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Article,

Assessing Groundwater Depletion in the Biskra Region (Algeria) Using Electrical Survey Techniques and GIS

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Abstract: The agricultural region of Biskra, characterized by very low annual rainfall (150–200 mm), suffers from limited renewable water resources. Overexploitation due to urbanization, industrial, and agricultural expansion has led to a significant decline in groundwater levels. This study integrates Geographic Information Systems (GIS) and geophysical prospecting methods, particularly Vertical Electrical Sounding (VES), to assess groundwater drawdown, determine causative factors, and locate high-risk areas. A total of 107 geophysical surveys were conducted, distributed across central, northern, eastern, southern, and western Biskra, using ArcGIS 10.3 for data analysis. The surveys revealed an annual groundwater depletion rate of approximately 5%, culminating in an overall decline of nearly 300% over 44 years. Interpolation methods, including Inverse Distance Weighting (IDW) and Kriging, were applied for spatial analysis. Findings indicate severe groundwater depletion, particularly in the northern and southern zones, necessitating urgent resource management measures, such as artificial recharge and modern irrigation techniques. This study provides critical insights for sustainable groundwater governance in arid regions.

Keywords: groundwater depletion; overexploitation; GIS mapping; VES, artificial recharge**;** Biskra

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1. Introduction

The Biskra region, located in southeastern Algeria, faces major challenges in managing groundwater resources. Covering an area of nearly 30,000 km², this region is characterized by an arid climate, marked by high temperatures and very low annual rainfall, often below 200 mm. Water availability is therefore limited, complicating the sustainable development of agricultural and industrial activities (Benhamza et al., 2018). The intensification of agriculture, driven by population growth and increased demand for food products, along with the expansion of irrigated areas, has led to alarming overexploitation of aquifers. This overexploitation is exacerbated by increasing urbanization, which places additional pressure on water resources. Inefficient agricultural practices, a lack of awareness of sustainable water management, and insufficient hydraulic infrastructure further aggravate the situation (Hamidi et al., 2020). Consequently, Significant declines in groundwater levels were observed, threatening not only the region's water security but also the balance of local ecosystems and the economic viability of dependent communities (Kheddam et al., 2016).

In light of this alarming situation, mapping groundwater drawdown emerges as a crucial step in understanding the scope of the problem. It helps identify high-risk areas, assess the impacts of overexploitation on water quality and quantity, and propose sustainable and appropriate solutions (Bencherif et al., 2019). Electrical prospecting techniques, which

enable the characterization of the geological and hydrogeological structure of the subsurface, combined with Geographic Information Systems (GIS), prove to be valuable tools for such studies. By integrating geospatial and hydrological data, it becomes possible to conduct a detailed inventory of aquifers, evaluate variations in groundwater depths, and produce accurate maps illustrating the state of water resources, as well as areas most vulnerable to climate change and human activity (Bouderbala et al., 2019).

This study aims to quantify and analyze groundwater depletion in Biskra using GIS and geophysical techniques. The primary objectives are:

1. To map groundwater level changes over the past four decades (1980–2023).
2. To identify key depletion factors and their spatial distribution.
3. To evaluate the effectiveness of existing water management strategies.
4. To propose sustainable solutions for mitigating groundwater overexploitation.

2. Materials and methods

2.1 Study Area Overview

The Biskra region, located in southeastern Algeria, is a strategic area that lies at the border between the Aurès Mountains and the Sahara Desert. It is part of the vast Zibans palm grove, known for its lush oases amid an arid environment. The region is characterized by a desert climate, with high summer temperatures and very low annual rainfall, generally not exceeding 150 to 200 mm. These climatic conditions make groundwater resources particularly precious and crucial for development (Tazir et al., 2018).

