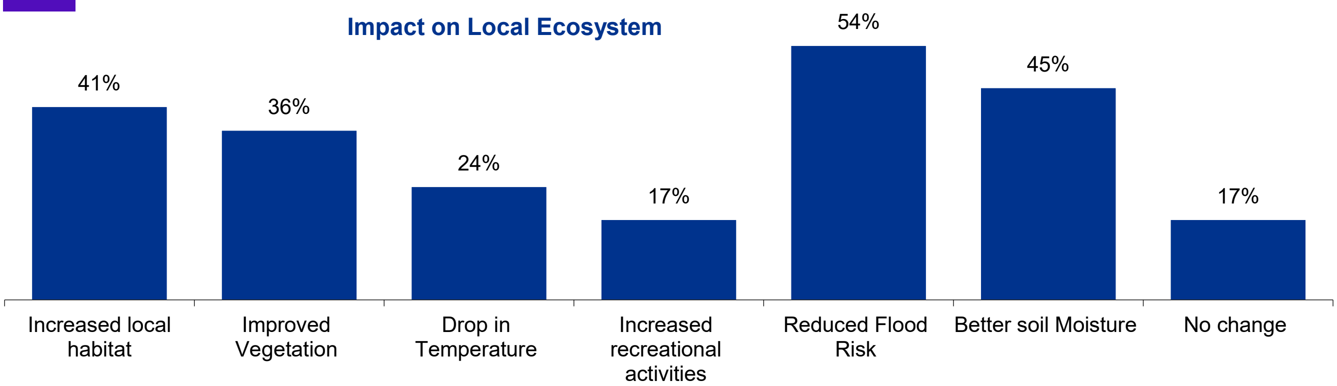






At Yaladabhag there is good level of ecological recovery occurred, with vegetation increasing by 19% and barren land reducing by 17%, despite a minor 2% dip in water spread (likely seasonal variation). Peak NDVI improved from 0.88 to 0.89, and maps show deeper green hues replacing barren patches, confirming healthier vegetation and moisture remained stable at 0.48, indicating consistent hydrological conditions despite fluctuations in surface water spread.





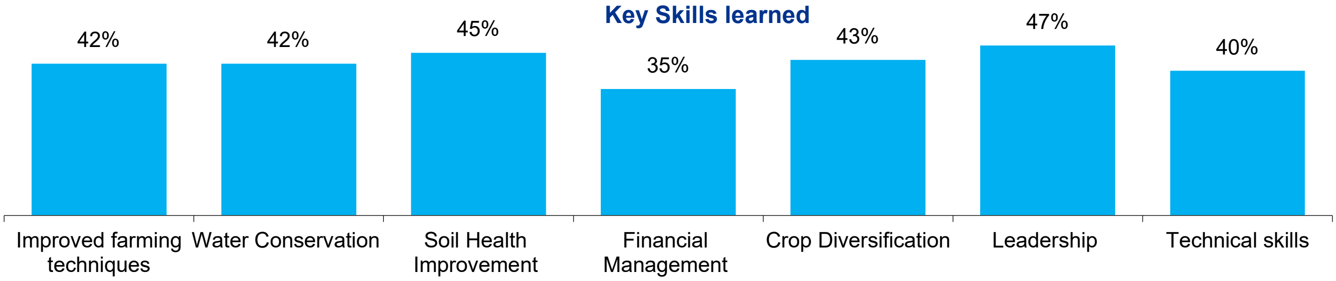
Further basis the interaction with the sampled beneficiaries it was observed that there is positive perceived ecological improvements resulting from the project interventions as reported. A majority of respondents identified reduced flood risk in the farms due to stagnation of rainwater during rains as the most significant outcome due to the increased water capacity in the desilted tanks (54%), indicating that desiltation and channel restoration have effectively improved water flow. Better soil moisture (45%) and improved vegetation (36%) were also widely acknowledged, confirming that restored water bodies and enhanced recharge have positively influenced soil-water-plant interactions, supporting agriculture and ecological health. Additionally, increased local habitat (41%) points to biodiversity gains, while drop in temperature (24%) suggests microclimatic improvements due to expanded green cover and water presence. Social benefits are evident too, with 17% noting increased recreational activities, showing that restored lakes and greenery have become community assets. Although 17% reported no change, the overall response highlights an enhanced positive shift in ecological health and ecosystem services.

Thus, it can be concluded basis the combined evidence from LULC, NDVI, and NDMI analyses, supported by interaction with the sampled beneficiaries that the project has enhanced watershed ecosystems and ecological balance across all sites. Water bodies have been revived or expanded, improving hydrological stability and reducing flood risk. Large-scale conversion of barren land into vegetated zones has strengthened soil health, while NDVI and NDMI trends confirm improved vegetation vigor and moisture retention. These ecological gains have also translated into social and economic benefits, including diversified livelihoods, improved microclimate, and enhanced community spaces. Overall, the project has successfully transformed degraded, water-stressed landscapes into resilient ecosystems that support agriculture, biodiversity, and community well-being. Sustaining these gains through long-term maintenance, participatory governance, and crop-water planning will be essential to ensure continued ecological, social, and economic benefits.

Multi cropping done by farmers

Strengthened data-driven governance and community ownership

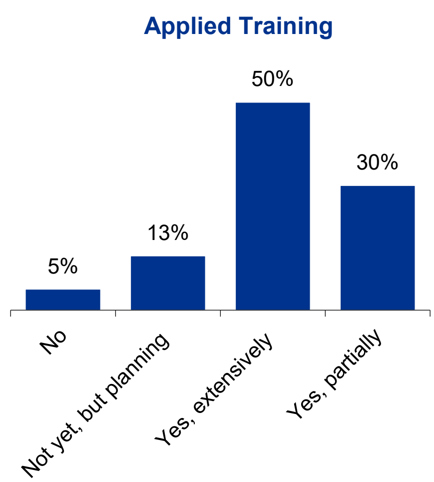
Community engagement is the cornerstone of sustainable water and ecosystem management. When local people are actively involved in planning, monitoring, and decision-making, they develop a sense of ownership and responsibility toward shared resources. This participation ensures that interventions are not just top-down directives but reflect the real needs and priorities of the community. Engaged communities are more likely to maintain structures, adopt water-saving practices, and cooperate in setting fair water-use norms. Moreover, collective action fosters trust, transparency, and accountability, reducing conflicts and promoting equitable access to resources. Ultimately, community-driven governance transforms projects from short-term fixes into long-term solutions that strengthen resilience, improve livelihoods, and create a culture of stewardship for both water and land.



Basis the interaction with the sampled beneficiaries that there is a strong capacity development across the community. Leadership (47%) ranks highest, indicating that more people are convening meetings, coordinating maintenance of water structures, and mobilizing collective action. Soil health improvement (45%) and crop diversification (43%) point to better agronomic decisions use of organic matter, mulching, and a shift toward resilient/high-value crops. Improved farming techniques (42%) and water conservation (42%) reflect adoption of practices like contour bunding, efficient irrigation, and timely operations that reduce input costs and water stress. Technical skills (40%) suggest growing confidence in using basic tools, record-keeping, and simple monitoring methods, while financial management (35%) though lower shows emerging attention to budgeting and market planning. Overall, the skill profile signals strong community readiness to sustain ecological gains and translate them into stable livelihoods.

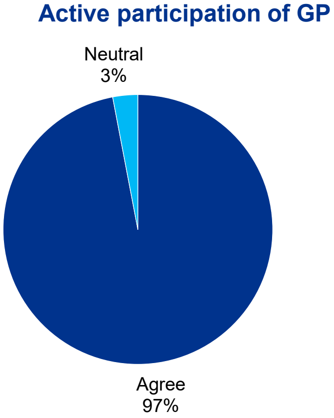
Training Application on Farms

The majority of participants have actively applied the training received to their farming practices. 50% reported applying the training extensively, demonstrating strong adoption of improved techniques and water management practices. Additionally, 30% have partially implemented the learnings, suggesting gradual integration into their operations. 13% stated they are planning to apply the training soon, reflecting readiness and intent for future adoption. Only 5% reported no application, highlighting minimal resistance or constraints. Overall, these results confirm that the capacity-building efforts have translated into practical action on the ground, with most farmers leveraging new knowledge to enhance productivity, conserve water, and improve soil health.



Participation of Gram Panchayat in sustaining the project

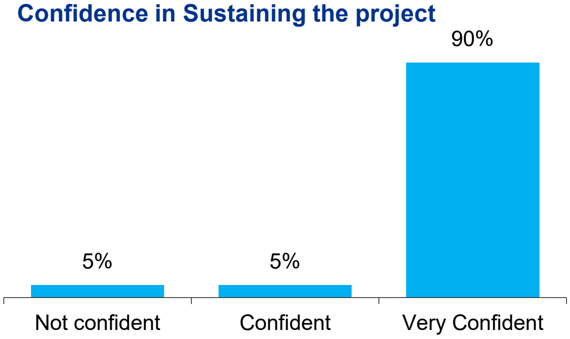
Basis the interaction with the sampled beneficiaries it was noted that 97% of respondents agreed that their GP is actively participating, which reflects strong institutional engagement in planning, monitoring, and implementation of interventions. Only 3% indicated no active participation, suggesting minimal gaps that may require targeted awareness or capacity-building. This high level of involvement underscores the success of the project in fostering decentralized governance and ensuring that local institutions play a pivotal role in sustaining water and ecological improvements.



Silt applied to the farmland

Outlet channel dug at Yaldabhag lake

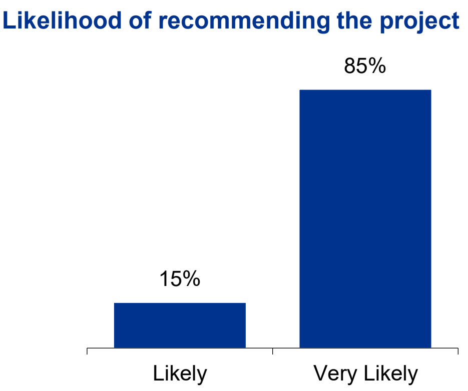
Confidence in Sustaining Project Interventions



The majority of participants represents high level of confidence among participants regarding the long-term sustainability of project interventions. A dominant 90% of respondents reported being very confident, indicating strong belief in their ability to maintain water structures, adopt improved practices, and continue ecological restoration efforts. An additional 5% expressed confidence, while only 5% reported not feeling confident, suggesting minimal gaps that may require targeted support or capacity-building. This overwhelming confidence reflects the success of community engagement, skill development, and participatory governance strategies implemented during the project, ensuring that the benefits achieved will endure well beyond the intervention period.

Community Participation & Sustainability Impact

The project demonstrates good community endorsement, with 85% of respondents reporting they are very likely to recommend the initiative, and an additional 15% indicating they are likely to recommend it. This high recommendation rate reflects that communities recognize benefits from lake desiltation, such as improved water availability and ecological restoration, willingness to recommend suggests trust in the long-term viability and maintenance of the project and advocacy potential within the community persists, which is critical for continued participation and scaling similar interventions.



Technical Analysis conducted at farms

Enhanced soil quality and water retention leading to sustainable farming practices

Healthy soil is the cornerstone of sustainable agriculture, and its ability to retain water directly influences crop resilience and productivity. Through the restoration of traditional waterbodies, this project has addressed critical challenges of soil degradation and moisture scarcity that often undermine farming in semi-arid regions. By improving soil structure and enhancing water retention, the initiative not only supports better crop yields but also reduces dependence on external irrigation, fostering long-term sustainability. This impact is central to the program's vision of creating climate-adaptive farming systems that empower rural communities.

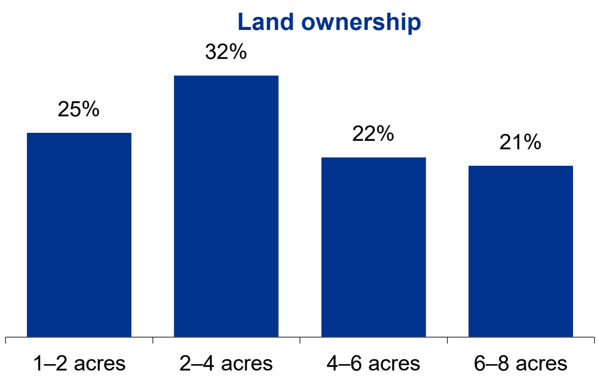
To enhance soil quality and water retention, the project focused on scientific desiltation of traditional waterbodies, repurposing nutrient-rich silt to farmlands, and restoring surface water capacity to improve groundwater recharge. These interventions were supported by farmer awareness programs, Gram Panchayat engagement, and capacity-building initiatives to promote soil-friendly practices and ensure long-term community stewardship.

For accurate impact assessment, soil samples from adjacent agricultural fields were analyzed using a paired sampling approach. Comprehensive laboratory tests evaluated physico-chemical properties, nutrient profiles, physical characteristics, and biological activity, providing a holistic understanding of improvements in soil health and water retention.

As discussed earlier, NDMI values have shown an increase across the restored sites, indicating improved moisture availability in the soil. This directly correlates with enhanced water retention and soil health achieved through desiltation and waterbody restoration, reinforcing the sustainability of farming practices in these regions.

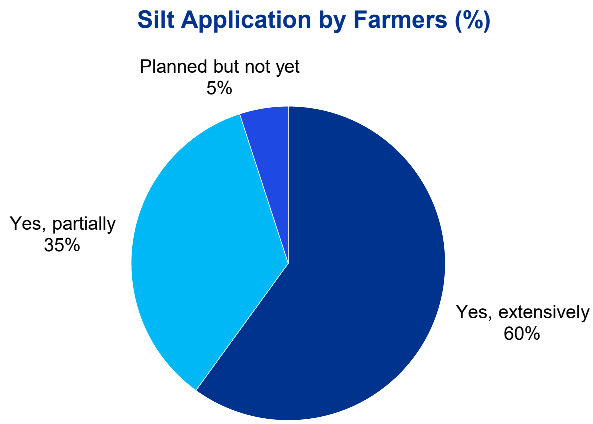
Land ownership

The assessment of landholding sizes among farmers reveals a varied distribution that influences cropping choices, productivity, and the potential impact of desiltation interventions. The largest proportion of farmers (32%) reported owning land between 2–4 acres, suggesting a moderate



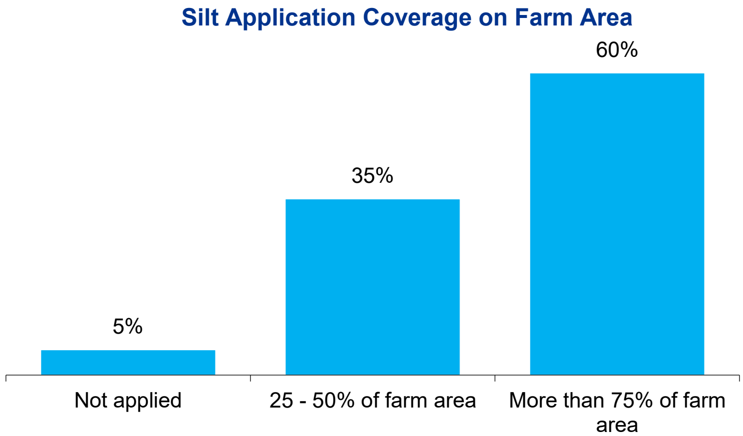
scale of farming that can support diversified cropping and improved water management practices. Additionally, 25% of farmers hold 1–2 acres, representing smaller-scale cultivators who are more vulnerable to rainfall variability and stand to gain significantly from enhanced soil moisture and water retention. Farmers with 4–6 acres (22%) and 6–8 acres (21%) form a substantial segment, indicating opportunities for adopting sustainable practices such as crop rotation and soil conservation measures. This distribution underscores the importance of tailored interventions that address the needs of both small and medium landholders to maximize the benefits of tank rejuvenation.

Silt Application by Farmers



It was reported basis the interaction with the sampled beneficiaries that there is good adoption of silt application among farmers, with 60% reporting extensive use and another 35% applying it partially suggesting that the majority recognize the benefits of silt in improving soil fertility, water retention, and crop productivity. The small proportion (5%) who have planned but not yet implemented silt application mentioned that it was due to the logistical or resource constraints rather than lack of awareness. The high uptake reflects positive progress toward sustainable soil management practices, which can lead to enhanced agricultural output and resilience against soil degradation.

Silt Application Coverage



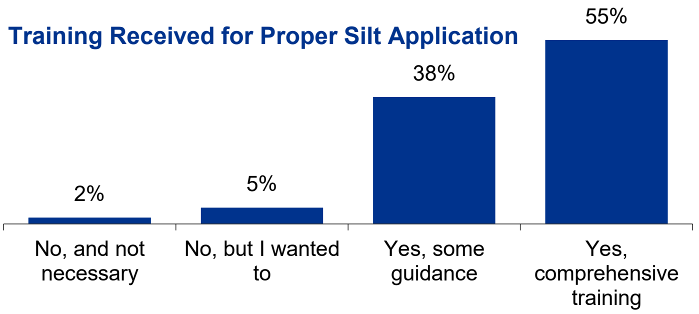
It was observed basis the interaction with the sampled beneficiaries that most of the farmers had applied the silt on substantial part of their farms , with 60% of respondents reporting that they applied it on more than 75% of their farm area. This indicates a strong commitment to improving soil health and productivity through widespread coverage. Additionally, 35% applied silt on 25–50% of their land, suggesting a phased or resource-dependent approach. Only 5% reported no application, due to logistical constraints. Overall, the trend demonstrates that silt application is not only widely accepted but also prioritized across large farm areas, which has also led to substantial improvements in crop yield and lesser drop off in soil nutrients, moisture content.

“The quality and quantity of coconuts have improved significantly. Soil moisture and water retention have allowed us to grow vegetables, marigold flowers, and areca nut, while also shifting toward livestock and dairy farming.”

— Farmer at Karekyatna Lake

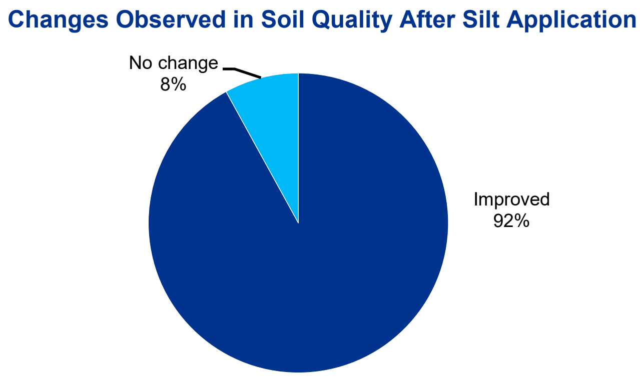
Training received on proper silt application

It was observed that a most farmers received support in applying silt effectively, with 55% reporting comprehensive training and 38% receiving some guidance. This high level of training coverage suggests strong efforts to ensure proper techniques for optimum results, which can significantly enhance soil quality and crop productivity. However, few respondents did not receive any guidance, with 5% expressing a desire for training, highlighting a small gap in outreach. Overall, the emphasis on training reflects a proactive approach to capacity building, ensuring that silt application is not only widespread but also carried out correctly for maximum impact.

