TIME SERIES ANALYSIS OF GROUNDWATER LEVELS USING GEOGRAPHIC INFORMATION SYSTEMS IN AL AIN REGION, IN THE UNITED ARAB EMIRATES

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ABSTRACT: Management of groundwater recourses has been one of the most critical challenges facing human beings in the past few decades. Mapping groundwater levels and fluctuations provide a valuable source of information for various applications of human and urban activities as well as their impact on the environment. Al Ain region in the United Arab Emirates has been facing serious problems with the depletion of its groundwater resources in the past few decades. This problem has been intensified by the rising urban population, and expansion in agricultural activities. It has been judged to be prudent to continuously monitor groundwater levels from different observations well. Such study shall be useful for integrating water resources management, planning groundwater development, and sustainable water resources for agricultural and urban utilization. The water table levels from different observation wells around Al Ain city were interpolated using stochastic interpolation techniques to predict the spatial distribution of water levels for the period between 2014 to 2017. It has been observed that groundwater level ranges from 2 m inside Al Ain city to 154 m at Remah district western of Al Ain city. The fluctuations of the groundwater level during the mentioned period will be presented and discussed. Furthermore, the study will provide the necessary steps in generating a hydrogeological model for sustainable water resources management.

1. INTRODUCTION

Groundwater is considered as the major source for water in arid and semi-arid zones. These zones face a problem of drawdown in groundwater level due to either overexploitation or limited sources of recharge. Growing population, increasing cultivated areas, and other human uses of water (industrial, residential, etc.) are the main reasons for overexploitation of the groundwater resources.

The United Arab Emirates is located at the southeastern part of the Arabian Peninsula between latitudes 22˚ 50′- 26˚ 4′ N and longitudes 51˚ 5′ - 56˚ 25′ E. It forms a major part of the Arabian Peninsula which is one of the driest places on earth with an average annual rainfall of less than 200 mm. Groundwater resources have historically been the primary source of water for human and animal use and for limited scale agriculture. With the recent urban development desalinization has been a major water resource, particularly for urban and industrial use, however. Groundwater use is still vibrant and continuously used in rural areas and for dates and vegetable plantations. With limited groundwater recharge, proper management of groundwater is extremely important.

Management of the groundwater resource became one of the highest demands to establish a sustainable water management resource. Mapping drawdown in groundwater can provide valuable information for various applications of human and urban activities and their impacts on the environment. Investigating groundwater fluctuations can be performed through combining concentration maps of groundwater level. This is particularly so with the UAE high population growth and increasing of agriculture activities. Al Ain region is located in the southeastern part of the country with an average precipitation of 100 mm per year and evaporation rate of 2-3 m per year (Mohamed, 2014), also it has historically been an oasis where the use of groundwater resources is still vibrant.

In recent years deterministic and stochastic interpolation techniques have been utilized to predict the spatiotemporal variability of water table levels inside the GIS environment (Zhou, 2013). The benefit of using a GIS environment that is providing better use of interpolation techniques to predict the spatiotemporal variations. This paper is focusing on finding the variations of water table levels over space and time in the Al Ain region to provide a better understanding of groundwater dynamics in the study area.

