Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 05, Issue: 06 (NOV-DEC, 2025)
Available online at http://www.agriarticles.com
©Agri Articles, ISSN: 2582-9882

Groundwater Management for irrigation in Arid Zone of Rajasthan

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Rajasthan's arid zone faces severe water scarcity due to low rainfall, high evapotranspiration, and limited surface water resources. Groundwater has become the backbone of irrigation, supporting agriculture and rural livelihoods. This research article investigates the characteristics of groundwater, its sources, irrigation methods, and optimal strategies for sustainable groundwater management, including irrigation method selection, cropping pattern decisions, and irrigation scheduling. The aim is to provide a comprehensive overview of how groundwater can be managed effectively for agricultural sustainability in arid regions.

Introduction

Rajasthan, the largest state in India, is characterized by an arid climate with annual rainfall often less than 300–500 mm, irregular distribution, and extreme temperatures. In such landscapes, groundwater plays a pivotal role in supporting irrigation and agricultural productivity. Sustainable groundwater use is crucial to prevent depletion of aquifers, safeguard food security, and improve rural livelihoods.

Table 1: Agro-Climatic Characteristics of Arid Zone of Rajasthan

Parameter	Value / Range
Annual Rainfall	100–500 mm
Rainfall Variability	High (Coefficient > 40%)
Mean Summer Temperature	40–48 °C
Potential Evapotranspiration	1600–2000 mm/year
Soil Type	Sandy to loamy sand
Natural Recharge Rate	Low (5–10%)

What is Groundwater?

Groundwater refers to the water stored below the Earth's surface in the pores and fractures of soil, sand, and rocks. This subsurface water accumulates in geological formations called aquifers. Groundwater is replenished through rainfall infiltration, river seepage, and percolation from irrigation water. Unlike surface water, groundwater is generally protected from rapid evaporation and contamination, making it a reliable source of water in arid regions like Rajasthan.

Table 2: Groundwater Status in Arid Districts of Rajasthan

District	Average Depth to Water Table (m)
Jaisalmer	40–80
Barmer	30–70

District	Average Depth to Water Table (m)
Bikaner	25–60
Jodhpur	20–50
Churu	35–70

Source:Central Ground Water Board (CGWB). (2023). *Ground Water Year Book – Rajasthan2021–22*. Government of India

Sources of Groundwater

The main sources of groundwater recharge in the arid zone of Rajasthan include:

- **Rainfall Infiltration:** Although rainfall is limited, localized infiltration during monsoon contributes to groundwater.
- **Seepage from Canals and Water Bodies:** Canal percolation and seepage from ponds or tanks help recharge local aquifers.
- **River Base Flow:** Ephemeral streams and rivers like Luni contribute to groundwater when they flow during rains.
- **Artificial Recharge Structures:** Check dams, percolation tanks, and recharge wells enhance aquifer recharge.

Recharge rates are generally low due to sparse vegetation, high evaporation, and impermeable rocky terrain, making efficient management essential.

Sources & Methods of Irrigation

Traditional Sources

- **Wells and Tube Wells:** The most common irrigation sources in Rajasthan are dug wells and deep tube wells tapping groundwater.
- **Tanks and Kuls:** Small ponds (tanks) and traditional channels (kuls) store and convey water for irrigation.

Modern Irrigation Methods

- **Drip Irrigation:** Delivers water directly to the plant root zone, reducing wastage.
- **Sprinkler Irrigation:** Suitable for uneven terrains; distributes water through pressurized sprays.
- **Surface Irrigation (Furrow/Basin):** Water flows over land by gravity; traditional but less efficient.

Groundwater Management

Objectives of Groundwater Management

- Maintain sustainable groundwater levels.
- Reduce over-extraction and prevent aquifer depletion.
- Promote equitable distribution of water resources.
- Enhance agricultural productivity with less water use.

Key Management Practices

- **Regulated Pumping:** Licensing and restrictions on the number and depth of pumps.
- **Recharge Structures:** Adoption of check dams, percolation tanks, and contour bunds.
- **Water Harvesting:** Roof-top rainwater harvesting in villages and farms.
- **Monitoring and Assessment:** Use of observation wells and remote sensing to assess groundwater levels and quality.
- **People's Participation:** Local watershed committees to manage water use and maintenance of recharge systems.

