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Geographical Study of Water Crisis in Alwar District, Rajasthan

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Abstract
Rajasthan is one of the most water-stressed states in India, characterized by arid-to-semi-arid climates, erratic rainfall, and fragile geological formations. Alwar district, nestled in the lap of the Aravalli mountain range, presents a unique paradox: historically water-dense with numerous traditional water harvesting structures (baories, jhohars, and lakes like Siliserh and Jaysamand), it is currently facing an unprecedented groundwater crisis. Rapid urbanization, intensive industrialization in hubs like Bhiwadi and Neemrana, and shifting agricultural practices towards water-intensive crops have resulted in severe over-exploitation. Over 74% of groundwater resources in the state are in the over-exploited category, with Alwar recording alarming groundwater table depths exceeding 60–70 meters, and up to 150 meters in industrial zones. This research paper explores the hydro-geomorphology, climatic variability, spatial rainfall distribution, water quality degradation (TDS, iron, magnesium), and socio-economic implications of the crisis, while proposing scientifically robust watershed management, rainwater harvesting, and policy interventions.
Keywords: Alwar District, Groundwater Depletion, Hydro-Geomorphology, Aravalli Range, Rainwater Harvesting, Water Crisis, Semi-Arid Climate.

I. Introduction

Rajasthan state stands out as one of the most severely water-affected regions in India. The state's geographical structure, arid climate, and erratic precipitation patterns make water availability a perpetual challenge. While the north-eastern part of Rajasthan receives relatively higher rainfall, increasing population pressure and rapid urbanization have severely intensified water scarcity issues in these zones.

Alwar district serves as a particularly notable case study within this geographical framework. Nestled in the lap of the Aravalli mountain range, Alwar features a diverse natural landscape comprising hilly terrain, valleys, fertile alluvial plains, and seasonal river basins. Historically, the region was water-abundant, sustained by an intricate network of stepwells (baories), tanks (talabs), and lakes that served as primary reservoirs for drinking water and irrigation.

However, over the past few decades, evolving lifestyles, aggressive industrialization, and an over-reliance on groundwater have disrupted this delicate ecological balance. Today, groundwater tables in several blocks have plummeted to depths of 60–70 meters, while traditional water bodies remain dried up or encroached upon. This research paper undertakes a rigorous geographical investigation into the root causes, current status, and multi-dimensional impacts of Alwar's water crisis, offering scientifically grounded remediation strategies.

II. Geographical Introduction and Study Area

Alwar district is situated in the north-eastern part of Rajasthan, positioned strategically between the semi-arid expanses of the Thar Desert and the fertile Indo-Gangetic plains, making it a crucial transition zone (Transition Zone) in terms of climate and hydrology.

Physiography and Topography
The physiographic makeup of Alwar is a blend of rugged uplands and productive alluvial plains:
• Aravalli Range: The district is heavily influenced by the Aravalli hills. The principal ridges traverse the central part of the district, bifurcating it into two distinct geographical tracts: the western hilly region and the eastern plain tract.
• Plain Areas: A substantial portion of the district comprises fertile alluvial plains, highly suitable for agriculture under favorable water availability.
• Valleys and Depressions: Inter-montane valleys formed by fluvial deposits of seasonal streams provide localized pockets of agricultural productivity.

• Mineral Resources: Rich deposits of quartzite, marble, limestone, and metallic ores influence the regional subsurface hydrogeology and alter local drainage patterns.

