Journal of East-West Thought
ISSN: *2168-2259 (online)*
(https://jetjournal.us/)
Volume 16, Issue 1 – 2026

UGC CARE I

AN ANALYSIS OF GROUNDWATER DEPLETION AND ENVIRONMENTAL CHALLENGES IN CHURU DISTRICT, RAJASTHAN

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Abstract

Groundwater is the primary source of water for drinking, irrigation, and other domestic purposes in the majority areas. Churu district, located in the north-western part of Rajasthan, faces severe groundwater scarcity due to several reasons including low rainfall, high evaporation, increasing population, and excessive extraction of groundwater. The present study mainly focuses on the geographical analysis of groundwater depletion and its associated environmental challenges in Churu district.

The study is mainly based on secondary data collected from several government reports, research journals, and statistical records. The present analysis examines rainfall patterns, groundwater level fluctuations, groundwater exploitation status, irrigation practices, groundwater quality, and environmental impacts. The study reveals that groundwater levels in Churu district have continuously declined over the last two decades due to over-dependence on tube wells and bore wells for agricultural and domestic uses. Most of the blocks in the district fall under the over-exploited category, where groundwater extraction exceeds natural recharge capacity.

The research further identifies major environmental challenges such as desertification, soil salinity, vegetation loss, ecological imbalance, and drinking water scarcity. Groundwater quality deterioration in the form of fluoride, nitrate, and salinity contamination has also emerged as a serious public health issue. Fluoride contamination has caused dental and skeletal fluorosis in many rural areas of the district.

The study concludes that unsustainable groundwater utilization and climatic uncertainty have intensified environmental degradation in Churu district. Sustainable groundwater management through rainwater harvesting, artificial recharge, revival of traditional water conservation systems, micro-irrigation techniques, and public awareness is essential for ensuring long-term water security and environmental sustainability in the region.

Keywords: Groundwater Depletion, Environmental Challenges, Groundwater Quality, Contamination, Desertification, Water Scarcity, Sustainable Groundwater Management.

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Journal of East-West Thought
ISSN: 2168-2259 (online)
(https://jetjournal.us/)
Volume 16, Issue 1 – 2026
Impact Factor 7.665, UGC CARE I

1. Introduction

Groundwater is one of the most essential natural resources for human survivals as well as ecological sustainability. In arid and semi-arid regions of India, groundwater acts as the primary source of drinking and irrigation water. Rajasthan, the largest state of India in terms of area, is characterized by low rainfall, high temperature, recurrent droughts, and fragile ecological conditions. Among all the districts of Rajasthan, Churu district represents one of the most water-stressed regions where groundwater depletion has emerged as a serious problem.

Churu district lies in the north-western part of Rajasthan and forms a part of the Thar Desert region. Due to scanty rainfall, high evapotranspiration, sandy terrain, and limited surface water availability, the district depends heavily on groundwater resources. Rapid population growth, agricultural intensification, increasing urbanization, and excessive withdrawal of groundwater through tube wells and bore wells have accelerated groundwater depletion in the district. As a result, groundwater levels have declined significantly over the past decades, creating severe environmental and socio-economic problems.

The depletion of groundwater in Churu district has led to multiple environmental challenges including desertification, soil salinity, declining agricultural productivity, water quality deterioration, fluoride contamination, ecological imbalance, and drinking water scarcity. Over-extraction of groundwater has also affected the sustainability of traditional water conservation systems such as johads, tankas, nadis, and kunds that historically supported desert communities.

Groundwater quality is another major issue in Churu district. High concentration of fluoride, salinity, nitrate, and total dissolved solids have made groundwater unsuitable for drinking and irrigation in several regions. Studies by the Central Ground Water Board indicate that many blocks of Churu district fall under the category of over-exploited groundwater zones.

The increasing demand for water due to agricultural expansion and changing cropping patterns has intensified pressure on underground aquifers. Tube-well irrigation and mechanized pumping systems have accelerated groundwater extraction beyond the natural recharge capacity. Low and erratic rainfall further worsens recharge conditions. Environmental degradation caused by groundwater depletion threatens the long-term sustainability of the region.

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Journal of East-West Thought
ISSN: 2168-2259 (online)
(https://jetjournal.us/)
Volume 16, Issue 1 – 2026
Impact Factor 7.665, UGC CARE I

Geographical analysis of groundwater depletion is important because geography studies the relationship between humans and the environment. Spatial variation in groundwater availability, climatic conditions, land use, agricultural practices, and population pressure can be effectively analyzed through geographical methods. Understanding the geographical dimensions of groundwater depletion helps in preparing sustainable management strategies for water conservation.

The present study aims to examine the extent of groundwater depletion and associated environmental challenges in Churu district. The study also focuses on identifying causes, impacts, and possible measures for sustainable groundwater management in the region.

