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Research Article

Temporal and spatial modeling of underground water level using Kriging models and Artificial Neural Networks (case study: Minab Plain)

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Abstract

Introduction

Groundwater resources constitute a significant portion of the world's water supply, and their management is crucial, especially in arid and semi-arid regions. Rapid population growth, agricultural expansion, and insufficient surface water availability have led to increased groundwater extraction, resulting in declining water tables and depletion of aquifers. In these dry regions, where rainfall is scarce, groundwater is vital for sustaining life. Therefore, effective management of groundwater resources is essential. This study aims to model the spatial and temporal dynamics of groundwater levels in the Minab plain. To assess the impact of excessive groundwater extraction, data from observation wells and hydrogeological information over a 17-year period (1997-2014) were analyzed. The study utilized both kriging geostatistical methods and Radial Basis Function (RBF) neural network interpolation techniques to evaluate groundwater level fluctuations. By employing time series analysis through the Mann-Kendall test, the research examined the trends in groundwater levels during the specified period. The results indicated a consistent declining trend in average groundwater levels, with the simple exponential kriging method exhibiting the highest accuracy among the models tested. The study concluded that groundwater depletion in the Minab plain is spatially heterogeneous, with significant variations in water level changes across different regions.

Materials and Method

This research adopts an applied approach with a descriptive-analytical framework. Data from 38 observation wells over the period of 1997 to 2014 were utilized, focusing on groundwater levels and hydrogeological characteristics. The study involved the calculation of spatial positions and average water levels from the observation wells. To interpolate groundwater levels across the Minab plain, both kriging and RBF neural network methods were employed. The Mann-Kendall test was applied to analyze temporal trends in groundwater levels, and the spatial-temporal modeling was conducted for the years 1997 to 2014. The kriging methods used included spherical, circular, and exponential models, while RBF neural network models were

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also developed for comparison. The spatial interpolation results were visualized using ArcGIS software, allowing for comprehensive analysis of groundwater level changes.

Results and Discussion

The spatial interpolation results indicated a significant decline in groundwater levels across the Minab plain. The average groundwater level trend showed a steady decrease over the years, with some periods exhibiting slight increases due to rainfall variations. The kriging method, particularly the simple exponential model, demonstrated the highest correlation coefficient ($R^2 = 0.89$), indicating its effectiveness in modeling groundwater fluctuations. In contrast, the RBF method, specifically the completely regular spline model, yielded a lower correlation coefficient ($R^2 = 0.67$). The Mann-Kendall test revealed a significant declining trend in groundwater levels, particularly in the eastern regions of the study area, which experienced the most severe reductions. The spatial distribution of groundwater levels was heterogeneous, with certain areas showing more drastic changes than others.

Conclusion

The findings of this study highlight the critical state of groundwater resources in the Minab plain, emphasizing the need for effective management strategies to address the challenges of groundwater depletion. The research demonstrates the utility of advanced modeling techniques, such as kriging and neural networks, in assessing and predicting groundwater level fluctuations. The results indicate a persistent declining trend in groundwater levels, underscoring the importance of monitoring and managing these vital resources. The study advocates for the implementation of sustainable groundwater management practices, including public awareness campaigns and policy interventions, to mitigate the impacts of over-extraction and ensure the long-term viability of groundwater supplies in arid regions like Minab.

Conflict of Interest

The author declares no conflict of interest regarding the authorship or publication of this article.

Data availability statement

The data and results used in this research will be available through correspondence with the author.