Impact Assessment of Groundwater Collectivisation
In Andhra Pradesh and Telangana

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About WELL Labs

Water, Environment, Land and Livelihoods (WELL) Labs is transforming water systems at scale across India through research, partnerships, and collective action. WELL Labs takes on audacious challenges, tackling complex problems where we believe that we have a reasonable chance of success, with large social returns. Our work is science-led and community-focused. We address the interconnections between water, environment, land, and livelihoods. To create impact at scale, we embed solutions within governments, work with the private sector, and collaborate with civil society and active citizens. WELL Labs is part of the Institute for Financial Management and Research (IFMR) Society.

About EDF

A global non-profit, Environmental Defense Fund collaborates with governments, NGOs, research and academic institutions, corporates, and others to support and advance India's vision of shared, sustainable prosperity. EDF combines scientific and economic foundations, a broad network of partnerships and a pragmatic approach in support of India's ambitions. Its areas of interest include demonstrating the viability of sustainable livelihoods in agriculture, ensuring sustainable groundwater supplies for agriculture, livestock and fisheries, establishing the shareholder value potential through responsible business, informing of the potential of market-based mechanisms, and catalysing the climate technology ecosystem in India.

About the Technical Consulting Programme at WELL Labs

The Technical Consulting programme enables better decision-making in the natural resources management sector through the use of data, models, and evidence-based approaches. It focuses on systematising monitoring, evaluation, and learning (MEL) for the water sector while developing simple, accurate indicators to assess water security. Additionally, the team is building tools and frameworks to improve problem diagnosis in the sector.

About WASSAN

WASSAN (Watershed Support Services & Activities Network) is a non-profit working towards ecological security with the prosperity of rainfed areas in India. It works in a network approach in the intersections of practice, research and policy, evolving scalable models for rainfed areas development. Its work spans from intensively working with community organisations on the ground in rainfed landscapes to generate approaches, collate evidence from the experiences of large civil society organisations and networks, and work with state and central governments in evolving scale programmes. Water resources, NRM and agro-ecological transformations at the landscape level are some of the core areas of work.

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Executive Summary

Increasing water scarcity and unreliable monsoons have heightened the urgency for innovative solutions to support rural livelihoods and ensure water security for farmers across India. The challenge is particularly urgent in semi-arid, hard-rock regions of South India. In the Rayalaseema region of Andhra Pradesh, high water scarcity is the result of both low and erratic rainfall, excessive extraction of groundwater through borewells, and the limited water storage capacity of aquifers. Climate change has further exacerbated these issues, with rainfall becoming increasingly concentrated within fewer days each year and longer dry spells during the monsoon.

Rainfed farmers, lacking access to irrigation, face a growing risk of crop failure and often accumulate debt searching for new adaptation strategies. For farmers with the ability to drill borewells, groundwater serves as a critical buffer, both during the dry season and in times of drought. But groundwater levels deplete rapidly in response to pumping, due to the limited storage of the hard rock aquifers. Borewell failures have increased as farmers engage in competitive drilling to chase a rapidly declining water table.

Over the years, several initiatives have attempted to address the issue of limited water availability in Andhra Pradesh and Telangana, initially through supply-side solutions and later through participatory governance programmes. However, they have not managed to address the problem of continued competitive borewell drilling and the needs of rainfed farmers.

To address these concerns, Watershed Support Services & Activities Network (WASSAN) and partner NGOs have developed an innovative solution of 'collectivising groundwater resources' through new community institutions and infrastructure. The **Groundwater Collectivisation Programme** aims to provide security to rainfed crops, stabilise groundwater levels, and reduce competitive drilling to secure kharif crop yields and ensure the programme's long-term sustainability.

WELL Labs and Environmental Defense Fund (EDF) conducted a monitoring, evaluation, and learning (MEL) assessment of WASSAN's Groundwater Collectivisation Programme.

What Does WASSAN's Programme Do?

The Groundwater Collectivisation Programme helps establish water collectives with formal arrangements for water sharing, and aids in the construction of pipe networks to distribute water from borewells to fields that previously lacked irrigation. WASSAN provides financing for the pipe networks after ensuring that formal agreements are signed, and after getting financial commitments from water collective members to maintain the pipe network. While the specifics of the agreements differ from village to village, every water collective has to commit to sharing during monsoonal dry spells and to not drill new borewells for at least 10 years. They also have to incorporate water-saving strategies, including the use of less water-intensive crops and the adoption of micro-irrigation.

This way, the programme seeks to simultaneously address the issue of groundwater sustainability, reduce competitive drilling, and protect crop yields for rainfed farmers in the face of greater monsoon variability.

MEL Assessment of the Collectivisation Programme

Since the programme has the potential to expand key elements to other regions, WELL Labs and EDF conducted a detailed MEL assessment to understand how the approach functions and how it shapes outcomes within the villages that create water collectives.

We began this assessment by developing a **theory of change** to conceptualise how the programme was designed to achieve the intended outcomes. We then developed a set of research questions and six hypotheses to isolate and analyse key aspects of the programme.
Two main aspects were evaluated:

- Effectiveness of the programme in terms of generating positive outcomes such as secure crop yields, reduced borewell failures, groundwater sustainability, and improved economic outcomes.

- Functionality of the water collectives in terms of governance practices, motivation to participate, trust in the implementing agency, and knowledge and skills for participatory resource management.

To complete this assessment, we conducted surveys, interviews, and focused group discussions with farmers within and outside water collectives. We collected data in 12 villages with established water collectives, from farmers within the water collectives (the treatment group) and farmers outside the water collectives (a control group). We studied two types of control groups: farmers in the treatment village but not part of the water collective, and farmers from 12 additional villages with no intervention but which otherwise exhibited similar characteristics to the treatment villages. We used survey data to test each of the six hypotheses quantitatively, and conducted a qualitative analysis of interviews and discussions, to provide context and calculate functionality and effectiveness scores for each treatment village.

Findings of the MEL Assessment

Our findings highlight many ways in which the intervention is functioning on the ground as intended:

- Water access for irrigation has expanded to rainfed farms without groundwater access. The pipe network provides critical irrigation for rainfed farmers in the monsoon season, and expands irrigation in the post-monsoon rabi season to previously unirrigated fields.

- Crop diversification strategies have helped reduce the sowing of high water-intensive crops, and increase moderate water-intensive crops in the drier rabi season.

- Farmers in the treatment groups have reduced drilling new borewells and are maintaining the pipe networks.

Additional components of the programme were promising, albeit inconclusive, either due to sparse data, spillover effects, or other structural aspects of the system. For instance, the average profit and yield increased in the treatment groups more than the control groups, but the results were not statistically significant across all seasons. We lacked sufficient longitudinal data to demonstrate stabilisation of crop production across multiple years and the effects of micro-irrigation systems. Borewell failures continue to be prevalent in both the treatment and control groups, since the study area did not cover the entire village, and spillover effects were expected. Fully assessing these characteristics of the system would require additional, disaggregated data beyond the scope of this report.

Despite these uncertainties, clear overarching themes emerged from the study. Figure 1 summarises the findings for different indicators with the direction of impact and level of statistical significance:

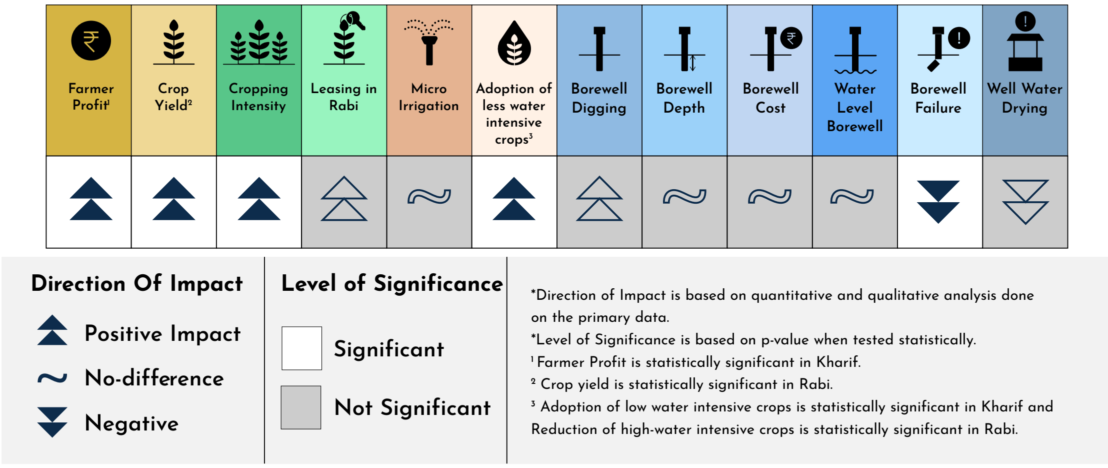

Figure 1: A summary of findings for different indicators.

Importantly, the results reveal key insights into the durability of the programme. A key aspect of the programme that motivates and maintains participation is the expansion of water access to fields without borewells or even groundwater availability. As one farmer put it, “Our lands are scattered. But after forming the water collectives, pipelines were extended to reach even the farthest fields.” The continued maintenance of pipe networks, financed by the members of the water collectives, is a testament to the ability of the intervention to expand water access in ways that bring tangible benefits to farmers. The ongoing shift towards moderately water-intensive crops underscores the long-term value of the training given to water collectives members.

The programme demonstrates how social and physical infrastructural changes can lead to the collectivisation of groundwater resources. It also offers lessons for approaching this challenge at larger scales. An objective of this evaluation is to understand the factors that enable or inhibit the success of the programme in new geographies.

We postulate that the programme would do well in areas with fragmented land ownership, inequity in access to irrigation, heterogeneous aquifers, and socially homogeneous groups. The biggest barrier identified for expansion is the ‘free rider problem’ where farmers inside the group may agree to not dig more borewells or to switch to water-efficient crops, but farmers outside continue older practices. This hinders improvement in groundwater levels, which continue to decline, and also discourages the farmers who have committed to not drill new borewells.

Recommendations

We suggest the following recommendations to build on the core strengths of the programme:

1 **Manage spillover effects by matching the scale of collectives to the scale of the aquifer.**
Currently, borewell drilling outside the area can deplete the groundwater table for the collectives. While expanding collectives to the aquifer level would reduce the spillover effect, the increase in members and area for governance would also increase the complexity of the programme.

2 **Expand monitoring and incorporate new information and communication technologies (ICTs).**
ICT tools can facilitate information sharing, crop planning, and real-time monitoring across the members of water collectives. Remote sensing may be the most viable approach to monitoring, given the readily scalable ability to observe crop choices and water consumption.

3 **Bridge scales by incorporating water collectives into larger governance networks.**
As the number of members increases and the collectives become more heterogeneous and widely distributed, clearer systems of governance become essential. Higher levels of governance (for example, at the taluk level) can then be used for authority and oversight, and enable poly-centric decision making.

4 **Design and implement graduated incentives and sanctions.**
Scaling of the programme would require stronger and effective governance mechanisms within the water collectives. Having both graduated incentives and sanctions would create conflict regulation mechanisms within the system. The incentives could be granted on electricity savings, water savings, or water trading within the group. Graduated sanctions could include revoking access to the pipeline network. Designing and implementing such sanctions would likely require substantial efforts on the part of organisers and village representatives.

The challenges faced by farmers in Rayalaseema and similar regions are not easily solved. The Groundwater Collectivisation Programme represents an important example of how institutions and infrastructure can be designed together to shift behaviour towards collective action. Further steps to improve information systems, governance, and incentives can help align the demand- and supply-side components of the programme. Such solutions are needed not only in Rayalaseema but across regions that have uneven distribution of irrigation and limited subsurface water storage.


Photo credit: WELL Labs

Chapter One

Evaluation Context

In India, agriculture employs about 42% of the workforce and contributes significantly to the gross domestic product (FAO, 2021; GoI, 2024). The climate crisis disproportionately affects rural communities that rely heavily on agriculture for their livelihoods, reducing crop yields and increasing economic instability (Nguyen et al., 2023).

Erratic rainfall patterns and prolonged droughts, exacerbated by climate change, are leading to the overexploitation of groundwater, threatening the sustainability of this vital sector (Mahadevan et al., 2024). In India, groundwater extraction has surged by 500% over the past 50 years, making India the largest global user (Rodella et al., 2023).

The semi-arid regions of southern India are especially vulnerable to the challenges of climate change. Increasingly erratic rainfall patterns and prolonged droughts have intensified groundwater depletion, severely impacting agrarian communities (Ferrant et al., 2014). In rainfed regions, the lack of dependable irrigation infrastructure and declining groundwater levels make farming highly vulnerable to climatic variability, leading to inconsistent yields and heightened risks of crop failure (Rao et al., 2017). This, in turn, destabilises the agrarian economy, pushing farmers into debt and forcing many to migrate in search of alternative livelihoods (Taylor, 2013).

1.1 Rayalaseema's Agri-Livelihood Scape and its Challenges

1.1.1 Rainfall: Patterns and Challenges

The Rayalaseema region, in southwest Andhra Pradesh, exemplifies the challenges described above. Rayalaseema experiences a semi-arid climate with low and erratic rainfall. The region's average annual rainfall is approximately 500-750 mm, mostly concentrated during the southwest monsoon (Guhathakurta et al., 2020). However, rainfall is highly unreliable, with significant spatial and temporal variability. Prolonged dry spells and frequent droughts are common, disrupting agricultural cycles and leading to inconsistent crop yields (Sainath, 2019; Sankriti et al., 2021).

According to the Indian Meteorological Department (IMD), the Rayalaseema region exhibits a concerning pattern of declining annual rainfall over the past three decades (1989–2018) (Guhathakurta et al., 2020). The effects of this reduction are compounded by the fact that rainfall is concentrated in a small number of rainy days (35 days ≥2.5 mm rain, on average), compared with approximately 270 dry days (<0.1 mm rain) per year. The IMD also identifies a significantly increasing trend in the annual frequency of dry days in Rayalaseema. The growing unpredictability of rainfall and extended periods without precipitation have concerning implications for soil moisture levels, groundwater recharge, and agricultural sustainability (Guhathakurta et al., 2020; Narasimhareddy et al., 2020; Sankriti et al., 2021).

1.1.2 Groundwater Resources and Current Status

Rayalaseema's groundwater is a critical lifeline for the region. The landscape is predominantly underlain by crystalline hard rocks with low primary porosity. Groundwater is stored in weathered and fractured zones, offering limited capacity for natural recharge (Dash et al., 2021; Reddy, 2012).

Each hard rock aquifer has limited capacity and an isolated presence, so the water behaves the way it would if it is stored in pockets of an egg carton (Alley et al., 1999). Over recent decades, the region has seen a dramatic increase in borewell drilling, leading to significant groundwater depletion. In many areas, borewells extend to depths of 500–600 ft, with some reaching beyond 1,000 ft, reflecting the acute stress on aquifers (Reddy, 2012; Sainath, 2019). Many wells now run dry, intensifying water scarcity. Farmers are having to repeatedly invest in drilling deeper borewells.

