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SUMMARY OF ARTICLE: HTTPS://DX.DOI.ORG/10.12795/REA.2024.I48.10

Combined impact of drought and land use changes on water resources in the Tabular Middle Atlas, Morocco

El impacto combinado de la sequía y los cambios en el uso del suelo sobre los recursos hídricos en el Tabular Atlas Medio, Marruecos

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KEYWORDS

Water resources
Drought
Irrigated areas
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INTRODUCTION

In Morocco, water resources in different regions have been the subject of several studies in recent. The results indicate a continuous decline in the piezometric level of groundwater across the Moroccan territory (Souss Massa, El Gharb, Saïs, Middle Atlas, Tadla, Chtouka, etc.). Generally, the extent of groundwater degradation varies from one region to another depending on climatic and hydrogeological characteristics and the degree of exploitation. In some areas like Essaouira, the groundwater level has decreased by varying amounts between 5 meters and 17 meters over three decades. In the Berrechid aquifer, the piezometric level continuously decreased between 1980 and 2008. In the Saïss aquifer, measurements conducted by the Sebou Hydraulic Basin Agency (ABHS) between 1968 and 2017 show a significant decrease in the groundwater table. The findings from these studies indicate that water resources have reached a critical stage. This situation may worsen in the coming years. This concerning situation in a country already facing water stress necessitates increased efforts and a deeper scientific understanding of the relationship between water, human activities, and climate change to propose adaptation strategies and water resource management measures that align with current realities and future scenarios.

This study aims to emphasize the current status of water resources in the Tabular Middle Atlas by conducting piezometric measurements in the Guigou depression and tracking changes in the water surface area of Aoua lake. Thus, a discussion of the factors contributing to the quantitative degradation of water resources will be addressed, namely climate and land use. To achieve these objectives, we adopted an approach that relies primarily on fieldwork (piezometric measurements, land use inventory, and surveys with farmers), processing of Landsat satellite images (TM, OLI, and OLI2) to extract the water surface area of Aoua lake and detect changes in irrigated areas in two sectors of the Tabular Middle Atlas (Imouzzer-Aoua

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depressions and Guigou depression), as well as the analysis of precipitation data series using the standardized precipitation index (SPI) to determine drought periods.

METHODOLOGY

The objectives highlighted in this study are addressed by utilizing multi-source and multi-date data (satellite images, climatic data, fieldwork) and following a multidisciplinary methodology. The processing of data and the application of methodological steps were based on R-statistical software and geographic information systems (GIS). The exploitation of data from various sources has allowed for outlining the situation of water resources in the Tabular Middle Atlas and providing crucial information on the factors contributing to their quantitative degradation. The methodological steps followed and the data used in this study are presented in the following sections:

- Inventory of land use and piezometric measurements.
- Satellite data processing.
- Characterization of drought.

RESULTS

In the Tabular Middle Atlas and the areas surrounding it, the condition of water resources has become very critical over the past few decades. This situation results in a worrying decline in the groundwater level (Middle Atlas Lias aquifer, Fez Meknes aquifer), a sharp drop in the flow rates of springs and streams, and a remarkable variation in the surface area of lakes. The highlighting of the water resources situation is illustrated through the analysis of data measured by the Sebou Hydraulic Basin Agency in the Tabular Middle Atlas and its environs, piezometric measurements carried out in the Guigou depression, and the detection of changes in the surface area of Aoua lake using Landsat satellite images over the period from September 1984 to September 2022.

In the Tabular Middle Atlas, groundwater levels are declining. In the lack of accurate data on the groundwater levels, we based our analysis on precise indicators collected directly in the field. We used data on well depth to illustrate the concerning situation of water resources. In the Imouzzer depression, farmers have deepened their wells, with 33% of them adding between 15 m and 20 m in depth after the initial digging. In the Guigou depression, the added depth exceeds 30 m, and most farmers have added less than 15 m. Thus, the piezometric measurements conducted by the ABHS between 1982 and 2017 indicate a significant decline in the Fez-Meknes aquifer over the past three decades. It decreased from approximately 10 m in 1982 to 40 m in 1998, with a relatively slow rate of decline during this period.

In this study, the highlighting of the groundwater resource situation in the Guigou depression is based on piezometric measurements and interviews conducted with local populations regarding the current and past state of the aquifer. Collecting data directly from the field allowed us to overcome the issue of groundwater measurement availability and to demonstrate the alarming situation of the aquifer in the Guigou depression. The responses obtained from interviews with farmers indicate the alarming decline of the Guigou aquifer since the 1980s. The deepening of wells serves as a precise indicator of the aquifer's decline. The depth of a well in 1984 was 6 m, and it increased to 89 m in 2020. The spatial distribution of the measured wells in March 2020 shows that the piezometric level varies depending on the locations, based on topographic and lithological characteristics, ranging from 7 m to 68 m. Although the water table level in the Guigou depression was very close to the ground during the 1980s, it has become profound in recent years. The continuous decline in the water table level has led to the emergence of abandoned wells in several areas of the depression.

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The monitoring of the water surface area in Aoua lake from September 1984 to September 2022 using Landsat satellite images shows that it recorded remarkable variations. From 2017 to 2022, Aoua lake experienced worrying drying, the most severe during the study period. This situation indicates that in recent years, the hydrological deficit of the lake has increased alarmingly. In the Middle Atlas region, the degradation of lakes and the decline of wetlands reflect the highly critical situation of water resources under the influence of unfavourable climatic conditions and increasing anthropogenic pressure.

The Middle Atlas and its surroundings provide a typical example of the quantitative degradation of surface and groundwater resources. Results obtained from the analysis of official data, fieldwork, and processing of Landsat satellite images indicate that water stress has reached an advanced stage. Changes in water resources offer significant indicators of climatic conditions and anthropogenic pressure. Decreasing rainfall, rising temperatures, and the gradual extension of irrigated agricultural areas in the depressions of the Tabular Middle Atlas have significantly impacted water resources. Alongside the extension of irrigated areas, the demand for irrigation water increases, especially during the summer, exerting intense pressure on groundwater aquifers. The intensification of irrigation and the continuous growth in extraction volumes in the context of rainfall deficits have widely contributed to the disruption of the hydrological regime in the study area.

CONCLUSION

The analysis of hydrological data shows that water resources in the Tabular Middle Atlas and its vicinities have been subject to remarkable quantitative degradation in recent decades. This degradation primarily lies in the decline of groundwater levels and the drying up of lakes. The critical situation of water resources in the study area is due to both natural and anthropogenic factors. Analysis of precipitation using the Standardized Precipitation Index shows a recurrence of drought periods of varying severity since the 1980s. Concurrently, with prolonged droughts, agricultural practices have undergone significant modifications. These changes are observed in several depressions, characterized by the progressive degradation of traditional land management elements and the continuous growth of modern land use practices.

The hydrological deficit observed in the study area has led to successive changes in the hydro-agricultural system as a form of adaptation to the continuous quantitative degradation of water resources. The latest phase of irrigation system development observed in the field is the emergence of water collection basins from groundwater, as in several locations within the depressions, wells have become incapable of supplying the pump for irrigation for a sufficient duration. The landscape and environmental changes in the Tabular Middle Atlas have adversely impacted local ecosystems, natural resources, and human activities. Finally, understanding the complex interactions between climate, land use practices, and water resources is crucial for developing sustainable water and local ecosystem management strategies in the Tabular Middle Atlas. Strategies considering local population needs and ensuring sustainable water management.

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