Assessment of Groundwater Storage Trends in the Jel Aquifer (Guercif Basin, Morocco) Using GRACE Data and Innovative Trend Analysis

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Abstract

This study provides an in-depth examination of groundwater storage (GWS) dynamics within the Jel aquifer, located in the Guercif Basin of northeastern Morocco, over an extended period from 2002 to 2023. In response to intensifying water stress exacerbated by climate variability and the growing demand for irrigation, this research integrates satellite data from the GRACE (Gravity Recovery and Climate Experiment) mission with the Innovative Trend Analysis (ITA) statistical method. The primary objective is to quantify terrestrial water storage (TWS) anomalies while accounting for soil moisture and precipitation variations to isolate the specific groundwater signal. The methodology relies on processing GRACE data coupled with FLDAS models, effectively overcoming the lack of continuous in situ piezometric data in this semi-arid region. The findings highlight a critical decline in groundwater resources, with 40% of monitoring sites exhibiting significant downward trends and 60% of the areas identified as being in a state of severe depletion. Although the overall maximum loss rate was estimated at 0.20 cm/year, the application of the ITA method identified complex and non-monotonic trends, particularly in monthly precipitation, which traditional Mann-Kendall tests had failed to detect. The temporal analysis reveals three distinct phases: a moderate decline between 2002 and 2008 (-0.36 cm/year), a brief recovery period between 2008 and 2013 (+0.45 cm/year) following surplus rainfall episodes, and finally, a phase of accelerated depletion from 2013 to 2023 (-1.02 cm/year). A robust correlation ($r > 0.75$) between precipitation deficits and TWS anomalies underscores the profound impact of recurrent droughts on natural recharge. In conclusion, these results demonstrate the unsustainable nature of current exploitation patterns and emphasize the urgent need for implementing adaptive water management strategies, such as artificial aquifer recharge or strict regulation of agricultural pumping, to safeguard water security in semi-arid Mediterranean regions.

Keywords: Groundwater, GRACE Mission, Innovative Trend Analysis (ITA), Guercif Basin, Climate Change.