Crop choices are influenced by economic pressures, the promise of higher returns, and subsidies and procurement incentives. This has caused farmers to shift from traditional, drought-resistant crops like millets (which are well-suited to the region's arid conditions) to water-intensive cash crops such as groundnut and sunflower. This transition has not only deepened groundwater depletion but also heightened agriculture's vulnerability to climatic stress, creating a cycle of overexploitation and declining crop yields, further entrenching the agrarian crisis (Fischer et al., 2022; Sainath, 2019).

This scenario is worsened by environmental degradation and land use change, including deforestation and soil erosion, which severely limit aquifer recharge. Groundwater quality is also deteriorating in certain areas due to salinity and fluoride contamination, making it unsuitable for both drinking and irrigation.

The combined effects of groundwater depletion, agricultural decline, and environmental degradation have led to economic instability among farming communities. Many farmers face mounting debts, often leading to the selling of productive assets. In many cases, the younger male population from the regions migrates in search of alternative livelihoods. This dynamic has disrupted rural social structures and exacerbated poverty, straining the resilience of farming communities (Sainath, 2019).

Addressing these interconnected challenges is imperative for ensuring the region's ecological balance and safeguarding its agrarian economy.

1.1.3 Agrarian Livelihoods and Challenges

In Rayalaseema, over 70% of the population depends on agriculture for their income. In the Anantapur district, 90% of the 1.1 million hectares of cultivated land is rainfed and entirely dependent on the monsoon (ICAR-CRIDA, 2017). Groundnut dominates agriculture in Anantapur, occupying about 76% of the cropped area. This monocropping trend has intensified over the decades, with groundnut cultivation increasing from 18% in 1960 to 74% in 2005, with a decline in traditional crops like millets and pulses (Gupta et al., 2023). As the majority of rainfall arrives during the southwest monsoon, rainfed farming is practiced during the kharif season (June-September). Only about 6% of the agricultural area is double-cropped, with limited cultivation in the drier rabi season (October-March) due to inadequate soil moisture and irrigation. This reflects the challenges in adopting multiple cropping cycles under rainfed conditions (ICAR-CRIDA, 2017).

Irrigation covers only about 9.8% of the net sown area, with tubewells (i.e., borewells) contributing to 76.3% of the irrigated land (Vincent & Balasubramani, 2019). Protective irrigation is practiced during dry spells of the monsoon season, but overexploitation of groundwater increasingly limits its effectiveness as wells go dry.

The lack of irrigation infrastructure combined with frequent droughts and erratic rainfall creates a highly vulnerable agricultural landscape; crop failures, reduced yields, and increased farmer distress are common in years of monsoon failure (Ferrant et al., 2014; Rao et al., 2017).

The difficulties of governing common-pool resources across large and complex landscapes exacerbate the above challenges. New institutional arrangements are needed to overcome these hurdles and provide a measure of livelihood security. A holistic approach emphasising resilient cropping systems, robust infrastructure, and farmer support is vital to sustain both communities and the environment.

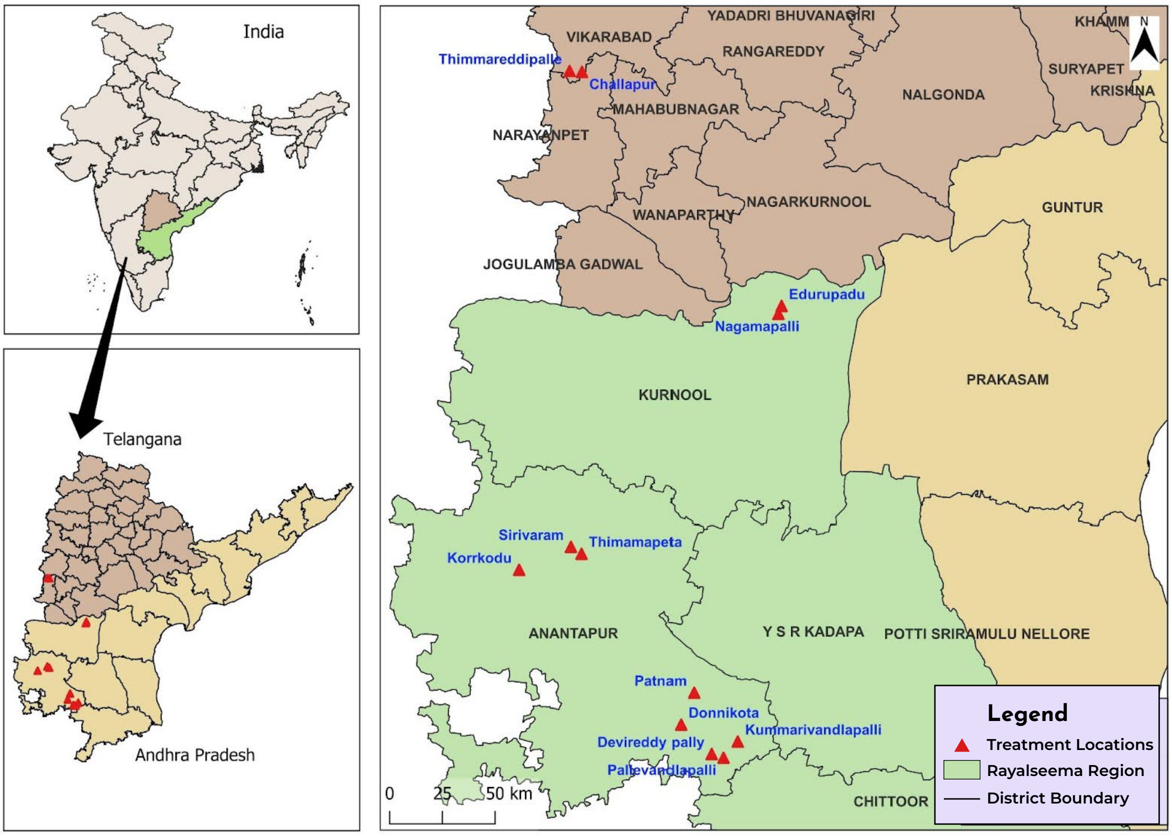

Figure 2: Demographic map of Andhra Pradesh with sampled study villages highlighted in red.

Figure 3: Rayalaseema's agri-livelihood-scape and its challenges.

1.2 Historical Attempts to Address the Challenges in Rayalaseema

To address chronic water scarcity, soil erosion, and agrarian distress in semi-arid landscapes in Rayalaseema, both supply- and demand-side solutions have been attempted over the last two decades.

1.2.1 Phase 1: Watershed Development Programme in Rayalaseema (1980-2000)

Watershed development programmes (WDP) were a key supply-side initiative implemented since the 1970s, outside the canal command regions in India (Gray & Srinidhi, 2013; Kerr et al., 2002). The Rayalaseema region fell into this category.

These programmes aimed to address the challenges of degrading natural resources and agricultural productivity by focusing on soil and water conservation through interventions like check dams, bunding, and afforestation (Ratna Reddy et al., 2004). By enhancing groundwater recharge, reducing erosion, and fostering sustainable farming systems, watershed development programmes strived to build resilience among farming communities.

A key feature of these programmes was the involvement of local communities in resource management, emphasising participatory decision-making and equitable distribution of benefits. The ultimate goal was to enable farming communities to sustain livelihoods while conserving the region's ecological balance.

These programmes have contributed significantly to increased groundwater availability, improved crop productivity, and enhanced rural livelihoods (Diwakara & Chandrakanth, 2007; Pradhan & Ranjan, 2015). However, they have not fully achieved the desired socio-ecological and economic resilience in rainfed landscapes.

An unintended consequence of watershed development programmes is increased groundwater extraction due to the perceived availability of resources (Bharucha et al., 2014). Many farmers responded to groundwater recharge efforts by drilling more borewells and adopting high water-intensive crops, such as paddy, that are perceived as more financially viable (Pradhan & Ranjan, 2015). Water-intensive crops require more investment and also carry greater risks of failure during moisture stress (Ranjan et al., 2014; Vaidyanathan, 2006). Adopting water-intensive crops makes farmers vulnerable to indebtedness, while also leading to competitive borewell extraction, negating the recharge benefits of the interventions (Rodell et al., 2009; Sharif & Ashok, 2011).

This race to extract groundwater embodies the tragedy of the commons, where wealthier farmers with access to advanced technologies overexploit resources at the expense of poorer farmers (Kasala et al., 2024). This imbalance has not only perpetuated socio-economic inequalities but also led to borewell failures (Pradhan & Ranjan, 2015), widespread bankruptcies, and resource exhaustion (Vaidyanathan, 2006).

Thus, while watershed development programmes have made notable strides in improving water availability, facilitating groundwater extraction, and implementing demand-side interventions, they have largely fallen short in mitigating the impacts of prolonged dry spells and ensuring irrigation for the rabi season. Competitive behaviour among farmers often undermines collective resource management, as the emphasis remains on individual gains rather than cooperative solutions, creating a barrier to transforming the agrarian landscape of the region.

1.2.2 Phase 2: Participatory Groundwater Management in Rayalaseema (1990-2010)

To address the persistent challenges of watershed development programmes, development practitioners realised that supply-side approaches are insufficient, and began to explore participatory governance (Ramachandrudu 2015).

This was done through two transformative strategies:

1 **Demystification of groundwater resources**	**2** **Promotion of collective management practices**

These principles were operationalised through NGO-supported projects such as the Andhra Pradesh Farmer Managed Groundwater System (APFAMGS) and the Andhra Pradesh Drought Adaptation Initiative (APDAI).

Demystifying Groundwater: Understanding the Commons

Since groundwater lies beneath the land and out of sight, it is often referred to as a hidden resource and is largely misunderstood by those who depend on it. The first step toward sustainable groundwater management is to make the resource visible and comprehensible to communities.

Demystifying groundwater involves simplifying complex hydro-geological concepts and communicating them in accessible ways that resonate with farmers and local stakeholders. The essence of this approach is to explain that groundwater, while beneath individually owned parcels of land, behaves as a common-pool resource (Aslekar, Kulkarni, and Upmanyu 2013; Ramachandrudu 2015). People who extract water need to be educated about the two defining characteristics of groundwater:

Non-excludability	Subtractability
Aquifers span across property boundaries. Thus, no individual can be entirely excluded from accessing the resource.	When one user extracts groundwater, it reduces the availability for others.

The hypothesis was that this knowledge would encourage a collective approach to groundwater management, emphasising that actions must be cooperative, either leading to collective conservation or collective depletion.

Participatory Governance: A Foundation for Collective Action

Once the shared nature of groundwater is understood, the next step is to develop community-driven frameworks for its management. Participatory governance recognises that local stakeholders are best positioned to manage shared resources when empowered with decision-making authority and tools. This framing aligns with Elinor Ostrom's principles of common-pool resource management, emphasising localised, inclusive governance structures (Aslekar, Kulkarni, and Upmanyu 2013; Ostrom, 2009). Participatory governance systems empowered communities to take ownership of groundwater management by involving all stakeholders in decision-making processes. Participatory governance in groundwater management is seen as a way to address the socio-economic disparities that lead to over-extraction by some farmers, and to help marginal and small-scale farmers access water resources. Inclusive governance can ensure that all stakeholders have a voice in decision-making, contributing to a fair and equitable system.

Collective groundwater management allows communities to actively participate in decisions affecting their water resources. It uses a structured, community-driven approach to ensure equitable water access, resource sustainability, and informed agricultural planning. It includes practices such as borewell measurement (monitoring water levels and tracking seasonal fluctuations for water budgeting and efficient allocation of resources) and crop planning (choosing cropping patterns based on groundwater availability and encouraging the adoption of low water-intensive crops).

1.2.3 Phase 3: Groundwater Collectivisation Project by WASSAN

Participatory groundwater management programmes have been successful in motivating individual borewell-owning farmers to tune their crop systems and water use to groundwater availability. But existing programmes were unable to stop competitive digging of new borewells, since this was usually done by rainfed farmers without access to borewells.

With this understanding, WASSAN framed the 'groundwater problem' as one of providing access to protective or (crop) life-saving irrigation to rainfed farmers. This can reduce their propensity to dig new borewells. An early attempt at groundwater collectivisation was piloted under the Andhra Pradesh Drought Adaptation Initiatives (APDAI) with the state's Agriculture Department subsequently investing ₹16 crores to scale the project. Later, WASSAN and its partner NGOs, with the continued support of the Agriculture Department, further extended the project across Andhra Pradesh and Telangana with the Groundwater Collectivisation Programme.

The programme sought to bring groundwater into a management system to enhance water security, reduce crop losses, and improve agricultural productivity. Key interventions included the establishment of water collectives, creating norms for groundwater use, developing water-sharing infrastructure, and promoting sustainable agricultural practices.

Borewell Pooling: A Response to Competitive Drilling

The programme emerged as a response to the widespread issue of competitive borewell drilling. Water collectives were introduced to bring groundwater into a collective management system. Rather than drilling new borewells, the initiative encouraged borewell-owning farmers to share their water resources with farmers without borewells, within a defined cluster of farms. In each programme village, water collectives were established to formalise this sharing arrangement. A pipeline network was laid into which all borewells pump groundwater to provide critical irrigation access to farmers without borewells during the dry parts of the kharif season.

Group members developed norms and agreements on maintenance and water sharing. The arrangements and agreements by each water collective vary from place to place to accommodate pre-existing norms. The arrangements typically include:

(i) Groundwater Use and Drilling Restrictions:

- Drilling of new borewells is prohibited for at least 10 years, except in emergencies, which require approval from the group and the groundwater management committee.
- Any new borewell, if permitted, is to be integrated into the existing pipeline system.

(ii) Water Distribution and Crop Management:

- Water is to be provided for all members for critical irrigation at key stages of the kharif season—sowing, flowering, seed setting, and harvesting—irrespective of their ownership of borewells. Access to protective irrigation at least three to four times without any cost is regarded as a right for all in the kharif season, while the farmers are free to make their own agreements during the rabi season.
- Crop choice and its areas are to be determined based on estimated groundwater availability.
- Paddy cultivation is to be reduced to 50% of the total cultivated area, with a preference for using the System of Rice Intensification (SRI) method[1].

(iii) Technology Adoption:

- Farmers are provided with water-efficient irrigation technologies such as drip and sprinkler irrigation on a group basis as part of the infrastructure.
- Ponds and earthen dams are constructed to enhance water conservation.
- Biomass generation and composting are done to improve soil health.

(iv) Maintenance and Fund Utilisation:

- Members are required to contribute an annual membership fee to a common fund.
- The common fund is to be used for pipeline and borewell repairs during the kharif season, while individual borewell repairs in rabi are the responsibility of respective borewell-owning farmers.

(v) Water Distribution:

- Water distribution is to follow agreed procedures to ensure all members receive access to protective irrigation three to four times during dry spells.

By addressing the security of crops against drought spells and fostering cooperation, the programme aims to achieve multiple objectives: ensuring water access for farmers without borewells in dry periods of the monsoon season, providing backup sources for borewell-owning farmers in case of failure, and stabilising farm incomes. Additionally, it aims to reduce the pressure on groundwater resources, enhance cropping intensity, and improve soil and vegetation health in the project areas.

[1] The SRI is a method of paddy cultivation that aims to increase the crop yield and raise the productivity of the land and soil, while reducing the use of resources.

