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Assessment of the Piezometric and Rainfall Levels of the Groundwater in the Angads Plain, Northern Morocco

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ABSTRACT

In Morocco, the scarcity of rainfall is linked to global warming and to the overexploitation of groundwater due to demographic and socio-economic pressures, which generates a major problem, namely a significant decline of the piezometric level. The goal of this study is to assess the piezometric and rainfall levels of the groundwater in the Angads aquifer, which is one of the most important in the Eastern part of Morocco. To do so, graphs were drawn from the piezometric data of three piezometers, namely AP1, AP2, and AP3 located respectively in the Eastern, Central, and Western part of the country, and from the rainfall data of the Oujda station during the period from 1985 to 2015. The main results revealed a fluctuation in rainfall over time, with an increase recorded in 2009. Indeed, the results of the variation of piezometric levels over the years generally showed a downward trend, especially in the area between the aquifer outlet and the Maghnia plain in Algeria, while the results of the assessment of the piezometric land rainfall levels over time generally show a downward trend. In the face of this decline, effective strategies need to be considered to protect these resources from depletion, including artificial recharge of the aquifer, wastewater reuse which aims to restore an aquifer overexploited by excessive pumping, whose drawdown is detrimental, and multi-purpose water storage.

Keywords: Piezometric level, drawdown; rainfall, aquifer, Angads, Morocco.

Introduction

To date, water availability in Morocco is very limited and could decrease significantly in the long term due to several factors,[1] namely global warming leading to prolonged periods of drought,[2] and the intensive development of urban agglomerations and agricultural and industrial activities. These factors aggravate the hydrogeological situation in the region, as well as the quality of the water[3-6]. Indeed, the scarcity of surface water resources[7,8] has led in recent years to the overexploitation of groundwater, and consequently to a drop in piezometric levels, which leads to an intensive drawdown of the aquifer.[9]Groundwater in Morocco is an important part of the country's water heritage. It is a resource intended for human consumption because it is more protected from pollutants than surface water.[10- 12.]

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Currently, Morocco is in a situation of water stress (less than 1,000 m^3/inhab/yr) and consequently, it will experience a water shortage (less than 500 m^3/inhab/yr) after 2025.[13]In addition, the scarcity of rainfall, given Morocco's climatic conditions, and the development of various activities; have made the hydrogeological situation more fragile.[14]The Angad aquifer, which is one of the most important aquifers in north-east Morocco, is vulnerable both in terms of quantity and quality. In fact, the natural recharge rate has become very low and withdrawals are only increasing.[15] This implies a drop in the piezometric levels of the aquifer due to the scarcity of rainfall over the years. Most previous studies have focused on the vulnerability and quality of the Angads water table,[16,17] but this work takes a different approach, assessing the piezometric and rainfall levels of this water table over recent years in order to consider an effective strategy and rational management aimed at protecting this vital resource.

Materials and Methods

Presentation of the study area

The Angads aquifer is part of the Angads plain (Figure 1), which extends to the Algerian border, over 460 km².[18, 19,20] This aquifer is bordered to the north by the Beni Snassen chain, to the south by the Jbel Hamra, to the west by the Jbels Megrez and Tarraza, and to the east, extends into Algeria up to the Maghnia plain. [18, 21]The hydrographic network of the study area is mainly made up of the Isly wadi and its tributaries, the main ones being the Sedra, Nachef, Tiouli, Es SafSaf, Taouslet, and Fekrana.

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Study design and sampling

The Angads water table is located at the eastern end of the Taourirt-Oujda corridor. Due to the shortage of groundwater linked to global warming and due to demographic and socio-economic development, this study aims to determine the current state of this aquifer in the face of all these constraints, based on the evaluation of the piezometric and rainfall levels over time. To do this, several piezometric measurements were carried out on three piezometers distributed over the study area, namely AP1, AP2 and AP3, located respectively in the east, in the center; and in the west. These measurements were carried out every month between 1985 and 2015. The choice of these piezometers is linked to the fact that they are the most used ones for human consumption and irrigation in the Angads plain. On the other hand, rainfall measurements at the Oujda station were carried out monthly over the 2000-2015 period. Indeed, this work was carried out on a database obtained from the Moulouya Hydraulic Basin Agency. Furthermore, the geographical coordinates of the piezometers were conceptualized using a GPS (GARMIN - GPSMAP64s).

