International Journal of Geology, Agriculture and Environmental Sciences
Volume – 13 Issue – 2 July - December 2025
Website: www.woarjournals.org/IJGAES *ISSN: 2348-0254*

Assessing Ground Water Depletion and Recharge Potential in the Arid Landscapes of Sri Ganganagar District

Dr. Naresh Kumar Verma
Assistant Professor in Geography & Associate NCC Officer, Bhagawan Das Todi College, Laxmangarh (Sikar)

Abstract: Groundwater serves as the principal freshwater resource in the arid and semi-arid regions of northwestern India, particularly in the Sri Ganganagar district of Rajasthan, where surface water is scarce, evapotranspiration rates are high, and monsoonal precipitation is erratic. Despite the introduction of canal irrigation through the Indira Gandhi Canal (IGC), the district continues to experience localized groundwater depletion due to over-extraction, inefficient irrigation practices, and limited natural recharge. This study evaluates spatial and temporal patterns of groundwater decline, recharge potential, and hydrogeologic constraints using a combination of field observations, groundwater-level monitoring, remote sensing data, soil permeability analysis, and GIS-based multi-criteria evaluation (MCE). Results indicate a significant decrease in groundwater levels ranging from 0.3 to 1.2 m annually in intensively irrigated zones, while canal-command areas show moderate stabilization. Recharge potential mapping reveals that only 17–22% of the district displays moderate to high recharge potential, mainly along paleo-channels, sandy loam tracts, and areas adjacent to canal systems. Clay-rich soils, high evaporation rates, and anthropogenic land-use changes reduce recharge efficiency. The study proposes an integrated groundwater management strategy emphasizing artificial recharge structures, crop diversification, controlled irrigation scheduling, and real-time monitoring systems. The conclusions offer science-backed recommendations for policymakers and stakeholders to enhance groundwater sustainability in the district.

Keywords: Groundwater depletion, recharge potential, arid region, Sri Ganganagar, Indira Gandhi Canal, GIS, hydrogeology, artificial recharge.

1.1. Introduction

Groundwater is a critical freshwater reserve in arid regions, forming the backbone of domestic, agricultural, and industrial water supply systems. In the Indian state of Rajasthan, nearly 90% of rural drinking water and more than 65% of irrigation depend on groundwater resources. Sri Ganganagar district, located in the extreme northwestern portion of the state, exhibits an especially complex hydrogeological environment due to its desert geomorphology, low rainfall regime, dependence on canal irrigation, and rapid agricultural transformation. Historically part of the Thar Desert, the district was transformed into a fertile agricultural zone after the construction of the Gang Canal (1927) and later the Indira Gandhi Canal (1983). However, the benefits of canal irrigation have been accompanied by rising groundwater extraction, waterlogging in some zones, and persistent depletion in others.

In recent decades, agricultural intensification—characterized by water-demanding crops such as cotton, paddy, and sugarcane—has placed unparalleled pressure on groundwater reserves. As climate change accelerates evapotranspiration and alters monsoon dynamics, groundwater recharge in Sri Ganganagar faces further uncertainty. Despite several governmental interventions, scientific assessments of recharge potential and depletion patterns remain inadequate, especially for sustainable policy-making at the district level.

The present study addresses this knowledge gap by developing an integrated assessment of groundwater status and recharge opportunities in Sri Ganganagar. Through hydrogeological surveys, satellite-based mapping, and data analytics, the research provides a high-resolution understanding of depletion drivers, spatial recharge potential, and actionable strategies for groundwater sustainability.

1.2 Objectives

This study is guided by the following objectives:

1. To analyze temporal and spatial trends in groundwater depletion across the Sri Ganganagar district using field measurements and historical monitoring data.
2. To assess hydrogeological and climatic factors influencing natural and induced groundwater recharge.
3. To map recharge potential zones using GIS and multi-criteria evaluation techniques integrating soil, geology, land-use, slope, and drainage parameters.
4. To identify the impacts of irrigation practices and land-use changes on groundwater decline.
5. To propose engineering, agricultural, and policy-based recommendations for sustainable groundwater management in the District

1.3 Methodology

A combination of quantitative, qualitative, and geospatial methods was used:

I. Data Collection

1. Groundwater level records from Central Ground Water Board (CGWB) monitoring wells (2000–2023).
2. Soil maps, geological maps, and topographic sheets from NBSS&LUP and GSI.