Photo credit: WELL Labs

Chapter Two

Evaluation Design

2.1 Objectives of the Evaluation Study

The evaluation study aimed to assess the design and impact of the Groundwater Collectivisation Programme on groundwater management, agricultural productivity, and agricultural livelihoods. It sought to understand the key enablers and barriers influencing the programme's outcomes and institutional functioning. Additionally, the study evaluated the success of collective action mechanisms to share groundwater more equitably, increase water use productivity, and reduce the propensity of farmers to dig borewells.

The key objectives of the evaluation study were to:

- Analyse institutional functioning
- Identify key enablers and barriers
- Assess the programme's effectiveness
- Guide future programmes

The programme's success was judged by examining groundwater access, agricultural productivity, and long-term viability, as well as the factors that have helped or hindered its success in different settings. Additionally, the study examined the role and performance of water collectives in fostering collective action and sustaining groundwater management. Based on these findings, the study proposes actionable recommendations for designing, scaling, and implementing similar programmes with enhanced effectiveness and sustainability.

In addition to measuring the programme's success, the evaluation also provides critical insights for shaping future groundwater management initiatives.

We followed a four-step process for our evaluation:

i. Componentise the intervention through a theory of change.

ii. Formulate testable hypotheses that allow the assessment of key outcomes of the intervention.

iii. Collect and analyse data from surveys, interviews, and focus group discussions.

iv. Synthesise our work to develop a cohesive understanding of the collectivisation programme.

2.2 Theory of Change for Groundwater Collectivisation

We developed the theory of change (ToC) for the Groundwater Collectivisation Programme to capture the intended mechanisms by which the programme alleviates systemic issues of groundwater depletion, socio-economic inequalities, and agrarian distress. The ToC (Figure 4) allowed for a structured framework to link actions with intermediate outputs and long-term impacts.

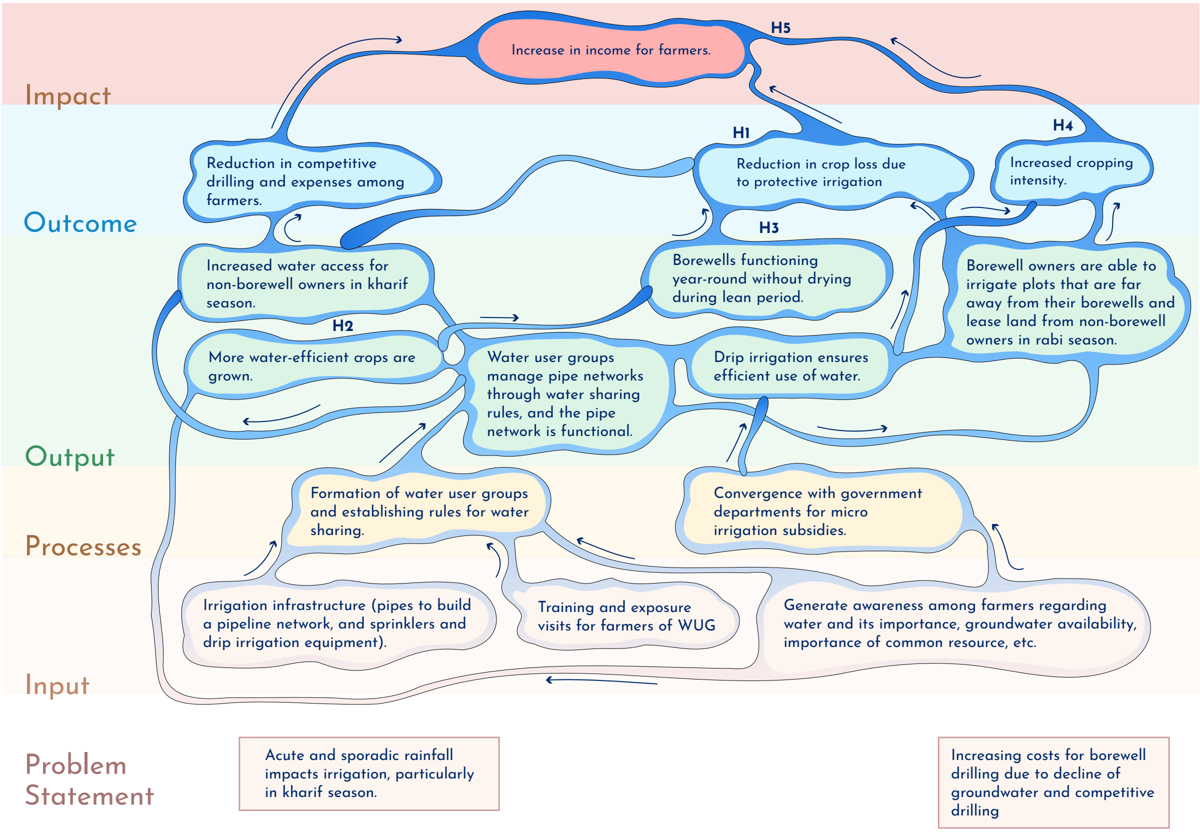

Figure 4: WASSAN's theory of change: Mapping problem statements to inputs, processes, outputs, outcomes, and impact.

The theory of change underscored the importance of aligning participatory governance with strategic interventions to achieve sustainable outcomes. By integrating science-based solutions with grassroots participation, the programme demonstrated how collective action could address complex challenges and improve socio-economic resilience.

2.3 Research Questions

The goal of this evaluation is to understand the effectiveness of the Groundwater Collectivisation Programme, and how well the water collectives have functioned. We have divided the overall objective into two sets of research questions, Set A and Set B, which focus on effectiveness and functionality, respectively.

A. Research Questions on Effectiveness

A1. How has the programme improved the overall economic status of farmers?
A2. What are the programme's effects on yields for both borewell-owning farmers and farmers without borewells?
A3. How has the programme affected access to irrigation water and cropping intensity?
A4. How has groundwater pooling improved water use efficiency?
A5. To what extent has the programme reduced competitive groundwater drilling and increased collective management?
A6. Has the programme led to a stabilisation of groundwater levels, particularly in the dry season?

S.No	Hypothesis	Indicators
A1	The programme has improved farmers' economic status.	• Average income of farmers from primary source. • Reduction in debt levels among farmers.
A2	The programme has reduced crop loss and led to an improvement in yield for farmers without borewells.	• Crop yield differences between borewell-owning farmers and farmers without borewells.
A3	Improved ability to move water has enhanced access to irrigation for both types of farmers, and thus in rabi-cropped areas. This has increased cropping intensity in project areas.	• Increase in area under rabi cropping • Change in land leased-in and leased-out during rabi
A4	Farmers participating in the programme exhibit higher water use efficiency through micro-irrigation and crop diversification.	• Crop diversity (past and present): Prevalence of high-water requirement crops for each season • Use of micro-irrigation (drips/sprinkler), installation time
A5	The programme has led to a reduction in competitive drilling within the project area as evidenced by the depth and frequency of new borewell drilling.	• Depth of borewells drilled over time • Borewell expenses (deepening of borewells + O&M) • Frequency of borewell failures, instances of deepening
A6	The programme has led to a reduction in competitive drilling within the project area as evidenced by the depth and frequency of new borewell drilling.	• Water level at the time of installation (in ft)

Table 1: Hypotheses for effectiveness-related research questions and their indicators.

B. Research Questions on Functionality

B1. To what extent are the water collectives functional and reflect Ostrom's principles for successful collective action?

B2. What factors have influenced the success of participatory governance across different user groups?

To assess functionality, we borrowed from Ostrom's Design Principles (Ostrom, 2009). These were contextualised for this study to ensure a nuanced assessment of the functionality of water collectives. The table below includes indicators drawn from interviews and focus group discussions (FGDs) and used to assess water collectives' functionality.

S.No	Hypothesis	Indicators
B1	**Practices:** Water collectives have created robust management practices—clear rules, regular meetings, continuous monitoring, and effective conflict resolution—that secure long-term sustainability.	• Conflict resolution mechanisms • Monitoring systems (for resources and users) • Formal written rules and agreements • Regular group meetings • Informal/verbal/mutual agreements • Graduated sanctions • Minimal recognition of rights
B2	**Motivation:** Water collective members have a strong motivation to sustain engagement and participation.	• Access to water/water scarcity • Fragmented lands • Pipeline networks
	Trust: Water collective members trust that the implementation partner will help improve their livelihoods and local water management.	• Trust in the implementation agency
	Capacity: The members are equipped with essential knowledge about the programme and skills for better water resource management.	• Awareness and mobilisation meetings • Exposure visits • Training on cropping practices

Table 2: Hypotheses for functionality-related research questions and their indicators.

2.4 Research Methodology

A mixed-methods approach was adopted to evaluate the Groundwater Collectivisation Programme, combining qualitative and quantitative data collection techniques. The evaluation was based on the six hypotheses for programme effectiveness and two hypotheses for programme functionality, detailed above. These were tested through structured farmer surveys, focus group discussions (FGDs), in-depth interviews, remote sensing data analysis, and a comprehensive borewell inventory.

The evaluation of the **effectiveness of the programme (Set A) was conducted using quantitative data** from surveys, while the **functionality of the water collectives (Set B) was analysed with qualitative surveys.**

The analysis consisted of a quasi-experimental design with a special three-arm structure to assess the programme's impact on multiple dimensions. This design included three groups:

1

Treatment group:

Comprised members of water collectives established in the villages where the groundwater collectivisation programme (intervention) was implemented.

2

Control 1 group:

Consisted of farmers in the treatment villages who were not members of water collectives. Hypotheses A1 to A4 were compared between the treatment group and control 1 group, as these were related to agricultural outcomes where direct spillover is not expected.

3

Control 2 group:

Included farmers from neighbouring villages with no exposure to the programme. Hypothesis A5 and A6 were compared between treatment group and control 2 group, as these were hydrogeological outcomes (like well depths and water levels) that would have a direct spillover effect in the village if a part of the village was under intervention.

The borewell inventory was conducted with every borewell owner in the study village to collect critical data on groundwater use and availability. The survey recorded key parameters such as borewell depth, water yield, failure rates, and usage patterns.

We also used Normalised Difference Vegetation Index (NDVI) to analyse changes in rabi cropping to triangulate the cropping intensity data reported in farmer surveys with remote sensing analysis. WASSAN was able to provide the geolocations of the area covered by the intervention pipeline network in five out of 12 treatment villages. We calculated the seasonal median NDVI for the rabi months (December to March) using Sentinel satellite data from 2005 to 2023 to analyse changes in cropping intensity. This was compared to the NDVI on the agricultural area of the control plots for differential change in agricultural NDVI during the rabi months.

2.5 Quantitative Data Collection

2.5.1 Sampling Strategy for the Farmer Survey

A multi-stage stratified cluster sampling approach was used to ensure representativeness and reliability in all three groups—treatment, spillover and control.

Stage 1: Selection of water collectives and treatment villages

Selection of treatment groups:
There were a total of 73 water collectives where the collectivisation programme was implemented. WASSAN categorised them into three success categories—high, medium, and low—based on subjective assessments by the implementation partners. From each category, four water collectives were randomly selected, resulting in a total of 12 water collectives located in 12 different villages forming the treatment group. This stratified random sampling approach in the first stage of the sampling design was critical for identifying enablers and barriers influencing programme success.

Selection of control groups:
For each treatment village, we identified a neighbouring control village. These control villages (control group 2) shared similar biophysical conditions but had no exposure to the programme, serving as a counterfactual to assess impact. There were thus 12 control villages. Additionally, we considered another control group—farmers in the treatment village who were not members of the water collective—to capture potential spillover effects (spillover group/control group 1).

Stage 2: Respondent Selection

- From each of the 12 treatment villages, 35 farmers were selected across two groups: the treatment group (water collective members) and the spillover group/control group 1 (farmers not part of the water collective). While the idea was to distribute the farmers equally between these two groups, the actual distribution varied depending on the programme's success in each village.
- From each of the 12 control villages, 15-16 farmers were selected to form the control group 2, comprising farmers who were not exposed to the programme.
- This resulted in approximately 200 farmers from each of the three groups: treatment group, control group 1, and control group 2.
- This stratified, random sampling ensured comparability between the treatment and control groups while accounting for geographic and socio-economic variation.

Group	Villages	Respondents per village (on average)	Total respondents
Treatment group	12	16	195
Control group 1 (spillover group)	12	19	223
Control group 2 (neighbouring village)	24	16	188
Total	24		606

Table 3: Overview of quantitative sampling.

2.5.2 Analytical Approaches

- For the analysis of the data, farmers in the study villages were distributed across the three groups: treatment, control group 1, and control group 2. A total of 418 farmers in the treatment villages were approximately equally distributed across the first two groups (195 farmers as the treatment group, and 223 in the control group 1). 188 farmers were part of control group 2, in villages where no intervention was implemented.

- For the quantitative surveys, we collected data on indicators related to our hypothesis from all the farmers belonging to three intervention groups. Besides collecting data about the current period, we also tried to collect retrospective data from the pre-intervention period for most indicators. For example, we collected cultivation-related data for the kharif 2010 and rabi 2011 seasons. This enabled us to adopt the difference-in-difference approach[2] to compare the three intervention groups.

- The study's analysis of socio-economic indicators could have been more pronounced if data had been collected for the past five years, allowing for an assessment of farmers' stabilisation over time, especially across dry and drought years. However, gathering reliable recall data from farmers for each individual year is a challenge. Hence, this approach was not adopted in the study.

- All hypotheses were tested at the 5% level of significance. If the p-value corresponding to a statistical test is below 0.05, we reject the null hypothesis and assume the intervention to be effective with respect to the corresponding indicators.

2.6 Qualitative Data Collection

To assess the subjective impact of groundwater collectivisation and the functionality of water collectives, a detailed qualitative survey was conducted. The data was gathered through 17 focus group discussions and 33 in-depth interviews across different participant categories. The sample included members of water collectives with representation from both borewell-owning farmers, non-borewell-owning farmers, and farmers who were not members of the water collective.

[2] *A controlled before-and-after study method*

2.6.1 Sampling Overview

The distribution of focused group discussions and interviews across participant categories is detailed below.

Type	Members of water collectives (borewell-owning farmers)	Members of water collectives (non-bore-well-owning farmers)	Non-members of water collectives
Focus group discussions	5	3	9
In-depth interviews	11	11	11

Table 4: Overview of qualitative sampling.

Participant Recruitment

The selection of participants for the focus group discussions and in-depth interviews employed a combination of purposive and convenience sampling techniques. Farmers from all the above-mentioned categories were invited to participate in the discussion based on their expressed interest. Each discussion comprised six to eight participants per group, drawn from the villages under study. In cases where it was not feasible to convene sufficient participants for the discussion, the research team conducted in-depth interviews as an alternative data collection method.

Data collection tools

A systematically designed structured interview guide was developed to maintain methodological consistency across focus group discussions and in-depth interviews, for the water collectives' members and farmers who were not members of the water collectives. The discussions and interviews were recorded and transcribed to maintain data accuracy and depth.