Data analysis method and mapping

The piezometric and rainfall data were used to draw up graphs showing two assessments, the first one relating to annual and monthly rainfall and the second one relating to the piezometric level as a function of rainfall using Microsoft Excel. In addition, a map shows the hydrographic networks and the location of the piezometers using a geographic information system. This tool makes it possible to anticipate risks, to manage a lot of information on objects, to store data in a clear manner, to definitely know the nature of the phenomena, to create quick maps, and to locate them in time and space.

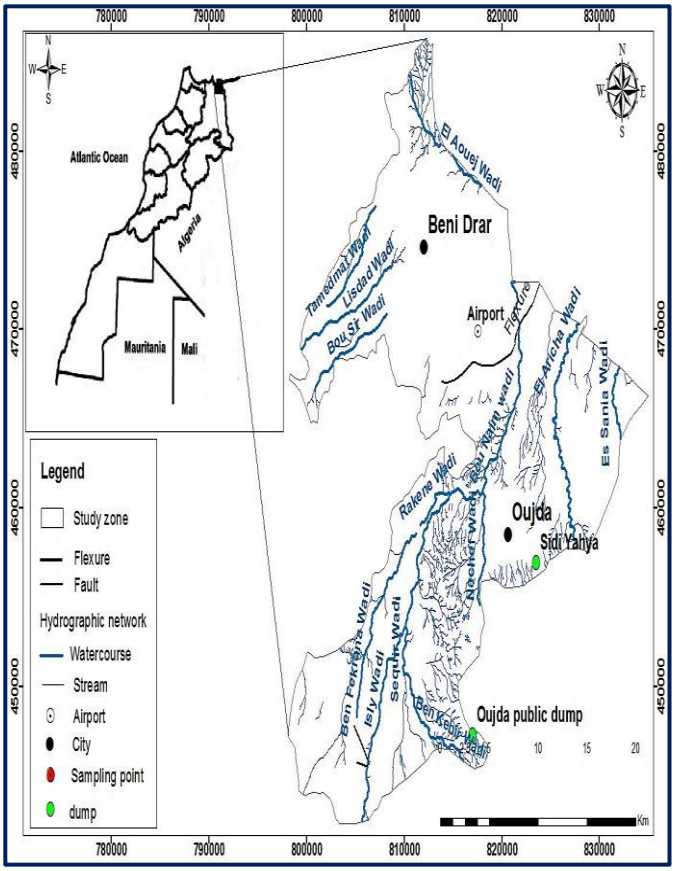

Figure 1: Presentation of the Angads aquifer, Morocco.

Results and Discussion

Rainfall trends

In the Angads plain, where the Angads aquifer is located and where agriculture is the main activity, inter-annual variations are determined based on an analysis of annual rainfall over the period ranging from 2000 to 2015 in the Oujda station (Figure 2). The rainfall values recorded over this period range from 0.00 mm to 137.10 mm, with an average of 23.21 mm and a standard deviation of 26.36. The results in this figure show a fluctuation in rainfall over time, with the lowest figures recorded in 2005 and the highest in 2009.

Figure 3 shows the variation in average monthly rainfall recorded at the Oujda station over the same period. The results show that the months with the highest rainfall are October, November, December, January, February; and March, while the months with the lowest rainfall are June, July; and August.

From these analyses, one can deduce that rainfall decreases over time. This study has been confirmed internationally by a previous study in the deep aquifer of North Gafsa.[22] The results of this study showed that low rainfall results in low natural recharge of this deep-water table, and consequently a significant drop in the piezometric level, particularly downstream of the plain, with a drawdown varying between 2 and 6 m, and that rainfall generally tends to decrease over the years.

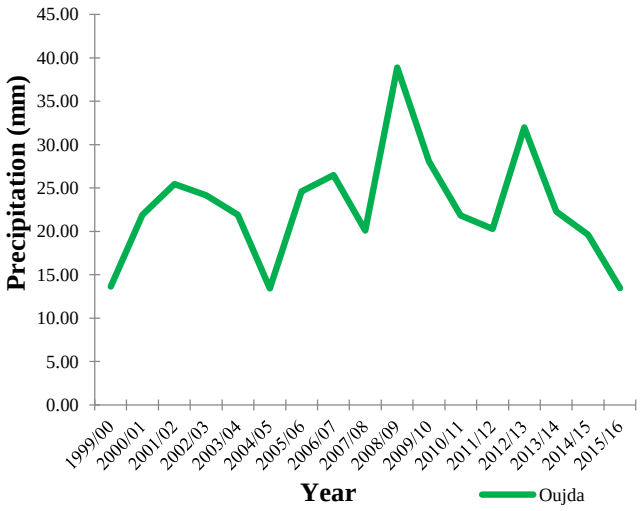

Figure 2: Variation in mean annual precipitation at the two Oujda weather stations over the 1999-2016 period.