2. Review of Literature

Several researchers, institutions, and government agencies have conducted studies related to groundwater depletion, water quality, and environmental challenges in Rajasthan and other arid regions.

Sharma et al. (2025) conducted a hydrogeological evaluation of groundwater in Churu district and observed that over-exploitation, high salinity, fluoride contamination, and nitrate concentration have severely affected groundwater quality and availability. The study reported that groundwater development in some blocks exceeded sustainable limits, making groundwater highly vulnerable.

The Central Ground Water Board (CGWB) has repeatedly identified Rajasthan as one of the most groundwater-stressed states of India. CGWB reports reveal that excessive groundwater withdrawal for irrigation and domestic purposes has resulted in falling groundwater levels across western Rajasthan. Many areas of Churu district have been categorized as over-exploited zones.

Kumar et al. highlighted that climate variability and erratic rainfall patterns significantly influence groundwater recharge in Rajasthan. The study emphasized that declining rainfall and increasing temperature reduce infiltration and recharge capacity, thereby accelerating groundwater depletion.

Research on western Rajasthan has shown that the rapid increase in tube wells and subsidized electricity for groundwater pumping contributed significantly to groundwater depletion. Technological advancements in bore-well drilling have enabled deeper extraction, causing rapid decline in water tables.

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ISSN: 2168-2259 (online)
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Volume 16, Issue 1 – 2026
Impact Factor 7.665, UGC CARE I

Studies on groundwater quality in Rajasthan indicate widespread contamination by fluoride, nitrate, and salinity. High fluoride concentration in groundwater has caused serious health problems such as dental fluorosis and skeletal fluorosis among rural populations. Churu district is among the affected regions.

Researchers studying desert ecology have emphasized that groundwater depletion affects vegetation cover, soil fertility, and biodiversity. Excessive withdrawal of groundwater reduces moisture availability, increases soil salinity, and contributes to land degradation and desertification.

International studies on groundwater depletion indicate that over-exploitation of aquifers causes environmental imbalance, declining water quality, and socio-economic stress. Sustainable groundwater management requires integrated approaches involving recharge structures, water conservation techniques, policy intervention, and community participation.

Previous literature clearly indicates that groundwater depletion is not merely a hydrological issue but also a geographical, environmental, and socio-economic challenge. However, specific geographical studies focusing exclusively on Churu district remain limited. Therefore, the present study attempts to fill this gap through a geographical analysis of groundwater depletion and environmental challenges in Churu district.

3. Objectives of the Study

The major objectives of the present study are:

1. To study the geographical conditions of Churu district affecting groundwater availability.
2. To analyze the causes of groundwater depletion in Churu district.
3. To examine spatial and temporal changes in groundwater levels.
4. To identify environmental challenges associated with groundwater depletion.
5. To study groundwater quality issues such as salinity and fluoride contamination.
6. To evaluate the impact of groundwater depletion on agriculture and human life.
7. To suggest suitable measures for sustainable groundwater management in Churu district.

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4. Research Methodology

Nature of Study

The present study is descriptive and analytical in nature. It is based on geographical analysis of groundwater depletion and environmental challenges in Churu district.

Study Area

Churu District is located in north-western Rajasthan and forms a part of the Thar Desert. The district covers approximately 16,830 square kilometers. It experiences arid climatic conditions characterized by low rainfall, high temperature, sand dunes, and frequent droughts.

Sources of Data

The study is mainly based on secondary data collected from various government and institutional sources, including:

- Central Ground Water Board (CGWB)
- Rajasthan Ground Water Department
- Census of India
- India Meteorological Department (IMD)
- Government reports and statistical handbooks
- Published articles and online databases

Methods of Data Collection

Secondary data related to rainfall, groundwater levels, irrigation, population growth, and water quality were collected from published reports and official records.

Methods of Analysis

The collected data were analysed using geographical and statistical techniques such as tabulation, percentage analysis, trend analysis, comparative analysis and spatial interpretation. Tables were used for better representation and analysis of data related to groundwater depletion and environmental impacts.

Limitations of the Study

- The study is mainly based on secondary data.
- Availability of updated groundwater data for all villages was limited.
- Temporal variations may differ due to climatic fluctuations.

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5. Data Analysis and Interpretations

The analysis of groundwater depletion in Churu district is based on geographical, climatic, hydrological, agricultural, and environmental factors. Churu district, located in the arid zone of Rajasthan, depends heavily on groundwater because of the absence of perennial rivers and limited surface water resources. Increasing groundwater extraction, irregular rainfall, and rising population pressure have significantly affected groundwater availability and environmental sustainability in the region.