2.6.2 Analytical Approach

We employed a deductive approach for data analysis using a structured deductive coding framework. To interpret the qualitative findings, a scoring approach was adopted to evaluate village-level outcomes and functionality scores.

To assess the functionality of water collectives at the village level, structured questions were used to evaluate multiple dimensions. A binary coding scheme was applied (1 for the presence of a feature, 0 for its absence), and the total presence of key elements was aggregated to derive the functionality score. (For detailed coding categories, refer to Annexure I.)

Photo credit: WELL Labs

Chapter Three

Evaluation Findings

This chapter presents the key findings from the evaluation of the Groundwater Collectivisation Project (hereafter called 'intervention').

The first section, i.e. the analysis of effectiveness of the Groundwater Collectivisation Programme, represents the quantitative analysis, and the second section, the analysis of functionality of water collectives, represents the qualitative analysis. Each section has a set of research questions which provide the results and analysis.

The farmer survey evaluating the socio-economic indicators was administered to 418 farmers. The descriptive statistics of the sample were calculated in terms of farmer survey respondents' district of residence, age, gender, caste, and borewell ownership (Table 5).

Characteristic	Overall N = 418	Control 1 N = 223	Treatment N = 195
District			
Anantapur	319 (76%)	161 (72%)	158 (81%)
Kurnool	52 (12%)	29 (13%)	23 (12%)
Mahabubnagar	47 (11%)	33 (15%)	14 (7.2%)
Gender of respondent			
Male	391 (94%)	207 (93%)	184 (94%)
Female	27 (6.5%)	16 (7.2%)	11 (5.6%)
Caste of respondent			
General	148 (35%)	68 (30%)	80 (41%)
Other Backward Caste	165 (39%)	89 (40%)	76 (39%)
Scheduled Caste	70 (17%)	46 (21%)	24 (12%)
Scheduled Tribe	12 (2.9%)	7 (3.1%)	5 (2.6%)
Caste not reported	23 (5.5%)	13 (5.8%)	10 (5.1%)
Borewell ownership	240 (57%)	105 (47%)	135 (69%)

Table 5: Descriptive sample characteristics of respondents by their intervention status: n (%)

The treatment group had a significantly higher proportion of farmers belonging to the general caste category, and were borewell-owners. It is acknowledged that this could point towards some possible selection bias in the way farmers became a part of the water collectives.

3.1. Analysis of Effectiveness of the Groundwater Collectivisation Programme (Quantitative Analysis)

3.1.1. How has the programme improved the overall economic status of farmers?

Finding: Farming profit increased relatively more for the treatment group than the control group 1 (within the village). The increase was statistically significant during the kharif season and insignificant during the rabi season.

One of the key objectives of the programme, besides reducing competitive drilling, is to enhance farmers' incomes. To achieve this, it focuses on increasing cropping yield and reducing the risk and intensity of droughts in the treatment areas. Different activities have been conducted over the years for the water collective members, including training, awareness programmes and exposure visits to understand intercropping and organic farming. An increase in profit can also be considered a key factor motivating farmers' interest in the programme.

The percentage increase in profit per acre between 2011 and 2024 showed that profits increased by around 50% for all the groups (Figure 5). The profit of the treatment group was somewhat better than the control group 1 (within the village) across seasons. The increase was statistically significant in the kharif season (p-value = 0.05) and not significant in the rabi season. The increase in profit could be due to increased cropping intensity, and a moderate increase in yields after the programme.

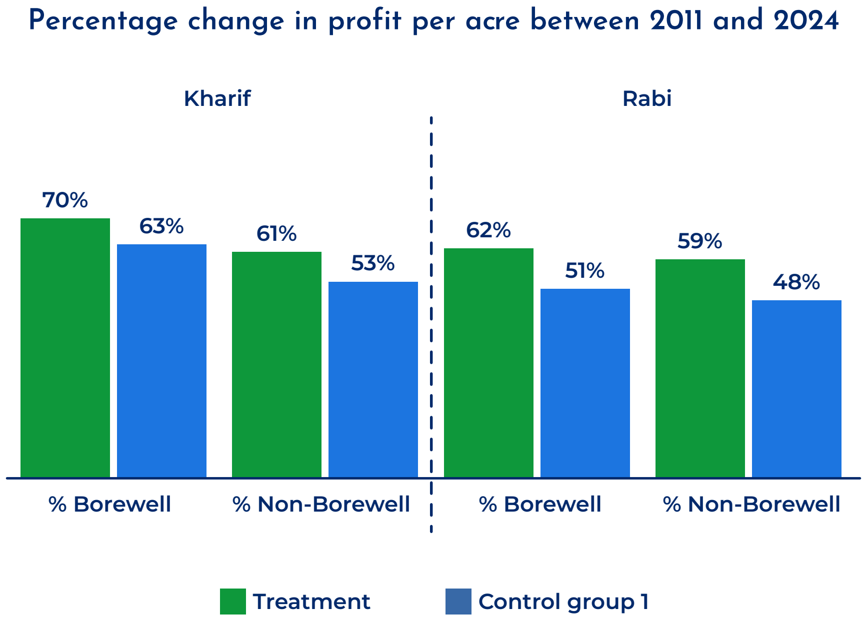

Figure 5: Percentage change in profit per acre between 2011 and 2024 across the treatment group and control group 1.

The mechanism for an increase in income through the availability of irrigation was described in a focused group discussion by a farmer who was part of the water collective, but did not own a borewell:

"When we increase irrigation, our production and income also increase. For example, if I grow on one acre of land, I can earn around one lakh, and if I grow on a larger area, my production increases and income also increases. This shows that a larger irrigated area contributes to higher earnings."

– A farmer without borewell in Kumaravandlapalli

3.1.2 What are the programme's effects on crop yields for both borewell-owning and non-borewell-owning farmers?

Finding: Crop yields increased for farmers in the treatment group in both kharif and rabi seasons. The increase was statistically significant during the rabi season and not in the kharif season.

One of WASSAN's primary objectives is to enable the provision of protective irrigation through pipeline networks for farmers without borewells during the critical crop growth phase, to help increase their crop yield. Therefore, we should expect to see a difference in yield between farmers without borewells in the treatment village and farmers without borewells in villages without intervention.

The programme is also designed to boost rabi yields for borewell-owning farmers. In the rabi season, borewell water outputs typically decrease as the groundwater table declines. If the programme results in higher water use efficiency and reduces the total abstraction, the water may stay in the ground for longer. This should ideally improve the availability of water in the rabi season.

If the two hypotheses above are true, then farmers in the treatment group—both farmers with borewells as well as without borewells—are expected to have better yields compared to control group 1 (without any intervention).

Figure 6 shows the reported increase in crop yields, before and after the intervention, for the different groups. The crop yield was found to have increased across all farmers over the years. The average increase in yield for the treatment group was somewhat higher than that in the control group 1 (within the village). The difference was statistically significant in the rabi season (p-value is 0.038) and not in the kharif season.

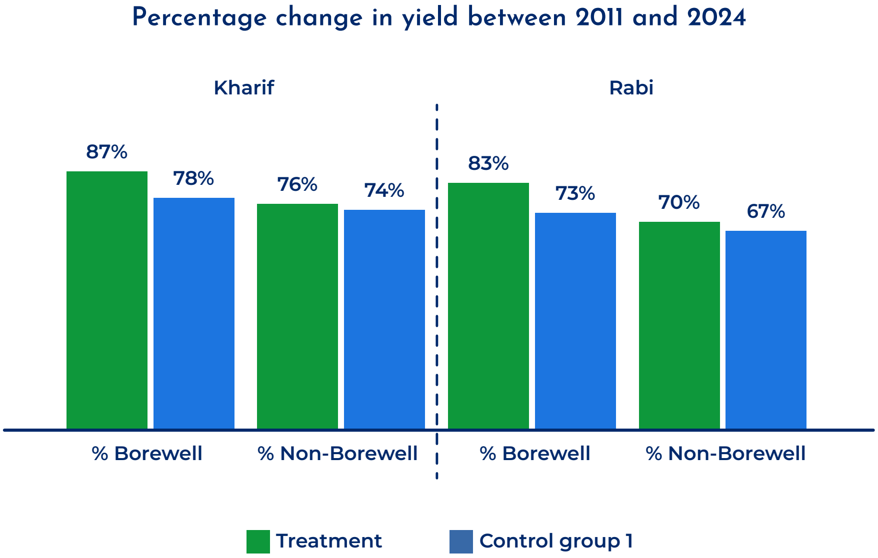

Figure 6: Percentage change in yield across treatment and control group 1 (within the village).

Characteristic	N (responses)	Control group 1 N = 603 (Median, 1st quartile, 2nd quartile)	Treatment group N = 546 (Median, 1st quartile, 2nd quartile)	p-value[3]
Profit per acre kharif (2010)	333	13,200 (8,863 , 18,856)	12,100 (7,700 , 24,356)	0.5
Profit per acre kharif (2023)	463	20,000 (11,000 , 34,000)	22,833 (14,583 , 36,833)	0.05
Profit per acre kharif (2011)	103	5,940 (3,300 , 15,462)	11,314 (6,600 , 20,742)	0.14
Profit per acre kharif (2024)	253	20,000 (10,000 , 30,000)	18,182 (10,000 , 32,000)	0.8
Profit per acre kharif (2010)	333	400 (300, 500)	400 (300, 600)	0.6
Profit per acre kharif (2023)	463	750 (600, 1,000)	800 (600, 1,000)	0.2
Profit per acre kharif (2011)	103	300 (250, 600)	367 (300, 500)	0.038
Profit per acre kharif (2024)	253	600 (450, 1,000)	700 (500, 1,000)	0.038

Table 6: Summary of outcome variables (revenue, profit, profit per acre, and yield per acre) across intervention groups, intervention periods, and seasons using crop-based data.

"They are growing groundnut or tur dal, and getting yields without fail. Instead of five bags, they are getting 10, as they are getting the water 2-3 times by adjusting the water from 3-4 borewells. At least, they can survive from it."

– A farmer from Kumaravandlapalli who wasn't part of a water collective

[3] *Wilcoxon rank sum test*

3.1.3. How has the programme affected access to irrigation water (in both seasons) and cropping intensity?

Finding: The intervention significantly increased access to irrigation in both seasons. The treatment group was able to cultivate more during the dry season. Therefore, cropping intensity increased.

The intervention has two core elements. First, there is the physical infrastructure in the form of the pipe network to increase access to groundwater. Second, there is the social infrastructure of the water collectives to manage the pipe network, increase water use efficiency, and decrease competitive drilling.

The farmer survey data reflected an increase in access to irrigation and thus cropping intensity. Before the intervention, there was no significant difference across treatment and control group 1 in terms of the proportion of farmers cultivating during the rabi season. 35% of the farmers in the treatment group and 33% in control group 1 were cultivating rabi crops in 2011 (Table 7).

After the intervention, this number increased to 51% in the treatment group and 40% in control group 1. The increase is statistically significant as evident from the p-value (0.02) of the chi-squared association test. Consequently, the average number of seasons cultivated during the 2023-24 agricultural year was significantly higher among water collectives farmers (1.39) compared to the control group 1 (1.20). (See Figure 7 for the visualisation of the relative percentage change by season and intervention groups.)

We did not see any significant difference in the proportion of farmers leasing in or leasing out during the kharif or rabi seasons across the intervention groups (Table 7).

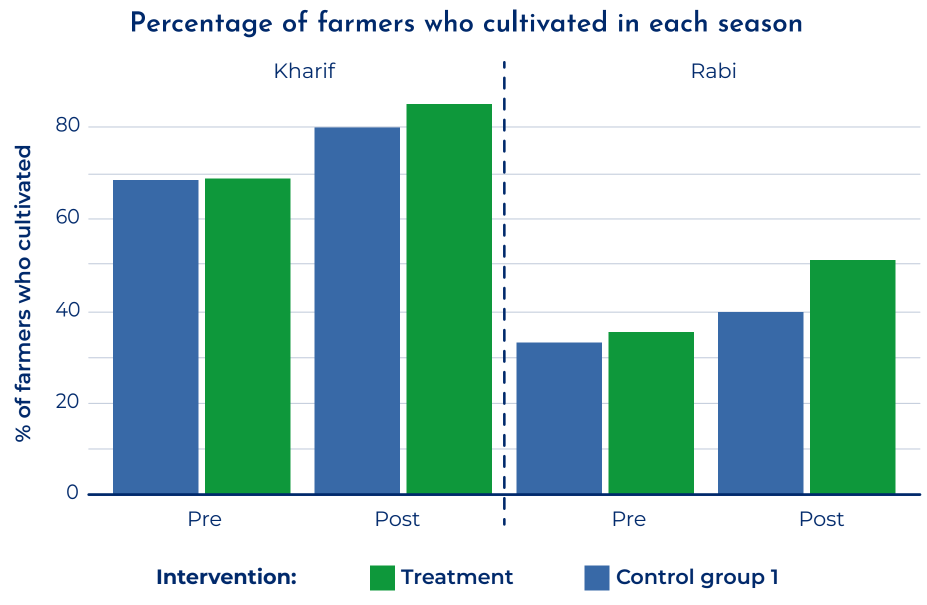

Figure 7: Percentage of farmers who cultivated in each season, across the treatment and control 1 groups

Characteristic	Control group 1 N = 223[1]	Treatment group N = 195[1]	p-value[2]
Cultivated in kharif: pre-intervention (2010)	152 (68%)	134 (69%)	>0.9
Cultivated in kharif: post-intervention (2023)	178 (80%)	158 (85%)	0.2
Cultivated in rabi: pre-intervention (2011)	74 (33%)	69 (35%)	0.6
Cultivated in rabi: post-intervention (2024)	89 (40%)	100 (51%)	0.020
Number of seasons cultivated: pre-intervention (2010-11)	1.01	1.04	0.7
Number of seasons cultivated: post-intervention (2023-24)	1.20	1.39	<0.001
Leased in land during kharif: post-intervention (2023)	23 (9.6%)	11 (6.2%)	0.2
Leased in land during rabi: post-intervention (2024)	17 (7.1%)	6 (3.4%)	0.10
Leased out land during kharif: post-intervention (2023)	16 (6.7%)	15 (8.4%)	0.5
Leased out land during rabi: post-intervention (2024)	7 (2.9%)	11 (6.2%)	0.10

Table 7: Selected indicators related to cultivating and leasing across the two groups.

We triangulated the farmer-reported data on cropping intensity with the changes in Normalised Difference Vegetation Index (NDVI) within agricultural lands during the rabi season (December-April), and the results are presented in Figure 8 below.

The NDVI values for both the treatment group and the control group 2 (neighbouring village) fluctuated over the years, with a notable upward trend from 2018 onwards. While both groups followed similar trajectories, the treatment group exhibited a steeper increase in NDVI after 2018, diverging from the control group 2.

[1] *n (%) for categorical variables; mean for continuous variables (last two).*

[2] *Pearson's Chi-squared test for categorical variables; Wilcoxon rank sum test for continuous variables (last two)*

This trend in treatment villages could indicate the benefits of improved water availability from the pipeline distribution system under the programme. The increased NDVI in the rabi season could have also been partially due to the increased rainfall for three consecutive years from 2020 to 2022, or the effect of the Handri-Neeva canal project of 2019 which brought additional water supply. But these changes affected both treatment and control districts similarly. Therefore, it can be understood through the analysis and remote sensing data that the pipeline system increased the cropping intensity in the treatment areas.