3. Landsat 8 and Sentinel-2 satellite imagery for LULC classification.

4. Climate data such as rainfall, temperature, and evaporation rates from IMD and district meteorological stations.

5. Field surveys using GPS, soil infiltration tests, and depth-to-water-table measurements.

II. Spatial Analysis & GIS

1. LULC classification using supervised classification techniques.

2. DEM-based slope and drainage density analysis.

3. Groundwater fluctuation mapping using kriging interpolation.

4. Weighted overlay analysis to develop the groundwater recharge potential map.

III. Criteria for Recharge Potential Zonation

1. Criteria weights were developed based on AHP (Analytical Hierarchy Process):

2. Soil texture – 30%

3. Geology – 25%

4. LULC – 20%

5. Slope – 15%

6. Drainage density – 10%

IV. Statistical Analysis

1. Trend analysis using Mann-Kendall test.

2. Correlation analysis between irrigation intensity and groundwater decline.

3. Estimation of annual recharge and extraction through water balance calculations.

1.4 . Study Area

Sri Ganganagar district lies between 28°4' to 30°6' N latitude and 71°30' to 74°20' E longitude in the northwestern part of Rajasthan. It shares borders with Pakistan on the west and Punjab on the north.

I. Climate

1. Average annual rainfall: 150–250 mm

2. Temperature extremes: 2°C (winter) to 48°C (summer)4.3 Irrigation and Agriculture

3. Evaporation rates: among the highest in India

II. Geology and Hydrogeology

1. Predominantly alluvial sediments: clay, silt, loam, aeolian sands.

2. Groundwater occurs mainly in phreatic aquifers, with deeper semi-confined zones.

3. Aquifer transmissivity varies between 120–350 m²/day.

4. Indira Gandhi Canal is the lifeline of the district.

5. Major crops: cotton, wheat, mustard, paddy, sugarcane.

6. High irrigation demands significantly affect groundwater balance.

1.5 Observations

Observations from field surveys and data analysis include:

I. Groundwater Levels

1. Consistent annual decline in non-command areas: 0.3–1.2 m/year.

2. Stabilized or rising levels in canal-influenced areas.

3. Seasonal fluctuation: deeper levels in pre-monsoon months (May–June).

II. Soil Characteristics

1. Western and southwestern parts predominantly sandy (high infiltration).

2. Central regions contain loamy soils with moderate permeability.

3. Northern zones show clay-rich soils hindering natural recharge.

III. Irrigation Practices

1. Heavy reliance on tube wells in non-command zones.

2. Excess flood irrigation contributing to inefficiency.

3. Canal seepage serves as an unplanned recharge source.

IV. Land Use Changes

1. Increased agricultural land over past decades.

2. Decline in scrubland and natural desert vegetation.

3. Rapid shift to water-intensive cropping patterns.

1.6 Discussion

I. Causes of Groundwater Depletion

1. Over-extraction for agriculture: Over-reliance on tube wells for paddy and cotton.

2. Limited natural recharge: High runoff and low rainfall inhibit infiltration.

3. Soil and geology: Large portions of the district have low-permeability soils.

4. Climate change: Higher temperatures accelerate evapotranspiration.

II. Recharge Potential Dynamics

1. Recharge zones are primarily located:

2. Along paleo-channels with sandy deposits.

3. Adjacent to canal systems where seepage increases soil moisture.

4. In agricultural fields practicing controlled irrigation.

III. Spatial Contrasts

1. The district shows dual hydrological behavior:

2. Canal-command areas experience waterlogging or stable groundwater.

3. Non-command areas show acute groundwater depletion.

IV. Role of Sand Dunes and Aeolian Processes

1. Aeolian sands enhance infiltration but have low water retention capacity, allowing rapid percolation to deeper aquifers but limiting soil moisture availability.