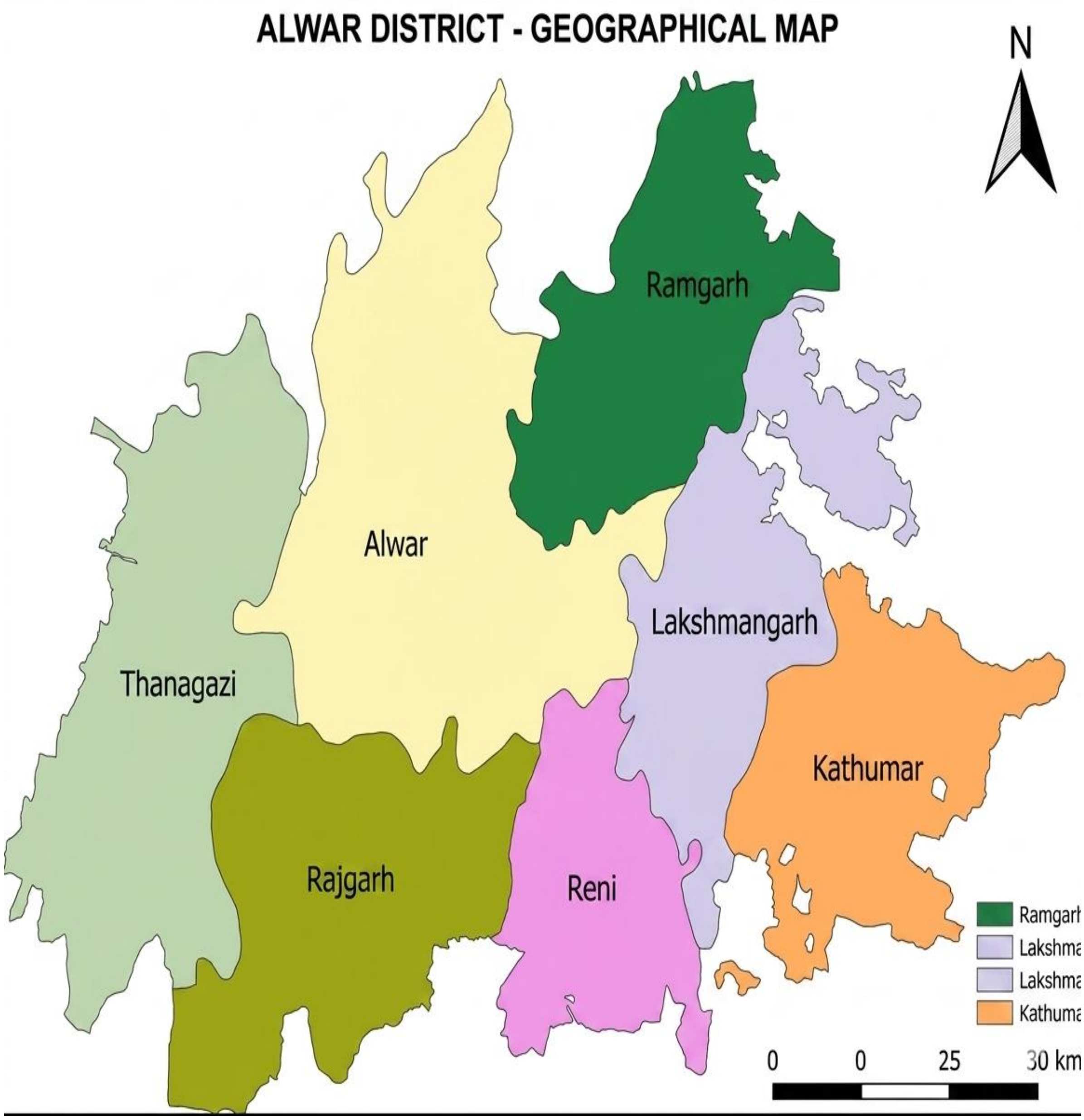

Figure 1: *Geographical and Hydrological Map of Alwar District showing Aravalli Divide, River Basins, and Key Industrial/Urban Hubs.*

Climate and Temperature

Alwar experiences a semi-arid (steppe) climate characterized by extremes in temperature:

• Summer Season: Ambient temperatures range between 30°C and 45°C, creating high evaporative stress.

• Winter Season: Temperatures drop between 2°C and 18°C, with an annual average of approximately 25°C.

• Thermal Variability: The extreme volatility between scorching summers and chilly winters exerts a direct influence on regional hydrological evaporation rates and soil moisture retention.

III. Research Objectives and Hypothesis

The primary aim of this research is to evaluate the hydro-geographical dimensions of water stress in Alwar. The specific objectives are outlined below:

1. To analyze the physiographical, climatic, and hydrological setting of Alwar district.
2. To assess the contemporary groundwater status and spatial depth distribution across various administrative blocks.

