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BRIDGING CAPACITY GAPS FOR SUSTAINABLE WATER MANAGEMENT: ADVANCING SDG6 IN THE DESERT AREA OF RAJASTHAN STATE, INDIA

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Abstract: *The Western Indian Thar desert is the most widely populated desert in the world, with a population density of 83 people per sq. km. About 40 percent of the total population of Rajasthan lives in the Thar desert, which covers 4.56 percent of India's total geographical area. More than 60 percent of the desert lies in the Indian state of Rajasthan. Development in the Thar desert faces challenges such as extreme temperatures exceeding 50°C, making it difficult for people to work and sustain economic activities. The highest temperature of 50.50^0 C has been recorded at Churu City (West Rajasthan on 28th May 2024. Water scarcity, with only 120–240 mm of annual rainfall, limits farming and economic development. Human settlements face increasing pressures due to water scarcity, food insecurity, and economic hardships. The sustainable management of water resources in arid regions, such as Rajasthan, India, is critical to achieving SDG6 (clean water and sanitation) and addressing interlinked Sustainable Development Goals. This study aims to assess and bridge the capacity gaps in the Thar desert area of Rajasthan state by identifying barriers, evaluating enablers, and proposing actionable pathways for sustainable water resource management. Using a mixed-methods approach, the study combines a comprehensive review of existing water policies, field surveys in water-scarce districts, and stakeholder consultations to analyse challenges such as water scarcity, inadequate infrastructure, and talent retention in the region.*

Key words: Bridging Capacity Gaps, Sustainable Water Management, SDG 06, Desert

Introduction

The Thar Desert of western India stands out as one of the most densely populated desert regions in the world, with a population density of 83 people per sq. km. Covering approximately 4.56 percent of India's total geographical area, the Thar desert is home to about 40 percent of Rajasthan's population. Despite the harsh living conditions, including extreme temperatures that can exceed 50°C, with Churu City recording 50.5°C on May 28, 2024, human settlements continue to persist and grow. However, limited water availability, with annual rainfall averaging between 120 to 240 mm, severely restricts agricultural productivity, economic activities, and basic living conditions. Water security is a cornerstone of sustainable development, particularly in arid and semi-arid regions where scarcity defines human-environment interactions. Rajasthan, home to the majority of the Thar Desert, exemplifies these challenges with declining per capita water availability now below 800 cubic meters annually, well below the internationally accepted water-scarcity threshold of 1,000 m^3 (Falkenmark, 1989). Water is a fundamental resource for life, yet its scarcity poses one of the greatest challenges to sustainable development worldwide. According to the United Nations, over 2.2 billion people lack access to safely managed drinking water services globally (UN-Water, 2021). In arid and semi-arid regions, where rainfall is sparse and unpredictable, managing water resources sustainably becomes even more critical for survival, livelihoods, and economic growth. In the context of Rajasthan, sustainable water management is not just a necessity but a pathway to achieving Sustainable Development Goal 6 (SDG 6) - ensuring availability and sustainable management of water and sanitation for all. Addressing water scarcity in such arid zones also contributes to broader SDGs, including poverty reduction (SDG 1), food security (SDG 2), and climate resilience (SDG 13).

Global Desert Area Water Scenario

Globally, desert regions cover nearly one-third of the Earth’s land surface and are characterized by extremely low and erratic rainfall, usually less than 250 mm annually, with high evaporation rates. These conditions make water a scarce and precious resource in deserts such as the Sahara, Arabian, Kalahari, Atacama, and Australian Outback. Water availability in these regions primarily depends on deep groundwater aquifers, ephemeral rivers, rainwater harvesting, and increasingly, desalination technology. For instance, countries like Saudi Arabia and the United Arab Emirates meet over 70 percent of their domestic water needs through desalination. North Africa's Nubian Sandstone Aquifer and Libya’s Great Man-Made River project are examples of massive groundwater extraction systems. However, over-extraction, salinization, and climate change-induced aridity pose significant challenges to water sustainability in desert regions. Efforts are being made globally to improve water-use efficiency and invest in alternative water sources to sustain desert populations.