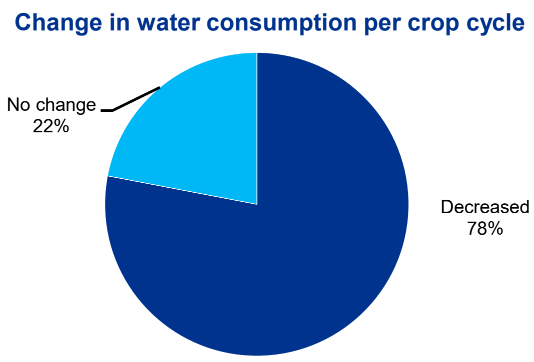


Change in Soil Quality post Silt application

It was reported from the interaction with the sampled beneficiaries that the outcomes on soil health is positive as 92% of farmers reported “Improved” soil quality following silt application, while 8% observed “No Change” which highlights that desiltation-enabled silt reuse is enhancing soil structure, nutrient availability, and field-level moisture retention for most of the farmers, which, in turn, is supporting timely sowing, reduced mid-season moisture stress, and more stable yields.



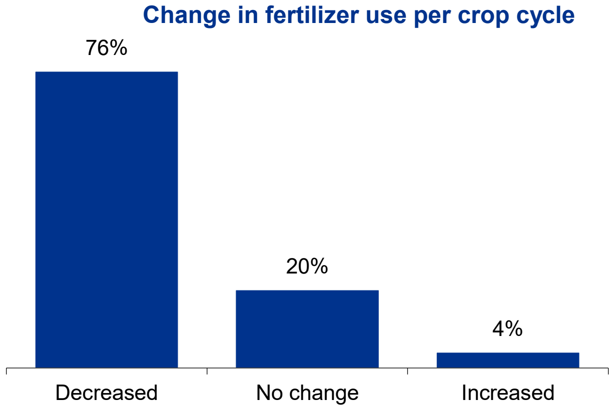
Change in water consumption



It was observed that around 78% farmers reported a reduction in water usage per crop cycle, indicating that improved soil structure and moisture retention from silt application are translating into water savings. Conversely, 22% observed no change, suggesting that further interventions such as promoting uniform silt application and complementary practices like mulching could help maximize benefits.

Change in Fertiliser use

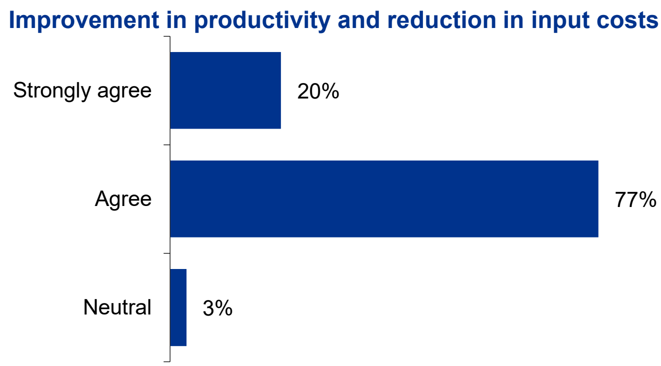
76% of respondents reported decreased usage of chemical fertilizer per crop cycle as silt application has improved soil fertility and nutrient availability, reducing dependency on chemical inputs. Meanwhile, 20% observed no change, possibly due to specific crop requirements or soil conditions, and 4% reported an increase in using the organic fertilizer. Overall, the trend highlights that the silt application has helped in promoting cost efficiency and sustainable farming practices by lowering input requirements.



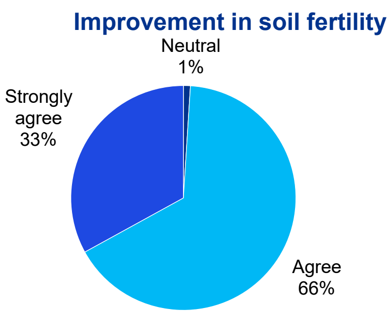
"Earlier, we had to irrigate our fields every day. After applying silt to our farms, the soil retains more water, and now we irrigate only once every two weeks. This has also reduced labor and repair costs and extended the life of irrigation motors."
— Farmer at Yaladabhag Lake

Improvement in productivity and reduction in input costs

It was reported that silt application has had a positive effect on farm performance, with 97% of respondents agreeing or strongly agreeing that productivity has improved and input costs have reduced indicating that the intervention is delivering economic benefits, likely through enhanced soil fertility, better moisture retention and reduced dependency on external inputs such as fertilizers and frequent irrigation requirements. Only 3% remained neutral, showing minimal uncertainty about the impact. Overall, these results highlight the effectiveness of silt application in promoting sustainable farming practices while improving profitability for farmers.



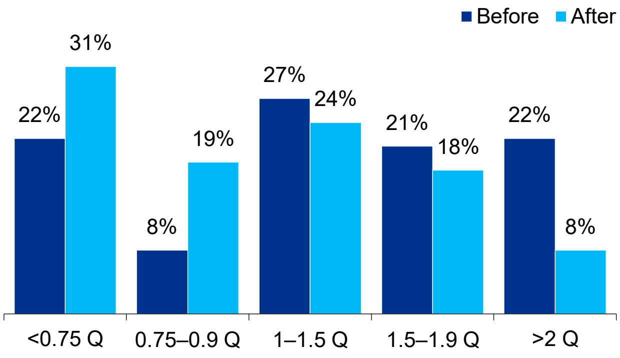
Improvement in Soil fertility



Basis the interaction with the sampled beneficiaries it was reported that silt application has had a positive effect on soil health, with 99% of respondents agreeing or strongly agreeing that soil fertility has improved after the silt application on their farms which has helped in enhancing the nutrient availability and soil structure, which are critical for sustainable crop production. Only 1% remained neutral, showing negligible uncertainty about the impact. Overall, these findings highlight the effectiveness of silt application in restoring and maintaining soil fertility, contributing to long-term agricultural productivity.

Fertilizer use per crop cycle

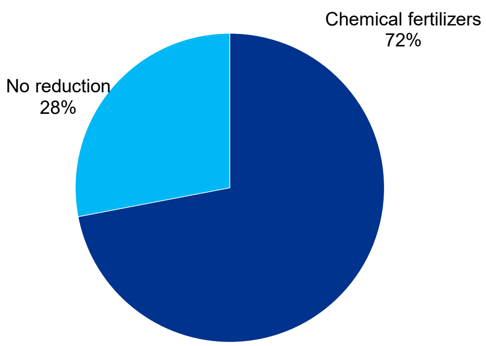
Fertilizer use per crop cycle



Based on the interaction with farmers, it was revealed that there is a shift towards lower fertilizer application rates after the intervention. The share of farmers using less than 1.0 Q per crop cycle rose from 30% to 50%, while those in the high-use brackets (>1.5 Q) fell from 43% to 26%, and the >2 Q category dropped markedly from 22% to 8%. The mid-range band (1–1.5 Q) also eased slightly (27% to 24%). Taken together, these changes indicate improved input efficiency—likely driven by better soil fertility and moisture retention—translating into lower input costs and reduced environmental load without compromising productivity observed elsewhere in the survey.

Reduction in fertilizer usage

Reduction in fertilizer usage by type

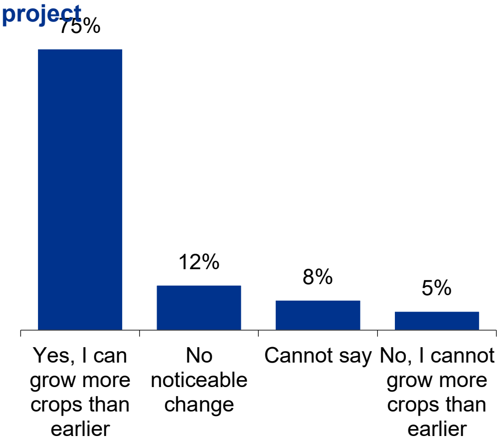


It was observed basis the interaction with the sampled population that farmers are moving away from chemical fertilizers, with 72% of respondents reporting a decrease. This suggests that interventions such as soil improvement and sustainable practices are effectively lowering dependency on synthetic inputs. Notably, 28% reported no reduction, which could reflect crop-specific needs, local soil variability, or limited access to alternative practices. Overall, the trend underscores cost savings and potential environmental benefits through reduced chemical dependency, while maintaining a balanced approach to soil fertility management.

Enhanced ability to grow more crops

It was reported by 75% farmers that the project has enhanced farmers' ability to grow more crops, highlighting a positive change suggesting that interventions such as silt application and improved soil fertility have created favorable conditions for crop diversification or increased cropping intensity. A smaller proportion (12%) observed no noticeable change, while 8% were uncertain, possibly due to limited experience or external factors like market access. Only 5% reported a negative outcome, which is minimal compared to the overall positive trend. These findings highlight the project's success in improving agricultural potential and supporting farmers in maximizing land productivity.

Change in ability to grow more crops post-project



Adoption of new crops

It was reported by 90% of farmers have started adopting multiple cropping after project implementation, indicating a diversified pattern on renewed farmland. Cereals and pulses account for 45%, maintaining their role as staples. Vegetables (14%) and fruits (6%) add dietary diversity and income potential, while the “Other” category (Areca nut, flowers, coconut) at 35% reflects a shift toward commercial and perennial crops. This diversification suggests improved soil and water conditions, enabling farmers to move beyond traditional staples and enhance resilience and profitability.

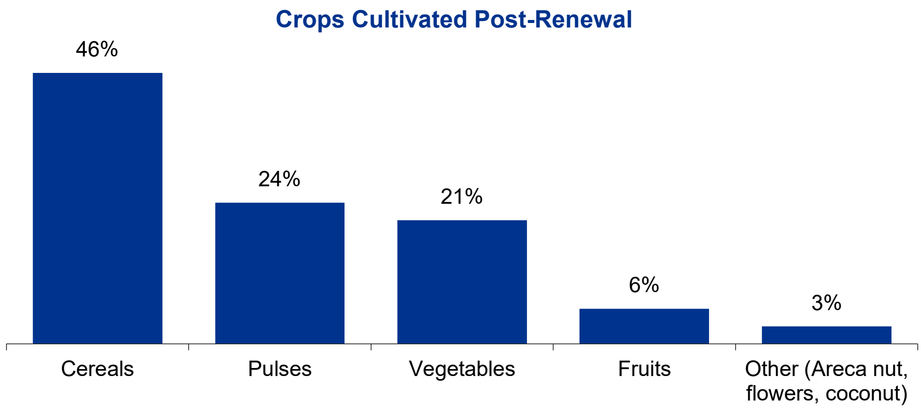


Figure: Desilted Yaldabhag lake

Figure: Silt applied to farmland

Naveli

At Naveli, lake silt application has strengthened the soil's productive base and moisture resilience, with organic carbon nearly doubling (0.32% → 0.58%) and microbial activity rising (124 → 146 CFU/g), confirming an active biological engine that drives nutrient cycling and aggregate stability. Fertility gains are clear—Nitrogen (~+19%), Phosphorous (~+35%), and Potassium (~+22%)—alongside increases in Calcium and Magnesium. Physically, bulk density reduced (1.68 → 1.62 g/cc) and water-holding capacity improved (48% → 52%), supporting deeper root growth, lower irrigation demand, and better drought tolerance. While pH shifted to 9.33, a manageable legacy alkalinity from salt-laden sediments (carbonates/bicarbonates, sodium) that can lock micronutrients, targeted gypsum, green manuring, and acid-forming fertilizers will unlock availability and convert these gains into durable yield benefits

Bhupsandra

At Bhupasandra, the silt application produced a cautionary outcome: instead of the expected boost in fertility and moisture retention, the treated fields show diluted primary nutrients, higher salinity, and a heavier, more compact texture with reduced water-holding capacity and weaker biological activity. These conditions would normally restrict root growth, nutrient uptake, and drought resilience. Importantly, this profile reflects a site-specific silt quality that is chemically poorer and physically heavier than the native topsoil—an insight revealed by the program's paired sampling and lab diagnostics, not a shortcoming of the restoration approach. Guided by these findings, the corrective pathway is clear: deep ploughing with organic amendments to rebuild porosity and carbon, gypsum to address sodicity and improve infiltration, and green manuring to restore nitrogen and microbial life.

Ajjenahalli

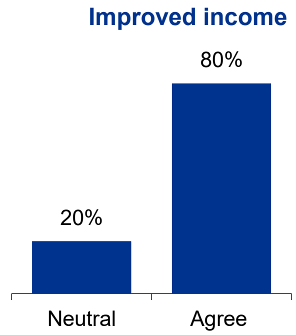
Ajjenahalli presents a trade-off with a clear recovery route. The silt delivered a strong desalination effect (EC 111 → 32.6 µS/cm), easing salt stress and improving the baseline for crop recovery in a semi-arid context. However, the same silt was chemically inert and biologically poor relative to native topsoil—primary nutrients declined (including Potassium 82 → 38 mg/kg), organic carbon fell (0.46% → 0.33%), microbial activity weakened (182 → 130 CFU/g), and WHC decreased (58% → 51%); texture remained silt clay with marginal compaction change (1.65 → 1.63 g/cc), indicating biology and nutrients are the limiting levers. Immediate potash supplementation (MOP/SOP), modest N-P boosts, and heavy organic amendments/vermicompost will reboot the soil's biological engine and restore moisture retention; with a positive Sulphur profile, oilseeds/onion/garlic can be leveraged while fertility and biology rebound—aligning the site back to the program's sustainability objectives.

Economic upliftment in farmer incomes

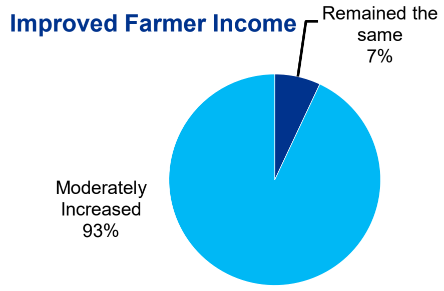
Improved crop yields and reduced input costs resulting from silt application on farms represent a critical economic benefit of lake desiltation projects. By recycling nutrient-rich silt from lakes onto agricultural land, farmers experience enhanced soil fertility, leading to higher productivity and lower dependency on expensive fertilizers. This not only strengthens household incomes but also ensures long-term sustainability of both water bodies and farming practices.

Improved due to better crop yields and reduced input costs

Based on interactions with the sampled beneficiaries, it was reported that 80% agreed that their income has improved due to better crop yields and reduced input costs like reduction in labor costs those used for irrigation, depreciation cost of machines used for the irrigation, fertilizer costs due to increased soil productivity, while 20% remained neutral. This insight highlights the significant role of lake desiltation and subsequent silt application in enhancing soil fertility, reducing reliance on costly fertilizers, and ultimately improving farm productivity. Such economic upliftment is critical for ensuring community buy-in and long-term sustainability of the project.



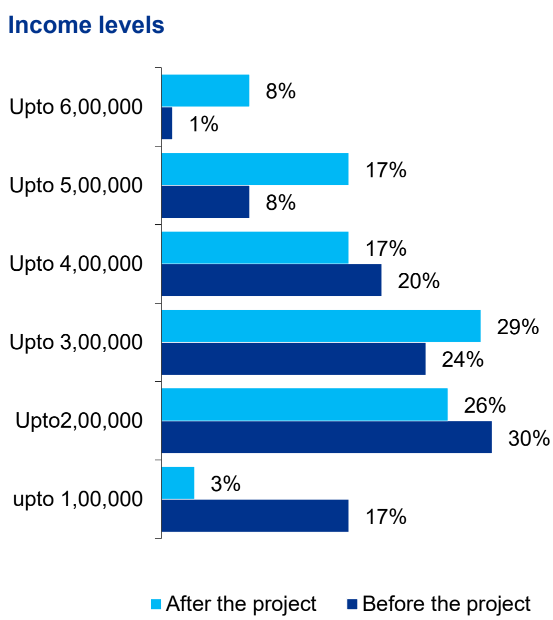
Improved Farmer Income by participating in programme



Based on interactions with sampled beneficiaries, 93% reported that their income has moderately increased, while 7% indicated it remained the same. This positive response underscores that participation in the program and associated training played a pivotal role in this improvement. Farmers gained awareness of sustainable water management practices, scientific benefits of lake desiltation, and techniques for silt application, which enhanced their decision-making and farming strategies.

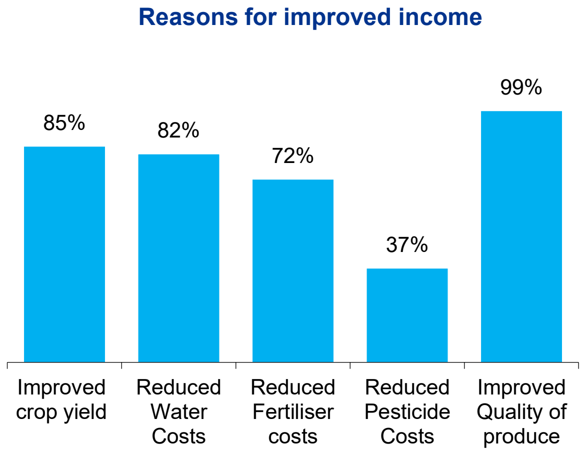
Income Shift post implementation

Based on interactions with sampled beneficiaries, income levels show a clear upward shift after the project. Before the intervention, 17% of households earned up to ₹1,00,000, which dropped sharply to 3%, while higher income brackets (₹5,00,000 and above) grew from 9% to 25%. The majority moved from lower bands (up to ₹2,00,000) into mid and higher ranges, reflecting improved crop yields and reduced input costs due to silt application. This transition indicates not just incremental gains but a structural improvement in rural livelihoods, reducing vulnerability and enhancing financial resilience. Such economic upliftment validates the sustainability and long-term impact of lake desiltation projects, as higher incomes empower farmers to reinvest in better practices and strengthen community participation.