Biskra's economy has traditionally relied on agriculture, particularly the cultivation of Deglet Nour dates, renowned throughout the country. However, the region has recently diversified its agricultural activities by turning to vegetable crops, which has revitalized the local economy and established Biskra as one of Algeria's leading vegetable production centers (Benguedour et al., 2021)



Figure 1. Geographic Location Map of Biskra City (NOUI et al., 2019)

2.2 Geology and Geophysics of the Study Area

The Biskra region has been the subject of numerous geological and geophysical studies, notably those conducted by N. Gouskov (1964), Cornée (1989), G. Mauget (1967), as well

as institutions like CGG, ENAGEO, SONATRACH and ANRH. These works serve as essential references for the geological and geophysical synthesis of the Algerian Sahara and have significantly advanced the understanding of Biskra's geological characteristics.

The lithostratigraphy of this plain is dominated by Cretaceous formations, comprising sandstones, marls, limestones, and clays (Noui et al., 2022). The Turonian is primarily composed of limestone layers, while the Eocene and Senonian are distinguished by fractured limestones, marls, clays, and gypsums (Noui et al., 2023). Mio-Pliocene deposits are well-developed, consisting of sandstones, sands, and marls at the top. Lastly, the Quaternary period is characterized by the presence of alluvial deposits, travertines formed by springs, as well as scree from slopes and piedmonts (Benyelles et al., 2017).

This stratigraphic and structural diversity reflects the geological richness of the Biskra region and its significant role in shaping the area's hydrological dynamics.

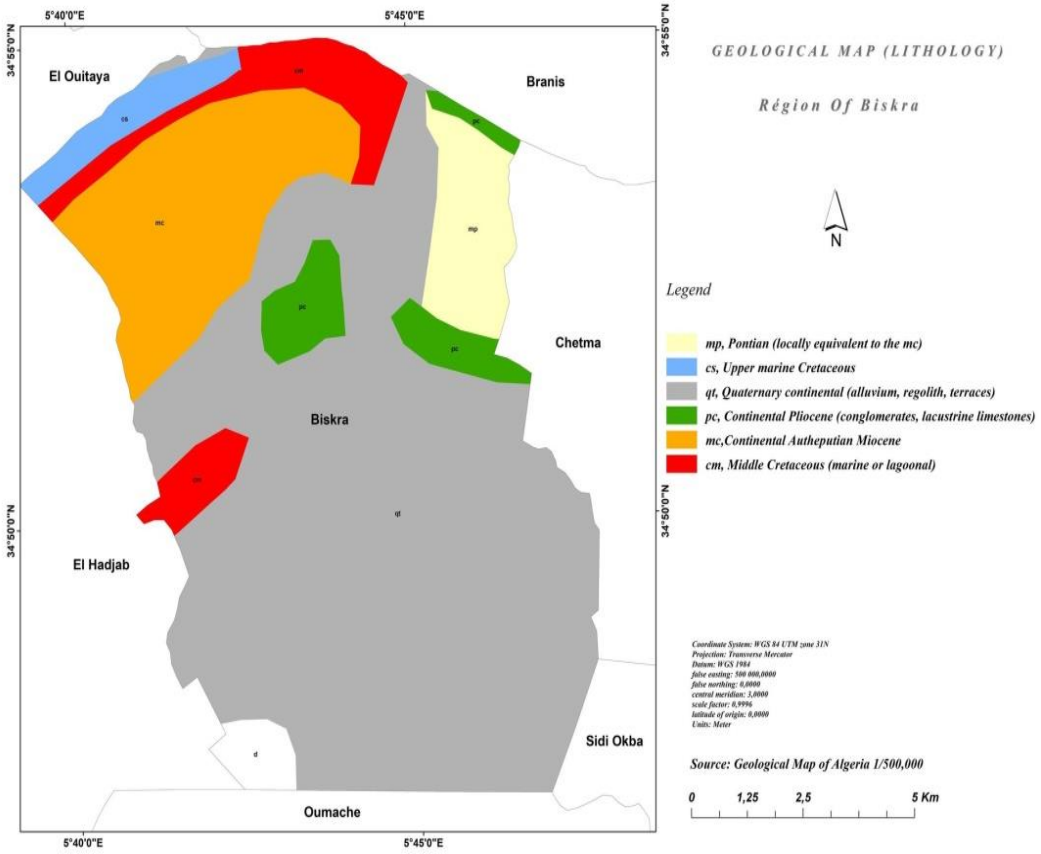


Figure 2. Geological map of Biskra region (NOUI et al., 2022)

2.3 *Materials*

Vertical Electrical Sounding (VES) data was collected using the WF 303 GH Underground Water Detector, which measures subsurface resistivity variations.