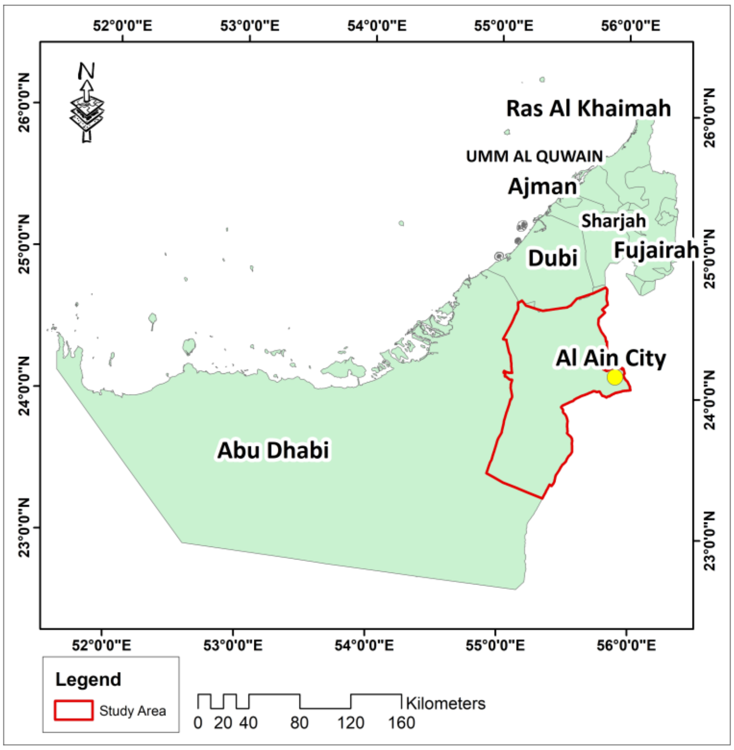

Figure 1. Location of the study area.

2. DATA & METHODS

Water wells in the study area offer information about the depth to water provided from Environmental Agency of Abu Dhabi (EAD), some of these wells are productive wells which they use for farming and some are observation wells to monitor water table dynamics. Data provided cover the period between 2014 to 2017. For the analysis minimum and maximum measurements in 2014, 2015, and 2017 have been selected.

Both stochastic and deterministic techniques create the predicted surface from close points. Stochastic interpolation methods import the spatial variability of the variable by using the spatial autocorrelation property, while deterministic interpolation methods use the values of the variable only. Stochastic interpolation techniques use both statistics and mathematical functions for interpolation, while deterministic interpolation techniques use only mathematical functions. The main methods of deterministic interpolation available in GIS software include triangulation with linear interpolation, Inverse Distance Weighted (IDW), spline and spline modified.

Stochastic techniques provide both prediction surface and some measure of the certainty or accuracy of the predictions. Kriging is a stochastic method commonly available in GIS analysis tools. Kriging is similar to IDW (deterministic method) in the main idea of weighting the neighbor known points to estimate value for each unknown point (Nayak, 2015). Moreover, the way of calculating weights is more rigorous by using not only the distance between known points but also the overall spatial arrangement of measured points.

Kriging techniques investigate the spatial autocorrelation through empirical Semivariogram to evaluate the similarity between close points. Semivariogram model is the plotting of variance between points against the distance separates these points. Empirical Semivariogram has a variety of models (Spherical, Exponential, Gaussian, etc.) that use to fit the plotting points. The best fit model should be selected carefully because it will affect the prediction surface.

Data provided from Environmental Agency of Abu Dhabi is the measurements of depth to water from the ground surface. In order to map the water level is better to convert these measurements relative to the sea level. This is done by subtracting the depth to water measurement from well elevation to calculate the water height inside the well relative to sea level.

Data have been divided into five sets as May and December in 2014, July in 2015, and May and December in 2017. Processing was performed on each group separately to produce a time series of five prediction surfaces. In order to use all available points to calculate each output pixel value, Simple Kriging was utilized. In the beginning, the semi-variogram model has been created for the first set of data. After that, the semi-variogram model has been fitted with different models and compared to select the best model that calculates the most accurate prediction surface. The best model has been selected based on Standardized Root Mean Squared (RMS), which the closest standardized RMS to one is the best fit model (Filho, 2016). Next step was using the parameters of this model (range, sill, nugget) to calculate the prediction surface. Finally, this process was applied to other data sets. Table (1) summarizes the best fit model with the standardized RMS for each dataset.

Table (1): shows the best fit model with the standardized RMS for each prediction surface.

Dataset	**Best Fit Model**	**Standardized RMS**
May 2014	Gaussian	1.01
December 2014	Spherical	0.73
July 2015	Tetra spherical	1.04
May 2017	Spherical	0.68
December 2017	Gaussian	0.85

3. RESULTS & DISCUSSION

The water table level maps (figure 2) showed a common trend at all dates, this trend shows high values for static water level at eastern and northern parts of the study area which is Al Ain city and it is surrounding, and low values at the western and southern parts at Remah and Al Wagan districts, respectively.