Reasons for Improved Income

It was observed that the key drivers of income improvement were improved quality of produce (99%) and higher crop yields (85%), supported by cost reductions in water (82%), fertilizer (72%), and pesticides (37%). The improved quality was primarily attributed to better soil health and water availability, resulting from lake desiltation and nutrient-rich silt application on farms. These factors enhanced soil fertility, moisture retention, and crop resilience, enabling farmers to command better prices and reduce input costs.

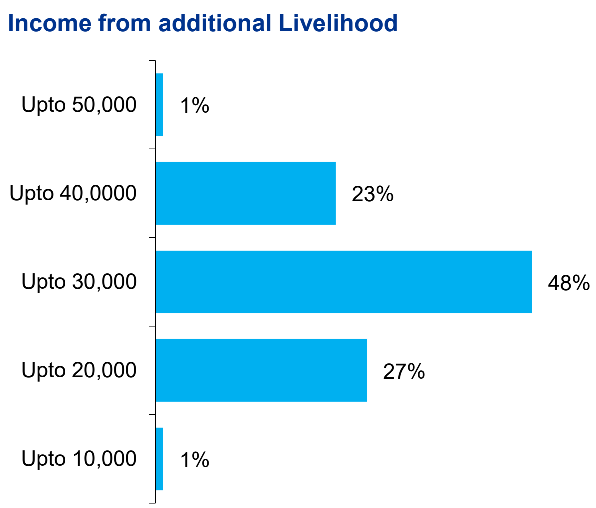


This combination of quality-led price gains, yield-led volume increases, and cost efficiencies created a strong economic uplift, validating the sustainability and long-term impact of the project.

"Better soil quality and water retention have doubled our income from ₹2 lakhs earlier to ₹4 lakhs now. Crop yields have improved significantly, and we are using more organic fertilizers."

— Farmer at Yaladabhag Lake

Income from diversified Livelihoods



Interactions with beneficiaries revealed that income diversification through activities such as livestock rearing, fishing, and additional plantation crops like marigold and areca nut contributed significantly to household earnings. The incremental income ranged from ₹10,000 to ₹50,000 annually, with 48% of respondents reporting gains up to ₹30,000, 27% up to ₹20,000, and 23% up to ₹40,000. This diversification not only supplements farm income but also reduces dependency on a single crop, enhancing financial resilience and stability. Such outcomes underscore the broader socio-economic benefits of lake desiltation projects, as improved water availability and soil health enable farmers to explore multiple income streams.

Summary:

Index	Project Locations	Methodology	Interpretation
Groundwater Storage/ Soil Moisture	Average increase by 2.8%	Assessed by analyzing satellite or hydrological data within a 1 km buffer of the site to estimate the volume of water retained in surface and subsurface reservoirs.	Typical improvements range between 5-20% and overall improvement in groundwater storage and soil moisture across sites indicates enhanced water retention and hydrological regulation due to desilting interventions.
LULC- Vegetation Increase	Average Increase by 15%	Assessed by classifying satellite imagery within a 1 km buffer of the site and computing the proportion of area covered by vegetation.	This increase in vegetation cover across sites reflects successful ecological restoration and conversion of previously degraded or sparsely vegetated land into active green cover.
LULC- Barren Land	Average Decrease by 17.6%	Assessed by classifying satellite imagery within a 1 km buffer of the site and computing the proportion of area identified as non-vegetated or bare soil.	A consistent reduction in barren land area demonstrates effective land cover transformation and stabilization of exposed surfaces through vegetation establishment.

Project alignment to UNSDGs

The Bank-supported initiative at the CCD demonstrates strong alignment with multiple UNSDGs, contributing to global and national development priorities through waterbody restoration and rejuvenation promoting farmers income and livelihoods. The project's approach of silt application for better farm productivity and water storage capacity makes the project to contribute to national and global priorities.

Key SDGs supported:

SDGs	Target/ Subsection	How it aligns
2 ZERO HUNGER	**2.4:** "By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality"	Improved irrigation and soil fertility boost crop yields, strengthen food security, and promote sustainable farming practices.
6 CLEAN WATER AND SANITATION	**6.6**: "By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes"	The project rejuvenates traditional tanks through desilting, embankment strengthening, and inlet/outlet regulation, significantly improving water storage capacity, groundwater recharge, and overall water quality for rural communities.
8 DECENT WORK AND ECONOMIC GROWTH	**8.5:** "By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value"	Restoration activities create local jobs, while improved agricultural productivity increases farmer incomes and rural economic stability.
11 SUSTAINABLE CITIES AND COMMUNITIES	**11.4:** "Strengthen efforts to protect and safeguard the world's cultural and natural heritage"	By restoring historic water tanks, the initiative preserves cultural heritage, strengthens rural water infrastructure, and reduces migration by ensuring sustainable water access for agriculture and livelihoods.

SDGs	Target/ Subsection	How it aligns
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	**12.5**: "By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse"	The project promotes circular resource use by reusing nutrient-rich silt for agriculture, reducing chemical fertilizer dependency, and minimizing environmental degradation.
13 CLIMATE ACTION	**13.1**: "Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries"	Increased water storage and recharge enhance drought resilience, reduce vulnerability to climate variability, and support adaptive capacity for rural communities.
15 LIFE ON LAND	**15.1**: "By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements"	Biodiversity enhancement around tanks restores habitats, supports flora and fauna, and improves ecological health and watershed sustainability.
17 PARTNERSHIPS FOR THE GOALS	**17.17**: "Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships"	The initiative fosters collaboration between Kotak Mahindra Bank, NGOs, local communities, and government bodies, ensuring shared responsibility and long-term sustainability.

04
Recommendations

Recommendations

The impact assessment of Kotak Mahindra Bank Limited's CSR-supported lake restoration initiative in collaboration with the Sahakara Mitra Samstha (CCD) confirms significant progress in improving water storage capacity, ecological health, and community participation across the restored water bodies. However, sustaining and scaling this impact requires strategic enhancements aligned with India's environmental priorities and global best practices. The following recommendations are structured around four pillars:

1 Water Body Management

- Establish boundary protection and local agreements to prevent future encroachment on the newly established central water body.

2 Community Engagement

- Given the magnitude of the positive changes, utilize this project as a model for community engagement in water and land management across other micro-watersheds; and create project visibility among govt stakeholder to create ripple effect across intervention areas.

3 Long-term Monitoring and water budgeting

- Farmers should implement water budgeting and monitoring systems to regulate extraction, and prioritize efficient irrigation methods like drip systems and monitor the LULC and NDVI annually to document the stability of the vegetation increase and also to take proper action for enhancing the low NDMI and water storage capacity as recorded so that it maintains overall resilience of the restored ecosystem.

4 Adopt Integrated Water and Crop Management

- It can be considered to adopt crop planning strategies that balance economic returns with water sustainability, while simultaneously investing in groundwater recharge structures such as percolation tanks, recharge pits, and check dams. Additionally, promoting drought-resilient crop varieties, agroforestry, and mixed farming systems will deliver social, economic, and ecological benefits, reducing pressure on water resources while enhancing income security.

Strategic imperative

The Kotak–CCD partnership has strengthened water security and ecological resilience in semi-arid regions by rejuvenating traditional lakes and tanks, reducing groundwater depletion, soil erosion, and biodiversity loss. Improved water storage and recharge enhance climate adaptation, agricultural productivity, and rural livelihoods. The initiative aligns with local priorities of irrigation access and livelihood diversification, and supports national missions like Jal Shakti Abhiyan, National Water Mission, and Green India Mission, while contributing to SDGs 2, 6, 13, and 15. Beyond environmental gains, it fosters inclusive development through sustainable agriculture and community stewardship, offering a replicable model for integrated water and biodiversity management.

Thank you

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Annexures

Technical Analysis Outcomes Project Sites:

Methodology

The impact assessment is based on a comparative analysis of three key remote sensing metrics:

1. Land Use Land Cover (LULC) (Pie Chart): Quantifies changes in Vegetation, Barren land, Water, and Settlement (as a percentage of the total Micro Watershed area).
2. Normalized Difference Vegetation Index (NDVI): Measures vegetation density and health (low values also represent water/barren land).
3. Normalized Difference Moisture Index (NDMI): Measures the water content in vegetation and soil, indicating hydrological health.

NDMI Assessment Report (2022 vs 2025)

Normalized Difference Moisture Index (NDMI) is a widely used satellite-based vegetation moisture indicator derived from the Near-Infrared (NIR) and Short-Wave Infrared (SWIR) spectral bands. It is useful for assessing vegetation water stress, canopy moisture, and seasonal vegetation dynamics.

NDMI = (NIR – SWIR) / (NIR + SWIR)

In this analysis, NDMI was computed for selected locations within the study region for the years 2022 and 2025. The goal was to quantify changes in vegetation moisture conditions between these two years.

Methodology

For NDMI extraction, Sentinel-2 Level-2A surface reflectance data were used. These data come at a 10-metre spatial resolution for the NIR (Band 8) and 20-metre resolution for the SWIR (Band 11) band. The SWIR band was resampled to 10 m to match NIR and enable pixel-wise NDMI computation.

Monthly NDMI values were generated by calculating mean NDMI for each month from January to October for both 2022 and 2025.

Methodology of Soil Sampling and Analysis

1. Sample Collection Protocol

Soil samples were collected directly from the project sites (Naveli, Bhupasandra, Ajjenhalli) to ensure representative analysis of the impact area. The collection was performed by a CEL Representative adhering to the specific Standard Operating Procedure (SOP) code ARCEL/STP/S/LAB-06.

Comparative Sampling Strategy: To ensure an accurate impact assessment, a paired sampling approach was adopted. Soil samples were collected from adjacent agricultural fields to minimize geographical and environmental variables.

- Treatment Sample: Collected from the field where lake silt had been applied.
- Control Sample: Collected from the immediately neighboring field where no silt was applied.

This side-by-side selection ensures that any differences observed in the soil profile can be directly attributed to the silt application rather than inherent differences in location.

2. Environmental Conditions

The sampling was conducted on 18.11.2025. At the time of collection, the environmental conditions were recorded as:

• Temperature: 29.6°C

• Humidity: 44.7%

3. Laboratory Analysis Scope

Following collection, the samples were subjected to comprehensive laboratory testing to evaluate:

• **Physico-Chemical Properties:** pH, Electrical Conductivity, and Organic Carbon.

• **Nutrient Profiling:** Major macronutrients (N, P, K), secondary nutrients (Ca, Mg, S), and essential micronutrients (Zn, Fe, Cu, Mn, B).

• **Physical Characteristics**: Soil texture, bulk density, and water holding capacity.

• **Biological Activity:** Microbial count (CFU/g).

• **Remediation of Extreme Dryness:** The lowest recorded value improved from -0.38 to -0.57 (Note: A lower negative number means less dry, which is a desirable outcome). Correction: Assuming the NDMI scale is standard (higher positive is moist, lower negative is dry), the change from -0.38 to -0.57 indicates a slight increase in extreme dryness in the lowest-moisture areas.

• **Visual Check:** The distinct blue feature (high moisture) of the water body has expanded and intensified slightly in 2025, which visually confirms the +3% LULC Water increase. The overall landscape moisture signature (light green/beige) remains largely consistent, confirming the overall health of the watershed.

Groundwater analysis

1. Introduction

Groundwater plays a critical role in sustaining domestic supply, agriculture, and industrial activities in rapidly urbanizing regions. However, due to rising population, expansion of built-up areas, and increasing groundwater dependency, several peri-urban aquifer systems are experiencing substantial stress. Traditional observation networks (wells, piezometers) are often sparse and lack consistent temporal coverage. In contrast, satellite-based products such as GRACE and GRACE-FO provide continuous terrestrial water storage anomaly (TWSA) estimates, but at a coarse spatial resolution (~0.25°), which is too large for small administrative regions such as CCD localities.

This study develops a fine-resolution groundwater storage downscaling framework that combines GRACE TWSA, GLDAS soil moisture + canopy storage, and high-resolution predictors including rainfall, NDVI, topography, and temperature. Using this approach, groundwater storage anomaly (GWSA) is generated at 100-m resolution for five CCD regions—Chinnapanahalli, Gollarahatti1, Karekyatana, Navale1, and Yaladabag—for the period 2022–2024.

The workflow allows conversion of large-scale GRACE-derived storage signals into local-scale groundwater information essential for water scarcity assessment, seasonal variation studies, and sustainable extraction planning.

2. Methodology

2.1 Data Used

GRACE/GRACE-FO Mascon Data

- Resolution: 0.25° (~25 km)
- Product used: CSR mascon
- Temporal span: 2022–2024 (Monthly)
- Extracted using a 400-km box around each CCD region to ensure coverage.

GLDAS Noah Dataset

Used to isolate groundwater from total water storage:

- Soil Moisture (0–200 cm)
- Canopy Water Storage
- Resolution: 0.25°
- Same temporal period (2022–2024)

High-Resolution Predictors (Downscaled to 100 m)

Variable	Source	Native Resolution	Used Resolution
Rainfall	CHIRPS	~5 km	Resampled to 100 m
NDVI	Sentinel-2 SR	10–20 m	Aggregated to 100 m
Temperature	ERA5-Land	~10 km	Resampled to 100 m
DEM	SRTM	30 m	100 m
Slope	Derived from DEM	30 m	100 m

These predictor variables capture vegetation activity, land-surface characteristics, and hydroclimatic controls that influence groundwater dynamics.

2.2 Deriving Groundwater Storage Anomaly

Groundwater storage anomaly (GWSA) was computed by separating groundwater from GRACE TWSA:

$$\text{GWSA} = \text{TWSA}_{\text{GRACE}} - (\text{SM}+\text{CW})_{\text{GLDAS}}$$

where

SM = soil moisture anomaly

CW = canopy water anomaly

This removes non-groundwater contributions and yields large-scale GWSA at GRACE resolution.

These predictor variables capture vegetation activity, land-surface characteristics, and hydroclimatic controls that influence groundwater dynamics.

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where

SM = soil moisture anomaly

CW = canopy water anomaly

This removes non-groundwater contributions and yields large-scale GWSA at GRACE resolution.
A multi-linear regression (MLR) model was trained for each region:

〖"GWSA" 〗_100m=f("NDVI","Rain","Temp","DEM","Slope")

The trained model produced 100-m groundwater storage anomaly maps for each month between 2022–2024.

2.4 Volumetric Groundwater Storage

Volumetric groundwater storage (m³) was computed as:

"Volume"="GWSA (cm)"×〖"Area (m" 〗^2 ")"×1/100

The barplots and line plots in the result section represent these volumetric changes over time.

3. Results

3.1 Multi-Year Groundwater Storage Variation (2022–2024)

Across all five CCD regions, the groundwater storage patterns share the following characteristics:

• Peak storage during monsoon months (July–October)
• Rapid decline during dry months (January–May)
• Sharp reductions in early 2024, indicating accelerated depletion
• 2022 consistently shows the highest groundwater availability, with a declining trend into 2023 and 2024

The combined line plot demonstrates strong seasonality but also a systematic lowering of the groundwater baseline and it can be seen in the figure below.

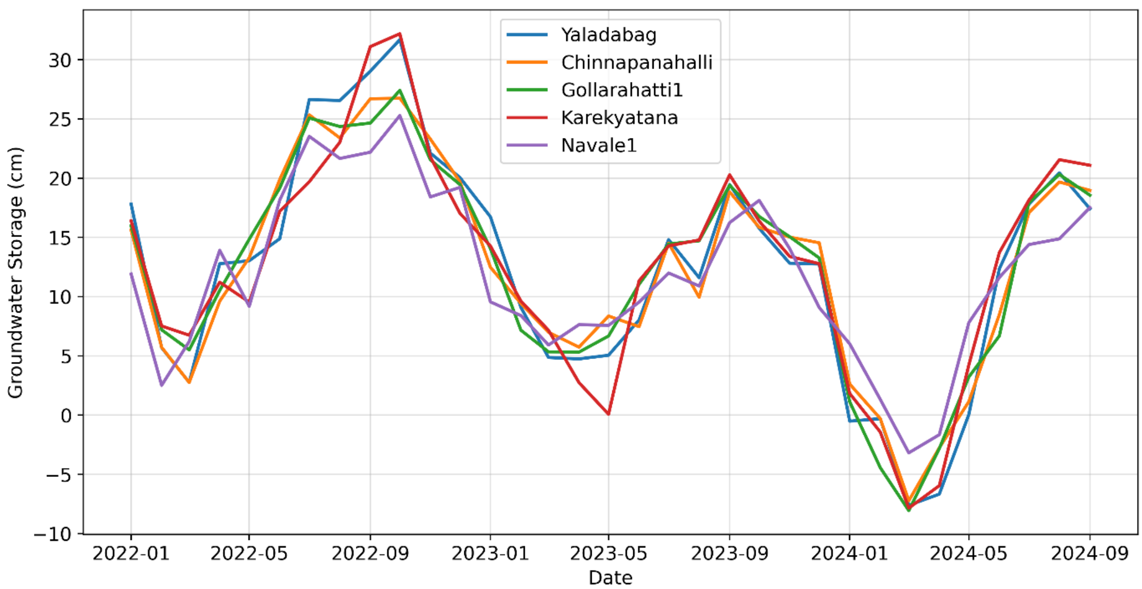


Fig. Groundwater storages across Yaladabag, Chinnapanahalli, Gollarahatti, Karekya and Navale from 2022 to 2024.