The data was processed using standard inversion techniques to determine aquifer depths and characteristics. Interpretation involved correlating resistivity profiles with geological formations identified in the lithostratigraphy of the region.

This device measures the density of underground reservoirs, determines water quality (fresh or saline), and detects aquifer depth up to 1000 meters.

- GPS Device: For accurate positioning and data recording.

- Topographic, Geological, and Hydrogeological Maps: To assist in spatial analysis and planning.

- ArcGIS 10.3 Software: For mapping and spatial data analysis.

- Field Tools: Including hammers, field kits, etc.

- Transportation Means: To facilitate movement across the study area.

These materials and tools were essential for conducting the fieldwork, geophysical surveys, and the subsequent GIS-based analyses. The combination of advanced detection technologies and geographic tools provided detailed insights into the groundwater resources of the Biskra region.



Figure 3. Electrical Prospecting Device WF 303 GH (GUESBAYA & al, 2024)

Our working method involves two main phases: fieldwork and office work. The ultimate goal is to generate a detailed groundwater drawdown map for the city of Biskra using Geographic Information Systems (GIS), which will support effective resource management in this arid region.

Spatial analysis was performed using ArcGIS 10.3. Interpolation methods, including Inverse Distance Weighting (IDW) and Kriging, were applied to generate groundwater drawdown maps. Kriging was chosen for its ability to account for spatial autocorrelation, providing more accurate predictions of groundwater level changes.

- Fieldwork

Fieldwork involved electrical prospecting campaigns, operator surveys, and site studies, while office work included map consultation and GIS-based analysis.

Operator Surveys: Operator surveys were conducted with local stakeholders to gather historical data on groundwater exploitation. Results are summarized in Table 1.

Site Studies: Analyzed the topography and morphology of the terrain.

Vertical Electrical Sounding (VES): Data was collected to evaluate subsurface characteristics and aquifer depths.

- Office Work

Map Consultation: Reviewed topographic, geological, and hydrogeological maps to correlate field data with existing resources.
The 107 geophysical surveys were strategically distributed across five zones (central, northern, eastern, southern, and western Biskra) based on historical borehole locations

documented by ANRH in 2008. Sampling locations were selected to ensure comprehensive coverage of the region while prioritizing high-risk areas identified through preliminary analyses.

3. Results

- Over 107 geophysical surveys were conducted across various sectors of the Biskra region, including the center, north, east, south, and west.

-A limitation of this study is the time gap between surveys (1980–2023), which may introduce uncertainty in trend estimation. However, robust interpolation techniques were employed to minimize these effects.

- These surveys were performed on boreholes drilled between 1980 and 2007.

- All boreholes were documented and cataloged by the ANRH (National Agency of Hydraulic Resources) in Biskra in 2008.

Table 1: Groundwater depth measurements obtained from boreholes drilled between 1980 and 2007, compared with 2023 electrical prospecting data.

Region	Longitude	Latitude	Altitude	year	depth (m)	depth measured by electrical prospecting in 2023 (m)
Biskra	05° 47' 07''	34° 48' 33''58		1980	80	280
Biskra	05° 44' 03''	34° 47' 18''67		1982	70	300
Biskra	05° 46' 10''	34° 49' 27''73		1984	100	320
Biskra	05° 46' 34''	34° 48' 04''71		1985	100	310
Biskra	05° 56' 38''	34° 47' 53''65		1985	100	315
Biskra	05° 56' 40''	34° 47' 36''65		1985	100	320
Biskra	05° 46' 33''	34° 50' 54''92		1985	100	350
Biskra	05° 45' 00''	34° 50' 17''145		1985	100	340
	05° 47' 07''	34° 48' 33''58		1980	80	310
Biskra	05° 44' 03''	34° 47' 18''67		1982	70	320
	05° 46' 10''	34° 49' 27''73		1984	100	290