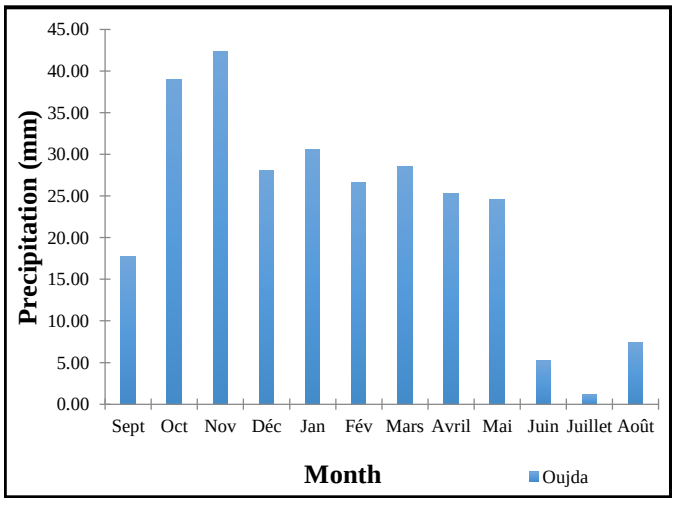

Figure 3: Variation in average monthly precipitation at the Oujda weather station during the 1999-2016 period.

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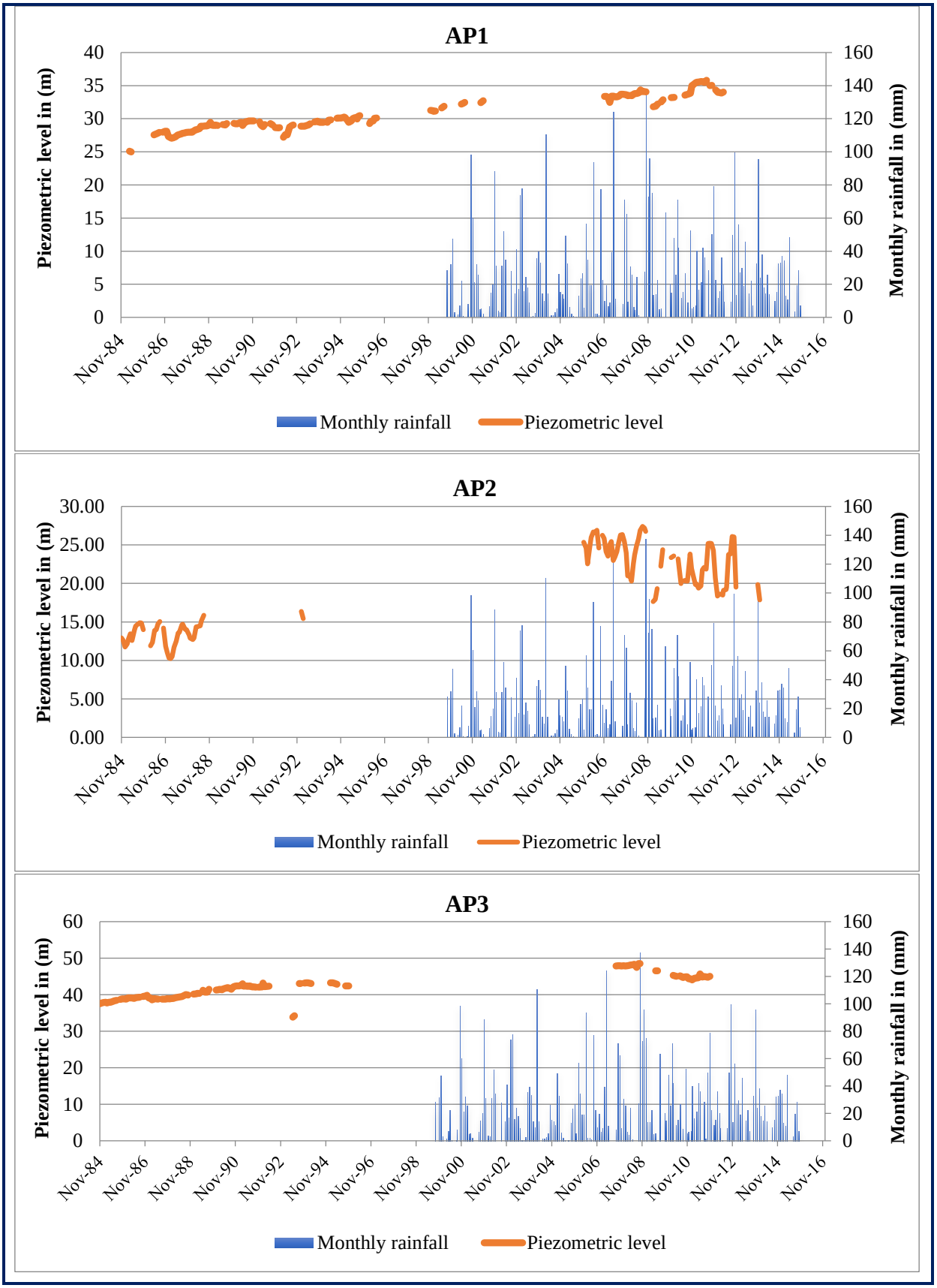