3. To examine the primary drivers of water scarcity, including anthropogenic pressure, industrialization, and agricultural intensification.
4. To formulate scientifically sound, geographically viable mitigation strategies encompassing rainwater harvesting, watershed restoration, and policy enforcement.

Research Hypothesis
It is hypothesized that Alwar district's severe water deficit is not merely a consequence of natural climatic aridity or deficient rainfall, but is primarily driven by anthropogenic over-exploitation of aquifers, unchecked industrial groundwater extraction in hubs like Bhiwadi and Neemrana, and the systemic decay of traditional rainwater harvesting structures.

IV. Sources of Data and Methodology

This study adopts an empirical and analytical methodology combining secondary spatial data, hydro-meteorological reports, and government assessments. The primary data sources include:
• Central Ground Water Board (CGWB) Reports and groundwater assessment ledgers.
• Rajasthan Post-Monsoon Assessment Reports (2024–2025).
• India Meteorological Department (IMD) monthly rainfall datasets and decadal district profiles.
• Published geographical literature on Aravalli hydrology and watershed management.

V. Rainfall Analysis and Spatial Distribution

Rainfall in Alwar district is largely governed by the South-West monsoon, active primarily between July and September. The average annual rainfall ranges between 600 mm and 700 mm, exhibiting sharp spatial inequality.
• Eastern Tract: Receives relatively higher precipitation (650–700 mm) due to proximity to moisture-bearing wind pathways.
• Western Tract: Receives lower rainfall (500–550 mm) as the Aravalli range acts as an orographic barrier, creating a rain shadow effect in interior valleys.

Table 3.1: Long-Term Rainfall Characteristics (CGWB Data)

S.No.	Source / Parameter	Average Annual Rainfall (mm)	Special Remarks
1	Long-term Average (CGWB)	645.6	Approximately 95% precipitation occurs via South-West Monsoon.
2	2020–21 Annual Report	662.0	Exhibits significant inter-annual fluctuation and erratic temporal distribution.

Table 3.3: Alwar District Rainfall Performance (2025 IMD Data)

S.No.	Time Period	Actual Rainfall (mm)	Normal Rainfall (mm)	Departure (%) / Remarks
1	June 2025 (IMD)	~ 180.0	~ 145.0	+24% (Early monsoon surplus)
2	July 2025 (Cumulative)	~ 280.0	~ 210.0	+33% (Strong recharge phase)
3	August 2025 (Cumulative)	~ 195.0	~ 140.0	+39% (Heavy downpours, localized logging)
4	September 2025 (01–23)	~ 72.0	~ 45.0	+60% (Active late monsoon spells)
Total	**01 June – 23 Sept 2025**	**727.0**	**539.8**	**+35% (Above normal overall precipitation)**