India Desert Area Water Scenario

India’s primary desert region is the Thar Desert, located in the northwestern part of the country, mainly in Rajasthan and extending into Gujarat, Punjab, and Haryana. Spanning around 200,000 sq. km, the Thar faces frequent droughts, low rainfall (100 - 500 mm per year), and high temperatures that further intensify water scarcity. The key lifeline for this desert region is the Indira Gandhi Canal, which transports water from the Satluj-Beas River system into arid parts of Rajasthan. Groundwater is another important source, but it is often saline and over-exploited. Traditional rainwater harvesting techniques like kunds, tankas, and nadis continue to be valuable for storing seasonal rainfall. Water issues such as salinity, declining groundwater levels, and increasing desertification have prompted the government to implement programs like the Desert Development Programme and promote water-efficient

agricultural practices. Despite infrastructural development, the region still faces acute water stress, requiring integrated and climate-resilient water management strategies.

Rajasthan Desert Area Water Scenario

Rajasthan, India's largest state, has nearly 61 percent of its land classified as desert, primarily in the western districts such as Jaisalmer, Barmer, Bikaner, and Jodhpur. With average annual rainfall ranging from just 100 to 500 mm and high evapotranspiration rates, the region is highly water-stressed. The Indira Gandhi Canal has been a game-changer, bringing much-needed water to arid districts and supporting agriculture, drinking, and industrial needs. However, over-reliance on canal water, alongside excessive and unregulated groundwater extraction, has led to falling water tables and increased salinity and fluoride contamination in many areas. Traditional water harvesting systems like tankas, kunds, baoris, and johads still play a significant role, particularly in rural and semi-arid zones. To address water scarcity, the state government has launched initiatives like the Mukhyamantri Jal Swavlamban Abhiyan (MJSA), focusing on watershed development, and the Jal Jeevan Mission for household water supply. Despite these efforts, ensuring water security in Rajasthan’s desert region remains a major environmental and policy challenge.

Goal 6: Clean Water and Sanitation

The importance of clean water and sanitation in human life needs no emphasis. Clean water and Sanitation protects people from disease and enables them to be economically more productive. Water scarcity, poor water quality and inadequate sanitation negatively impacts food security, livelihood choices and educational opportunities for poor families across the world. The SDG 6 ensures availability and sustainable management of water and sanitation for all and reflects the increased attention on water and sanitation in the global political arena. The 2030 Agenda recognizes that social development and economic prosperity depends on the sustainable management of freshwater resources and ecosystems. There are 8 SDG targets under the goal to ensure the availability and sustainable management of water and sanitation for all. A total of 16 indicators have been identified in State Indicator Framework to measure and monitor the progress of these targets. (https://sdg.rajasthan.gov.in/GoalSDG)

Bridging capacity gaps for sustainable water management in Rajasthan’s desert region is critical to advancing Sustainable Development Goal 6 (SDG 6 - Clean Water and Sanitation). With over 60 percent of the state falling under arid and semi-arid zones, and average annual rainfall ranging from just 100 to 500 mm, the region faces acute water scarcity and high dependency on limited surface and groundwater resources - often saline or fluoride-contaminated. Despite the support of the Indira Gandhi Canal and traditional rainwater harvesting systems like *kunds*, *tankas*, and *johads*, many rural communities still lack reliable access to safe drinking water. Bridging the gap requires investment in capacity building at local levels, promotion of water-efficient technologies (e.g., drip irrigation), digitized groundwater monitoring, and community-led water governance. Government initiatives like the Jal Jeevan Mission and Mukhyamantri Jal Swavlamban Abhiyan (MJSA) have laid important groundwork, but scaling up these efforts with stronger institutional coordination, education, and inclusive participation is essential for achieving SDG 6 in the challenging desert landscape of Rajasthan.

Methodology

Data Collection and Contextual Analysis

Field surveys were conducted in five water-scarce districts: Barmer, Jaisalmer, Churu, Nagaur, and Bikaner. About 500 respondents were randomly selected from these districts. Interviews were held with government officials, community leaders, women’s self-help groups, and NGO

representatives. Policy documents such as the Rajasthan State Water Policy (2010), Jal Jeevan Mission guidelines, and SDG progress reports were reviewed.

Capacity Gap Assessment

Infrastructure deficits, talent outmigration, and administrative challenges were quantified using data from Rajasthan's Groundwater Department and Census 2011. Case studies were used to compare traditional and modern water conservation practices, including johads, baoris, and solar pumping systems.

Policy and Strategy Development

The findings were discussed in stakeholder workshops to develop actionable policy recommendations. A capacity-building framework was proposed with emphasis on decentralization, gender inclusion, and knowledge-sharing.