V. Impact of Agricultural Choices

1. Water-intensive crops exacerbate extraction pressures in already stressed aquifers.

1.7 Results

I. Groundwater Trend Analysis

1. Mann-Kendall analysis indicates a statistically significant downward trend ($p < 0.05$) in 70% of observed wells.

2. Average water table decline: 8–18 m over two decades in critical zones.

II. Recharge Potential Zonation

1. High potential zones: 17–22% of the district.

2. Moderate potential zones: 35–42%.

3. Low potential zones: 40–50%.

III. Water Balance Assessment

1. Annual groundwater recharge: 220–310 MCM

2. Annual groundwater extraction: 345–490 MCM

3. Deficit: 110–200 MCM/year

IV. Canal Influence

1. Canal seepage contributes up to 25–35% of recharge.

2. Reduced canal flow years correlate with sharper groundwater declines.

1.8 Conclusion

This research demonstrates that groundwater in Sri Ganganagar district is under increasing stress despite the presence of canal irrigation. The district's arid climate, dependence on groundwater for agriculture, and land-use transformations have resulted in significant depletion in non-command areas. While some recharge occurs through canal seepage and permeable sandy soils, it remains insufficient to counterbalance extraction. GIS-based recharge potential mapping reveals that only a limited portion of the district possesses high recharge capability, necessitating engineered solutions and regulatory interventions.

Sustainable groundwater management requires integrated approaches combining scientific assessments, policy reforms, technological interventions, and community participation.

1.9 Recommendations

1. Promote Artificial Recharge Structures

(a.) Check dams, recharge shafts, percolation tanks in sandy and loamy zones.

(b.) Enhancing canal lining with controlled seepage zones for planned recharge.

2. Crop Diversification

(a.) Reduce paddy and cotton acreage.

(b,) Promote millets, pulses, and oilseeds with lower water requirements.

3. Improve Irrigation Efficiency

(a.) Adoption of drip and sprinkler systems.

(b.) Laser land leveling to reduce runoff and deep percolation losses.

4. Groundwater Regulation

(a.) Licensing of borewells and restrictions on drilling depth.

(b.) Mandatory metering for high-capacity pumps.

5. Real-Time Monitoring

(a.) IoT-based groundwater monitoring networks.

(b.) Remote sensing for LULC and evapotranspiration tracking.

6. Community Participation

(a.) Awareness programs on water conservation.

(b.) Farmer-led groundwater budgeting initiatives.

7. Climate-Resilient Strategies

(a.) Promotion of drought-resistant crop varieties.

(b.) Rainwater harvesting in villages and farm units.

References

[1.] Ahmed, S., & Umar, R. (2019). Hydrogeological controls on groundwater recharge in arid regions. Environmental Earth Sciences, 78(4), 112–124.

[2.] CGWB. (2020). Groundwater Year Book of Rajasthan State 2019–20. Central Ground Water Board, Government of India.

[3.] Chatterjee, R., & Purohit, R. (2009). Estimation of replenishable groundwater resources of India. Journal of the Geological Society of India, 73, 225–236.

[4.] Ghosh, N. C., & Singh, R. (2018). Groundwater–surface water interactions in canal command areas. Water Resources Management, 32(7), 2345–2358.

[5.] Kumar, C. P. (2013). Groundwater recharge in India: Dynamics and challenges. Journal of Hydrology and Hydromechanics, 61(1), 1–14.

[6.] Misra, A. K. (2011). Impact of water-intensive cropping pattern on groundwater depletion. Current Science, 100(1), 19–25.

[7.] NBSS&LUP. (2011). Soil Resource Mapping of Rajasthan. National Bureau of Soil Survey and Land Use Planning.

[8.] Rao, N. H., & Singh, R. (2005). Water management in arid agricultural systems. Agricultural Water Management, 72(3), 233–245.

[9.] Sharma, K. D. (2008). Groundwater behavior in arid western India. Hydrogeology Journal, 16(5), 985–995.

[10.] Sharma M.K. et.al. (2022). Land Use and Utilization in Hindi. Woar Journals

[11.] Sharma M.K. et.al. (2023). Water Resource Development in Hindi. S. N. Publishing Company, Jaipur

[12.] Yadav, B. R., & Goyal, S. (2017). Evaluating groundwater status in the Indira Gandhi Canal region. Journal of Water Resource and Protection, 9, 311–329