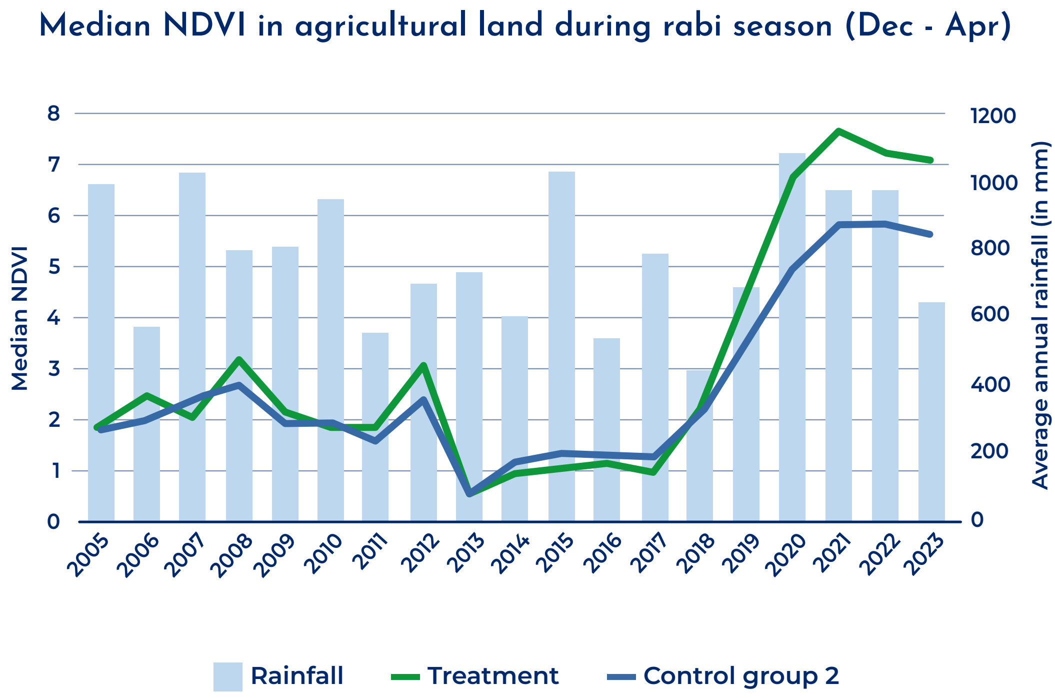

Figure 8: Median NDVI for rabi season alongside average annual rainfall for the treatment and control 2 (neighbouring village).

The increase in the number of farmers cultivating in the dry rabi season can occur through two possible pathways:

(i) Overcoming land fragmentation: There is a high degree of land fragmentation in the region. On average, farmers have 1.5 to 2 parcels per person, in both the treatment and control groups. The availability of a pipeline network would enable them to irrigate their land parcels, which may be away from their borewells. One of the farmers stated during a focused group discussion:

"Our lands are scattered. But after forming the water collectives, pipelines were extended to reach even the farthest fields."

– A farmer from Kumaravandlapalli without borewells

(ii) Increase in leasing of land: For farmers without borewells, the programme agreement only provides for irrigation in the kharif (monsoon) season. So, their land in the network cannot be directly cultivated in the dry season. However, farmers without borewells mention that they sometimes lease their land to borewell-owning farmers. Now that the physical infrastructure is available for irrigation on their land, it increases the utility of their land in the dry season. Around 9% of the farmers without borewells in the treatment group were found to lease out their land. This is higher than any other group of farmers leasing out their land (Figure 9). The leasing out by borewell owners is also slightly higher, possibly due to the availability of irrigation.

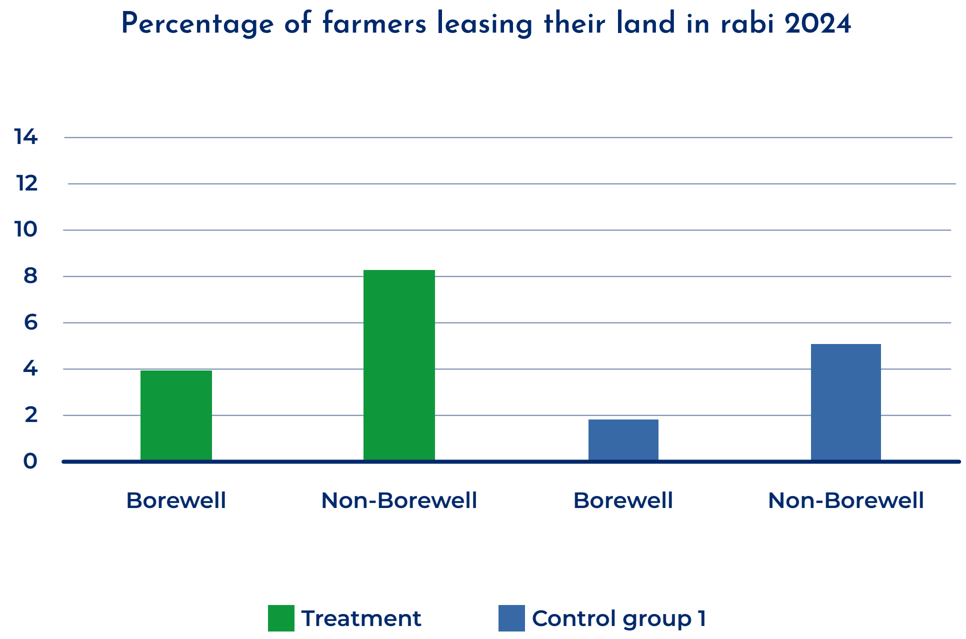

Figure 9: Percentage of farmers leasing out their land in rabi 2024 for the treatment and control 1 (within village) groups.

3.1.4. How has groundwater pooling improved water use efficiency?

Finding: The treatment group had reduced the cultivation of high water-intensity crops in the rabi season, but not in kharif.

The overall cultivation of paddy (highly water intensive) was reduced in the treatment group, but not in the control group 1 (within the village). The use of micro-irrigation increased to a similar level in the control group 1 and the treatment group.

The programme intends to change the crop choice behaviour of the farmers. A common clause in the agreement of the water-sharing rules is to limit the area of water-intensive paddy only to household use. Farmers in the project villages were trained on crop water budgeting and the importance of low water-intensive crops.

Based on secondary agronomic data, we divided the commonly grown crops in the area into three groups based on their water requirement: low, medium, and high (see Annexure IX). This helped us understand if the mix of crops grown had changed towards low-water-intensive crops, as indicated by the percentage change in the water intensity of the chosen crop from 2011 to 2024 (Figure 10).

In the kharif season, the medium water-intensive crops were replaced with more low water-intensive and high water-intensive crops. The increase in low water-intensive crops in the kharif season was statistically significant (p-value is 0.0015).

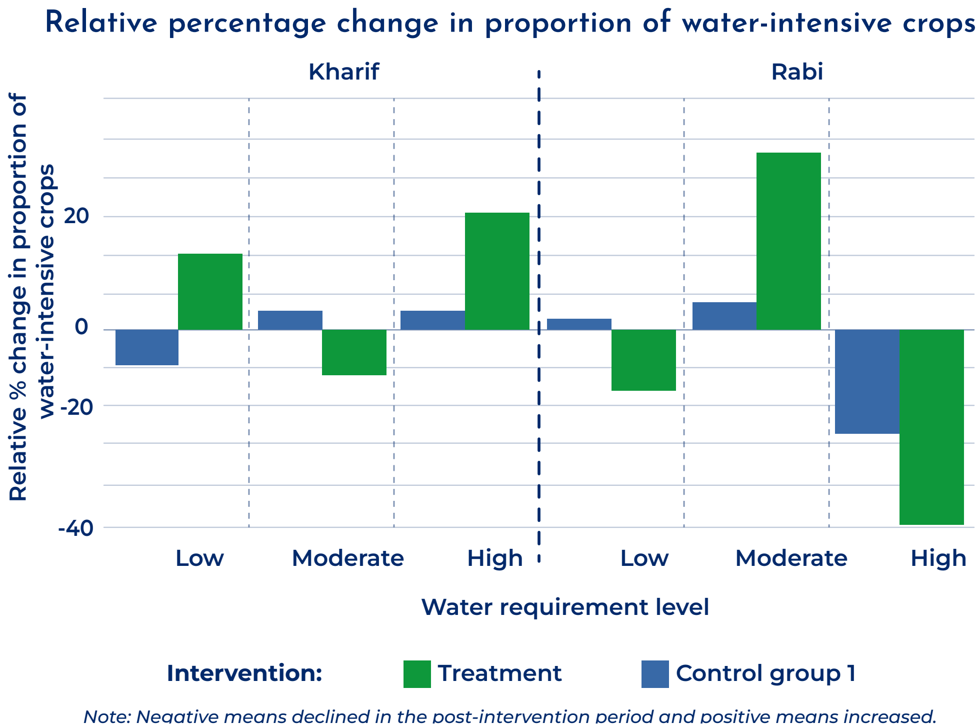

Figure 10: Relative percentage change in proportion of water-intensive crops across the treatment and control 1 (within village) groups.

In the rabi season, the highly water-intensive crops reduced by 39%, and the moderately water-intensive crops increased by 35% among the treatment group, showing a move towards more water-efficient crops.

Farmers in the treatment groups had somewhat changed their cropping patterns in line with the agreement, resulting in a reduction of approximately 21% in paddy cultivation area across both seasons. In contrast, farmers in the control group 1 had expanded their paddy cultivation area by around 48% across both seasons.

In recent years, farmers preferred medium water-intensive cash crops in the rabi season, like tobacco and castor, as seen in Figure 10. There was also an increasing preference for high water-intensive perennial crops in the kharif season like mango, pomegranate and sweet orange. The area under fruits increased by approximately 14% from 2011 to 2024. Low water-intensive crops like vegetables (beans, broad beans, onions, radish) had increased by 4% in the kharif season.

Farmers' crop choices are generally largely influenced by market prices and demand. Discussions with the community also indicated that agricultural traders played a key role in these decisions, alongside trends of rainfall from the previous year, as illustrated by the quotes below.

"Crop choices are determined by seasonal factors and water availability. Recently, we've been cultivating more corn. Crop decisions often depend on the trader's instructions."

– A farmer in Donikota with borewells

"In the past, we used to grow crops like tur dal, horse gram, pearl millet, little millet, and groundnut, yielding higher production. However, due to inconsistent rainfall over the past 5-6 years, only tur and groundnut are being cultivated now.

In some areas, the focus has shifted mainly to tomatoes, with occasional cultivation of vegetables, bitter gourds, brinjal, and chillies, though these are driven by market demands and better prices for the produce."

– A farmer in Devireddypalli without borewells

This statement indicates that middlemen play a significant role in influencing farmers' crop choices, guided by market price trends and rainfall patterns. In years of adequate rainfall and water availability, farmers tend to cultivate high water-intensive and perennial crops that offer better returns. Conversely, during drier years, they adapt by selecting medium and low water-intensive crops such as vegetables, maize, groundnut, and horse gram, which continue to hold good market value. The prevalence of crop choice by the farmers as per the market price and crop water requirement is plotted in a graph attached as part of Annexure IX.

The use of micro-irrigation increased among all farmers.

In addition to crop choice, the use of micro-irrigation, such as drip and sprinkler irrigation techniques, was seen as the second major mechanism for increasing water use efficiency in the programme. In some villages, the programme implementation agencies liaised with the government departments to provide members of the water collectives with micro-irrigation equipment on a higher priority.

At the start of the programme, this was also one of the motivating factors for farmers to join the water collectives. The use of micro-irrigation was also expected to increase crop productivity to an extent.

The adoption of micro-irrigation practices between 2011 and 2024 increased by over 60% across all groups (Figure 11). It was seen that farmers were more likely to adopt micro-irrigation, particularly in the rabi season, as compared to the kharif. This is partially because the kharif crop is primarily rainfed.

Overall, farmers across the groups showed an inclination towards the adoption of efficient water-saving micro-irrigation systems, with treatment groups showing an increase in adoption during rabi, when water is scarce.

While there were signs of improvement in access, the intervention had not clearly affected cropping intensity, yield, and profits relative to the control group 1. We did find evidence that the treatment group farmers shifted from high water-intensive crops to moderate water-intensive crops in the rabi season.

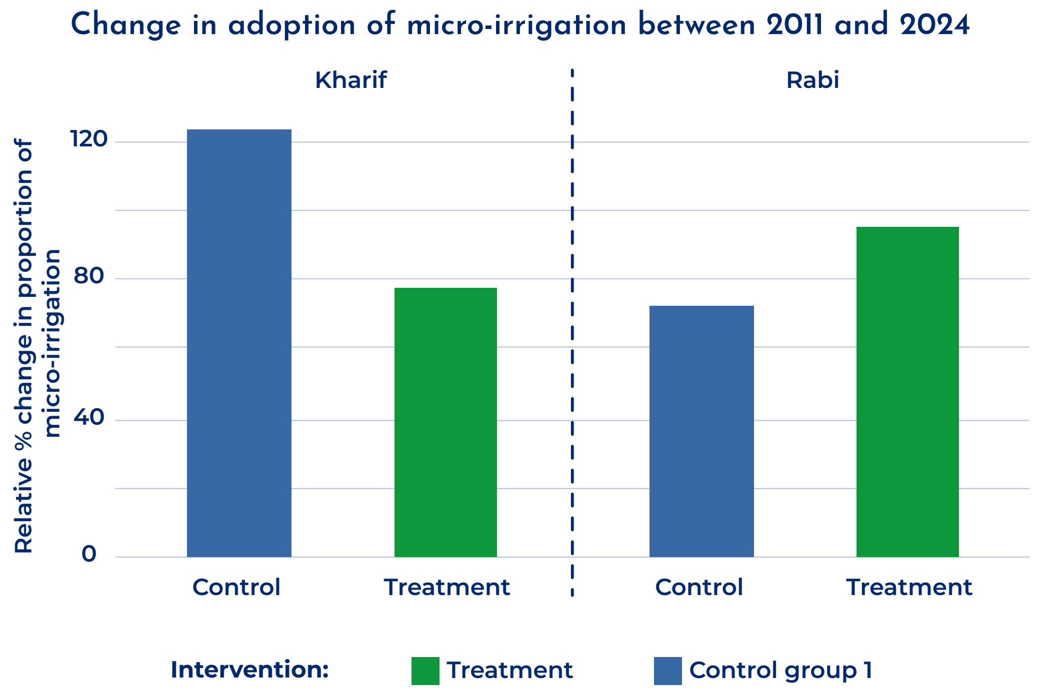

Figure 11: Change in adoption of micro-irrigation between 2011 and 2024, across the treatment and control 1 (within village) groups.

3.1.5. To what extent has the programme reduced competitive groundwater drilling and increased collective management?

Finding: Borewell drilling continued across all groups, but at a slower rate in the treatment villages. However, there was no significant difference in the depth of new borewells between the control 2 (neighbouring village) groups and the treatment groups.