Key Challenges in Water Management in Rajasthan

Physical and Climatic Barriers

Average rainfall ranges from 120–240 mm annually, with high interannual variability (IMD, 2021). High evaporation and low recharge rates contribute to severe water stress. Water quality is compromised due to high salinity and fluoride in groundwater (CGWB, 2019).

Socio-economic and Institutional Gaps

Per capita income in desert districts is lower than the state average, limiting investment in water infrastructure. Fragmented governance among PHED, Rural Development Department, and local panchayats results in policy overlap and weak accountability. Traditional water wisdom is underutilized in formal policy structures.

Discussion

The sustainable management of water resources in Rajasthan's desert regions presents a complex interplay of climatic, infrastructural, social, and institutional challenges. The data and findings suggest that while significant strides have been made through government initiatives like the Jal Jeevan Mission and the Mukhyamantri Jal Swavlamban Abhiyan, a large proportion of rural populations in arid zones still struggle with water insecurity. The rapid expansion of tap water connections - reaching over 43 lakh rural households - demonstrates commendable policy intent and financial commitment. However, disparities in coverage, especially in remote and scattered desert settlements, reveal the limitations of a one-size-fits-all approach. The underutilization of traditional water harvesting systems such as *tankas*, *kunds*, and *baoris*, which historically sustained desert communities indicates a missed opportunity for integrating indigenous knowledge with modern water governance. These systems are particularly valuable given the region’s low and erratic rainfall (100-500 mm annually) and high evaporation rates. The discussion also underscores the critical issue of groundwater depletion and salinity, especially in western districts like Barmer, Jaisalmer, and Bikaner, where groundwater is the only dependable source outside canal command areas.

Another key issue is the capacity gap at the community level. While water infrastructure is expanding, the sustainability of these assets is jeopardized by limited technical know-how, inadequate local participation, and poor maintenance. There is a pressing need for institutional strengthening and capacity building, not only among government engineers and field staff but also among local governance bodies like Gram Panchayats and Water User Associations. Moreover, as climate change continues to exacerbate rainfall variability and droughts, climate-resilient water planning must become a core component of all water-related interventions. The discussion also brings attention to the importance of convergence across schemes. While the

₹15,000 crore allocated by the Rajasthan government in 2024 is a landmark investment, its impact can be maximized through better alignment with existing national and state programs such as MGNREGA, PMKSY, and the Atal Bhujal Yojana. Finally, the integration of digital tools for monitoring, accountability, and transparency could greatly enhance decision-making and service delivery. The bridging capacity gaps in Rajasthan's desert areas is not merely a technical or financial challenge. It is a governance and participatory challenge. Meeting SDG 6 in this region requires a multi-dimensional approach that combines infrastructure, traditional wisdom, community empowerment, and climate resilience to ensure water security for current and future generations.

Awareness of Water Conservation Practices

The data reveals a mixed level of public understanding regarding water conservation. While 55 percent of respondents are either highly or moderately aware, a concerning 45 percent still show low or no awareness, which highlights a significant communication and outreach gap. In desert regions like the Thar, where water is scarce and unpredictable, community awareness is the first step towards adopting sustainable water practices such as drip irrigation, water recycling, or rainwater harvesting. The results imply that educational programs, local campaigns, and school-level interventions must be strengthened, especially in rural and semi-urban areas.

Table 01: Awareness of Water Conservation Practices

Awareness Level	Number of Respondents	Percentage
Highly Aware	95	19
Moderately Aware	180	36
Slightly Aware	140	28
Not Aware	85	17
Total	**500**	**100**

Major Sources of Water Supply

The overdependence on groundwater (58 percent) is a critical concern in a region already categorized as over-exploited in terms of water tables. The usage of tanker water (16 percent) is symptomatic of crisis-driven temporary solutions rather than sustainable planning. The relatively low adoption of rainwater harvesting (12 percent) suggests that existing government schemes (like Jal Shakti Abhiyan or MGNREGA-supported structures) may not be fully effective or properly implemented. Encouraging rainwater harvesting through incentives and decentralized water systems can reduce pressure on groundwater.