Figure 4: The variation of piezometric and rainfall levels of the Angads (Morocco) aquifer, as a function of time during the period between 1984 and 2016.

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Assessment of the piezometric and rainfall levels

Figure 4 below illustrates the variation in piezometric levels in the three piezometers AP1, AP2, and AP3, located to the east, center, and west respectively, as a function of rainfall over time. The results showed that the piezometric levels of these three piezometers generally tend to decrease over time. This decrease is more marked in the AP2 piezometer, which reaches a level of 10.25m, but in the AP1 piezometer, the piezometric level reaches 25m, while in the AP3 piezometer, the piezometric level reaches 33.87m. We also note that the piezometric level varies in proportion to rainfall in certain years, namely 2000, 2001, 2008, and 2011 for piezometer AP1, and 2007, 2008, 2011, and 2012 for AP2, and the years 2008, and 2011 for AP3 in. However, for the other years, the piezometric levels vary conversely.

These results showed that the variations in piezometric and rainfall levels as a function of time for the three piezometers AP1, AP2 and AP3 vary proportionally and inversely from one year to the next. This means that there is another source of water supply, namely the Bouhria water table, which is connected to our study area, which explains the increase in the piezometric level of AP3 compared with the other piezometers, given its location in the area where the aquifer is recharged by the Bouhria water table. The two piezometers AP1 and AP2 are located in the outflow zone of the aquifer towards the Maghnia plain in Algeria, which justifies the decreases in these piezometric levels.

In addition, other factors have contributed to these declines, namely: (a) the overexploitation of the aquifer due to the increasing demand for groundwater in the various sectors, whether agricultural, industrial; or domestic water; (b) the scarcity and irregularity of rainfall in the Angads plain, resulting in low natural recharge of the aquifer; and (c) the low permeability of the various geological formations located above this aquifer.

Indeed, at the national level, these results are similar to previous studies, in particular the study carried out in the Essaouira basin (Morocco).[23] Based on a series of piezometric maps produced over the 1990-2016 period, this study showed that piezometric levels are falling, especially in dry years such as 1995. Similarly, the study carried out in the N'fis sector in the central Haouz region near Marrakech (Morocco) showed a continuous drop in the piezometric level in the area irrigated by excessive pumping.[24]

Another international study on the Perche sands aquifer by Pelletier showed a regression on seven piezometers representing three major aquifer formations.[25] Another study carried out on the deep aquifer of Gafsa Nord showed that there is no correlation between rainfall and piezometry; and that rainfall generally tends to decrease over the years.[22]

Conclusion

This study presents, for the first time, an assessment of rainfall and the piezometric level of groundwater in the Angads plain over the period ranging from 1985 to 2015. The results of this study revealed a variation in rainfall over time, with the highest levels recorded in 2009 and the lowest levels in 2005. The results of variations in piezometric levels generally showed a downward trend. As for the assessment of piezometric levels and rainfall over this period, the results showed a decrease over the years. In the face of all these constraints, it is high time to find appropriate solutions to preserve Morocco's underground resources, including by recycling or reusing wastewater, and by artificially recharging the aquifer, which aims to restore an aquifer that has been overexploited by excessive pumping and whose drawdown is harmful.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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