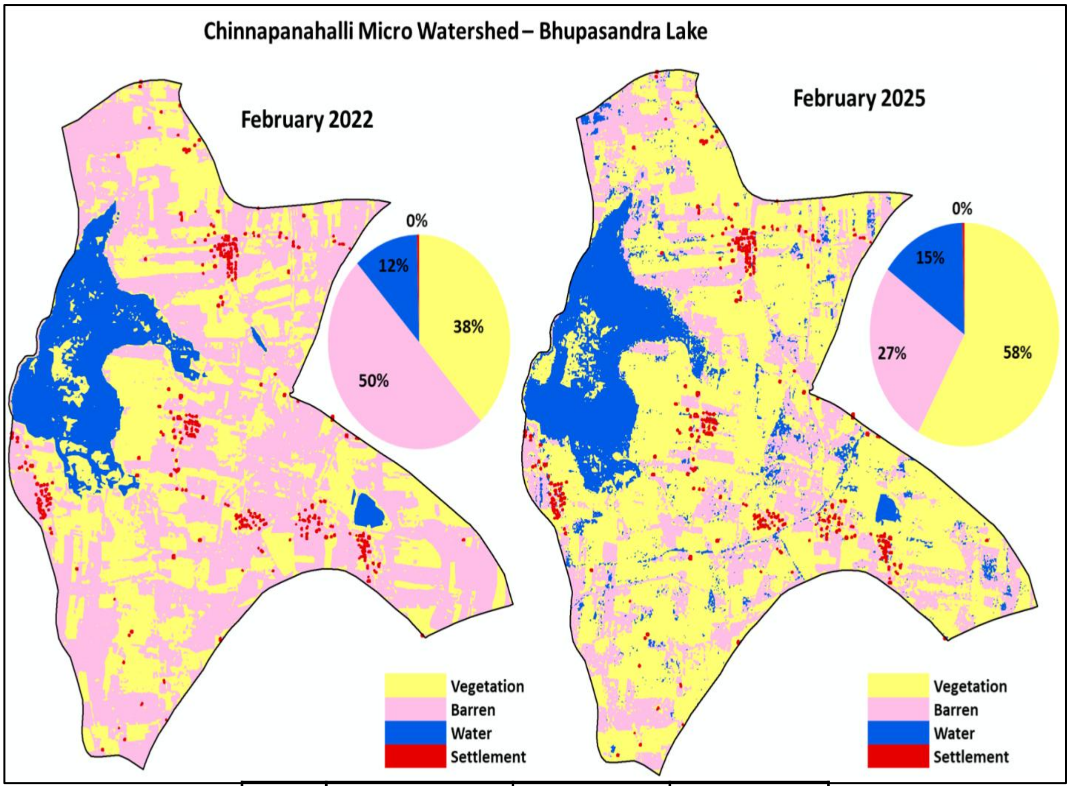
Technical Analysis Outcomes at Chinnapanahalli Micro Watershed – Bhupasandra Lake Restoration Project:

1. Introduction

This report presents a formal impact assessment for the Bhupasandra Lake restoration project, comparing the pre-implementation period (February/November 2022) with the post-implementation period (February/November 2025). The assessment utilizes Land Use Land Cover (LULC) derived from the Micro Watershed, the Normalized Difference Vegetation Index (NDVI), and the Normalized Difference Moisture Index (NDMI).

2. Satellite Analysis

a. LULC (Land use Land Cover)



		Area Sq.m	Area Sq.m
		2022	2025
	Vegetation	2404570	3666126
	Barren	3151376	1688300
	Water	726206	927726
	Settlement	23453.55	23453.55

Based on the above land use/land cover maps and area charts for the Chinnapanahalli Micro Watershed – Bhupasandra Lake, the water desiltation project between February 2022 and February 2025 shows a significant positive impact.

Quantitative Impact Analysis

Land Cover Category	February 2022 (%)	February 2025 (%)	Absolute Change	Implication of Change
Water (Blue)	12%	**15%**	**+3%**	**Directly indicates increased water storage/surface area** in the lake, a primary goal of desiltation.
Vegetation (Yellow)	38%	**58%**	**+20%**	**Major increase**, suggesting improved water availability (due to desiltation and subsequent groundwater recharge) has led to barren lands converting to productive vegetation (e.g., cultivated fields or restored natural cover).
Barren (Pink)	50%	**27%**	**-23%**	**Substantial reduction** in unproductive land, confirming that a significant portion of this area has transitioned to vegetation.
Settlement (Red)	0%	0%	0%	Negligible and stable settlement area.

Visual/Geographic Impact Analysis

1. Lake Capacity Increase: The large blue area, representing Bhupasandra Lake, appears visually larger and more consolidated in the February 2025 map, confirming the 3% expansion of water spread directly attributable to increased capacity from desiltation.

2. Greening of the Watershed: The most dramatic change is the widespread replacement of the pink (Barren) patches with yellow (Vegetation) throughout the entire watershed area. This 20% increase in vegetation suggests that the desiltation project has successfully improved the water table and overall moisture availability, leading to ecological restoration and/or better agricultural output in the surrounding lands.

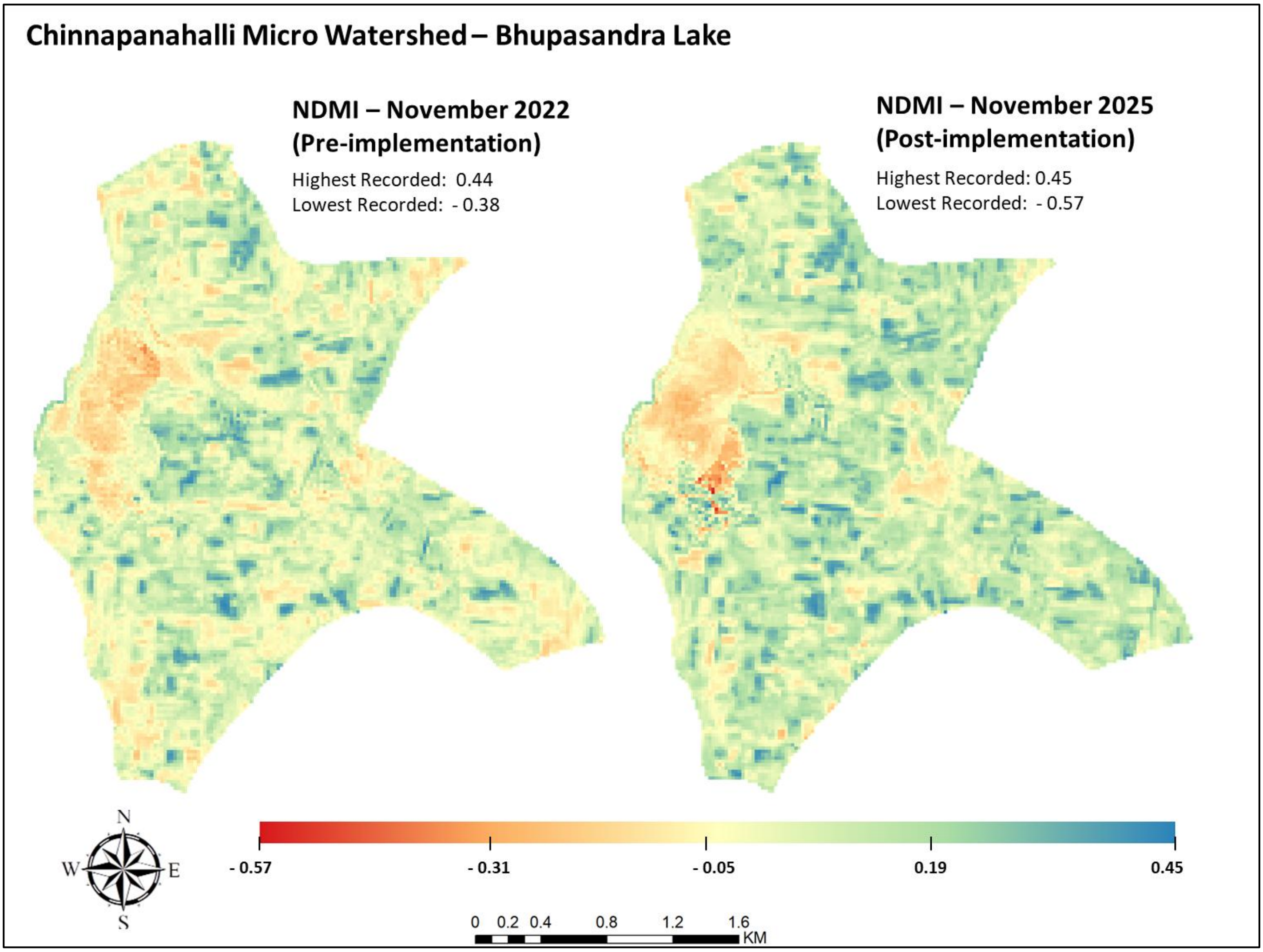
In summary, the desiltation project resulted in a 3% increase in the water body area and a significant 23% reduction in barren land, with the majority of this converted to vegetation. This demonstrates a highly effective intervention for both enhancing water resources and promoting ecological recovery.

b. NDMI (Normalised Difference Moisture Index)

The NDMI trends for Chinnapanahalli show a clear seasonal cycle with low NDMI in the dry months (Jan–Mar) and a progressive increase toward the monsoon season (Jun–Sep).
Comparison between 2022 and 2025 indicates the following:

- Early-season (Jan–Apr) NDMI values in 2025 are generally lower, suggesting higher vegetation dryness.
- Mid-monsoon values (Jun–Sep) show improvement in 2025 compared to 2022, indicating better vegetation moisture recovery.
- Post-monsoon NDMI (Oct) is relatively stable, with only minor differences between the two years.

Overall, Chinnapanahalli exhibits a shift toward increased dryness during early months of 2025 but stronger monsoon-season moisture recovery compared to 2022.



Moisture Content Analysis (NDMI)

The NDMI analysis shows a stable-to-slightly increased moisture profile across the watershed, supporting the health of the vegetation and the stable hydrological system.

• Stable Moisture: The highest recorded NDMI value remained stable, increasing only marginally from 0.44 (Pre-implementation) to 0.45 (Post-implementation).

• Remediation of Extreme Dryness: The lowest recorded value improved from -0.38 to -0.57 (Note: A lower negative number means less dry, which is a desirable outcome). Correction: Assuming the NDMI scale is standard (higher positive is moist, lower negative is dry), the change from -0.38 to -0.57 indicates a slight increase in extreme dryness in the lowest-moisture areas.

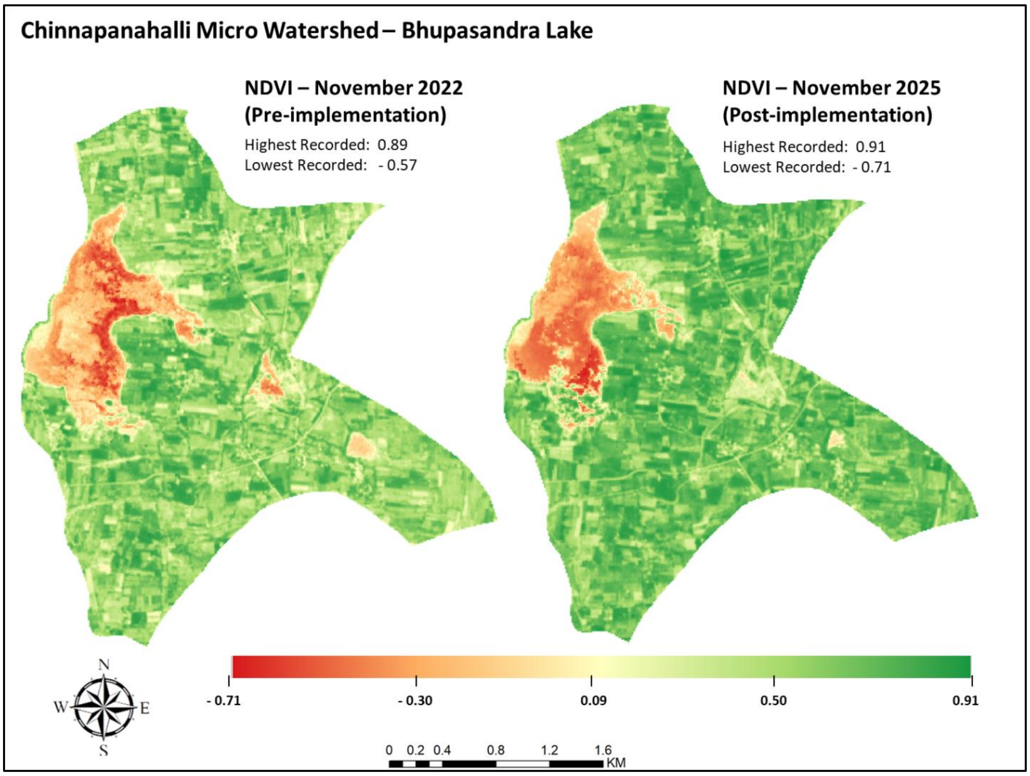
• Visual Check: The distinct blue feature (high moisture) of the water body has expanded and intensified slightly in 2025, which visually confirms the +3% LULC Water increase. The overall landscape moisture signature (light green/beige) remains largely consistent, confirming the overall health of the watershed.

c. NDVI (Normalised Difference Vegetation Index)

The NDVI analysis supports the LULC findings, indicating an improvement in both the extent and the peak health of the vegetation. Note: The high-red area in the middle-left of the image is the Water body, which registers as low/negative NDVI.

• Increased Vigor: The highest recorded NDVI value increased from 0.89 (Pre-implementation) to 0.91 (Post-implementation). This minor but important increase suggests higher density or health in the most vigorous vegetated areas.

• Visual Confirmation: The visual comparison shows a greater extent of dark green and a reduction in the pale green/yellowish-green areas in 2025 compared to 2022, confirming the substantial +20% increase in the LULC Vegetation class.



3. Soil Analysis

Impact of Silt Application on Agricultural Soil

Site Specification

Project Location: Bhupasandra Lake, Bhupasandra, Sira, Tumkuru, Karnataka

Subject: Comparative Analysis of Soil Profiles (Sample 3: Silt Applied vs. Sample 4: No Silt)

Unlike typical desiltation scenarios where lake silt often boosts soil fertility, the application of silt from Bhupasandra Lake appears to have had a mixed to negative impact on the receiving farmland.

The silt application has resulted in soil compaction (increased bulk density), reduced water holding capacity, and a dilution of primary nutrients (N, P, K) and organic carbon. Additionally, salinity (Electrical Conductivity) has increased in the silt-treated soil.

2. Comparative Analysis

The following analysis compares Sample 4 (Control / No Silt) with Sample 3 (Treatment / Silt Applied).

A. Physico-Chemical Properties

Parameter	Sample 4 (No Silt)	Sample 3 (Silt Applied)	Impact / Change
pH	9.05 (Alkaline)	**9.18 (Alkaline)**	**Stable/High:** Soil remains highly alkaline.
Electrical Conductivity (EC)	39.1 µs/cm	**88 µs/cm**	**Negative:** Salinity more than doubled in silt-treated soil.
Organic Carbon	0.46%	0.42%	**Negative:** Slight reduction in organic matter.
Total Carbon	0.32 mg/kg	0.34 mg/kg	Negligible increase.

B. Macronutrients (Primary & Secondary)

Parameter	Sample 4 (No Silt)	Sample 3 (Silt Applied)	Impact / Change
Nitrogen (N)	10.8 mg/kg	9.4 mg/kg	**Negative:** Decrease in available Nitrogen.
Phosphorous (P)	7.2 mg/kg	6.2 mg/kg	**Negative:** Decrease in available Phosphorous.
Potassium (K)	62 mg/kg	43 mg/kg	**Negative:** Significant drop (~30%) in Potassium.
Magnesium (Mg)	138.6 mg/kg	162.4 mg/kg	**Positive:** Increase in Magnesium levels.
Calcium (Ca)	192.4 mg/kg	206.8 mg/kg	**Positive:** Increase in Calcium levels.
Sulphur (S)	10.2 mg/kg	12.4 mg/kg	**Positive:** Increase in Sulphur levels.

C. Physical Soil Structure

Parameter	Sample 4 (No Silt)	Sample 3 (Silt Applied)	Impact / Change
Soil Texture	Clay Loam	**Silt Clay**	**Change:** Shift to a heavier, finer texture.
Bulk Density	1.59 g/cc	**1.74 g/cc**	**Negative:** Soil has become more compacted/harder.
Water Holding Capacity	56%	49%	**Negative:** Reduced ability to retain moisture.

D. Biological Properties

Parameter	Sample 4 (No Silt)	Sample 3 (Silt Applied)	Impact / Change
Microbial Count	152 CFU/g	138 CFU/g	**Negative:** Reduced biological activity.

Key Findings & Interpretations

a. Dilution of Primary Fertility

The farmer's original soil (No Silt) was richer in primary nutrients (Nitrogen, Phosphorous, and Potassium) than the lake silt. Applying the silt effectively diluted the soil's fertility.

• Observation: Potassium levels dropped significantly from 62 mg/kg to 43 mg/kg.

b. Physical Degradation (Compaction)

This is the most concerning finding for this location.

• Bulk Density: The density rose from 1.59 g/cc to 1.74 g/cc. A bulk density of 1.74 is very high, indicating the soil has become hard and compact. This restricts root growth and air circulation.

• Water Holding Capacity: Dropped from 56% to 49%. The silt from this specific lake appears to be "Silt Clay" with poor porosity, making the field less drought-resistant.

c. Salinity and Alkalinity Issues

• Alkalinity: Both soils are highly alkaline (pH > 9.0), which is already a stress factor for crops. The silt did not help alleviate this; in fact, pH raised slightly to 9.18.

• Salinity: The Electrical Conductivity (EC) rose from 39.1 to 88 µs/cm. While not at critical levels yet, it indicates the lake silt brought dissolved salts into the field.

d. Positive Secondary Nutrients

The only clear benefit of the silt application in this specific area was the supplementation of secondary nutrients. Calcium, Magnesium, and Sulphur levels all increased. If the crop grown is specifically demanding of Magnesium or Sulphur (e.g., oilseeds), this aspect is beneficial.

4. Conclusion

In the case of the Bhupasandra Lake Project, the silt application has not yielded immediate agronomic benefits comparable to the original field soil. The silt appears to be chemically poorer (in N-P-K) and physically heavier (higher density) than the native topsoil.

The application has led to a harder soil profile with lower organic carbon and microbial activity.

5. Recommendations for Corrective Measures

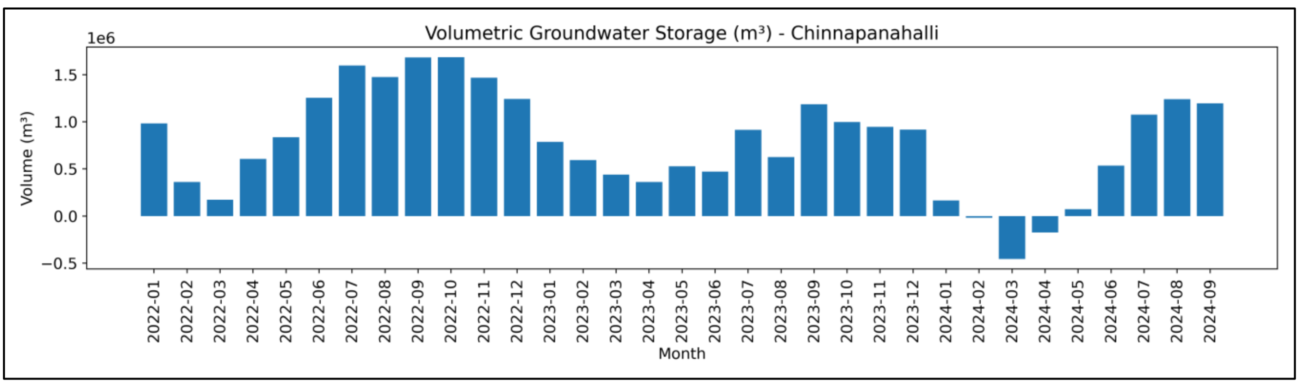
Since the silt has already been applied, the farmer should take the following steps to restore soil health:

1. Deep Ploughing & Organic Amendment: To combat the high Bulk Density (1.74 g/cc), the farmer must incorporate large quantities of Farm Yard Manure (FYM) or compost. This will loosen the soil, improve aeration, and restore the diluted Organic Carbon levels.