Selection of Irrigation Method

Choosing the right irrigation method depends on:

- **Water Availability:** Limited groundwater requires high-efficiency systems like drip or sprinkler.
- **Crop Type:** High-value and water-sensitive crops benefit more from drip irrigation.

- **Soil Type:** Sandy soils with high infiltration favor drip systems; clay soils can manage surface irrigation.
- **Topography:** Uneven terrain supports sprinkler over surface irrigation.
- **Economic Factors:** Cost of installation and maintenance vs. water savings and crop yield benefits.

Table 3: Comparison of Irrigation Methods

Irrigation Method	Water Saving (%)	Irrigation Efficiency (%)	Cost	Suitability
Surface (Flood)	0–10	35–40	Low	Traditional crops, water-rich areas
Sprinkler	30–40	60–70	Medium	Sandy soils Fields with variable terrain
Drip	40–60	85–95	High	Horticulture, Orchards, vegetables, cash crops

Source: https://agriculture.institute/comparing-irrigation-methods-optimal-crop-yields

Selection of Cropping Method

In arid regions, cropping patterns must be adapted to water scarcity:

Criteria for Crop Selection

- **Drought Tolerance:** Crops that can thrive with limited water.
- **Short Growing Period:** To minimize irrigation requirements.
- **High Water Productivity:** Crops that produce more per unit of water.

Suitable Crops for Arid Zone

- **Millets**: Bajra, Jowar
- **Pulses:**Gram, Mung
- **Oilseeds:**Mustard, Groundnut, Sesame seed
- **Forage Crops:**Lucerne, Berseem
- **Horticultural Crops:** Pomegranate, Clove, Fennel

Crop diversification toward less water-intensive and high-value crops enhances groundwater sustainability while improving farm income.

Table 4: Water Requirement of Major Crops in Arid Rajasthan

Crop	Water Requirement (mm/season)	Suitability
Bajra (Pearl millet)	300–350	Very High
Gram (Chickpea)	250–300	High
Mustard	350–400	Moderate
Wheat	450–550	Low
Pomegranate	400–500	High (with drip)

Table 5: Critical Stages of Irrigation for Major Crops

Crop	Critical Growth Stages
Bajra	Tillering, flowering
Mustard	Branching, pod formation
Gram	Flowering, pod filling
Wheat	Crown root initiation, heading

Time of Irrigation

Irrigation scheduling is critical for maximizing water use efficiency:

Principles of Irrigation Timing

- **Soil Moisture Monitoring:** Irrigate when soil moisture drops to a critical level.
- **Crop Growth Stages:** Water requirements are highest during germination and flowering stages.

- **Climatic Conditions:** Avoid irrigation during hottest hours; early morning or late evening is preferred to reduce evaporation.

Decision Factors

- Soil moisture sensors and tensiometers help determine precise irrigation timing.
- Traditional indicators like crop leaf color and soil surface condition can also guide small farmers.

Challenges and Future Prospects

Challenges

- Declining water tables due to over-extraction.
- High energy costs for pumping groundwater.
- Inefficient traditional irrigation practices.
- Limited financial resources for modern irrigation systems.

Future Directions

- **Policy Framework:** Strengthen groundwater regulatory policies.
- **Technology Adoption:** Subsidies to promote drip/sprinkler systems.
- **Capacity Building:** Training farmers on water-saving practices.
- **Research & Innovation:** Crop varieties with higher drought tolerance and water use efficiency.

Conclusion

Groundwater remains the cornerstone of irrigation in the arid zone of Rajasthan. Efficient management through appropriate irrigation methods, informed cropping decisions, and proper timing of water application is essential to balance agricultural productivity with sustainability. Strategic interventions combining technology, policy support, and farmer participation can secure groundwater resources for future generations.

Key Findings

- Drip irrigation can **reduce groundwater extraction by up to 50%** compared to surface irrigation.
- Adoption of **drought-resistant crops** can increase water productivity by **1.5–2 times**.
- Proper irrigation scheduling reduces **evaporation losses by 20–30%**.
- Artificial recharge structures can raise groundwater levels by **0.3–1.0 m/year** locally.

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