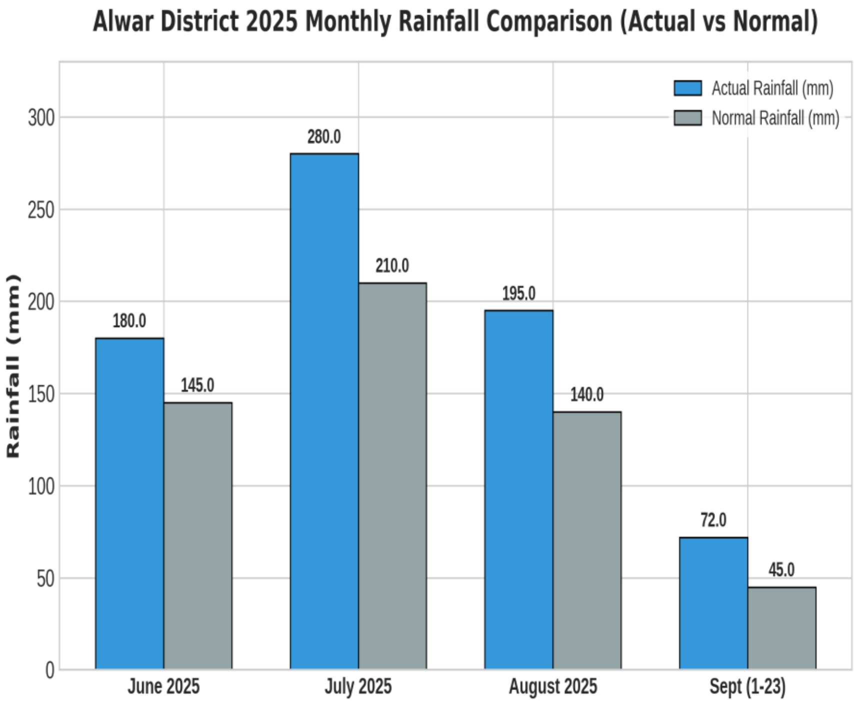

Figure 2: Actual vs. Normal Rainfall Comparison for Alwar District (2025 Monsoon Season).

VI. Current Water Status and Groundwater Dynamics

Despite recent seasonal surpluses (such as the +35% anomaly recorded in 2025), the cumulative historical groundwater deficit remains severe. State-level CGWB assessments indicate that approximately 74% of groundwater blocks in Rajasthan fall into the 'Over-Exploited' category. In Alwar, heavy abstraction for agriculture (83%), domestic consumption (15%), and industrial use (2%) has placed immense strain on aquifers.

Table 3.2: Groundwater Level Depth Distribution (Post-Monsoon 2025)

Depth Category (meters)	Percentage of Wells (%)	Hydrological Status
5 – 10 meters	5.3 %	Relatively Safe / Shallow Aquifers
10 – 20 meters	26.3 %	Moderate Depth / Seasonal Fluctuation
20 – 40 meters	36.8 %	Deep Water Table / High Pumping Pressure
≥ 40 meters	31.6 %	Critically Depleted / Severe Stress Zone

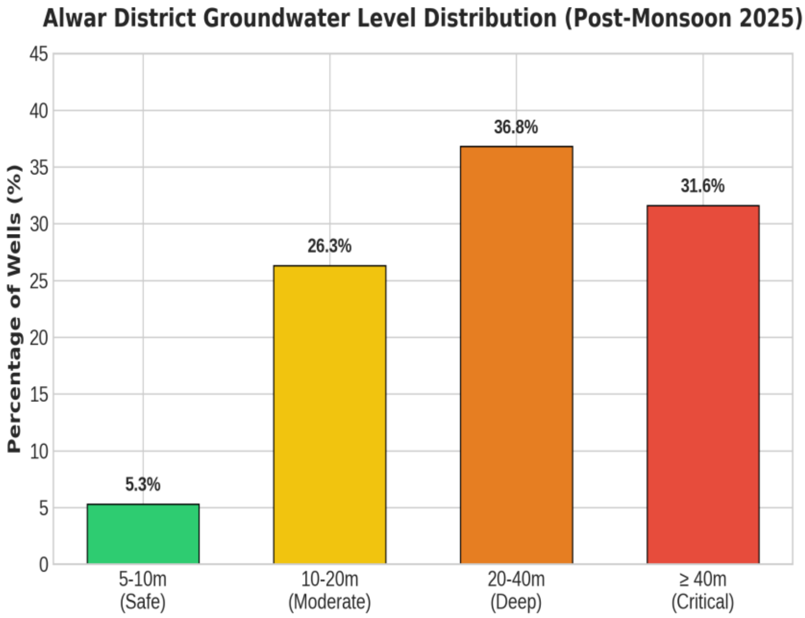

Figure 3: Percentage Distribution of Wells Across Groundwater Depth Categories in Alwar District.

Water Quality Degradation

Beyond volumetric scarcity, Alwar faces severe hydro-chemical challenges. Post-monsoon assessments reveal that groundwater in several blocks contains Total Dissolved Solids (TDS), iron, magnesium, and alkalinity levels exceeding permissible WHO standards. This deterioration poses serious public health risks, leading to fluorosis, gastrointestinal disorders, and long-term renal complications among rural and urban populations.