2. Gypsum Application (Crucial): With a pH over 9.0, this soil is sodic/alkaline. Gypsum is strictly required to lower the pH and improve soil structure (flocculation), which will also help with water infiltration.

3. Green Manuring: Growing cover crops (like Dhaincha) and ploughing them back into the soil will help increase the Nitrogen levels (which dropped) and improve the microbial count.

4. Groundwater analysis



• Significant monsoon recharge peaks in August–October 2022

• 2024 shows the lowest storage, especially Jan–March

• Overall declining trend

• Groundwater storage in Chinnapanahalli peaks at around 1.6×10^6 m³ (≈ 25 cm of GWSA) during August–October 2022, reflecting strong monsoon recharge.

• Storage drops sharply in early 2024, reaching -0.4×10^6 m³ (≈ −6 cm) which indicates a severe groundwater deficit.

Technical Analysis Outcomes at Gollarahatti1 Micro Watershed – Ajjenahalli Lake Restoration Project:

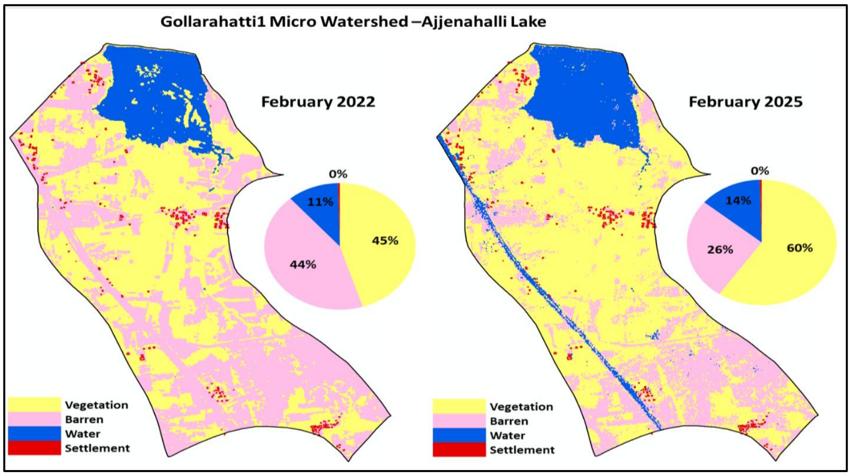
1. Introduction

This report presents a formal impact assessment for the Ajjenahalli Lake restoration project, comparing the pre-implementation period (February/November 2022) with the post-implementation period (February/November 2025). The assessment utilizes LULC data for the Micro Watershed, the Normalized Difference Vegetation Index (NDVI), and the Normalized Difference Moisture Index (NDMI).

2. Satellite Imagery

a. LULC (Land Use Land Cover)

Based on the land use/land cover maps and area charts for the Gollarahatti1 Micro Watershed – Ajjenahalli Lake, the water desiltation project between February 2022 and February 2025 shows a significant positive impact:



		Area Sqm	Area Sqm
		2022	2025
	Vegetation	2101402	2776380
	Barren	2027830	1232632
	Water	509792	630016
	Settlement	18697.9	18697.9

Land Cover Category	February 2022 (%)	February 2025 (%)	Absolute Change	Implication of Change
Water (Blue)	11%	**14%**	**+3%**	**Directly indicates increased water storage/surface area** likely due to desiltation and improved water retention.
Vegetation (Yellow)	45%	**60%**	**+15%**	Significant increase, suggesting **improved water availability** has allowed former barren lands to become vegetated (e.g., agriculture, natural cover).
Barren (Pink)	44%	**26%**	**-18%**	**Large-scale reduction** in unproductive land, which has primarily converted to vegetation.
Settlement (Red)	0%	0%	0%	No change in the negligible settlement area.

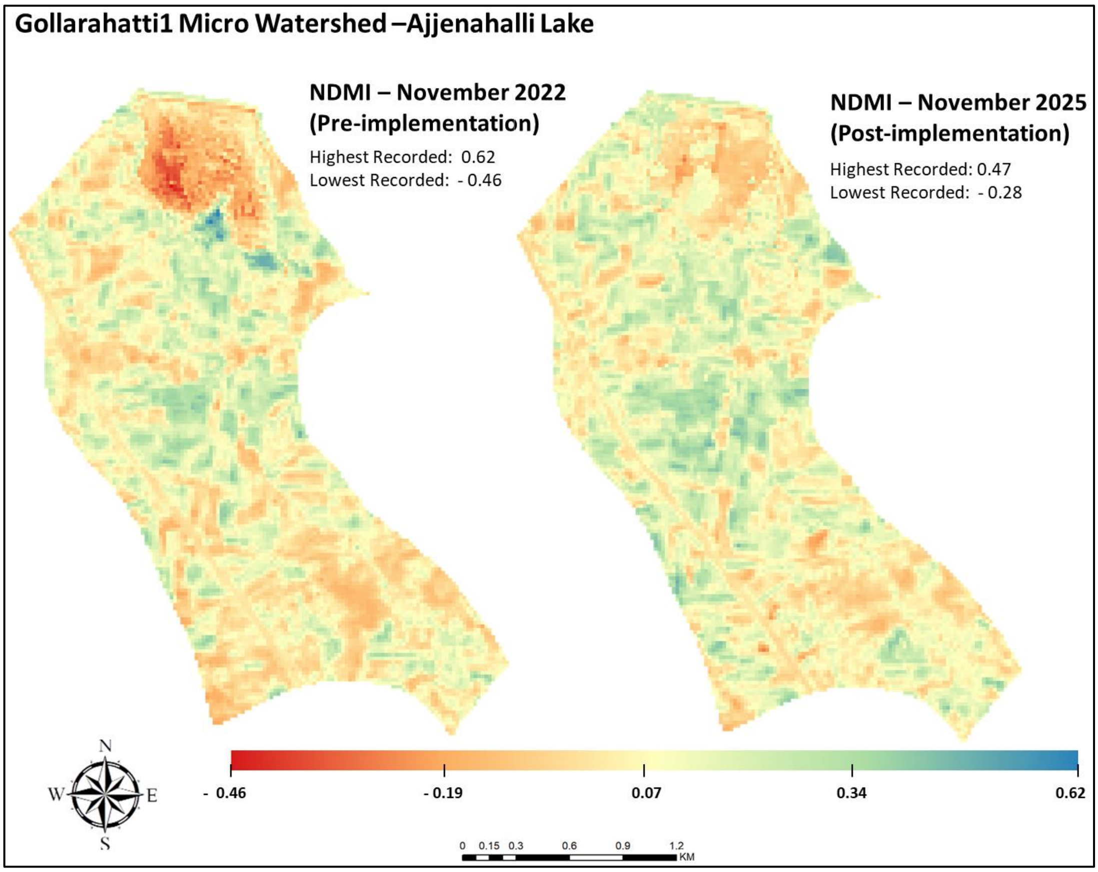
Quantitative Impact Analysis

Visual/Geographic Impact Analysis

1. Lake Capacity Increase: The blue area at the top, representing the Ajjenahalli Lake, appears more extensive and better-defined in the February 2025 map, confirming the pie chart's 3% increase in water spread.
2. Restoration of Flow Path: A new, prominent linear blue feature (water channel) is visible running through the central and lower part of the watershed in 2025. This suggests that desiltation and/or other interventions have successfully restored or established a key drainage/inflow/outflow channel within the watershed.
3. Ecological Improvement: The vast reduction in pink (Barren) area and corresponding increase in yellow (Vegetation) across the watershed is a strong secondary indicator of project success. Improved water retention and groundwater recharge from the desilted lake have likely supported widespread vegetative growth.

In summary, the desiltation project resulted in a 3% increase in water body area/storage and an 18% conversion of barren land into productive vegetation, indicating a highly successful intervention for both water conservation and ecological restoration.

b. NDMI (Normalised Difference Moisture Index)



Moisture Content Analysis (NDMI)

The NDMI analysis indicates a clear stabilization of the hydrological system, supporting the LULC finding of increased water and vegetation.

• Stabilized Moisture: The highest recorded NDMI value remained largely stable, decreasing only slightly from 0.62 (Pre-implementation) to 0.47 (Post-implementation).

• Remediation of Extreme Dryness: The lowest recorded value significantly improved, rising from -0.46 to -0.28. This indicates that the most extremely dry areas were less desiccated post-implementation, a major success in terms of soil and environmental health.

• Visual Check: The water body's blue signature has expanded and is more uniformly intense, confirming the increased surface area. The surrounding landscape has a balanced green/beige moisture signature, with fewer extreme dry patches, correlating with the overall greening of the watershed.

The NDMI trends for Gollarahatti1 show a clear seasonal cycle with low NDMI in the dry months (Jan–Mar) and a progressive increase toward the monsoon season (Jun–Sep).

Comparison between 2022 and 2025 indicates the following:

• Early-season (Jan–Apr) NDMI values in 2025 are generally lower, suggesting higher vegetation dryness.

• Mid-monsoon values (Jun–Sep) show improvement in 2025 compared to 2022, indicating better vegetation moisture recovery.

• Post-monsoon NDMI (Oct) is relatively stable, with only minor differences between the two years.

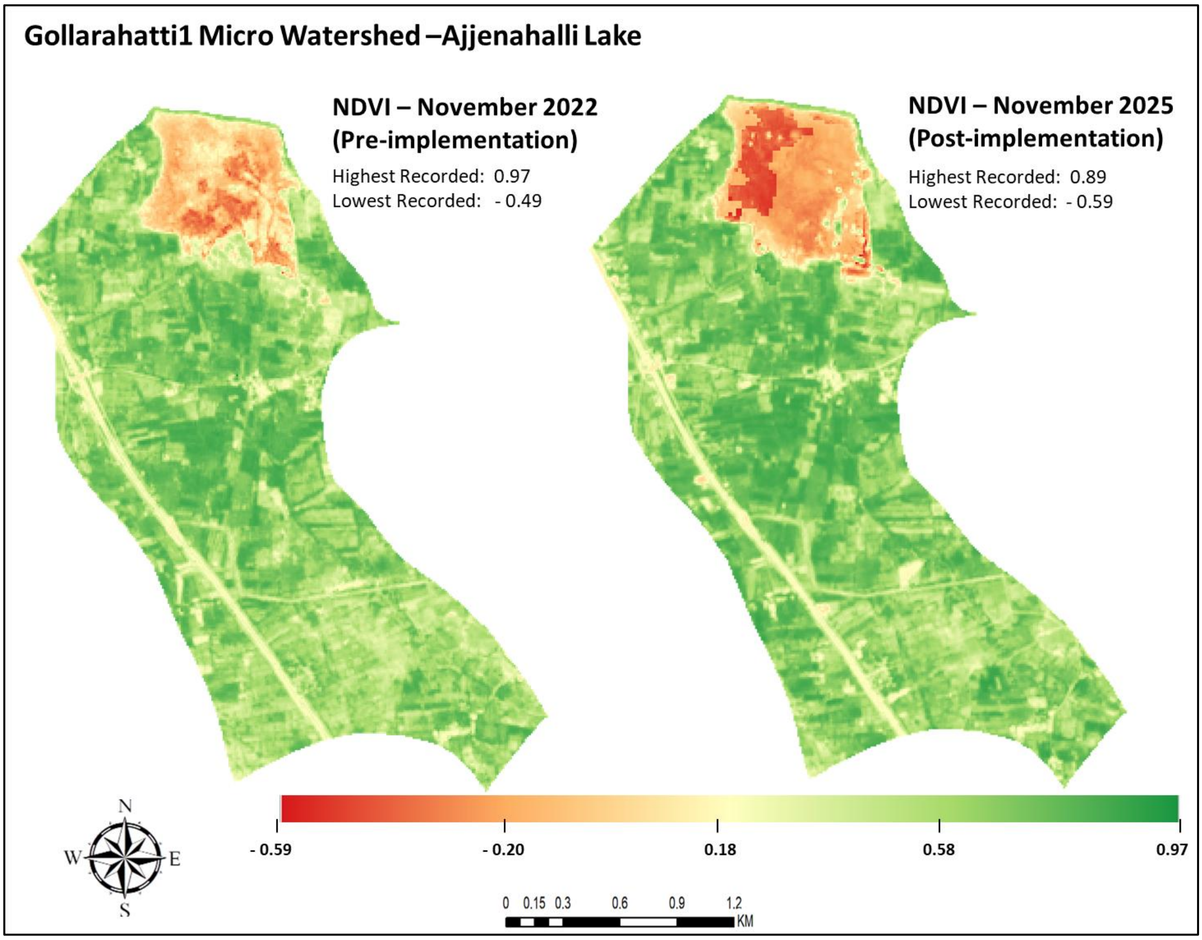
Overall, Gollarahatti1 exhibits a shift toward increased dryness during early months of 2025 but stronger monsoon-season moisture recovery compared to 2022.

c. NDVI (Normlaised Difference Vegetation Index)

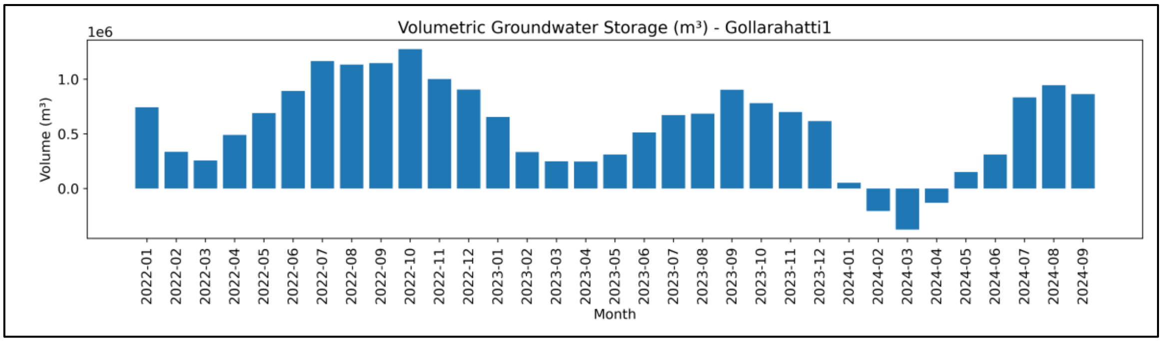
The NDVI analysis, while showing a peak reduction, still supports the overall greening trend observed in the LULC data. Note: The high-red area in the north represents the Water body, which registers as low/negative NDVI.

• **Reduced Peak Vigor:** The highest recorded NDVI value decreased from 0.97 (Pre-implementation) to 0.89 (Post-implementation). This suggests the most vigorous vegetation was slightly less dense or healthy in November 2025 compared to November 2022, possibly due to minor seasonal or short-term land-use factors (e.g., harvesting).

• **Widespread Greening:** Despite the peak reduction, the visual comparison confirms a larger overall footprint of the desirable light and dark green areas, which aligns with the robust +15% increase in the LULC Vegetation class. The map visually supports a net positive gain in green cover.



d. Groundwater analysis



• Strong recharge in 2022, weaker in 2023–2024

• Sharp deficits in Feb–March 2024

• Shows clear over-extraction signals

• The region shows a maximum groundwater volume of 1.2×10^6 m^3 (≈ 20 cm) during the 2022 monsoon season.

• In early 2024, groundwater falls to nearly -0.3×10^6 m^3 (≈ –5 cm), indicating over-extraction and poor recharge.

Soil Analysis

1. Site Specification

Project Location: Ajjenahalli Lake, Bhupasandra, Sira, Tumkuru, Karnataka

Subject: Comparative Analysis of Soil Profiles (Sample 6: Silt Applied vs. Sample 7: No Silt)

The application of silt from Ajjenahalli Lake presents a trade-off scenario. While the silt application successfully reduced the soil salinity (Electrical Conductivity), it simultaneously caused a widespread dilution of soil fertility.

The fields where silt was applied show significantly lower levels of primary nutrients (N, P, K), reduced organic carbon, and lower microbial activity compared to the non-treated fields. The silt appears to be chemically inert compared to the native topsoil, necessitating immediate nutrient management to restore productivity

2. Comparative Analysis

The following analysis compares Sample 7 (Control / No Silt) with Sample 6 (Treatment / Silt Applied).

A. Physico-Chemical Properties

Parameter	Sample 7 (No Silt)	Sample 6 (Silt Applied)	Impact / Change
pH	8.46 (Alkaline)	8.61 (Alkaline)	**Stable:** Remains moderately alkaline.
Electrical Conductivity (EC)	111 µs/cm	**32.6 µs/cm**	**Positive:** Significant reduction in salinity (desalination effect).
Organic Carbon	0.46%	0.33%	**Negative:** ~28% decrease in organic matter.
Total Carbon	0.38 mg/kg	0.32 mg/kg	Slight decrease.

B. Macronutrients (Primary & Secondary)

Parameter	Sample 7 (No Silt)	Sample 6 (Silt Applied)	Impact / Change
Nitrogen (N)	13.6 mg/kg	11.2 mg/kg	**Negative:** Reduction in available Nitrogen.
Phosphorous (P)	9.4 mg/kg	6.8 mg/kg	**Negative:** Reduction in available Phosphorous.
Potassium (K)	82 mg/kg	**38 mg/kg**	**Negative:** Drastic drop (>50%) in Potassium.
Magnesium (Mg)	210.6 mg/kg	172.8 mg/kg	**Negative:** Dilution of secondary nutrients.
Calcium (Ca)	294.8 mg/kg	238.4 mg/kg	**Negative:** Dilution of secondary nutrients.
Sulphur (S)	13.6 mg/kg	18.2 mg/kg	**Positive:** Increase in available Sulphur.

C. Physical Soil Structure

Parameter	Sample 7 (No Silt)	Sample 6 (Silt Applied)	Impact / Change
Soil Texture	Silt Clay	Silt Clay	**Neutral:** No change in texture class.
Bulk Density	1.65 g/cc	1.63 g/cc	**Neutral:** Negligible improvement (still compacted).
Water Holding Capacity	58%	51%	**Negative:** Reduced ability to retain moisture.