Table 02: Major Sources of Water Supply

Source of Water	Number of Respondents	Percentage
Groundwater	290	58
Surface Water	70	14
Rainwater Harvesting	60	12
Tanker Supply	80	16
Total	**500**	**100**

Barriers to Sustainable Water Management

Respondents clearly point to systemic gaps in infrastructure and governance as leading obstacles. The lack of efficient pipelines, storage systems, recharge wells, and proper water accounting hinders optimal utilization. In addition, 24 percent cite limited policy support

indicating a possible disconnect between local needs and existing water governance frameworks. Financial constraints (15 percent) reflect the inability of small farmers or households to invest in modern water-saving systems. Together, these barriers underscore the need for capacity building at both institutional and community levels.

Table 03: Barriers to Sustainable Water Management

Barrier Identified	Number of Respondents	Percentage
Lack of Infrastructure	155	31
Limited Government Support	120	24
Low Public Awareness	100	20
Financial Constraints	75	15
Climatic Extremes	50	10
Total	**500**	**100**

Preferred Solutions for Water Security

It is encouraging to see that 40 percent of respondents favour rainwater harvesting, a highly relevant, geography-aligned solution for arid zones. This suggests that communities recognize the potential of localized water capture methods. Support for canal expansion (24 percent) and groundwater recharge (20 percent) reflects a preference for long-term structural investments, though these may require significant capital and planning. The mention of desalination plants (16 percent) shows awareness of newer technologies, but cost and scale remain barriers.

Table 04: Preferred Solutions for Water Security

Proposed Solution	Number of Respondents	Percentage
Rainwater Harvesting	200	40
Expansion of Canal Networks	120	24
Groundwater Recharge	100	20
Desalination Plants	80	16
Total	**500**	**100**

Training Needs for Capacity Building

This table underscores the demand for practical and hands-on training. Water-saving techniques like drip and sprinkler irrigation are in demand (34 percent), showing that farmers and households are willing to adopt modern tools if given access and training. Community awareness (26 percent) ranks high, reaffirming the gap seen in Table 1. Interestingly, the equal importance given to governance training and infrastructure management (20 percent each) points to a growing recognition that sustainable water use is not just technical but also administrative and policy-driven.

Table 05: Training Needs for Capacity Building

Training Area Needed	Number of Respondents	Percentage
Water-Saving Techniques	**170**	**34**
Awareness Campaigns	**130**	**26**
Infrastructure Maintenance Skills	**100**	**20**
Policy and Governance Training	**100**	**20**
Total	**500**	**100**

Findings

Based on the analysis of the water scenario and recent initiatives in Rajasthan's desert areas in relation to SDG 6, the following key findings have emerged:

1. Inadequate Awareness of Water Conservation

A significant 45 percent of respondents demonstrated low or no awareness of water conservation practices. This indicates a major communication and education gap, particularly in rural and semi-urban areas. There is an urgent need to enhance awareness and behaviour change through targeted community outreach.

2. Over-Reliance on Groundwater

58 percent of respondents identified groundwater as their primary water source, reflecting over-dependence in an already overexploited region. The growing use of tanker water (16 percent) highlights the rising severity of water shortages. Sustainable alternatives such as rainwater harvesting and groundwater recharge remain underutilized despite their relevance.

3. Infrastructure and Policy Support Are Major Bottlenecks

31 percent cited lack of infrastructure as the biggest barrier to sustainable water management, including the absence of pipelines, storage tanks, and recharge systems. 24 percent pointed to weak government support and poor implementation of water-related schemes. These gaps indicate the need for greater investment in decentralized water infrastructure and policy accountability.

4. Community-Backed Solutions Favor Local Water Management

40 percent of respondents supported rainwater harvesting as a key solution—indicating community readiness for simple, climate-aligned practices. Other preferences included canal expansion (24 percent) and groundwater recharge (20 percent), emphasizing a desire for both traditional and modern water systems.

5. Strong Demand for Capacity Building and Training

34 percent requested training in water-saving techniques like drip and sprinkler irrigation. 26 percent called for awareness campaigns, while another 40 percent highlighted the need for skills in water infrastructure and policy governance. This clearly reflects a willingness among communities to participate in sustainable water efforts if supported by training and education.

6. Climate Vulnerability and Social Inequity are Underlying Issues

Though not the most cited barrier, 10 percent acknowledged climate extremes as a major constraint. The findings indirectly reflect socio-economic vulnerabilities, such as financial barriers and limited access to government schemes, especially in poor and remote communities. Climate Variability Intensifies water stress erratic rainfall patterns and recurring droughts are worsening water scarcity in the Thar region. Climate-resilient water planning is not yet fully integrated into mainstream rural development programs.