Reducing competitive drilling in the region is a key objective of the programme. The water collectives were formed not just to ensure the cooperative management of the pipeline network, but to prevent the overexploitation of groundwater through agreements. While the specifics of the agreements vary across the 12 villages, the condition for ‘no new borewells’ is common across all water collectives.

We looked at how many borewells were drilled in the five years before and after the intervention for both the treatment group and the control group 2 (neighbouring village) to see if the rule of ‘no new borewells' is common across all water collectives.

We looked at how many borewells were drilled in the five years before and after the intervention for both the treatment group and the control group 2 (neighbouring village) to see if the rule of 'no new borewells' was followed. This approach helped account for the variations in intervention time across the sampled villages.

Figure 12 shows the number of wells drilled before and after the intervention. We find that, despite the 'no new borewells' rule, the treatment group continued drilling borewells after the intervention. Their average drilling rate was around 100 wells in five years, and this rate remained the same across the 12 villages, before and after the intervention. In comparison, for the control group 2, the number of new wells continued to increase in the five years after the intervention.

Therefore, the water collective members dug fewer new borewells over the years, while the control group 2 (neighbouring village) continued to increase the number of new borewells.

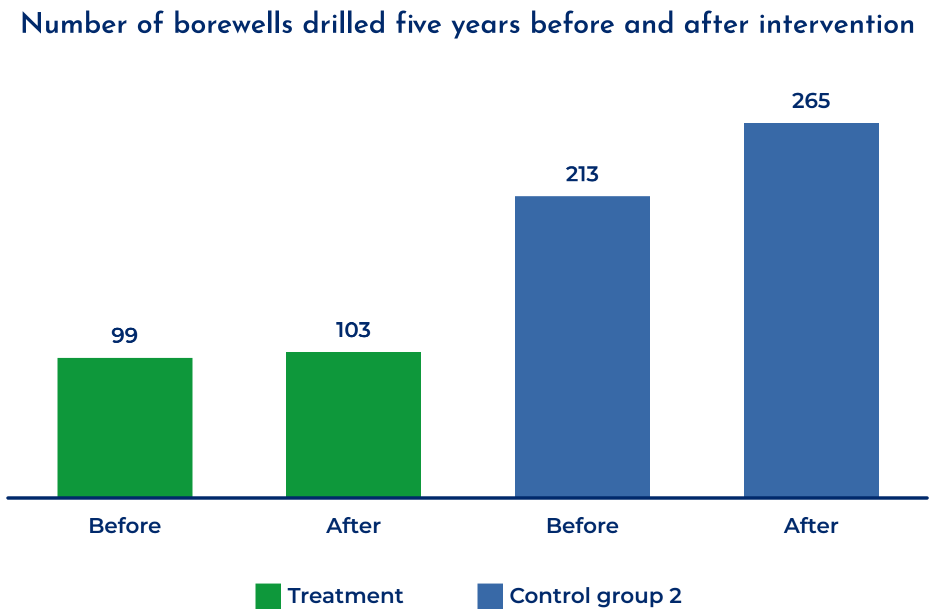

Figure 12: Number of borewells drilled five years before and after intervention, across treatment group and control group 2 (neighbouring village) groups.

It is to be noted that some of the borewells dug by farmers in the treatment group may be outside the 'treatment area', i.e. area owned by the farmers outside the pipeline grid. In hindsight, it would have been better to capture additional data on whether the drilling of new borewells was inside the pipeline area or not.

Despite the water collectives' agreements prohibiting drilling of new borewells, the drilling did not appear to create conflict within the water collectives. During one discussion, one of the water collective members agreed to the digging of new borewells, saying:

“As farmers without borewells, we eventually started digging new borewells, even outside our boundaries. After saving up some money, we all managed to install our own borewells over the past few months.”

– A farmer in Edurupadu without borewells

The results revealed a few more insights regarding borewells as described below.

(i) The depth of new borewells continued to increase across all groups, with no statistical difference between control group 2 (neighbouring village) and treatment groups.

The trend of digging deeper borewells continued despite awareness campaigns on the negative impacts of competitive borewell extraction. During the borewell census, we asked respondents to report the depth to which borewells were dug. The quality of recall of such data was expected to be reliable, as the farmers spend large amounts of money on digging, and the spending is proportional to the depth drilled.

We found that there is a clear increasing trend over the years for both treatment and control groups (Figure 13). Statistical analysis of the median borewell depths indicates no statistically significant variation between the treatment and control groups.

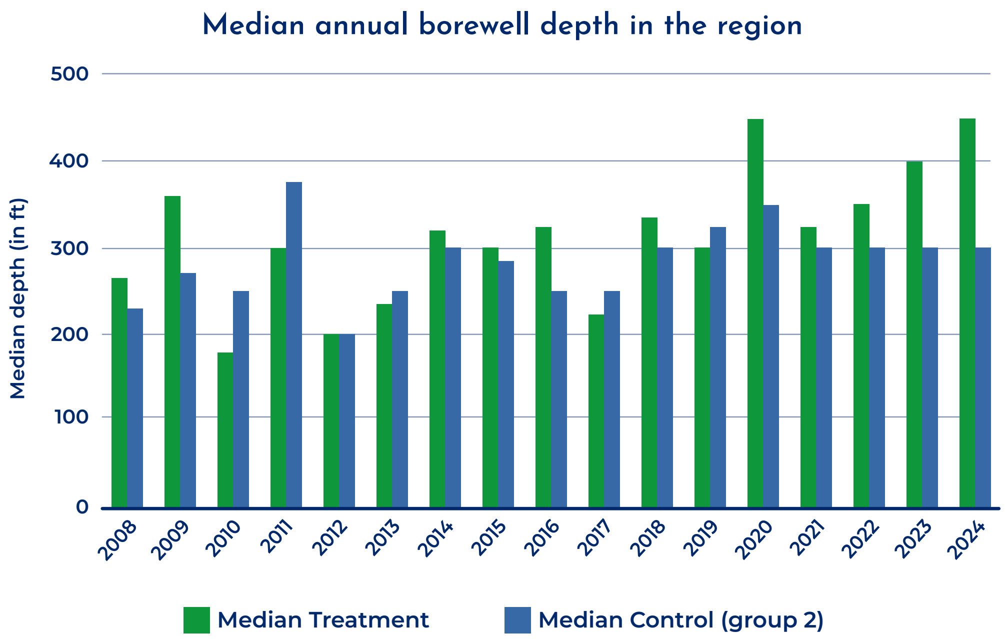

Figure 13: Median annual depths (ft) for all borewells in the region across the treatment and control 2 (neighbouring village) groups.

Members of the water collectives group voiced concern about increasing borewell depth in our focus group discussions. One member of a water collective stated:

"A few years ago, we could access water at 150–200 ft, but now, we're forced to drill much deeper to get water. In some places, borewells are going down to 600–700 ft or even deeper to find water. Even at these depths, the situation is still highly dependent on rainfall. Without sufficient rain, no matter how deep we dig, the borewells remain dry, and we can't rely on them to supply water."

– A farmer in Patnam with borewells

The reasoning for continued competitive drilling could be that the pipeline network facilitated access and increased water use, but without increasing water use efficiency sufficiently to offset the increased access. Another plausible explanation is a possible spillover effect of the increase in water usage by other farmers in the village. A detailed analysis of groundwater behaviour beyond the scope of this study would be needed to fully understand which of the two mechanisms is more prominent.

(ii) Borewell failure rates increased in both groups over the years.[4]

In granitic hard rock areas, much of the aquifer storage space for water is within the weathered aquifer layer and the stratified fractured layer, which extends to approximately 300 ft (Lachassagne, 2023). Below this, there are semi-vertical fractures that may connect with the high storage layers above, but the frequency of fractures reduces with depth, and the aquifer starts to be replaced with unweathered rock without much space. Therefore, deeper wells often fail in granitic aquifers.

The quote from one of the focused group discussions illustrated what borewell failures imply for farmers' livelihoods:

"We face frequent borewell failures, which result in significant losses. Out of the three borewells I own, only one works properly. Many of us have multiple borewells because of repeated failures. When a borewell fails, especially during critical cropping periods, it leads to total crop loss. We often have to wait for rain, as even digging up to 500 ft doesn't guarantee water."

– A farmer in Patnam with borewells

This was also reflected in the borewell census data. Figure 14 shows the percentage of borewell drilling attempts that fail to find water. Approximately 57% of borewells in the treatment group experienced failure upon installation, and 46% in the control group 2 (neighbouring village).

[4] Borewell failure here is defined as an instance where a newly-drilled borewell fails to yield adequate water at the time of installation, rendering it non-functional from the start. This is different from erstwhile successful borewells drying up.

There was a statistically significant increasing trend of borewell failure over the years across both groups (p-value is 0.0012).

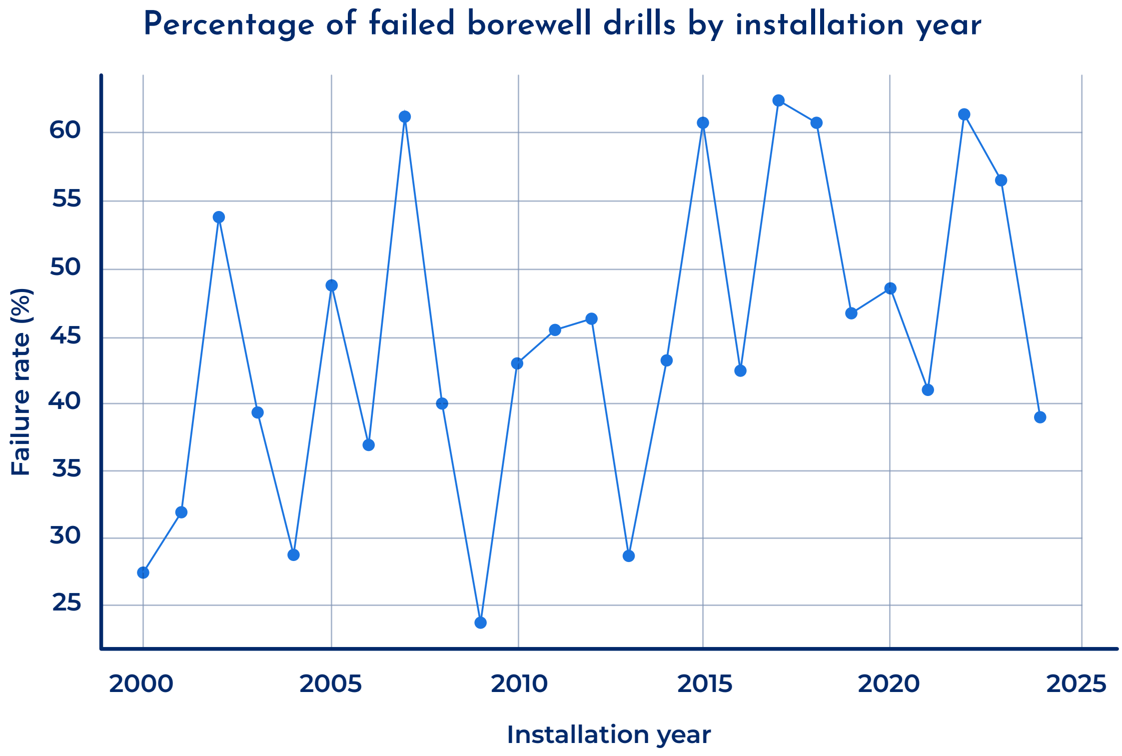

Figure 14: Percentage of borewell drilling attempts that fail to find water across treatment and control 2 (neighbouring village) groups.

iii) Farmers' expenses from borewell drilling were also increasing.

High rates of borewell failure were one of the fundamental motivations for WASSAN to take up this programme, to reduce the farmers' expenses by decreasing competitive drilling. The programme introduced a pipeline system precisely to avert cases of new borewell drilling and failure.

Deeper borewells also require pumping from deeper levels and more electricity. The electricity costs are subsidised by the government and are not linked to the per-unit cost. A reduction in deeper wells would also therefore benefit the government.

For this analysis, we focused on the initial borewell drilling and installation costs, which were the most variable. The other costs, like those of pumps and maintenance, were comparatively smaller and fixed.

The median cost of drilling a well was found to be increasing over the years. The treatment and control groups were found to be statistically similar (p-value=0.31). This could be because borewell depths were increasing across the groups over the years.

3.1.6. Has the programme led to a stabilisation of groundwater levels, particularly in the dry season?

Finding: There was no difference between the control group 2 (neighbouring village) and the treatment groups in inter-annual water level trends. Seasonal drying was actually worse in the treatment group.

In high-storage alluvial aquifers of the Indo-Gangetic plains, groundwater overexploitation results in a steady drop in water levels every year. In low-storage granitic hard rock aquifers on the other hand, groundwater overexploitation shows up as dramatic fluctuations in water levels with high inter- and intra-annual variations. Borewells frequently dry up in the summer.

Unlike in open wells where water is visible, farmers are often unable to get a good sense of water level fluctuations in the borewells. They only experience the water level when they first drill a well and discover when the water is struck. Given the sharp seasonal fluctuation of water levels and the lack of direct visibility on water levels, changes in the depth to groundwater levels must be interpreted carefully.

The only data on static water levels available to us was farmer recall data of the level when the borewell was dug, typically in the post-monsoon season. This reported water level can be assumed to be dependent on that year's rainfall. Analysis of this depth over time showed a long-term decline in water levels (Figure 15), similar to the increasing depth of new borewells over time (Figure 13). We did not find a statistical difference in the temporal trends between the treatment and control groups.

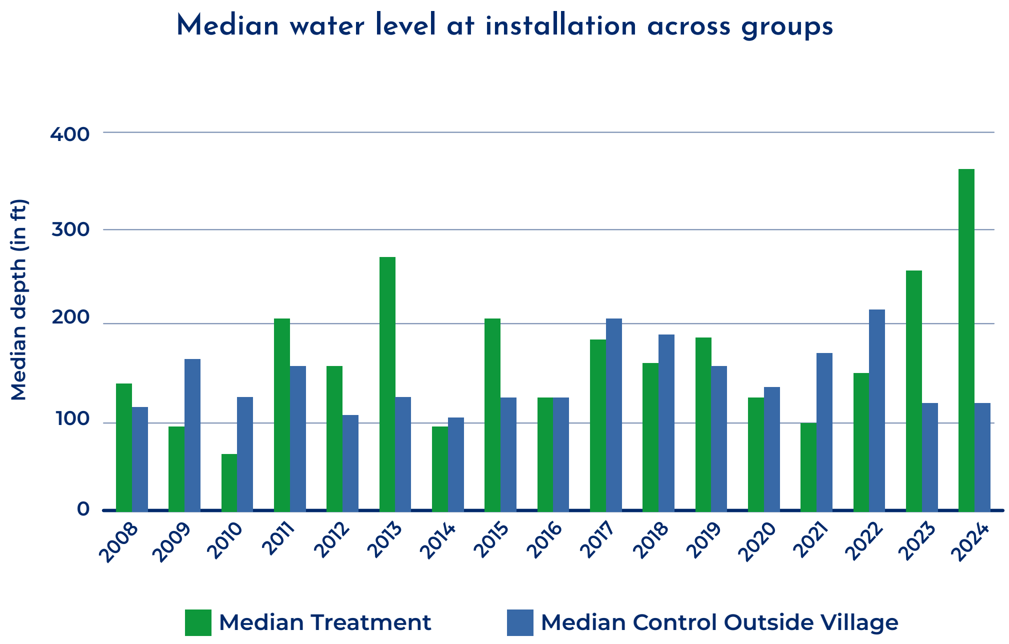

Figure 15: Median annual water level depth (ft) for all borewells in the region across the treatment and control 2 (neighbouring village) groups.