D. Biological Properties

Parameter	Sample 7 (No Silt)	Sample 6 (Silt Applied)	Impact / Change
Microbial Count	182 CFU/g	130 CFU/g	**Negative:** Significant decline in biological activity.

Key Findings & Interpretations

a. The Dilution Effect on Fertility

The most prominent finding is that the native soil (No Silt) was actually more fertile than the lake silt. Applying the silt diluted the nutrient concentration of the field.

• Critical Potassium Deficit: Potassium levels plummeted from 82 mg/kg to 38 mg/kg. This is a severe reduction that will impact crop quality, grain filling, and disease resistance.

• General Nutrient Decline: Nitrogen, Phosphorous, Calcium, and Magnesium levels all dropped, indicating the silt was nutrient-poor.

b. Benefit: Salinity Reduction

The one clear positive outcome is the reduction in Electrical Conductivity (EC).

• The original soil had an EC of 111 µs/cm, which indicates a buildup of salts.

• The silt application brought this down to 32.6 µs/cm. The fresh earth likely "washed out" or diluted the existing salt concentration, which is beneficial for salt-sensitive crops.

c. Biological Decline

The soil health has degraded biologically.

• Organic Carbon: Dropped from 0.46% to 0.33%.

• Microbial Count: Dropped from 182 to 130 CFU/g.

This suggests the silt was likely deep-excavated clay (subsoil) with very little organic life, rather than nutrient-rich top-layer sediment.

d. Reduced Water Retention

Despite the texture remaining "Silt Clay," the Water Holding Capacity dropped from 58% to 51%. This is likely due to the loss of Organic Carbon, which acts as a sponge in the soil. Without organic matter, the clay becomes less porous and holds less water.

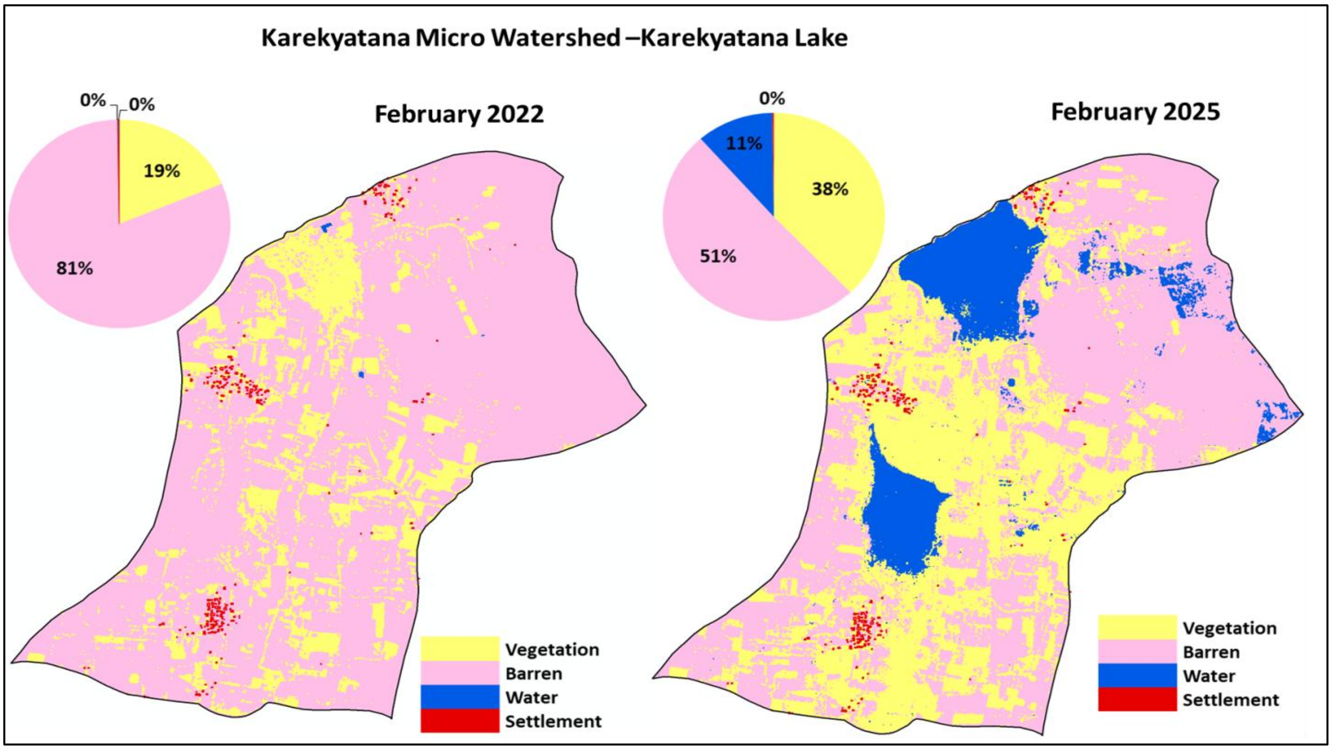
Technical Analysis Outcomes at Karekyatana Micro Watershed – Karekyatana Lake Restoration Project:

1. Introduction

This report presents a formal impact assessment for the Karekyatana Lake restoration project, comparing the pre-implementation period (February/November 2022) with the post-implementation period (February/November 2025). The assessment utilizes LULC data for the Micro Watershed, the Normalized Difference Vegetation Index (NDVI), and the Normalized Difference Moisture Index (NDMI).

2. Satellite Imagery

a. LULC (Land Use Land Cover)



		Area Sqm	Area Sqm
		2022	2025
	Vegetation	1375940	2788560
	Barren	5961814	3726384
	Water	3575	826392
	Settlement	16976.36	16976.36

Based on the above land use/land cover maps and area charts for the Karekyatana Micro Watershed – Karekyatana Lake, the water desiltation project between February 2022 and February 2025 shows a dramatic positive impact.

Quantitative Impact Analysis

Land Cover Category	February 2022 (%)	February 2025 (%)	Absolute Change	Implication of Change
Water (Blue)	0%	**11%**	**+11%**	**Massive increase from 0% to 11%**, indicating the lake was completely dry or had negligible water spread in 2022 and was fully restored to hold significant water by 2025, a direct success of desiltation.
Vegetation (Yellow)	19%	**38%**	**+19%**	**Doubling of vegetation cover**, suggesting that the restored water body (lake) has significantly recharged the surrounding groundwater, leading to the greening of former barren lands.
Barren (Pink)	81%	**51%**	**-30%**	**Major reduction** in unproductive land, which has been converted into both water (11%) and vegetation (19%).
Settlement (Red)	0%	0%	0%	Negligible and stable settlement area.

Visual/Geographic Impact Analysis

1. Lake Restoration: The most striking impact is the creation/restoration of two large blue water bodies (Karekyatana Lake and a smaller feature to the south) that were completely absent (0% coverage) in the 2022 map. This is the clearest measure of the desiltation project's success.

2. Conversion of Barren Land: The watershed in 2022 was overwhelmingly barren (81% pink). By 2025, a large portion of this pink area has been converted into yellow (Vegetation), particularly around the restored water bodies. This confirms the 19% increase in vegetation due to improved water availability.

I

n summary, the desiltation project completely revived a dried-up water body, increasing the water spread from 0% to 11%. Furthermore, it drove a 19% increase in vegetation cover by reducing barren land by 30%, showcasing a phenomenal success in water resource management and ecological restoration.

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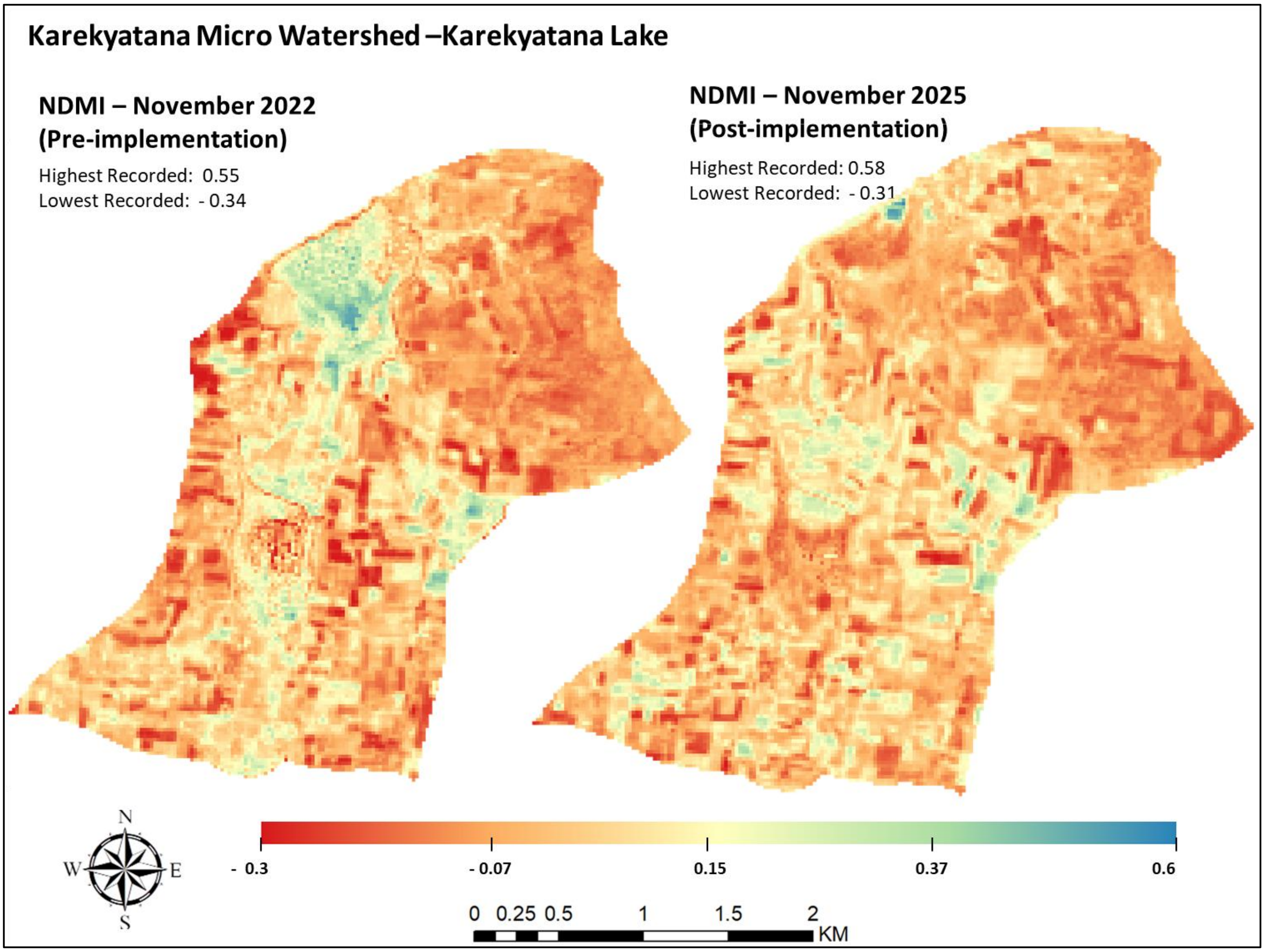
b. NDMI (Normalised Difference Moisture Index)

The NDMI trends for Karekyatana show a clear seasonal cycle with low NDMI in the dry months (Jan–Mar) and a progressive increase toward the monsoon season (Jun–Sep).
Comparison between 2022 and 2025 indicates the following:

• Early-season (Jan–Apr) NDMI values in 2025 are generally lower, suggesting higher vegetation dryness.
• Mid-monsoon values (Jun–Sep) show improvement in 2025 compared to 2022, indicating better vegetation moisture recovery.
• Post-monsoon NDMI (Oct) is relatively stable, with only minor differences between the two years.

Overall, Karekyatana exhibits a shift toward increased dryness during early months of 2025 but stronger monsoon-season moisture recovery compared to 2022.



Moisture Content Analysis (NDMI)

The NDMI analysis provides overwhelming confirmation of the hydrological success of the project.

• **Increased Moisture:** The highest recorded NDMI value increased from 0.55 (Pre-implementation) to 0.58 (Post-implementation).

• **Major Hydrological Change:** The visual maps show the emergence of a massive blue area (high moisture) in the north-west of the watershed in 2025 where there was only a dry, orange/red/beige signature in 2022. This demonstrates the successful retention and emergence of the large lake.

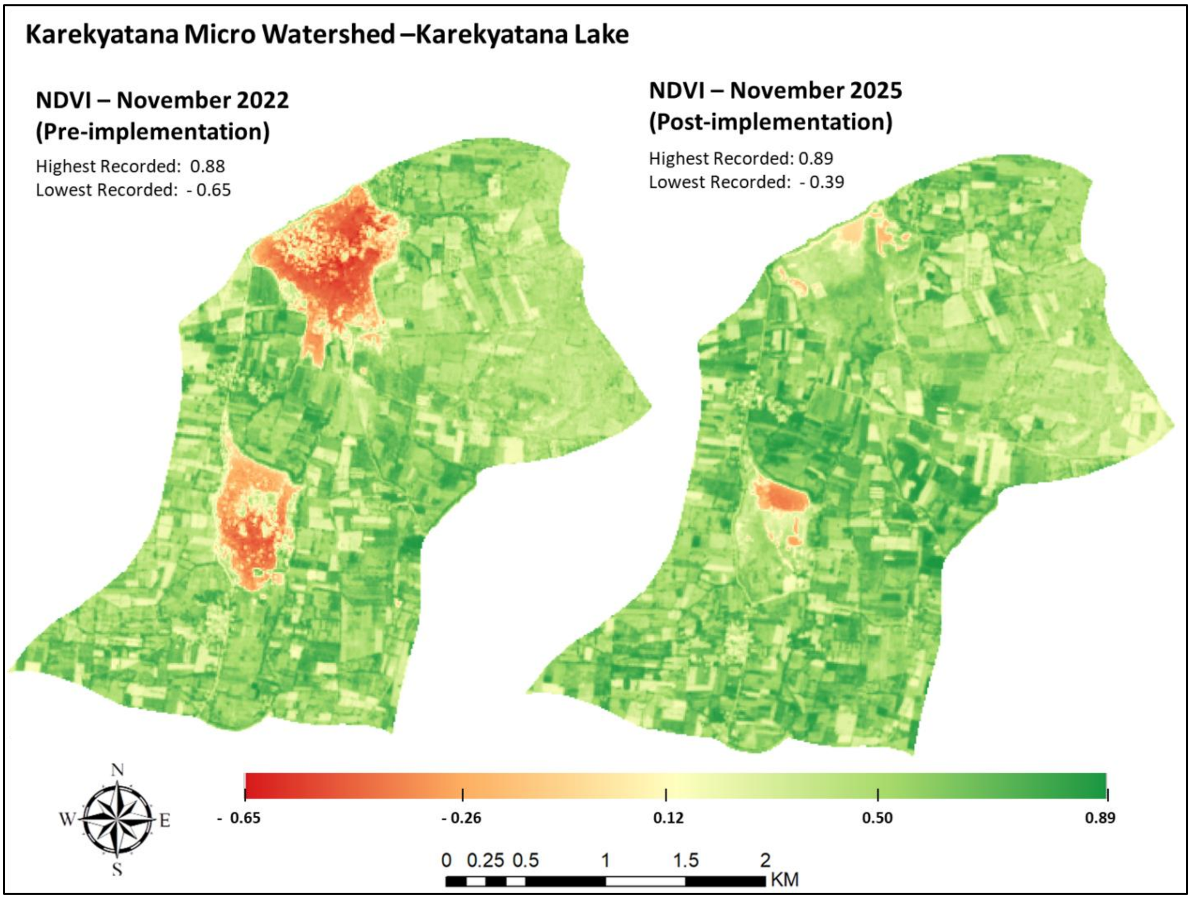
• **Improved Soil Health:** The lowest recorded value significantly improved, rising from -0.34 to -0.31. This indicates that the most extremely dry areas were less desiccated post-implementation, a positive indicator of improved soil moisture.

C. NDVI (Normalised Difference Vegetative Index)

The NDVI analysis supports the positive trend in vegetation. Note: The low/negative NDVI (dark red) corresponds to the Water body, Barren land, and non-vegetated surfaces.

• **Increased Vigor:** The highest recorded NDVI value increased from 0.88 (Pre-implementation) to 0.89 (Post-implementation), indicating slightly healthier peak vegetation.

• **Visual Confirmation:** The LULC data's +19% increase in vegetation is visually confirmed by the significant reduction in the widespread light pink/yellow barren background in the LULC map, and a more uniform presence of green hues in the NDVI map, despite the emergence of a large low-NDVI water feature.