We have prepared maps that illustrate the decline in groundwater approximately every ten years using ArcGIS 10.3

- Time period: 1980-1990

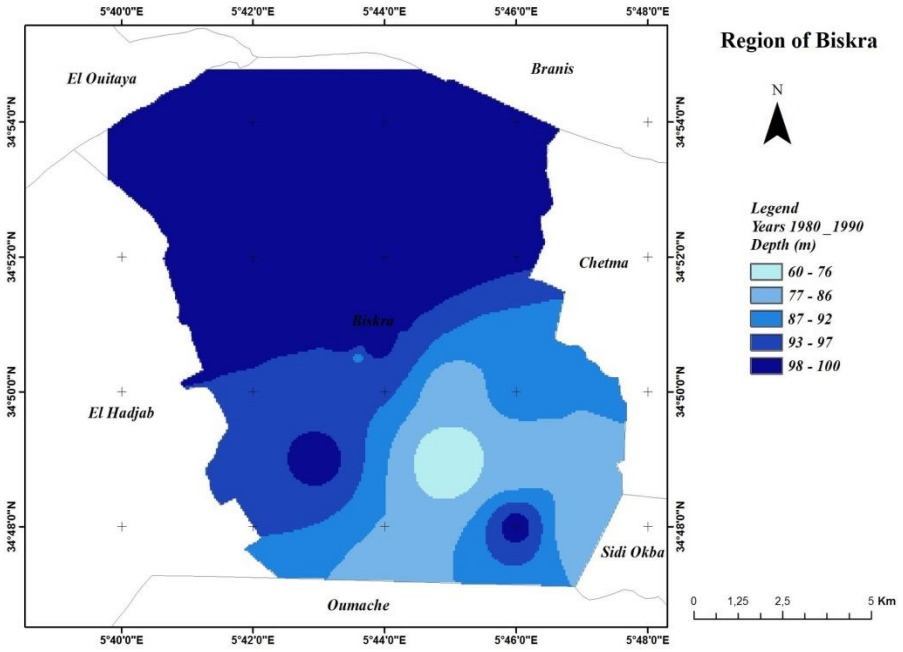


Figure 4. Groundwater drawdown map of the Biskra region (1980-1990)