The focus group discussions had similar reports, with the following quote from a farmer outside the water collectives:

"Water levels seem to be declining as more borewells are dug, and this fluctuation still depends largely on rainfall. While some improvements were made with pipelines, overall, water extraction hasn't changed significantly. There is less water available now, possibly due to overuse by borewell-owning farmers, but we can't pinpoint the exact cause Ultimately, water availability remains tied to rainfall."

– A farmer in Devireddypalli who wasn't part of the water collective

It should be noted that while the median depth of wells was close to 300 ft for both treatment and control groups, the median water level across the groups ranged between 135 ft and 150 ft. This was because while the water may be available at a shallower level, there was an anticipation of its seasonal fluctuation, and therefore, wells were dug to deeper levels.

Seasonal drying of borewells

Borewells within the treatment group did not exhibit a statistically significant degree of drying[5] (p-value is 0.11) compared to control 2 (neighbouring village) (Figure 16).

Status of borewell drying (in %)

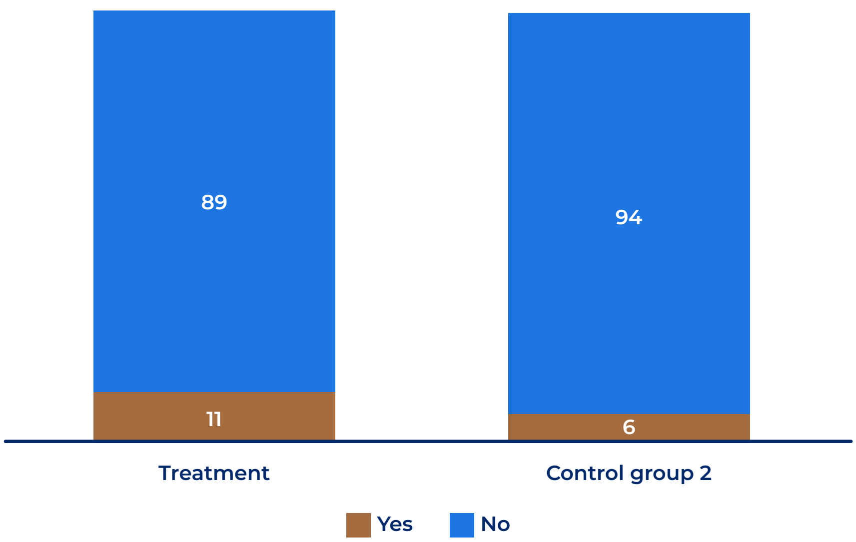

Figure 16: Status of borewell drying across treatment and control 2 (neighbouring village).

[5] *For the purpose of this analysis, 'borewell drying' refers to borewells that have experienced periods of drying anytime over the past few years.*

The observed increase in borewell drying and deepening may be attributed to two main factors. First, the pipeline programme facilitated improved access for irrigating distant lands using the same borewell. The programme design expected significant changes in water use efficiency to counterbalance the increased extraction. However, as seen in the sections above, there was increasing adoption of water-intensive crops in kharif. The overall increase in extraction could have led to more intense groundwater extraction. This could have caused the water level in the region's aquifers to drop, making it necessary to drill deeper borewells.

Second, spillover from groundwater depletion by farmers outside the collective would lower groundwater levels within the area of the collective, even if extraction within the collective remained the same or reduced.

Summarised Findings Across Indicators

Figure 17 shows the summarised impact for treatment villages across the indicators when compared with the control villages. Overall, the socio-economic indicators fared better than those related to groundwater sustainability.

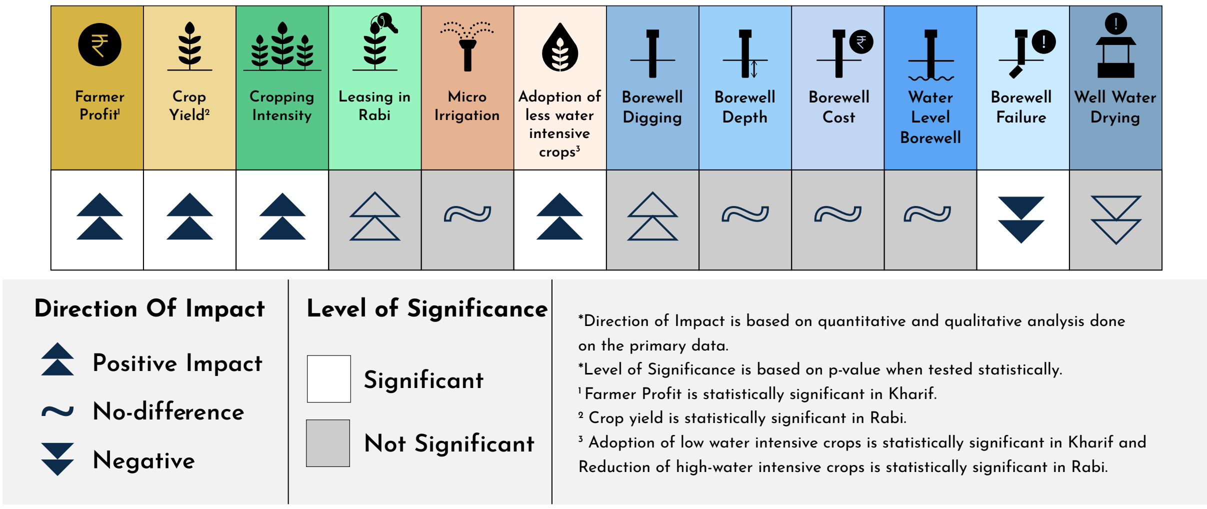

Figure 17: Direction of impact of the treatment relative to the control across indicators.

3.2. Analysis of Functionality of the Water Collectives: (Qualitative Analysis)

The assessment of how well the water collectives have functioned was done through the two research questions:

B1. To what extent are the water collectives functional and reflect Ostrom's principles for successful collective action?

B2. What factors have influenced the success of participatory governance across different user groups?

3.2.1. To what extent are the water collectives functional and reflect Ostrom's principles for successful collective action?

Finding: While many villages had informal or formal agreements, most lacked enforcement of these rules.

Only two out of the 12 treatment villages had water collectives broadly functioning as per Ostrom's design principles. Five water collectives continued to meet regularly, and only three had an active community resource person. Importantly, none of the groups had graduated sanctions for rule violations and conflict resolution mechanisms in place. The functionality of water collectives refers to their effectiveness in governing and managing shared groundwater through clearly established rules, formal agreements, participatory decision-making, and accountability mechanisms.

Ostrom's design principles provide a robust framework for assessing governance structures. Our study contextualises these principles and focuses on whether the governance practices were in place. Table 8 below shows the variation of different components of governance practices across the 12 intervention villages. The themes correspond to Ostrom's principles, while sub-themes and components are their contextualisation for our study.

Themes	Sub-themes	Components	Sampled villages											
			1	2	3	4	5	6	7	8	9	10	11	12
Conflict resolution mechanisms			●	●	●	●	●	●	●	●	●	●	●	●
Monitoring systems	Monitoring users(Active resource from the implementation agency)		●	●	●	✓	●	●	●	●	●	●	●	●
	Monitoring resources (Active community resource person)		✓	✓	✓	●	●	●	●	●	●	●	●	●
Collective choice arrangements	Agreements	Formal/written agreement	✓	✓	●	●	●	●	●	●	●	●	●	●
		Informal agreement	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Group meetings	Currently meeting regularly	✓	✓	✓	●	✓	✓	●	●	●	●	●	●
Graduated sanctions			●	●	●	●	●	●	●	●	●	●	●	●

Good
Medium
Low

Functionality Categories (see Annexures 4 and 5)
● Absence of a component
✓ Presence of a component

Table 8: Reported prevalence of governance practices across the 12 treatment villages as noted during focused group discussions and in-depth interviews.

(i) Rule enforcement was a challenge.
Many water collectives had formal or informal agreements about restrictions on digging new borewells and cropping choices. However, these rules were often not followed, and the water collectives did not have governance mechanisms to enforce them. None of the villages had graduated sanctions or conflict resolution mechanisms.

The rule on borewell digging was regularly flouted, without any reported response by the water collectives. This is also confirmed by the borewell survey results discussed in research question A5. The following statements from the focused group discussions illustrate this further:

"Eventually, I saved some money and installed my own borewell outside the group."

– A farmer in Devireddypalli without borewell

"I installed a borewell three months ago."

– A farmer in Nagampalli without borewell

"Farmers without borewells who are part of the group have dug new borewells out of the boundary."

– A farmer in Kumaravandlapalli with borewells

This behaviour challenges the principles of collective action and the idea that resource management groups, when equipped with shared goals and responsibilities, will naturally coordinate effectively. This may partially be because water collective members realise that the villagers outside the group who are within their 'resource boundary' are continuing to dig deeper. Thus, the members may be demotivated from following the rules of the group.

The agreements generally include the provision of a few rounds of irrigation for farmers without borewells in the monsoon season, but not in the drier rabi season. Farmers with borewells get one extra season of irrigation, in return for agreeing not to dig a borewell. But faced with this imbalance, farmers without borewells may attempt to bypass collective governance by digging new borewells outside the treatment area to reclaim agency over their water security.

(ii) Villages did not have sufficient resources for monitoring systems.
Regular and transparent monitoring is key to participatory resource management. The key agreement rules regarding cropping choice and borewell needed systematic monitoring. But only some villages had an active presence of NGO representatives or community resource persons. Some villages reported conducting crop budgeting meetings for the initial few years, but none of the

villages were currently doing active crop water budgeting or monitoring.

This gap highlights the need to move beyond need to move beyond initial facilitation and equip communities with the necessary skills and continued support for sustainable, self-reliant resource management.

(iii) Regular group meetings had reduced over time.
Regular group meetings conducted in villages improve community engagement among group members. They also serve as informal conflict resolution platforms, allowing members to address disputes, clarify misunderstandings, and prevent minor conflicts from escalating.

In the study villages, meetings had reduced slowly over the years, potentially as members grew accustomed to collective management. But they tend to take place when there is a need. For example, if the transformer fails, all farmers affected may come together to discuss and attempt to solve the problem, even though they do not meet regularly.

There were also some outlying instances of farmers without borewells being excluded from the meeting by the borewell-owning members of water collectives.

"Only borewell-owning farmers used to meet frequently. They didn't invite us to any meetings."

– A farmer in Kumaravandlapalli with borewells

3.2.2. What factors have influenced the success or failure of participatory governance across different user groups?

This research question is answered by exploring qualitative responses related to three indicators: motivation, trust, and capacity.

(i) Motivation: What was the intrinsic motivation for farmers to join the groups?

Finding: The installation of the subsidised pipe network was found to be the primary motivation for joining the water collectives across all treatment villages.

The need to avoid competitive deepening did not emerge as the primary motivation. In some villages, having fragmented lands also motivated farmers to join water collectives. This suggests that material benefits, such as improved irrigation infrastructure, serve as stronger motivators for collective action than long-term resource sustainability concerns. Several studies on farmer collectives highlight that economic and productivity gains tend to outweigh conservation imperatives in shaping decision-making (Shiferaw et al., 2008; Meinzen-Dick, 2014).
This is illustrated in the below response from a farmer:

"Before the programme, we only had about 10 to 15 acres of irrigated land between us. With the pipelines in place, each farmer is now irrigating 4-5 acres, and we have successfully brought over 30 acres of erstwhile rain-fed land under irrigation. This has allowed us to grow different crops on all the land, including areas that didn't even have borewells before."

– A farmer in Kumaravandlapalli with borewells

Farmers without borewells in water collectives cited access to water as their primary motivation for joining the water collectives. Their dependence on rainfall during dry seasons made participation in the group essential, as it provided them with access to borewell water when needed.

"I received water from the borewell-owning farmer when I needed it most, but I had to plead with them."

– A farmer in Devireddypalli without a borewell

"We joined the programme because they promised water access through borewell-owning farmers, and showed us pipelines installed in the fields."

– A farmer in Korakkodu without a borewell

"Pipelines were given to six of our borewell-owning farmers, and I hoped to get some water from them as well."

– A farmer in Nagampalli without a borewell

The success of pipeline installations in expanding the irrigated area demonstrated how infrastructure incentives can generate immediate and measurable advantages, making them a more persuasive entry point for engagement. Pipelines at such scales are rare in the region, and the idea of installing them was attractive for farmers in semi-arid areas. If access to groundwater was the main motivation for farmers without borewells, fragmented lands were a common reason for borewell-owning farmers. Collective water management became essential to ensure irrigation access to their distant land parcels, making water sharing a necessity and fostering stronger cooperation and group functionality.

"Our lands are scattered, but after forming the water collectives, pipelines were extended to reach even the farthest fields."

– A farmer in Kumaravandlapalli with borewells

ii) Trust: How did trust in the implementation agency influence collective action?

Finding: WASSAN's strong presence in certain villages significantly improved the functionality of the water collective. However, in villages with limited engagement, sustaining collective action was a challenge.

In the villages of Pallevandlapalli and Kumaravandlapalli, WASSAN had a long-standing presence, implementing multiple programmes over the years. This sustained engagement had led to positive views towards the organisation by community members. During interviews, respondents specifically mentioned Uthappa and Bakka Reddy from WASSAN, who have been visiting these villages for a long time, further reinforcing trust and continuity in implementation efforts. Such strongly positive responses were missing from some of the other villages.

"Utthappa from WASSAN introduced us to the scheme. We told him, 'Now that this has come to our village, we won't let it go—we'll convince our farmers to join.' Soon after, a team from WASSAN visited and spoke with the villagers. Uttappa, Bakka Reddy, and Venkaiah from Hyderabad organised meetings engaging with the men, often at night, to explain the scheme. Initially, the villagers were sceptical and hesitant, lacking confi dence in the initiative. For five months, discussions continued, but gradually, the farmers came around, opened bank accounts, and deposited the required amount."

– A farmer in Kumaravandlapalli with borewells

iii) Capacity: Are the farmers equipped with better knowledge, skills and attitudes towards better water management?

Finding: Although farmers have underdone training programmes, behavioural change in farming is not solely a function of training but is deeply tied to economic incentives, water access, and peer influence.

All sampled water collective members in the treatment villages have undergone training on crop water budgeting and natural farming. Only 3 out of 12 village water collectives participated in exposure visits to demonstrate the benefi ts of collective water management. The respondents relate the capacity-building efforts to improvements in micro-irrigation adoption. However, their effectiveness in reducing dependence on water-intensive crops and eliminating pesticide use remains limited.