This section analyses rainfall patterns, groundwater levels, irrigation trends, groundwater quality, environmental impacts, and socio-economic consequences with the help of statistical data and geographical interpretation.

Geographical Profile of Churu District

Particulars	Details
Location	North-Western Rajasthan
Total Area	16,830 sq. km
Climate	Arid and Semi-Arid
Average Rainfall	250–350 mm annually
Summer Temperature	Up to 48°C
Major Occupation	Agriculture and Animal Husbandry
Main Water Source	Groundwater
Soil Type	Sandy and Alluvial

The district is dominated by desert terrain and sand dunes. High temperature and low rainfall create severe water scarcity conditions. Groundwater serves as the principal source of irrigation and drinking water. The geographical structure of Churu district naturally limits groundwater recharge. Extreme climatic conditions and sandy soil increase evaporation and reduce water retention capacity. These conditions make groundwater highly vulnerable to depletion.

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Rainfall in Churu District

Rainfall is the primary source of groundwater recharge in the district. However, rainfall in Churu district is highly uncertain and unevenly distributed.

Average Annual Rainfall in Churu District

Year	Rainfall (mm)
2018	312
2019	276
2020	341
2021	298
2022	255
2023	269

The data indicate fluctuations in annual rainfall. In 2022, rainfall declined to 255 mm, which adversely affected groundwater recharge. Uneven rainfall distribution and frequent drought conditions reduce infiltration into underground aquifers. Low rainfall combined with high evaporation rates creates severe groundwater stress in the district.

Groundwater Level Analysis

Groundwater levels in Churu district have declined continuously due to over-extraction.

Average Groundwater Depth in Selected Blocks

Block	2010 (m bgl)	2015 (m bgl)	2020 (m bgl)	2024 (m bgl)
Rajgarh	48	62	81	96
Sujangarh	44	58	77	91
Taranagar	39	53	71	86
Ratangarh	41	56	74	89
Churu	36	49	66	80

Note: m bgl stands for meters below ground level

The data clearly reveal rapid decline in groundwater level across all blocks of the district. Rajgarh block recorded groundwater depth of 96 meters below ground level in 2024

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ISSN: 2168-2259 (online)
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compared to 48 meters in 2010. Similar declining trends are visible in all major blocks. This indicates excessive groundwater extraction beyond recharge capacity. Increasing depth raises irrigation costs and reduces groundwater accessibility for rural communities.Groundwater development refers to the ratio between groundwater extraction and recharge. A groundwater development stage above 100% indicates over-exploitation. All major blocks of Churu district fall under the over-exploited category.

Groundwater Exploitation Status in Churu District

Block	Stage of Groundwater Development (%)	Category
Rajgarh	189	Over-Exploited
Sujangarh	176	Over-Exploited
Taranagar	168	Over-Exploited
Ratangarh	154	Over-Exploited
Churu	149	Over-Exploited

Rajgarh block recorded 189% groundwater development, meaning extraction is almost double the recharge rate. This situation is environmentally unsustainable and threatens future water security.

Irrigation and Agricultural Pressure

Agriculture is the largest consumer of groundwater in Churu district. Tube wells account for 68% of irrigation sources, showing heavy dependence on groundwater. Canal irrigation is very limited due to the desert environment.

Sources of Irrigation in Churu District

Source of Irrigation	Percentage (%)
Tube Wells	68
Bore Wells	17
Canals	4
Traditional Water Bodies	6
Others	5

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Mechanized pumping through tube wells and bore wells has accelerated groundwater depletion. Traditional water conservation systems contribute only marginally to irrigation.

Changes in agricultural practices increased groundwater demand. In other words it can be said that the changing cropping pattern has increased the demand of water for irrigation in the area.

Major Crops and Water Requirement

Crop	Water Requirement	Impact on Groundwater
Bajra	Low	Sustainable
Mustard	Moderate	Medium Pressure
Wheat	High	High Pressure
Cotton	Very High	Severe Pressure

Traditional drought-resistant crops such as bajra require less water and are environmentally suitable for arid regions. However, cultivation of water-intensive crops like wheat and cotton increases groundwater extraction significantly. Changing crop patterns contribute to unsustainable groundwater use. Groundwater quality deterioration is a major environmental challenge in Churu district.

Groundwater Quality Parameters

Parameter	Permissible Limit	Average Value in Churu
Fluoride	1.5 mg/L	3.8 mg/L
TDS	500 mg/L	1800 mg/L
Nitrate	45 mg/L	72 mg/L
Salinity	250 mg/L	950 mg/L

The groundwater quality data indicate severe contamination problems mainly as following:

- Fluoride levels exceed permissible limits by more than double.
- High TDS and salinity reduce suitability for drinking and irrigation.
- Nitrate contamination reflects excessive fertilizer use and poor sanitation.