- Time period: 1991-1999

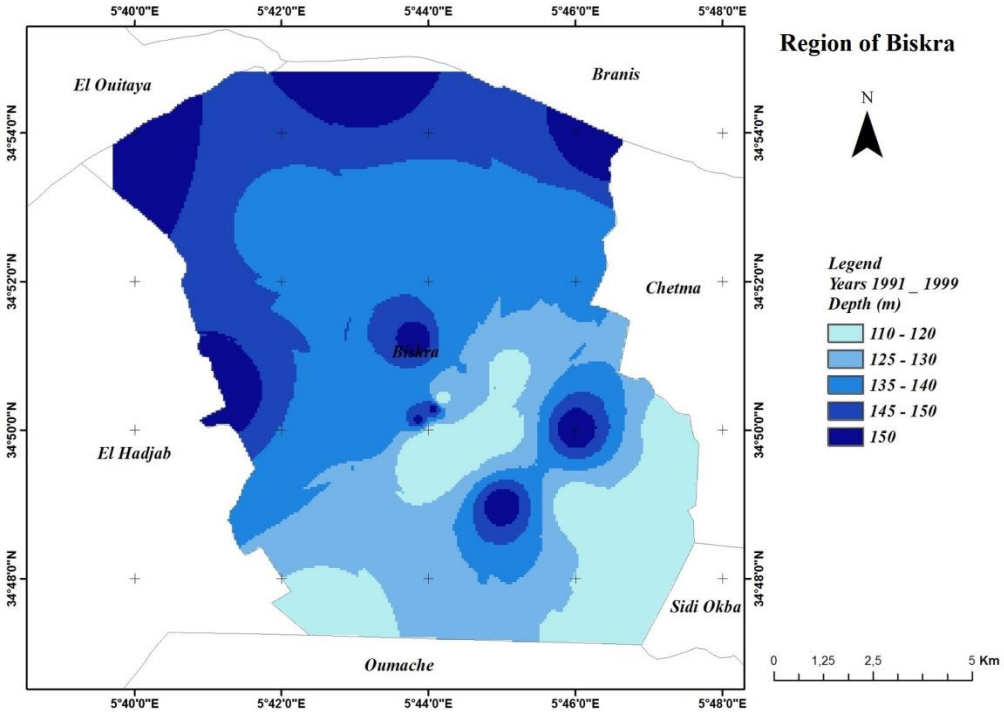


Figure 05. Groundwater drawdown map of the Biskra region (1991-1999)

- Time period: 2000-2007

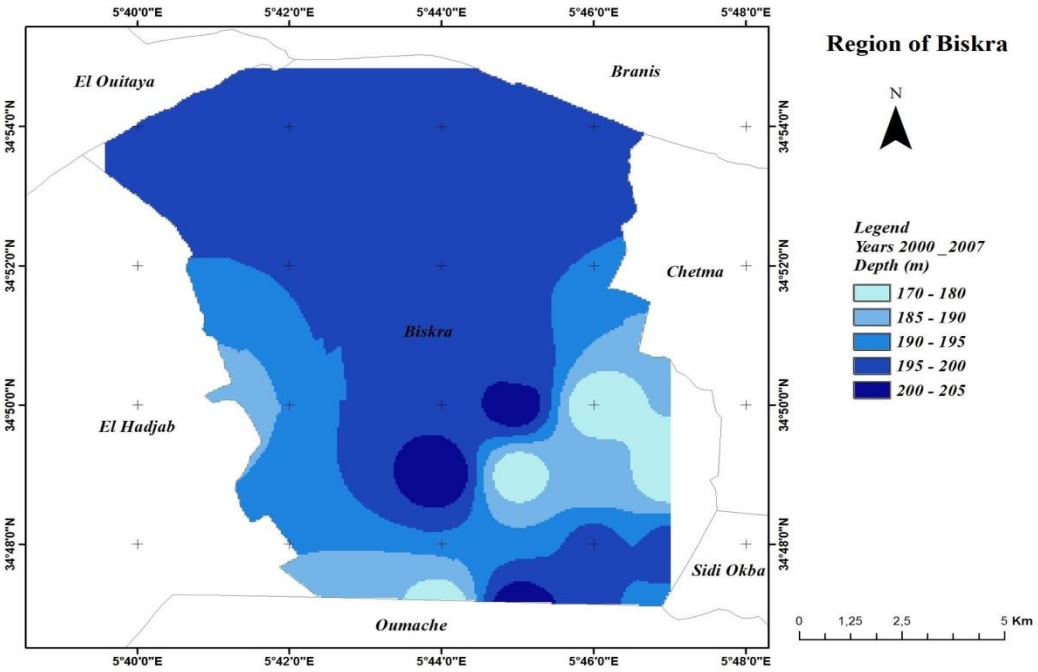


Figure 6. Groundwater drawdown map of the Biskra region (2000-2007)