Villages where community members have participated in exposure visits were functioning better. Learning from other communities played a crucial role in strengthening water collectives. Exposure visits provided villagers with first-hand experience of the benefits of collectivisation, serving as a strong motivator to adopt and implement best practices for water governance in their own villages.

"WASSAN took us to Ahobilam for an orientation visit, where we saw first-hand how farmers had formed water collectives and benefited from the programme. After returning, we also agreed to create the group"

– A farmer in Pallevandlapalli with borewells

The WASSAN-led intervention included training sessions aimed at equipping water collective members with essential skills in water management, efficient irrigation, natural farming, and land and crop management. In some places, it was clear that farmers were sensitised towards water conservation.

"Earlier, we used to use field channels and that needed more water. Irrigation using pipelines is more efficient as there is less water loss."

– A farmer in Kumaravandlapalli with borewells

"We received training on efficient water usage and crop protection against pests and diseases.

– A farmer in Korakkodu without borewells

"They organised one meeting where they guided us on using the pipelines and encouraged us to adopt natural farming."

– A farmer in Thimmampeta with borewells

"If there's excess water, we give it now and then, but with drip irrigation, things have changed. Micro-irrigation has increased, and so has drip usage. Water is saved, and we no longer need to flood the fields. With drip, water consumption has gone down significantly. Earlier, with the flooding system, the same amount of water that irrigated one acre can now cover four acres. Micro-irrigation has been a big advantage. Now, everywhere, farmers are using drip—just turning the valve, and the work is done."

– A farmer in Pallevandlapalli with borewells

However, the impact on reducing water-intensive farming and eliminating pesticide reliance remained limited. Field observations also revealed a disconnect between training efforts and actual farming practices. Despite efforts to promote natural farming, pesticide use remained prevalent, indicating a gap in behavioural change.

Similarly, while micro-irrigation practices gained traction, the anticipated shift toward less water-intensive crops had not materialised. Farmers continued to prioritise crop choices based on market demand and localised water availability. This highlighted the complexity of agricultural decision-making, where economic factors, water access, and risk perceptions often outweigh external advisories.

In some cases, there was a signifi cant infl uence of external infrastructure that overrode training-based behavioural shifts. Pallevandlapalli village, for instance, was a beneficiary of the Handri-Neeva canal project that aimed to provide water into the local ponds and recharge groundwater. After the introduction of the canal in 2019, many farmers from this village opted for paddy cultivation, directly contradicting the intervention's goal of reducing reliance on water-intensive crops. This underscored the critical role of resource access in shaping farmer choices, sometimes outweighing conservation-driven incentives.

On questions related to crop choice, farmers repeatedly mentioned peer success stories about certain crops like tomatoes. This 'demonstration effect' and social learning played a significant role in shaping agricultural decisions. Farmers were more likely to follow peer success stories rather than external recommendations. If a neighbouring farmer profited from a specific crop, others were inclined to replicate that strategy, assuming similar economic benefits.


Photo credit: WELL Labs

Chapter Four
Conclusions and Recommendations

4.1 Conclusion

The Groundwater Collectivisation Programme, spearheaded by WASSAN and its partner NGOs, has introduced a collaborative and community-centric approach to addressing inequitable access to irrigation in semi-arid areas of Andhra Pradesh and Telangana.

The supply side of the intervention worked well by significantly increasing access to irrigation.

To a limited extent, the agricultural yields and profits were also differentially better in the treatment group compared to the control group. The pipeline network introduced as a part of the programme helped farmers without borewells gain access to irrigation in the kharif season. It also led to significantly higher cropping in the rabi season. The pipeline network helped in overcoming land fragmentation and enabled borewell-owning farmers to irrigate their land parcels, which were away from their borewells.

The demand side saw mixed results due to the continuation of borewell digging

Competitive drilling continued with deeper borewells and increased costs. Among households in the treatment group, the borewell drilling continued but slowed down. Drilling may have occurred on plots of land outside the treatment area.

To counterbalance the increased access to water through pipelines, the intervention included an agreement by water collectives to dig new borewells and reduce the cultivation of water-intensive crops. But these rules did not apply to the area outside the collective boundary, meaning that households that are part of the water collective could still dig borewells outside the collective area.

Over the past decade, all farmers continued to drill deeper borewells. While the pace of drilling increased in the control group, it plateaued in the treatment group. However, the farmers part of the collectives continued to dig new borewells outside the water collective area. There was some reduction in the treatment group's cultivation of water-intensive crops in the rabi (water-scarce) season. However, there was no differential impact in the use of micro-irrigation.

Within the collectivisation area, the rate of drilling new borewells was slower than in outside areas.

Wells were being dug at a higher rate, to a deeper level, and with a higher failure rate, in both the treatment and control villages, but the rate was lower inside the intervention area.

Therefore, it can be understood that the programme's objective of reducing competitive drilling succeeded in terms of reducing the number of new borewells drilled. But it did not necessarily reduce the extraction of groundwater in the region. This may be partially due to the treatment group's own increased water use due to higher cropping intensity, or to the sharing of the aquifer with other villagers who are not a part of the water collectives.

The operation of water collectives became more passive and the number of meetings reduced based on requirements over the years.
Members reported that in the past, they used to meet more regularly to discuss crop choice and water budgeting. After the programme was implemented, regular meetings diluted over the years, potentially because members grew accustomed to collective management. None of the villages had any monitoring or conflict resolution mechanisms to implement agreements. In many villages, people also did not recall the presence of a written agreement on the reduction of water use.

The Groundwater Collectivisation Programme was successful in terms of providing more equitable access to water. The issue of groundwater sustainability remains a challenge in this region.
Access to adequate and timely irrigation is a major demand of the local community and a key enabler for socio-economic development of India. It is also a signifi cant climate adaptation measure in the face of increasingly erratic rainfall and increasing dry days in the area. In the intervention areas, the access to groundwater shifted from a privately used resource towards a common-pool resource, which is used and managed by a larger pool of farmers.

4.2 Enablers and Barriers

It is important to refl ect on the larger conditions that enable or inhibit the success of such an intervention.

4.2.1 Enabling Factors for the Programme

The intervention was successful in the aspect that the pipeline networks were functional even many years after their installation, and farmers reported benefi ting from them. The creation of community institutions such as water collectives was in itself a challenge, and the programme and the water collectives succeeded in keeping pipeline networks functional.

Through the focus group discussions and other interactions, the following factors were found to work in favour of the programme:

Land fragmentation: Borewell-owning farmers had two parcels of land on average, with some villages averaging 2.8 parcels per farmer. The subsidised pipelines helped them in converting their non-irrigated land into irrigated land. Therefore, in villages that had a high degree of land fragmentation, borewell-owning farmers were more likely to be amenable to the programme.

Semi-arid areas with erratic monsoon rainfall: The intervention design focuses on providing protective irrigation for farmers without borewells whose yields may be affected by dry spells during monsoon rainfall. Semi-arid areas tend to be vulnerable to this.
Thus, the intervention may be more relevant for rainfed farmers in such areas. In wetter areas, the programme may be more relevant for irrigated farmers and expansion of rabi cropping.

Heterogeneity in aquifer characteristics within the village: In peninsular India, valleys often have better groundwater availability and therefore more irrigated agriculture. In contrast, there is less groundwater availability in the uplands and the water drains downstream quickly, limiting the potential of wells and restricting farmers to a single rainfed crop in monsoon. In such situations, pipeline networks help overcome these limitations and provide more access to farmers in the upland areas.

Small and socially homogeneous groups: Villagers reported that water collectives formed are usually within the same caste or clan of people, as they have more trust among themselves.

4.2.1 Key Barriers for the Programme

The Groundwater Collectivisation Programme tried to counterbalance the increase in groundwater access for rainfed farmers with initiatives to increase water use efficiency. While the access clearly increased for rainfed farmers, the increase in water use efficiency was mixed, as discussed earlier. Some of the barriers to ensuring sustainability and reducing competitive drilling were:

Free rider problem: The water collectives often consisted of 10-30 farmers, which was a subset of all the farmers in the village. The remaining farmers who were part of the same aquifer system continued drilling deeper borewells and at a higher rate. The treatment group were drilling at a reduced rate, but had to drill to similarly deeper levels. This demonstrated that the demand-side benefits would not accrue to the treatment group if there were a large number of farmers ('free riders') who were not reducing their rate of water consumption, but were benefiting from the reduced overall consumption by others.

Lack of monitoring and regulatory mechanisms: By implementing a seasonal water budgeting process, the initiative attempted to introduce monitoring and regulation of water use. However, it did not last beyond a few years. Groundwater use in India remains largely unregulated (Shah, 2009). While the initiative sought to bring order to this system, farmers do not generally want their water use monitored or regulated. Moreover, monitoring is expensive, and there is no local incentive to bear the cost of monitoring.

Limited to villages with inequity in access to irrigation among farmers: The intervention helps overcome inequity in water access. Villages that have uniformly very high or very low access to irrigation might not be relevant for this intervention.

Lack of higher-level federated entities would hinder scaling: As Elinor Ostrom has postulated, commons work best when nested within larger networks. In this situation, the water collectives did not have any higher federated entities, which could reinforce the regulation of water. Some villages had multiple groups—for example, Pallevandlapalli had three groups, but they worked fully independently, focusing on the installation and management of the pipe network, without any clear focus on collectively managing their shared aquifer.

These key barriers relating to the design and implementation of the programme need to be overcome for the programme to become a holistic success for true collectivisation of groundwater as a common pool resource.

4.3 Structural Factors Incentivising Crop Choice

Farmers of the region mentioned clearly that the two most important factors in crop choice are market prices and water availability.

Farmers often rely on market incentives and rainfall predictions at the onset of the sowing season. Currently, crops like paddy and cotton, which consume a lot of water, are more feasible because they offer better market value and often provide good returns. Many farmers base their cropping decisions on fi nancial viability, risks, available farming inputs, and market value, making it challenging to encourage a large-scale shift toward water-effi cient agriculture. Addressing these structural challenges may require subsidies for water-effi cient crops, such as through minimum support prices (MSPs) or crop insurance, to help mitigate risk by increasing or ensuring revenue from crop sales.

The gradual shift towards water-effi cient crops can help address groundwater depletion. Another potential approach would be to link groundwater extraction to energy subsidies, where farmers or villages who utilise less electricity (due to less pumping or relying on shallower water sources) receive government transfers equivalent to electricity savings. Such approaches have the potential to encourage more sustainable groundwater extraction while reducing the economic burden on farmers. But they are yet to be demonstrated at scale.

4.4 Recommendations for Scaling

Sustainable solutions that can be integrated into existing systems are the need of the hour. The Groundwater Collectivisation Programme offers promise for enhancing the reliability of agricultural productivity and income in dryland regions. At the same time, expansion of the programme has relied on village-by-village relationship building, training, and implementation. Rapid scaling to larger geographies will require careful consideration of the institutional design, especially when programme leaders and advocates are unable to invest considerable time in each groundwater collective.

Building on the findings described above, we make the following recommendations when considering scaling the programme to larger areas.

1 **Manage spillover effects by matching the scale of collectives to the scale of the aquifer.**
Because groundwater collectives do not span the entire aquifer, borewell pumping outside the area of the collective can deplete groundwater levels in the collective. Expanding groundwater collectives to cover the entire aquifer will reduce the potential for spillover effects. While this will mean an increase in the area of the collective and the number of members, the other recommendations in this section may help address the complexities that come with this.

2 **Bridge scales by incorporating water collectives into larger governance networks.**
The formation of groundwater collectives was facilitated, in part, by small sizes of collectives, familiarity and existing relationships between group members, and similarity among members. Scaling collectives to larger areas will lead to greater heterogeneity among members. Effective governance will then require strong institutions to replace the trust, reciprocity, and information sharing that occur more naturally among smaller groups.

Well-designed and well-maintained institutions spanning multiple levels of governance may help protect collectives against exploitation for individual gain. For example, authority and oversight can be drawn from a taluk level. In addition to formal rules and processes, continuation of informal governance processes may contribute to the effective operation of groundwater collectives, including engagement with WASSAN representatives and collaboration with supporting NGOs.

3 Expand monitoring and incorporate new information and communication technologies (ICTs).

Expansion of collectives will lead to greater poly-centricity and a need for information sharing among actors with widely varying roles. ICTs can facilitate information sharing to enable monitoring and oversight, and build confidence among members in the operation of the collective.

More scientific and participatory water budgeting protocols must be explored. Although they may be expensive and difficult to implement, they may have long-term gains. For instance, remote sensing can be a viable approach to monitoring, given the readily scalable ability to observe crop choices and water consumption. Reasonable proxies for water consumption can be readily developed using existing technologies. Estimates of evapotranspiration would be ideal to measure crop water consumption (although reliable estimates are not yet available for the study regions).

Effective provisioning of remote sensing information, such as on soil moisture can also help farmers identify areas of crop stress within their fields. This has led to the rapid uptake of new farm management platforms in recent years. Such tools could be designed to better assess water availability each year, help farmers understand the risk of borewell failures in their aquifer, and contribute to collective planning of rabi crops to protect against such failures in dry years.

4 Design and implement graduated incentives and sanctions.

Incentives and sanctions are key to scaling. Without any sanctions, growth will come with undesirable consequences of elite capture and unsustainability. Building regulatory mechanisms into the governance structure can serve as a motivator of good behaviour. A structured regulatory mechanism should be established, incorporating incentives and graduated sanctions. Incentives may be predicated on electricity savings, water savings, or water trading within the group. Graduated sanctions could include revocation of access to the pipeline network. Without such institutions, farmers may have limited incentives to comply.

Such an approach will require higher levels of governance with the ability to monitor and enforce sanctions. These could include supporting organisations that maintain monitoring networks and existing government bodies, such as the local panchayati raj. While designing and implementing such sanctions would likely require substantial efforts on the part of organisers and village representatives, they will help the effective implementation of the programme across larger scales, including maintaining behavioural norms and sustaining trust and confidence in the programme among members.

Final Reflections

The Groundwater Collectivisation Programme demonstrated the potential of community-led governance models in managing common-pool groundwater resources.

The supply-side solutions, such as borewell pooling and pipeline networks, successfully brought farmers together and improved water access by providing critical irrigation for rainfed farmers and expanding irrigation for borewell-owning farmers. The programmes have increasingly functioned through informal institutions over time, built on familiarity, long-standing relationships, and repeated interactions among collective members. Future expansion of the programme must find ways to integrate governance across scales to avoid exploitation and protect confidence in the programme.

By expanding collectives to the scale of the aquifer, the collectivisation would become more holistic and the resource depletion issues may be addressed better. This could open the opportunity to further integrate demand-side interventions by promoting water-efficient practices and regulatory mechanisms, and incentives that encourage responsible groundwater usage. Supporting farmers to collectively adopt water-saving techniques alongside other demand-side interventions can support in maintaining long-term sustainability.

A long-term, multi-dimensional approach—combining governance, policy incentives, and technological interventions—will be essential for growing the programme and ensuring that groundwater remains a shared, sustainable resource for future generations.

Annexures related to this report are available in a separate document here

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