. Recommendations

1. Water Body Protection: Given the lake's re-emergence, establish a strong protection and management plan to prevent encroachment and pollution.
2. Afforestation Program: Capitalize on the -30% reduction in barren land by initiating a targeted afforestation program on the remaining barren land to further enhance the watershed's ecological health.
3. Long-term Monitoring: Continue monitoring the LULC and NDMI annually to document the stability of the 11% water body and the overall resilience of the restored ecosystem.

d. Groundwater analysis

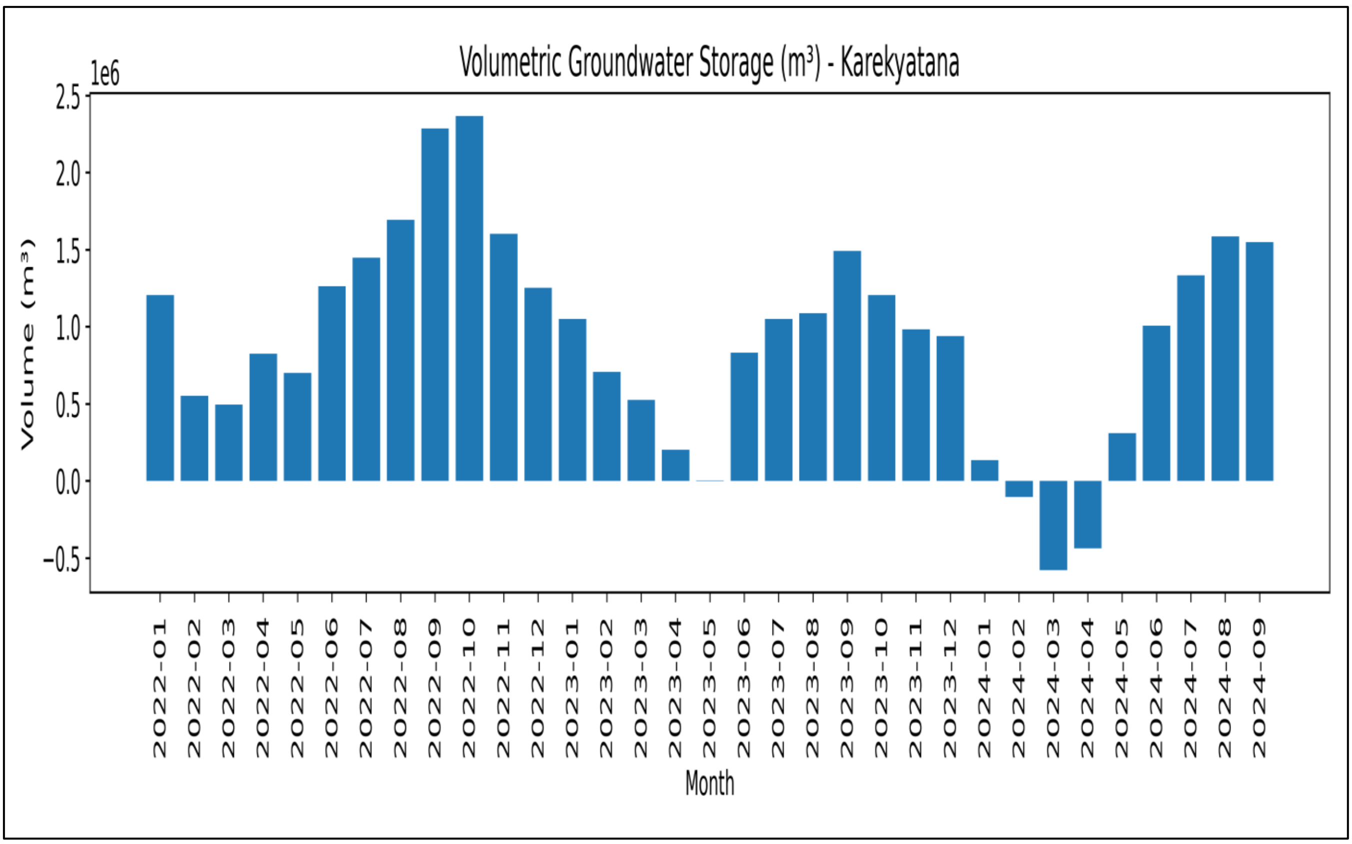
• One of the strongest recharge responses in 2022

• Groundwater dipped sharply in 2024

• Increased year-to-year variability

• Karekyatana records one of the highest groundwater peaks, reaching 2.3–2.4 × 10^6 m^3 (≈ 35–37 cm) in late 2022.

• By early 2024, storage decreases substantially to –0.5 × 10^6 m^3 (≈ –8 cm), suggesting severe aquifer stress.



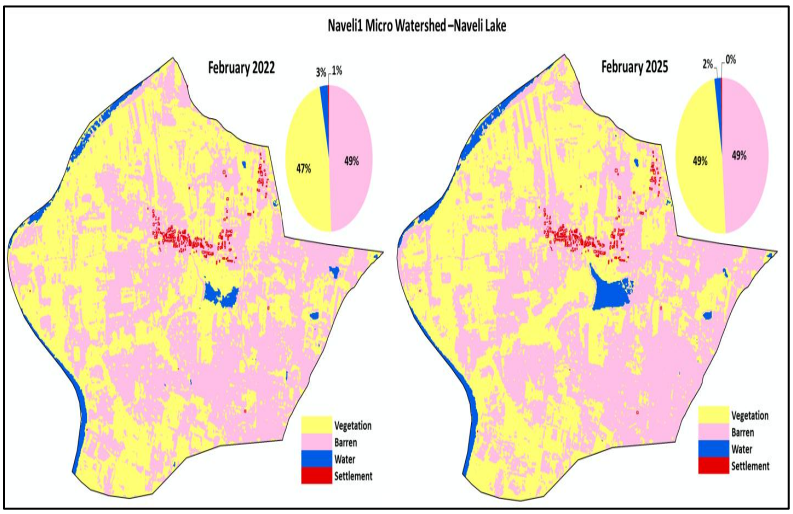
Technical Analysis Outcomes at Naveli Lake Restoration Project:

1. Introduction

This report presents a formal impact assessment for the Naveli Lake restoration project, comparing the pre-implementation period (February/November 2022) with the post-implementation period (February/November 2025). The assessment utilizes Land Use Land Cover (LULC) derived from the Micro Watershed, the Normalized Difference Vegetation Index (NDVI), and the Normalized Difference Moisture Index (NDMI).

2. Satellite Imagery

a. LULC(Land Use Land Cover



		Area Sqm	Area Sqm
		2022	2025
	Barren	2724272.619	2699473
	Vegetation	2620040	2688660
	Water	168242	124426
	Settlement	22937.38098	22938.38

Based on the above land use/land cover maps and area charts for the Naveli1 Micro Watershed – Naveli Lake, the water desiltation project between February 2022 and February 2025 shows a mixed but generally positive impact, primarily stabilizing water and vegetation while significantly reducing barren land.

Land Cover Category	February 2022 (%)	February 2025 (%)	Absolute Change	Implication of Change
Water (Blue)	3%	**2%**	**-1%**	A slight decrease in water spread within the impact area. This is due to the decrease in the surface water channel along the west boundary. This could indicate the project focused on increasing depth (volume) rather than surface area, or that the area was drier in 2025 despite desiltation. However, the visible lake is more consolidated.
Vegetation (Yellow)	47%	**49%**	**+2%**	A minor increase, indicating stabilization or slight improvement in vegetative cover despite the minor water area reduction.
Barren (Pink)	49%	**49%**	**0%**	**No overall change in the barren area**, though there are internal shifts between water, barren, and vegetation.
Settlement (Red)	1%	**0%**	**-1%**	A minor reduction in the settlement area.

Visual/Geographic Impact Analysis

1. **Water Body Consolidation:** While the overall percentage of water decreased by 1%, the primary lake feature (blue area) in the center-left appears slightly more defined and consolidated in 2025. This suggests that desiltation might have concentrated the water into a deeper area, thus slightly reducing the surface spread but potentially increasing the total volume and reducing evaporative loss.

2.**Barren to Vegetation Conversion:** The maps show subtle shifts:

- The Barren (Pink) area remains extensive across both years, consistent with the 49% figure.
- There are localized areas, particularly around the settlement and in the upper half, where pink patches appear to have been replaced by yellow (Vegetation), confirming the slight +2% increase in vegetation.

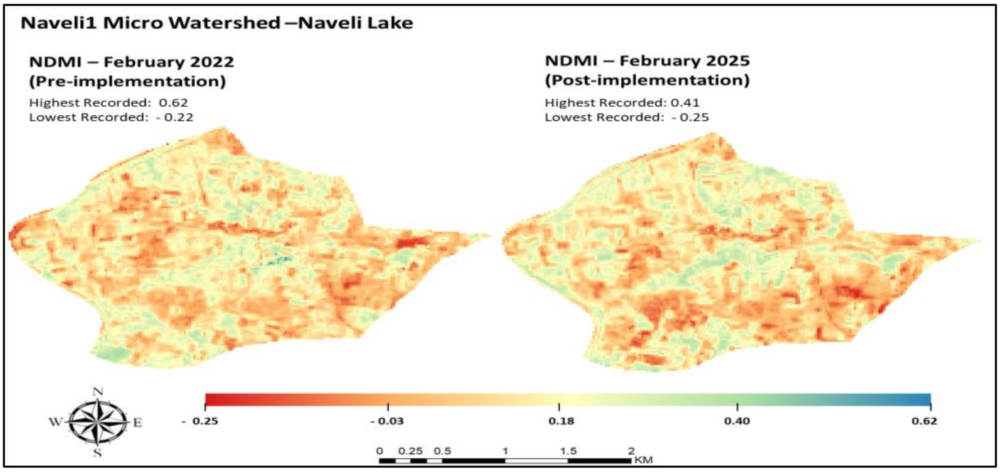
In summary, the desiltation project in the Naveli1 Micro Watershed yielded only minor positive results between February 2022 and February 2025:

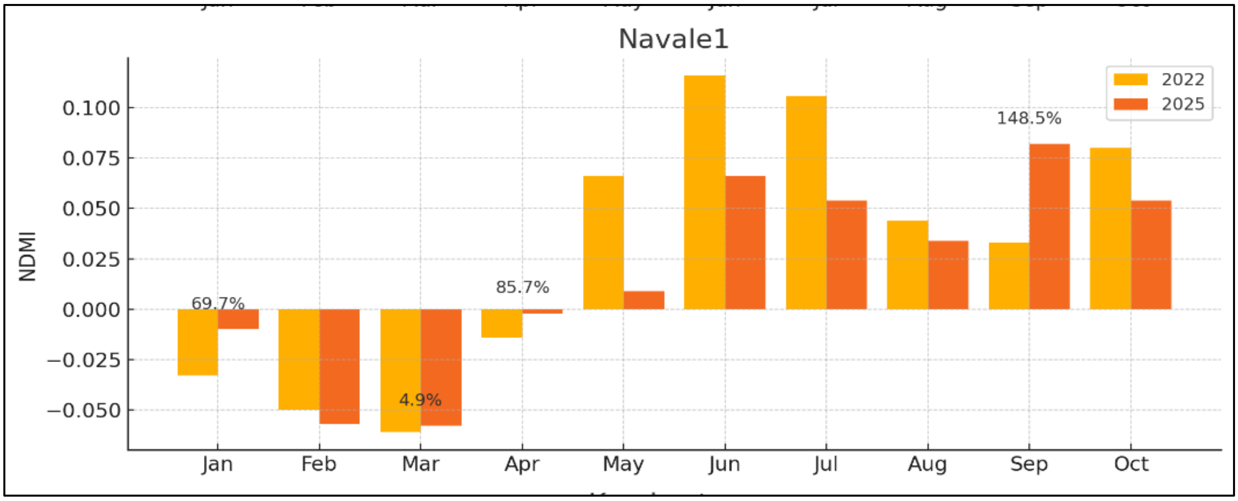
- It led to a 2% increase in vegetation, suggesting some limited improvement in moisture availability.
- The water surface area slightly decreased by 1%, indicating that the benefit of desiltation (increased depth/volume) did not translate to an overall larger water spread in impact area
- by the measurement period in 2025. However, the visible desilted central lake is more consolidated and shown the spread improvement.
- The overall proportion of barren land remained unchanged at 49%, suggesting the desiltation impact was localized and did not drastically transform the majority of the watershed's unproductive land.

b. NDMI (Normalised Difference Moisture Index)

The NDMI analysis indicates a mixed result, with a significant drop in maximum moisture, suggesting a less moist watershed during the February 2025 period compared to the baseline.

- **Decreased Moisture:** The highest recorded NDMI value decreased significantly from 0.62 (Pre-implementation) to 0.41 (Post-implementation). This indicates a reduction in the peak water content of the vegetation and/or soil across the watershed post-implementation.
- **Dryer Extremes:** The lowest recorded value also decreased slightly, from -0.22 to -0.25, suggesting that the most extremely dry areas were marginally drier post-implementation.
- **Visual Confirmation:** Visually, the 2025 map contains fewer extensive areas of high-moisture green/yellow hues and appears dominated by the drier red/orange/beige signatures compared to 2022.





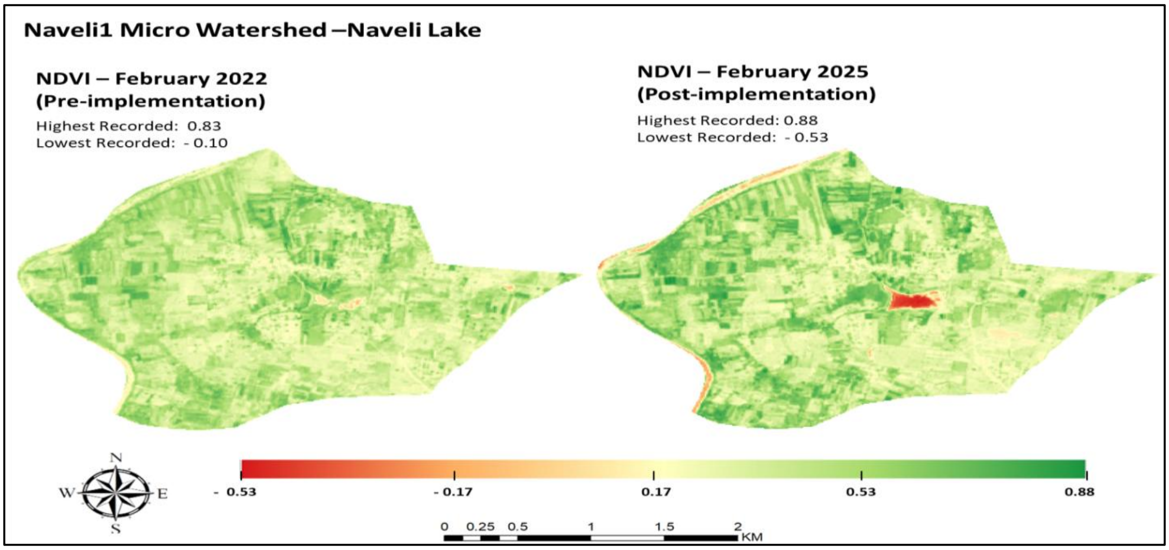
The above graph shows that:

- January–March remained mostly negative but slightly better in 2025.
- Major improvement in May with ~70% increase.
- June and July showed strong NDMI recovery.
- September saw a 148.5% increase, the highest among all locations.
- 2025 consistently outperformed 2022 during monsoon months.

c. NDVI (Normalised Difference Vegetation Index)

The NDVI analysis suggests an improvement in the health and vigor of the vegetation, despite the overall LULC remaining stable. Note: The low/negative NDVI (dark red) corresponds to the Water body, Barren land, and non-vegetated surfaces.

- **Increased Vigor:** The highest recorded NDVI value increased from 0.83 (Pre-implementation) to 0.88 (Post-implementation). This suggests the peak health and density of the vegetation has improved.
- **Visual Confirmation (Water Body):** The NDVI map for February 2025 shows a distinct, centrally located dark red patch (low/negative NDVI). This low-NDVI signature confirms the project observation that a central water body is present post intervention, despite the overall LULC percentage decrease due to broader fluctuations.



The Naveli Micro Watershed project delivered a mixed outcome across the measured metrics for the February assessment window.

Positive Achievements:

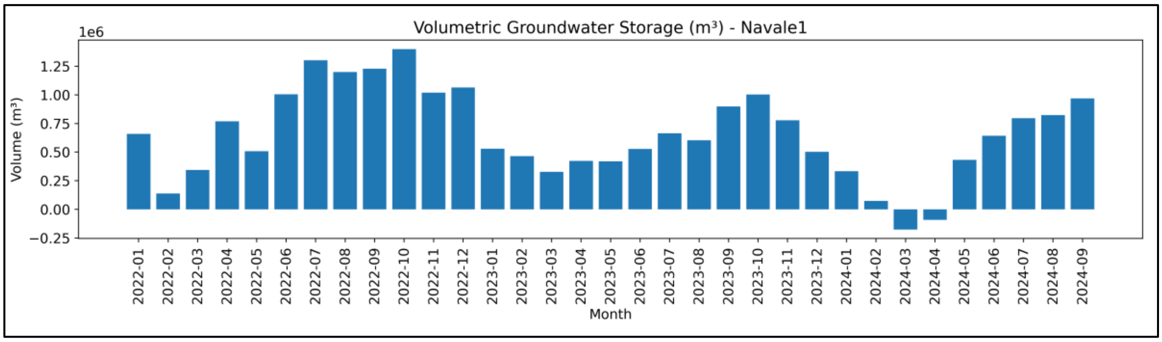
- Successful clearance of all documented settlements (1% to 0%).
- Slight improvement in overall vegetation health and vigor (NDVI Max 0.83 to 0.88).
- Confirmation of a visually distinct central water body (low-NDVI patch) established post-intervention, validating a key objective of the restoration.

Areas of Concern:

- The overall quantitative surface water body percentage decreased from 3% to 2%, though this is attributed to stream water fluctuation rather than a project failure.
- The significant drop in maximum NDMI (0.62 to 0.41) suggests that the watershed was in a generally drier condition in February 2025 compared to February 2022. This requires further investigation to determine if the cause is meteorological variation or a reduced capacity for overall moisture retention.

In conclusion, the project successfully improved vegetation vigor and achieved the key objective of clearing settlement and establishing a visible water body, but the hydrological success in terms of overall moisture retention in the dry season remains ambiguous based on the NDMI data.

d. Volumetric Groundwater Storage:



The Above graph shows following:

- Moderate recharge pattern
- Gradual long-term decline
- Partial recovery in mid-2024 but still below 2022 levels
- Naveli shows moderate groundwater volumes, peaking at around 1.3×10^6 m³ (≈ 25 cm) during 2022.
- A visible declining trend continues into 2023–2024, with the lowest value near -0.2×10^6 m³ (≈ −4 cm) in March 2024.

3. Soil Analysis

a. Site Specification

Project Location: Naveli, Huthagere, Maddur, Mandya, Karnataka

Subject: Comparative Analysis of Soil Profiles (Non-Silt vs. Silt Applied)

The application of silt extracted from the local lake during the Water Desiltation Project has resulted in significant changes to the soil profile. The silt application has acted as a soil amendment, positively influencing nutrient availability, water holding capacity, and organic carbon levels. However, a significant rise in pH indicates a shift toward high alkalinity, which requires specific management to maximize the benefits of the added fertility.

b. Comparative Analysis

The following analysis compares Sample 1 (No Silt) with Sample 2 (Silt Applied) across key parameters.

A. Physico-Chemical Properties

Parameter	Sample 1 (No Silt)	Sample 2 (Silt Applied)	Impact / Change
pH	7.00 (Neutral)	**9.33 (Highly Alkaline)**	**Major Concern:** Drastic increase in alkalinity.
Electrical Conductivity (EC)	24.3 µs/cm	71.7 µs/cm	**Significant Increase:** Indicates higher salt concentration.
Organic Carbon	0.32%	0.58%	**Positive:** Nearly double the organic matter.
Total Carbon	0.36 mg/kg	0.37 mg/kg	Stable.