- Time period: 1980-2007

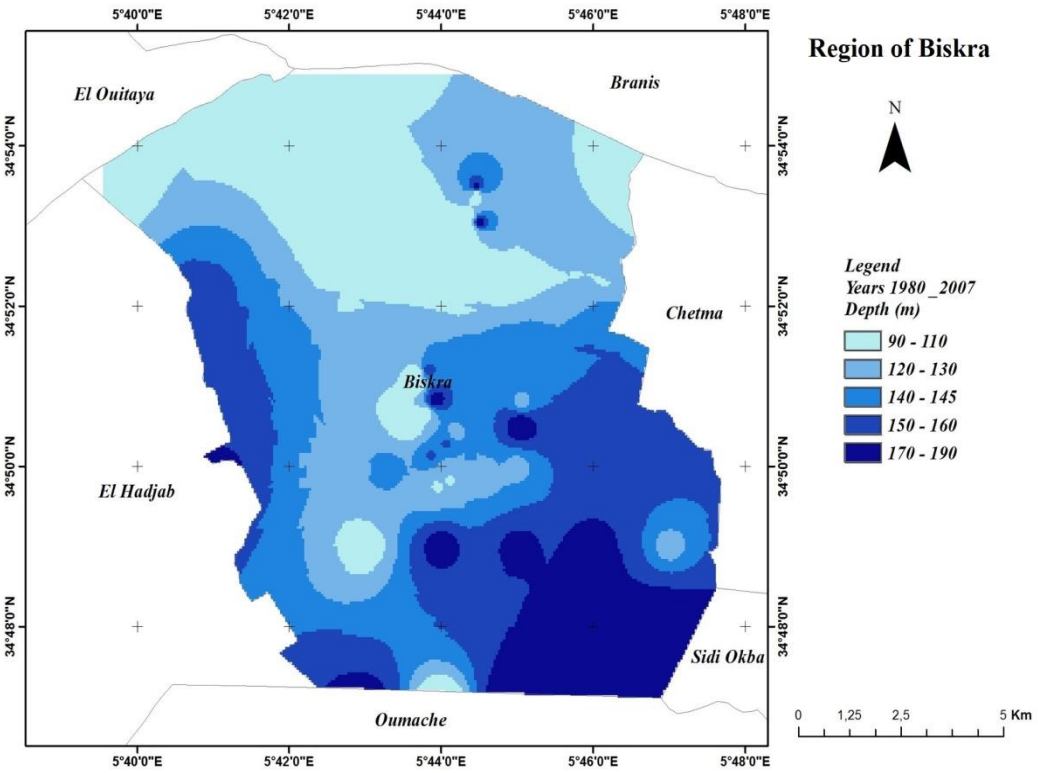


Figure 7. Groundwater drawdown map of the Biskra region (1980-2007)

Finally, we prepared a map illustrating the decline in groundwater based on electrical prospecting data.

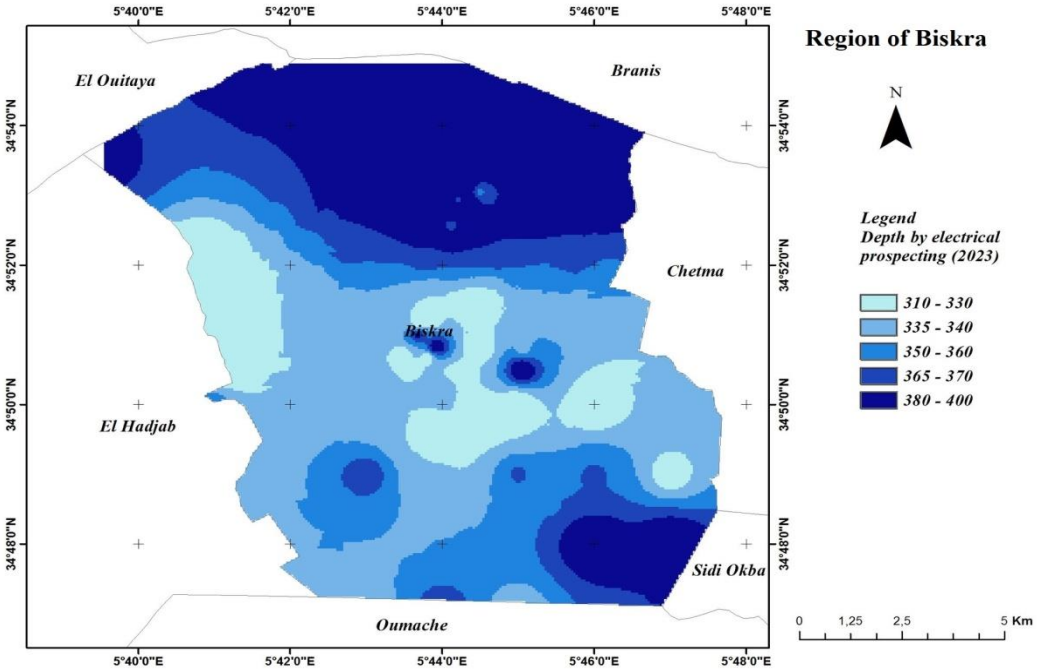


Figure 8. Groundwater drawdown map of the Biskra region by electrical Prospecting (2023)