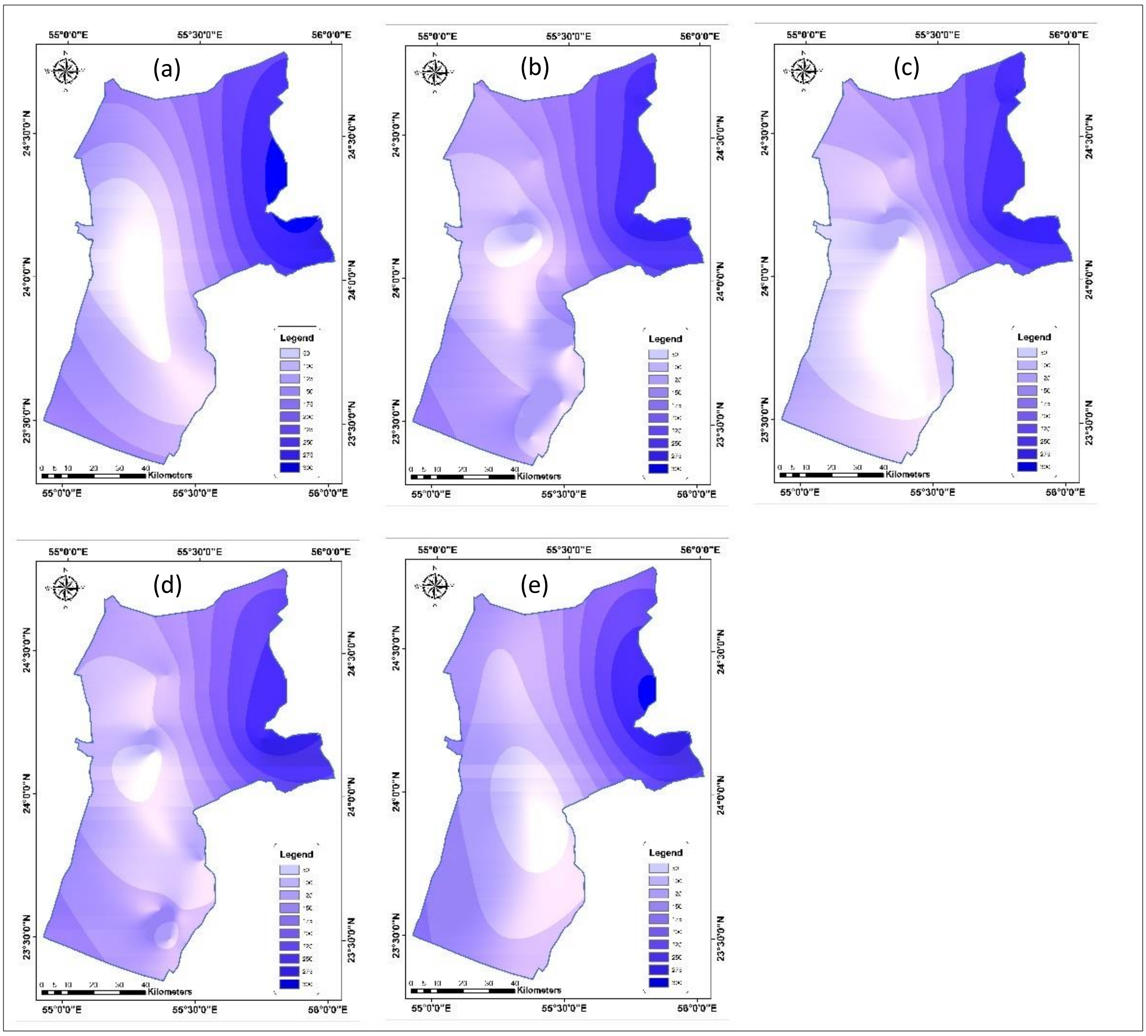

Figure 2. Shows the groundwater levels for dates mentioned above. a) May 2014, b) December 2014, c) July 2015, d) May 2017, and e) December 2017.

The water table levels have been dropped during the period between 2014 to 2017. The results showed a significant drawdown in Remah district at the western of the study area, which the static water level has been dropped from 93.44 m to 86.81 m.

Prediction surfaces from Kriging interpolation have been divided into zones starting from zone less than 50 m to more than 300 m with an interval of 25 m. The significant decrease is noticed at the zone less than 100 m, which is expanded through years of time series. The extension at this zone is showed deformed or unclear at prediction surfaces of December 2014 and May 2017, and this can be explained due to the lower standardized RMS values for both prediction surfaces (table 1).

4. CONCLUSION

Mapping groundwater levels for time series unveiled the behavior of groundwater level dynamics at the mentioned period. This behavior has a crucial role in groundwater management and the effect of groundwater overexploitation on the environment such as surface deformations. This is can be considered the first step for groundwater dynamic modeling to sustainable groundwater resources management.

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