**Restoring Livelihoods through Rainwater Harvesting and Community-Led Water Governance in Semi-Arid Eastern Rajasthan: Evidence from Karauli District**

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## ABSTRACT

This paper presents an impact assessment of community-based rainwater harvesting (RWH) and soil and water conservation (SWC) interventions implemented between 2020 and 2023 in the Dang region of Karauli district, located in the semi-arid eastern part of Rajasthan. The interventions were implemented by Gram Gaurav Sansthan with corporate social responsibility support from the CSR of Dharampal Satyapal Limited Noida, and an independent evaluation was undertaken by researchers from IIHMR University. Using a mixed-method design that combined household surveys (n = 100), focus group discussions, key informant interviews, hydro-geological field verification, and geospatial land-use and land-cover (LULC) analysis, the study examined physical performance of water harvesting structures, groundwater recharge, agricultural productivity, livelihood outcomes, and institutional sustainability. The findings demonstrate that revival and construction of traditional structures such as *tal, pokhar, pagara,* and *kunda* significantly improved water availability, expanded irrigated and cultivable areas, strengthened community governance systems, enhanced farm and livestock incomes, reduced seasonal migration, and generated measurable gender and social inclusion benefits. The paper argues that combining traditional knowledge systems with scientific planning and community co-financing offers a replicable pathway for sustainable water resource management and livelihood resilience in semi-arid rural India.

**KEY WORDS**

Rainwater Harvesting, CSR, rural India, Rajasthan, Livelihood

## INTRODUCTION

Water scarcity remains a central constraint to rural development and agricultural sustainability in semi-arid regions of India. The eastern belt of Rajasthan is characterized by high inter-annual rainfall variability, fragile hydro-geology, and persistent dependence on monsoon-fed agriculture. In such contexts, rainwater harvesting and decentralized soil and water conservation have historically played a critical role in ensuring water security and stabilizing livelihoods. However, over time, many traditional systems have fallen into disrepair due to institutional erosion, financial constraints, and changing land-use practices.

In response to these challenges, the Dharampal Satyapal Limited initiated the “Community Initiatives for Restoring Livelihood through Construction of Rainwater Harvesting Structures” project in the Dang region of Karauli district during 2020–2021 as part of its corporate social responsibility programme. The project aimed to enhance groundwater recharge, improve irrigation access, restore degraded lands, and strengthen livelihood opportunities for small and marginal farmers. A ridge-to-valley watershed approach guided the design, resulting in the construction and revival of 107 traditional water harvesting and soil conservation structures between 2020 and 2023.

The project emphasized four locally embedded and culturally recognised structures: (i) tal, small reservoirs constructed across natural drainage lines; (ii) pokhar, earthen ponds that capture runoff and facilitate percolation; (iii) pagara, earthen embankments across slopes to arrest erosion and retain soil moisture; and (iv) kunda, lined underground rainwater storage structures primarily used for domestic purposes. In addition to infrastructure creation, the intervention promoted micro-irrigation practices, solar-powered irrigation, crop diversification, and agro-horticulture-based livelihood models.

This paper presents an independent impact assessment of these interventions. It addresses six key questions: (a) whether the RWH and SWC structures are technically sound and well-located; (b) whether they contribute to improved groundwater recharge and irrigation access; (c) whether community ownership mechanisms support sustainability; (d) whether agricultural productivity and incomes have increased; (e) whether livelihood security and migration outcomes have improved; and (f) whether the intervention generated meaningful gender and social inclusion benefits.

## STUDY AREA

Karauli district, established in 1997, covers approximately 5,043 km² in eastern Rajasthan. The district is predominantly rural and agrarian, with wheat, mustard, and millet as major crops. The terrain is shaped by undulating hills and plains influenced by the Vindhyan and Aravalli geological systems. Soil types vary from recent alluvium in riverine stretches to lithosols and regosols in upland and hilly areas. These physical conditions result in rapid surface runoff, limited natural storage, and low soil moisture retention. The region experiences a mean annual rainfall of around 724 mm, but rainfall distribution is highly variable across years. Analysis of recent rainfall data sourced from the India Meteorological Department indicates alternating cycles of deficit and surplus years, with a noticeable decline in rainfall during 2017, followed by recovery during 2021 and 2022 and a subsequent drop in 2023. Such variability intensifies farmers' exposure to production risk and reinforces the importance of decentralized storage and recharge systems. Hydro-geologically, the project area comprises sandstone formations and fractured rock systems. Data and secondary information from the Geological Survey of India and the Central Ground Water Board indicate the presence of dense lineaments, fractures, and fault zones. These features create favourable conditions for groundwater recharge when surface water is retained and allowed to percolate. Consequently, the Dang region represents an appropriate setting for evaluating the performance of rainwater harvesting interventions.