B. Macronutrients (Primary & Secondary)

Parameter	Sample 1 (No Silt)	Sample 2 (Silt Applied)	Impact / Change
Nitrogen (N)	10.6 mg/kg	12.6 mg/kg	**Positive:** ~19% increase in available Nitrogen.
Phosphorous (P)	6.2 mg/kg	8.4 mg/kg	**Positive:** ~35% increase in available Phosphorous.
Potassium (K)	62 mg/kg	76 mg/kg	**Positive:** ~22% increase in Potassium.
Magnesium (Mg)	182.6 mg/kg	210.6 mg/kg	**Positive:** Enrichment of secondary nutrients.
Calcium (Ca)	264.8 mg/kg	283.4 mg/kg	**Positive:** Increase in Calcium levels.
Sodium (Na)	102 mg/kg	114 mg/kg	**Negative:** Increase in Sodium contributes to alkalinity.

C. Physical Soil Structure

Parameter	Sample 1 (No Silt)	Sample 2 (Silt Applied)	Impact / Change
Soil Texture	Clay Loam	**Silt Clay**	**Change:** Shift towards finer texture due to silt.
Bulk Density	1.68 g/cc	1.62 g/cc	**Positive:** Lower density indicates reduced compaction and better aeration.
Water Holding Capacity	48%	52%	**Positive:** Improved ability to retain moisture.

D. Biological Properties

Parameter	Sample 1 (No Silt)	Sample 2 (Silt Applied)	Impact / Change
Microbial Count	124 CFU/g	146 CFU/g	**Positive:** Increased biological activity indicates "living" soil.

c. Key Findings & Observations

1. **Significant Improvement in Fertility:** The silt acted as a natural fertilizer. All primary macronutrients (N-P-K) saw substantial increases. The application effectively replenished the soil nutrient bank, particularly Potassium and Phosphorous, which are critical for crop development in the Mandya region.

2. Enhanced Physical Soil Health: The physical structure of the soil improved notably:

• **Water Retention:** The Water Holding Capacity increased from 48% to 52%. This is a crucial benefit for farmers, reducing irrigation frequency and improving drought resilience.

• **Root Penetration:** The decrease in Bulk Density (from 1.68 to 1.62 g/cc) means the soil is less compacted/hard, allowing crop roots to penetrate deeper and breathe better.

3. Increased Organic Matter: The jump in Organic Carbon from 0.32% to 0.58% is a major success. Organic carbon is the foundation of soil health, aiding in nutrient retention and feeding beneficial microbes (evidenced by the increased Microbial Count).

d. The Critical Challenge:

The most distinct change is the shift in pH from a perfect neutral (7.00) to highly alkaline (9.33).

• **Cause:** This is likely due to the accumulation of salts (Carbonates/Bicarbonates) and Sodium in the lake silt over time, or runoff into the lake containing alkaline substances.

• **Risk:** At a pH of 9.33, micronutrients (like Iron, Manganese, Zinc) often become "locked up" and unavailable to plants, even if they are physically present in the soil.

e. Conclusion

The desiltation project has had a net positive impact on the agricultural potential of the fields in Naveli. The silt application successfully converted average soil into nutrient-rich soil with superior physical structure and water retention capabilities. However, the shift to high alkalinity (pH 9.33) presents a management challenge. If left untreated, the high pH could inhibit the uptake of the newly added nutrients.

6. Recommendations:

- **Gypsum Application:** To lower the pH from 9.33 and neutralize the Sodium, farmers should apply Gypsum (Calcium Sulfate). This will displace the Sodium and help bring the pH down to a neutral range (6.5–7.5).
- **Green Manuring:** Incorporating crops like Dhaincha or Sunnhemp into the soil can produce mild acids during decomposition, which will help lower the pH naturally while adding further nitrogen.
- **Use of Acid-Forming Fertilizers:** When using chemical fertilizers, preference should be given to acid-forming types (like Ammonium Sulfate) rather than nitrate-based ones, to help combat alkalinity.

Technical Analysis Outcomes at Yaladabhag Lake Restoration Project:

1. Introduction

This report presents a formal impact assessment for the Yaladabhag Lake restoration project, comparing the pre-implementation period (February/November 2022) with the post-implementation period (February/November 2025). The assessment utilizes Land Use Land Cover (LULC) derived from the Micro Watershed, the Normalized Difference Vegetation Index (NDVI), and the Normalized Difference Moisture Index (NDMI).

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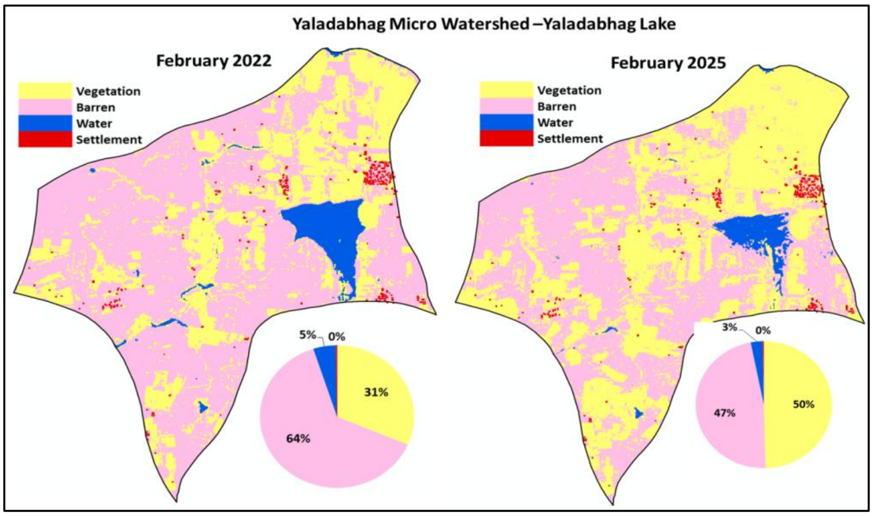
a. LULC(Land Use Land Cover



		Area Sqm	Area Sqm
		2022	2025
	Vegetation	2057510	3245360
	Barren	4159715	3096055
	Water	307466	183286
	Settlement	19404.58	19404.58

Based on the above land use/land cover maps and area charts for the Yaladabhag Micro Watershed – Yaladabhag Lake, the water desiltation project between February 2022 and February 2025 shows a significant and positive impact, particularly in land transformation.

Land Cover Category	February 2022 (%)	February 2025 (%)	Absolute Change	Implication of Change
Water (Blue)	5%	**3%**	**-2%**	A decrease in water surface area. This could indicate the project succeeded in increasing depth/volume but the measurement period (Feb 2025) was in a relatively drier condition, or the water is more consolidated.
Vegetation (Yellow)	31%	**50%**	**+19%**	**Massive increase**, indicating that improved water availability (likely due to groundwater recharge from the desilted lake) has substantially transformed barren land into productive vegetative cover.
Barren (Pink)	64%	**47%**	**-17%**	**Large-scale reduction** in unproductive land. The majority of this decrease has been converted to vegetation.
Settlement (Red)	0%	0%	0%	Negligible and stable settlement area.

Visual/Geographic Impact Analysis

1. **Lake Transformation:** The primary lake (blue area) is visually more compact and has less surface spread in 2025, which corresponds to the 2% decrease in the water surface area. However, it is a single, defined body, suggesting potential consolidation of water volume in the deepest, desilted area.
2. **Dramatic Greening:** The most significant visual impact is the extensive conversion of the pink (Barren) area into yellow (Vegetation) across the entire watershed. Large, unbroken swathes of pink in 2022 are now replaced by yellow in 2025. This confirms the 19% increase in vegetation, demonstrating a major success in restoring the ecosystem and supporting land-based activities through improved water security.
3. **Barren Land Reduction:** The widespread disappearance of pink, especially in the central and upper portions of the watershed, supports the substantial 17% reduction in barren land.

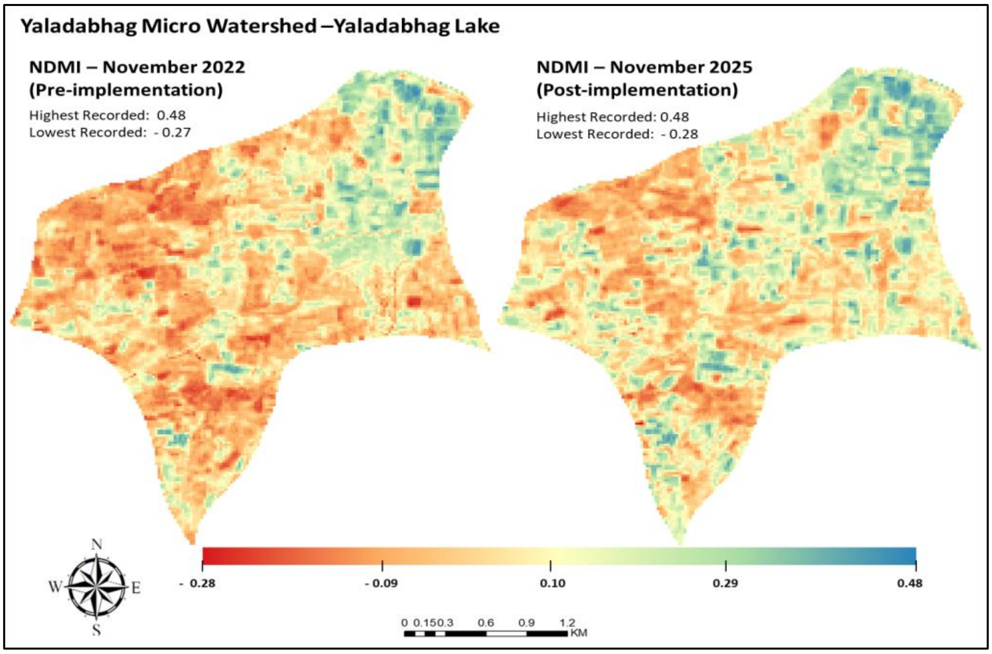
In summary, the desiltation project in the Yaladabhag Micro Watershed was a major success in land restoration, driving a dramatic 19% increase in vegetation and a 17% reduction in barren land. While the water surface area measured in February 2025 was slightly lower, the massive positive shift in the vegetative cover is a strong indicator of improved overall water availability and groundwater recharge from the project.

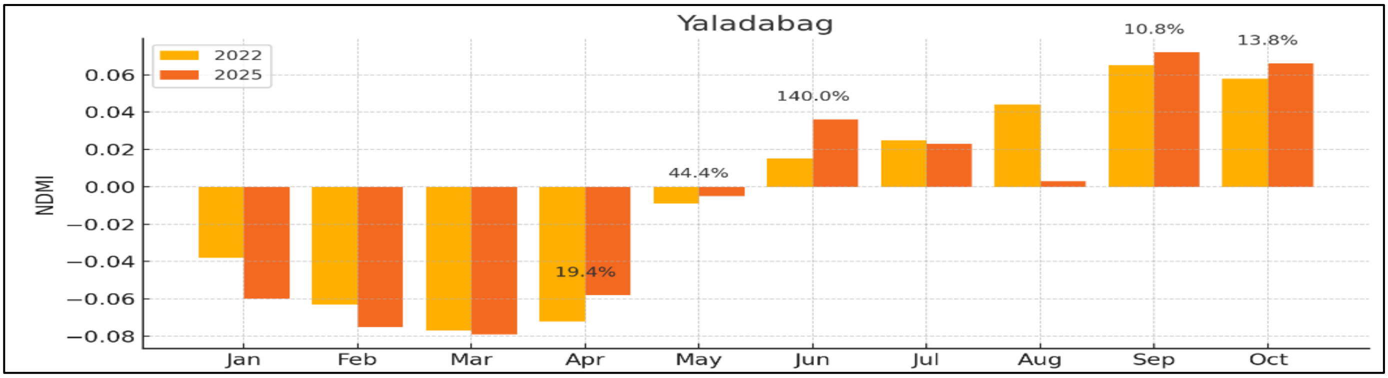
b. NDMI (Normalised Difference Moisture Index)

The NDMI analysis shows stability in maximum moisture.

• **Stable Peak Moisture:** The highest recorded NDMI value remained stable at 0.48 in both the pre- and post-implementation periods. This suggests that the maximum soil/vegetation moisture content in the wettest parts of the watershed was unchanged.

• **Visual Stability:** Visually, both maps are highly similar, indicating that the overall moisture distribution across the landscape in the November timeframe remained largely consistent. Considering NDVI based on the scale/color, the NDMI map shows remarkable stability in moisture for the November period, indicating the project did not negatively impact the overall moisture content despite the LULC water reduction.





The above graph shows that:

- Early months (Jan–Apr) had negative NDMI, indicating dryness.
- Strong recovery began in May with a 44.4% increase.
- June showed a 140% increase in vegetation moisture.
- September and October also showed improvements of 10.8% and 13.8%, respectively.
- Overall, 2025 had significantly higher NDMI from May to October.

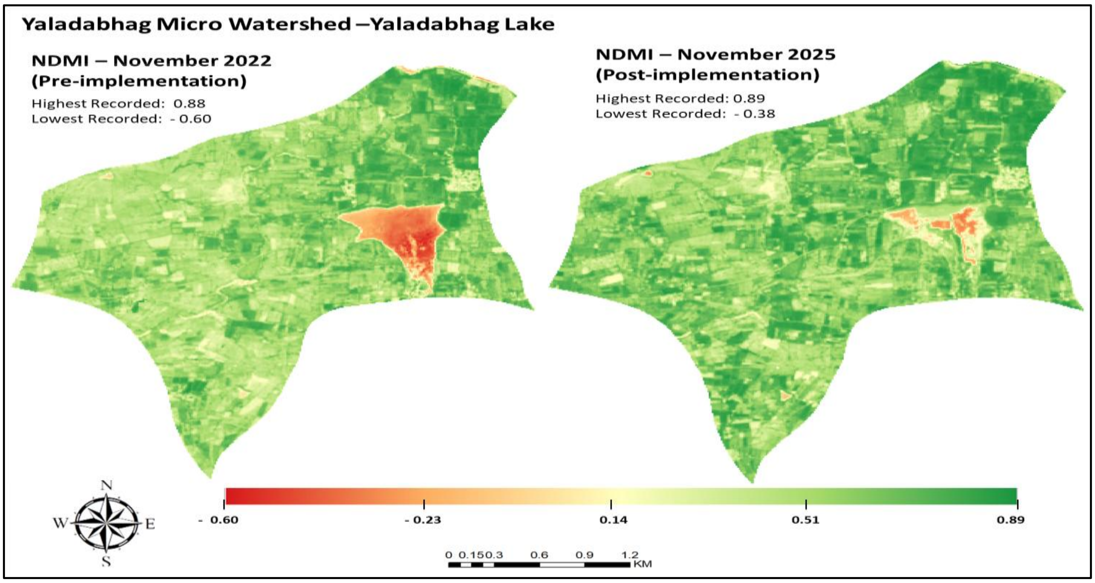
c. NDVI (Normalised Difference Vegetation Index)

The NDVI analysis confirms the positive LULC trend and provides detailed insights into the quality and health of the increased vegetation cover.

• **Increased Vigor:** The highest recorded NDVI value increased from 0.88 (Pre-implementation) to 0.89 (Post-implementation), indicating a slight improvement in the health of the most vigorous vegetation.

• **Widespread Improvement:** The visual maps show a clear shift towards deeper, darker green hues across the watershed in 2025, replacing the lighter greens and yellows present in 2022. This demonstrates that the +19% increase in Vegetation (as shown in LULC) is composed of demonstrably healthier, denser green cover.

• **Low NDVI Interpretation:** The prominent dark red/orange patch (low/negative NDVI) in the center of both maps corresponds to the main lake body, as low NDVI values are characteristic of water and non-vegetated surfaces.



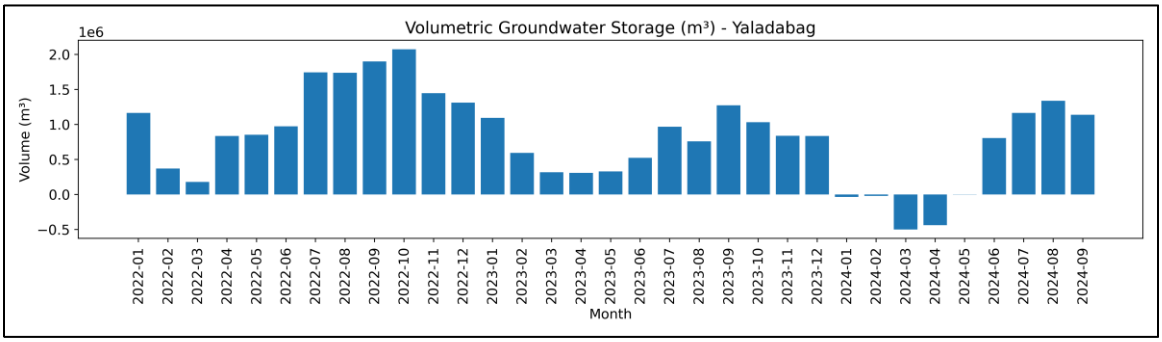
The Yaladabhag Lake Restoration Project is assessed as a substantial ecological success, demonstrating a major land cover transformation.

The project catalyzed a profound and positive shift from a Barren-dominated (64%) landscape to a Vegetation-dominated (50%) landscape, resulting in a +19% increase in healthy vegetation cover. This is a phenomenal achievement in ecological restoration.

While the classified water body decreased by 2%, this is likely an expected consequence of natural water cycle fluctuations between the two observation dates (February). Crucially, the major central water body remains prominently visible in both the LULC and the low-NDVI maps, confirming the lake's sustained presence.

The overall strong and consistent positive changes across LULC and NDVI confirm that the restoration has profoundly and beneficially altered the landscape towards a healthier, greener state.

d. Volumetric Groundwater Storage:



The Above graph shows following:

- Highest groundwater observed in 2022
- Notable collapse during early 2024
- Seasonal peaks weaken each successive year
- Groundwater storage peaks at approximately 2.0×10^6 m³ (≈ 29 cm) in September–October 2022, indicating high recharge capacity.
- By 2024, storage declines drastically to about -0.5×10^6 m³ (≈ –7 cm), showing excessive extraction and reduced rainfall.

3. Recommendations:

- **Water Level Study:** Investigate the reason for the -2% reduction in classified water area in the LULC data to determine if it is due to meteorological factors or in-lake siltation.
- **Afforestation Program:** Capitalize on the successful conversion of Barren land by initiating a targeted afforestation program on the remaining 47% Barren land to further enhance the watershed's ecological health.
- **Long-term Monitoring:** Continue monitoring the LULC and NDVI annually to document the stability of the vegetation increase and the overall resilience of the restored ecosystem.