These findings highlight that while progress is evident, bridging the capacity, equity, and sustainability gaps is essential for realizing the goals of SDG 6 in Rajasthan's desert ecosystems.

Recommendations

Bridging Capacity Gaps for Sustainable Water Management in the Thar Desert Region

Based on the survey of 500 respondents across water-scarce districts and the in-depth analysis of barriers and opportunities, the following recommendations are proposed to strengthen sustainable water resource management and support the achievement of SDG 6:

1. Increase Public Awareness through Community Engagement

- Strengthen mass awareness programs on water conservation, especially targeting rural and low-literacy populations.
- Use local languages, cultural platforms, and school-based initiatives to improve understanding of water-saving practices.
- Promote success stories and local role models who are effectively managing water.

2. Promote Rainwater Harvesting and Traditional Systems

- Scale up adoption of rainwater harvesting systems, as 40 percent of respondents expressed interest.
- Revive and modernize traditional desert systems like *tankas*, *kunds*, and *johads*, blending them with new technologies.
- Provide financial incentives and technical training to households and communities.

3. Strengthen Water Infrastructure in Remote Areas

- Address the infrastructure gap (reported by 31 percent respondents) by investing in:
  - ✓ Decentralized water storage,
  - ✓ Efficient distribution pipelines,
  - ✓ Recharge wells and check dams.
- Ensure regular maintenance and monitoring through local institutions like panchayats or water user groups.

4. Focus on Capacity Building and Technical Training

- Develop **training modules** for farmers, youth, and frontline workers on:
  - ✓ Water-saving irrigation (drip, sprinkler),
  - ✓ Infrastructure repair and upkeep,
  - ✓ Local water governance frameworks.
- Respondents' demand (34 percent) for training shows readiness to adopt modern water management if supported properly.

5. Improve Governance and Local Policy Implementation

- Strengthen coordination between state departments, local bodies, and NGOs to ensure effective policy delivery.
- Promote transparency, accountability, and participatory planning at the village and block levels.
- Integrate water planning into climate action plans, particularly in high-temperature zones like Churu.

6. Foster Inclusive and Equitable Access

- Ensure that marginalized communities, especially women and small farmers, are part of planning and benefit-sharing.
- Design water schemes that reduce burden on women, who are often primary water collectors in desert households.

7. Leverage Technology and Data Monitoring

- Use GIS mapping, remote sensing, and mobile-based applications to monitor water sources, usage, and availability.
- Establish community-led water monitoring teams trained in using digital tools for real-time decision-making.

These actionable recommendations can empower local communities, strengthen institutions, and build resilience in Rajasthan's desert ecosystem—helping fulfil the vision of

"Clean Water and Sanitation for All" (SDG 6) and sustainable livelihoods in one of India's most climate-vulnerable regions.

Conclusion

This study concludes that Rajasthan's water crisis requires context-sensitive, community-led, and multi-stakeholder solutions. Reviving indigenous systems such as johads and baoris, supported by capacity-building and technological innovation, provides a viable pathway for achieving SDG6 in desert areas. These solutions not only bridge capacity gaps but also serve as blueprints for other arid regions facing similar climate and resource constraints. The findings of this study clearly underscore the multifaceted challenges and opportunities in ensuring sustainable water management in the arid zones of Rajasthan, particularly in the Thar Desert region. Despite being one of the most densely populated desert regions globally, this area continues to grapple with severe water scarcity, infrastructure limitations, climatic extremes, and institutional capacity gaps. The over-dependence on groundwater and rising use of tanker water reflects a precarious water security situation, further exacerbated by low rainfall and extreme temperatures. While there is a growing community interest in solutions like rainwater harvesting and canal expansion, actual implementation is hindered by lack of awareness, insufficient infrastructure, and governance challenges. The bridging the capacity gaps in water management in Rajasthan's desert region is not only essential but urgent. Doing so will require a comprehensive, geography-sensitive strategy that integrates: Local water knowledge and technologies (e.g., traditional rainwater systems); Policy-level reforms that promote inclusive governance; Infrastructure development, especially for water capture and reuse, and Community-cantered training programs aligned with SDG 6 targets.

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