## STUDY DESIGN AND METHODOLOGY

A mixed-method research design was adopted to ensure triangulation of physical, environmental, and socio-economic outcomes. Quantitative data were generated through a structured household survey covering 100 households across eight villages selected on the basis of the presence and diversity of RWH structures. The sampling strategy was purposive, ensuring representation of households directly benefitting from tal, pokhar, pagara, and kunda structures. Landholding size, access to irrigation, livestock ownership, and crop diversity were considered as additional stratification criteria.

Qualitative data were collected through eight focus group discussions and eight key informant interviews with community leaders, village development committee members, implementing staff, and farmers. These methods were designed to capture experiential dimensions of water access, institutional arrangements, and livelihood change.

In parallel, hydro-geological field verification was conducted on 22 selected structures to assess location, design conformity, physical condition, and storage capacity. Satellite imagery and Google Earth Pro were used to estimate submergence area and storage volumes. Geospatial analysis of land-use and land-cover change was undertaken for Rabi and Kharif seasons between 2019 and 2024, enabling assessment of changes in agricultural land, barren land, and surface water bodies. The evaluation framework focused on four thematic domains: physical performance of structures, direct hydrological impacts, community ownership and sustainability, and socio-economic outcomes.

## PHYSICAL PERFORMANCE OF RAINWATER HARVESTING STRUCTURES

Field verification demonstrated that all surveyed structures were strategically located to intercept natural drainage lines and runoff pathways. Technical design followed standard watershed engineering specifications, including appropriate spillway dimensions and embankment profiles. Overall structural integrity was assessed as satisfactory across the majority of structures. Minor seepage was observed in three sites, primarily attributed to geological fractures in the submergence zone. These were identified as manageable through low-cost corrective measures such as core wall strengthening.

Using satellite-based measurements, the cumulative storage capacity of the 22 surveyed structures was estimated at approximately 434,720 cubic metres. Considerable variation in storage volumes was observed due to differences in catchment size, submergence area, and depth. Larger tal structures accounted for a substantial proportion of total capacity, while smaller pokhars and pagaras played complementary roles in slope stabilization and soil moisture retention.

From a recharge perspective, the alignment of structures along fault zones and fractured formations significantly enhances infiltration potential. The dense lineament network in the project area facilitates downward percolation and lateral movement of groundwater. Based on rainfall patterns in 2024 and regional hydro-geological studies, the frequency of effective recharge events is estimated at six to seven per year, with an average recharge efficiency of 25–30 percent. This implies that annual recharge volumes may reach approximately 1.75 times the static storage capacity under favourable conditions.

## HYDROLOGICAL AND AGRICULTURAL IMPACTS

Household survey data indicate widespread utilization of the newly constructed and revived water harvesting structures. Pokhars and tals emerged as the most frequently used sources of irrigation water, reflecting their central role in local water management systems. Nearly all surveyed households reported using these structures for agricultural purposes, underscoring their functional relevance.