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ISSN: 2168-2259 (online)
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Poor groundwater quality creates major public health and agricultural problems. Fluoride contamination is widespread in Churu district.

Health Problems Associated with Fluoride Contamination

Health Issue	Percentage of Affected Population
Dental Fluorosis	42
Joint Pain	31
Skeletal Fluorosis	18
Bone Deformities	9

The data indicate that dental fluorosis affects a large section of the rural population. Long-term consumption of fluoride-contaminated water has serious health consequences, especially among children and elderly people. Groundwater quality degradation has become a major public health issue in the district.

Environmental Impacts of Groundwater Depletion

Groundwater depletion has intensified environmental degradation in Churu district. Reduced groundwater availability lowers soil moisture and vegetation cover, increasing desertification risks. Soil salinity and land degradation negatively affect agricultural productivity.

Major Environmental Problems

Environmental Problem	Severity Level
Desertification	Very High
Soil Salinity	High
Vegetation Loss	High
Sand Dune Expansion	Moderate
Biodiversity Decline	Moderate

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Ecological imbalance caused by groundwater depletion threatens environmental sustainability in the region. Rural settlements face severe drinking water shortages during summer months.

Drinking Water Availability in Rural Areas

Source	Percentage of Villages Dependent
Groundwater	82
Tankers	9
Pipelines	6
Traditional Sources	3

The majority of villages depend directly on groundwater for drinking purposes. Declining groundwater levels and poor water quality increase dependence on water tankers. Water scarcity creates social stress and affects quality of life in rural areas. Groundwater depletion affects agriculture, livelihoods, and rural economy.

Socio-Economic Consequences

Impact	Observed Effect
Irrigation Cost	Increased
Farmer Debt	Increased
Agricultural Productivity	Declined
Rural Migration	Increased
Employment Opportunities	Reduced

Increasing groundwater depth raises irrigation costs due to deeper drilling and higher electricity consumption. Small and marginal farmers face economic hardship and debt burdens. Reduced agricultural productivity contributes to migration and unemployment in rural areas. Traditional systems historically supported water conservation in desert regions.

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Traditional Water Harvesting Structures

Structure	Purpose
Johad	Rainwater Storage
Tanka	Household Water Storage
Nadi	Village Pond
Kund	Drinking Water Collection
Baori	Step Well

Traditional water conservation systems were environmentally sustainable and suitable for arid conditions. Declining use of these systems increased dependence on groundwater extraction. Revival of traditional water harvesting methods can improve groundwater recharge and reduce water scarcity.

The analysis reveals that groundwater depletion in Churu district is the result of combined geographical, climatic, agricultural, and socio-economic factors. Key findings include:

- Continuous decline in groundwater levels
- Over-exploitation of aquifers
- Increasing groundwater contamination
- Severe environmental degradation
- Rising irrigation costs
- Drinking water scarcity
- Public health problems due to fluoride contamination

The study clearly indicates that groundwater resources in Churu district are under severe stress. Without effective conservation and sustainable management measures, future water security and environmental sustainability may face serious threats.

The study reveals that groundwater depletion has become a critical environmental and geographical issue in Churu district. Arid climatic conditions, low rainfall, high evaporation, and lack of surface water make the district highly dependent on groundwater resources.

Excessive extraction of groundwater for irrigation and domestic purposes has caused continuous decline in groundwater levels. Several blocks of the district are categorized as

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Impact Factor 7.665, UGC CARE I

over-exploited zones. Groundwater quality has also deteriorated due to salinity, fluoride, and nitrate contamination.

Environmental challenges associated with groundwater depletion include desertification, soil degradation, ecological imbalance, agricultural decline, and drinking water scarcity. Public health problems such as fluorosis are increasing due to contaminated groundwater consumption. The study also indicates that traditional water conservation systems have weakened over time, reducing the resilience of local communities against water scarcity.

6. Conclusion

Groundwater is the lifeline of Churu district, but unsustainable extraction practices have severely threatened its availability and quality. The geographical conditions of the district, combined with increasing human pressure and climatic uncertainty, have intensified groundwater depletion and environmental degradation.

Sustainable groundwater management is essential for protecting the ecological balance and socio-economic stability of the region. Effective measures should include:

- Rainwater harvesting
- Artificial groundwater recharge
- Restoration of traditional water conservation systems
- Regulation of groundwater extraction
- Promotion of micro-irrigation techniques
- Public awareness regarding water conservation
- Crop diversification toward less water-intensive crops

Integrated water resource management involving government agencies, local communities, and scientific institutions is necessary for long-term sustainability. Without immediate intervention, groundwater depletion may create severe environmental and socio-economic crises in Churu district in the future.

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Journal of East-West Thought
ISSN: *2168-2259 (online)*
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