VII. Major Causes of the Water Crisis

The alarming water crisis in Alwar is an interplay of physical vulnerabilities and anthropogenic mismanagement:

1. Over-Reliance on Groundwater: With over 80% of domestic and agricultural needs met through tube wells, unmitigated abstraction has lowered water tables by 1–1.5 meters annually, pushing depths beyond 100–150 meters in blocks like Neemrana and Behror.
2. Demise of Traditional Water Bodies: Historical rivers like Sahibi, Ruparel, and Chandan have been reduced to seasonal trickles. Traditional water structures (jhohars, baories, and historical lakes such as Siliserh and Jaysamand) have suffered from encroachment, siltation, and institutional neglect.
3. Rapid Industrialization and Urban Expansion: Industrial clusters in Bhiwadi, Neemrana, and Khushkhera host thousands of manufacturing, chemical, and automobile plants. Excessive industrial groundwater drafting combined with effluent discharge has polluted local aquifers.
4. Agricultural Intensification and Flood Irrigation: Shift from traditional drought-hardy millets (bajra, jowar) to water-intensive cash crops (paddy, wheat) driven by market incentives and power subsidies, coupled with inefficient flood irrigation, leads to massive water wastage.

VIII. Significance of Water Resources in Human and Ecological Systems

Water is the foundational pillar of life, economy, and ecological stability in semi-arid zones. Its significance spans seven critical dimensions:

• Essential Human Survival: Clean drinking water is a fundamental human right as per WHO guidelines, directly governing public health and community vitality.
• Agricultural Food Security: Sustaining crop production in semi-arid tracts depends entirely on balanced irrigation management.
• Industrial and Economic Growth: Industrial hubs require massive water allocations for processing, cooling, and manufacturing.
• Energy Generation: Water is indispensable for thermal power cooling and emerging renewable energy paradigms.
• Ecosystem and Biodiversity: Protecting wildlife corridors in sanctuaries like Sariska Tiger Reserve relies on sustained surface and subsurface water availability.
• Socio-Cultural Heritage: Alwar's historical stepwells and lakes formed the bedrock of communal interaction and cultural traditions.
• Strategic and Security Importance: Often termed 'Blue Gold', water availability dictates regional stability and geopolitical resilience.

IX. Mitigation Strategies and Recommendations

To reverse the alarming depletion trends and ensure long-term water security in Alwar district, a multi-pronged geographical and technological intervention framework is recommended:

1. Mandatory Rainwater Harvesting & Artificial Recharge: Institutionalize rooftop rainwater harvesting across all urban and rural public structures. Construct check dams, contour trenches, and percolation tanks along Aravalli foothill slopes to enhance groundwater recharge.
2. Revival of Traditional Water Structures: Dredge, desilt, and rejuvenate historical water bodies (Siliserh, Jaysamand, and village jhohars) with active community participation and NGO collaboration (emulating models by Tarun Bharat Sangh).
3. Agricultural Transformation & Micro-Irrigation: Promote micro-irrigation techniques (drip and sprinkler systems) and incentivize crop diversification away from water-intensive paddy toward drought-resistant millets and oilseeds.
4. Strict Industrial Regulation & Zero Liquid Discharge (ZLD): Enforce stringent groundwater extraction quotas for industries in Bhiwadi and Neemrana while mandating advanced effluent treatment and ZLD protocols.
5. Inter-Basin Water Transfer Projects: Accelerate long-term surface water integration projects, such as channeling surplus water from the Chambal River basin to deficit river networks in north-eastern Rajasthan.

X. Conclusion

The geographical investigation of Alwar district reveals that the escalating water crisis is a complex manifestation of natural aridity compounded by severe anthropogenic stress. While recent monsoonal surges (such as the +35% rainfall anomaly in 2025 and an estimated 9.87-meter post-monsoon water table recovery in select pockets) offer temporary relief, 74% of state aquifers remain critically over-exploited. Without immediate, legally binding regulatory frameworks, community-driven watershed management, and large-scale artificial recharge initiatives, Alwar faces an impending ecological and humanitarian crisis. Sustainable water governance is not merely an environmental option; it is the ultimate prerequisite for the district's future survival and prosperity.

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