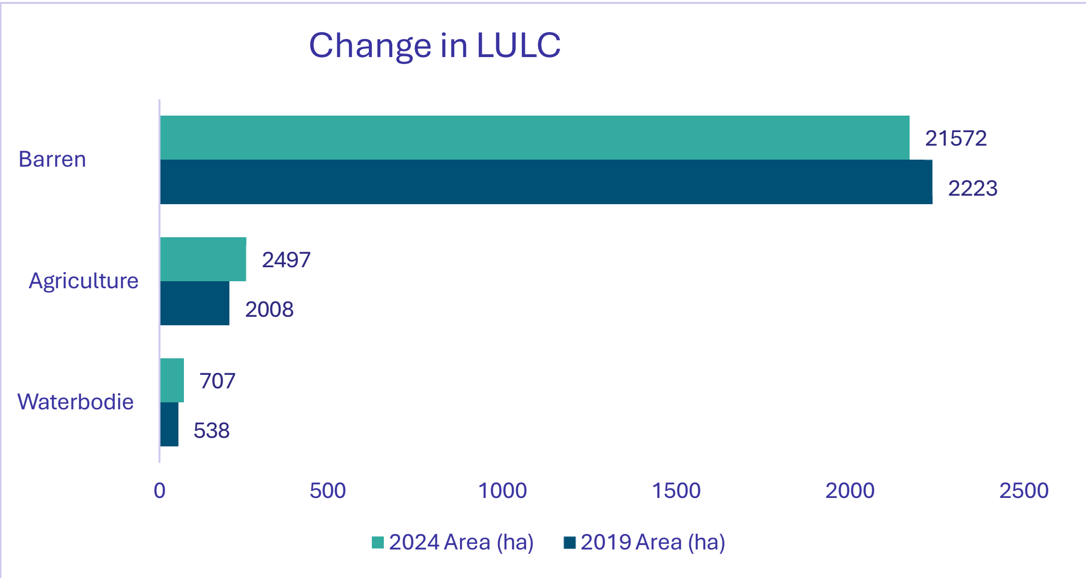
Land ownership patterns in the study area reveal a predominance of small and marginal farmers. More than two-thirds of landholding households own less than five acres. Despite this, irrigation coverage is relatively high, with nearly 86 percent of households reporting that more than three-quarters of their land is irrigated. The median irrigated area closely approximates the median landholding size, suggesting that the interventions have substantially reduced irrigation constraints. Water extraction volumes further illustrate this improvement. Nearly three-quarters of farmers reported using between 500 and 1,000 cubic metres of water per season, while only a small minority extracted less than 500 cubic metres. This shift reflects enhanced storage and recharge capacity and improved access through wells and surface structures.

The role of pagaras in soil and water conservation deserves particular attention. Located on sloping and rocky terrain, pagaras have reduced runoff velocity, trapped sediments, and facilitated the accumulation of fertile soil. Approximately 16 hectares of previously uncultivable land were brought under cultivation through pagara supported land formation, enabling wheat and mustard cultivation in areas previously dominated by rock outcrops and scrub.

## GROUND WATER RECHARGE AND LAND USE CHANGE

Hydro-geological analysis shows that sandstone formations in the area exhibit high permeability, while fractured formations permit moderate infiltration. Comparative LULC analysis between 2019 and 2024 reveals a substantial expansion in surface water bodies, increasing from 538 hectares to 707 hectares, representing a 31.4 percent rise. This increase reflects the cumulative effect of multiple decentralized storage structures across the watershed.

Agricultural land expanded from 2,008 hectares in 2019 to 2,497 hectares in 2024, while barren land declined correspondingly. These spatial changes indicate improved land productivity and resource utilization. Farmers' perceptions corroborate these findings, with many reporting a rise in groundwater levels of approximately one to two metres following the construction of RWH structures. The increased availability of surface and subsurface water has reduced dependence on erratic rainfall and enhanced farmers' capacity to undertake multi-season cropping. These trends suggest that water harvesting interventions contribute not only to short-term irrigation benefits but also to longer-term aquifer replenishment.




**Change in LULC**

## COMMUNITY OWNERSHIP AND SUSTAINABBILITY

A defining feature of the intervention is the emphasis on community-led planning and management. Initial resistance and distrust were reported by implementing staff, largely rooted in fears of land appropriation and uncertainty about benefits. Over time, repeated consultations, transparent decision-making, and recognition of traditional knowledge systems facilitated trust building. Community members actively participated in identifying sites, designing structures, naming facilities, and contributing approximately one-third of construction costs. This financial contribution reinforced a strong sense of ownership. Importantly, management arrangements are entirely community driven. Village Development Committees serve as the primary institutional mechanism for water governance. Their functions include regulating water extraction, maintaining infrastructure, resolving disputes, and managing maintenance funds.

The integration of customary norms with formal committee structures has reduced conflicts over water use and enhanced compliance with collectively agreed rules. Such hybrid governance arrangements strengthen the likelihood that infrastructure benefits will be sustained beyond the project lifecycle.