Figures 4–8 illustrate groundwater drawdown trends over four decades. Notably, the northern and southern zones experienced the most severe declines, with cumulative decreases exceeding 300%. Spatial variations suggest localized hotspots requiring targeted interventions.

4. Discussion

Data analysis reveals an alarming reduction in groundwater levels in the northern and southern regions of Biskra. This drawdown, averaging around 5% annually, results in a cumulative decrease of approximately 50% per decade and a total decline of up to 300% over 44 years. These figures highlight the severity of the water crisis in this arid region.

Several factors contribute to this drastic reduction in groundwater resources:

1- Impact of Climate Change:

While this study did not directly integrate climate models, historical precipitation trends indicate a significant decline in rainfall, exacerbating aquifer drawdown. Future research should incorporate predictive climate models to better forecast groundwater dynamics.

2- Expansion of Irrigated Areas:

Current water management practices, such as unregulated well drilling and inefficient irrigation techniques, have exacerbated groundwater depletion. Implementing artificial recharge systems and promoting modern irrigation methods (localized irrigation, sprinklers, pivot systems) could significantly mitigate these issues.

3- Use of Traditional Irrigation Methods:

Widely practiced but inefficient traditional irrigation techniques result in significant water waste, further depleting groundwater reserves.

4- Proliferation of Unauthorized Agricultural Wells:

The rise in illegal and unregulated wells intensifies water extraction, depleting resources in an uncontrolled and unsustainable manner.

These combined factors exert immense pressure on Biskra's water resources, threatening both the sustainability of groundwater reserves and the region's agricultural future and drinking water supply. Rigorous management measures, including modernizing irrigation techniques and strictly regulating wells, are critical to preserving these vital resources for future generations.

Our findings align with studies in other arid regions, such as those in Saudi Arabia and Tunisia, where overexploitation and climate change have similarly impacted groundwater resources. However, the severity of depletion in Biskra underscores the urgency of regional-specific interventions.

Artificial recharge and modern irrigation techniques are promising solutions but face challenges such as high implementation costs and infrastructure requirements. Policymakers must prioritize funding and capacity-building initiatives to overcome these barriers.

5. Conclusions

Geophysical and cartographic analysis has revealed significant groundwater level declines in Biskra, particularly in its northern and southern parts. Observed drawdowns amount to approximately 5% annually, with average reductions of 50% over a decade and reaching 300% over 44 years.

The main causes of this crisis are attributed to:

- Climate change effects,
- Agricultural expansion,
- Inefficient irrigation practices,
- The proliferation of unauthorized wells.

In response to these issues, the following recommendations are proposed:

- Conduct detailed studies on soil and irrigation water quality in wells affected by drawdown.
- Implement urgent measures to ban unauthorized well drilling.
- Raise awareness among farmers about modern irrigation techniques such as localized irrigation, sprinklers, and pivot systems to minimize water waste.
- Investigate the potential for direct artificial recharge of the Quaternary aquifer using the Continental Intercalaire aquifer.
- Develop a smart application/platform for groundwater monitoring and governance in the Biskra region.

These actions aim to ensure the sustainable management of groundwater resources while supporting agricultural and economic development in the region.

This study provides critical insights into groundwater depletion in Biskra, highlighting the need for urgent resource management measures. By integrating GIS and geophysical techniques, we have identified high-risk areas and proposed sustainable solutions. Future research should focus on monitoring long-term impacts and exploring innovative technologies to enhance water governance in arid regions.

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