## SOCIO-ECONOMIC IMPACTS

### Adoption of Micro-Irrigation and Solar Technologies

Approximately two-thirds of surveyed households adopted micro-irrigation practices or solar-powered irrigation systems. Water conservation emerged as the primary motivation, followed by labour cost reduction and productivity enhancement. Nearly all adopters reported improved agricultural productivity and reduced water consumption, while more than 95 percent experienced a decline in input costs related to labour, electricity, and fertilizer use. These findings suggest that complementary investments in irrigation efficiency significantly amplify the benefits of water harvesting infrastructure.

### Conversion of Wasteland into Arable Land

A major livelihood outcome of the intervention is the conversion of wasteland into productive agricultural land. Seventy-four percent of households reported bringing new land under cultivation, typically between one and three acres. Improved access to irrigation was cited as the dominant driver of this transformation. For resource-constrained households, this shift represents a critical expansion of productive assets and an important buffer against climatic variability.

### Changes in Cropping Patterns and Productivity

Prior to the intervention, bajra dominated the cropping system, with limited cultivation of wheat and mustard. Following the implementation of RWH structures, wheat cultivation increased dramatically, mustard production nearly doubled, and green fodder cultivation expanded fivefold. Farmers also reported the emergence of summer vegetable and fodder crops, enabled by solar-based irrigation.

Yield improvements were widely reported, with gains ranging from 50 kg per acre to over 900 kg per acre across different crops. The combination of diversified cropping, improved irrigation reliability, and better soil moisture conditions has contributed to enhanced food security and income stability.

### Livestock and Dairy-Based Livelihoods

Livestock ownership is widespread, particularly buffalo and cattle. Improved water availability and expanded fodder cultivation have strengthened livestock health and productivity. Household income from livestock shows a marked upward shift, with the proportion of households earning less than ₹25,000 annually declining sharply and those earning between ₹25,000 and ₹50,000 increasing substantially. These trends indicate growing economic resilience and diversification of income sources.

### WADI-Based Agro-Horticulture and Nutrition

Agro-horticulture interventions under the WADI model were enabled by assured irrigation from RWH structures. Households established fruit trees such as mango, guava, lemon, and papaya, alongside vegetables and multipurpose tree species. Increased survival rates of saplings during dry periods were attributed to improved water access. The intervention generated both income and nutritional benefits, particularly through greater availability of fruits and vegetables at the household level.

### Migration, Livelihood Security, and Well-Being

Reduced seasonal migration is one of the most significant outcomes of the project. Eighty-seven percent of households reported that migration for work had declined following the intervention. The shift in primary income sources from daily wage labour to agriculture and livestock reflects greater livelihood stability and local employment opportunities

## GENDER AND SOCIAL INCLUSION OUTCOMES

The intervention generated strong gender-differentiated benefits. Nearly all women reported a significant reduction in time spent collecting water, as water sources became available closer to households. This freed time was reallocated to childcare, education, and productive activities. Women's participation in agriculture and income-generating activities increased, enhancing their visibility within household and community economies.

Qualitative narratives highlight the transformative nature of water access for women's well-being and social status. Improved water security has also influenced household decisions related to marriage and settlement, reflecting broader social impacts beyond economic indicators. These findings underscore the importance of embedding gender considerations within water governance and livelihood programmes.

## CONCLUSION AND POLICY IMPLICATIONS

The rainwater harvesting and soil conservation interventions implemented in the Dang region of Karauli district have generated substantial environmental, economic, and social benefits. Increased groundwater recharge, expansion of irrigated and cultivable land, enhanced agricultural and livestock incomes, reduced migration, and improved gender outcomes collectively demonstrate the transformative potential of community-driven water management systems.

For policy and practice, the findings suggest several priorities. First, systematic maintenance and desiltation of structures must be institutionalised through community committees and local government support. Second, centralized inventories of watershed interventions should be developed to improve coordination among multiple implementing agencies. Third, stronger linkages with public schemes for micro-irrigation and renewable energy can enhance efficiency gains. Fourth, women's collectives should be formally integrated into water governance structures to consolidate gender inclusion outcomes. Finally, future interventions should combine traditional knowledge systems with scientific hydrological modelling to optimise site selection and design.

Overall, the Karauli experience provides robust empirical evidence that participatory rainwater harvesting, and soil conservation can serve as a cornerstone for sustainable rural development in semi-arid regions of India.

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## CONFLICT OF INTEREST

The author declares that there is no conflict of interest regarding the publication of this article.

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