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Comparison Between Deterministic and Stochastic Interpolation Methods for Predicting Ground Water Level in Baghdad

Abstract- *Surface interpolation techniques are usually used to create continuous data (i.e. raster data) from distributed set of point data over a geographical region. There are deterministic and stochastic (geostatistical) interpolation techniques can be used to create spatial raster surface. In this paper, the comparison between the Inverse Distance Weight (IDW) interpolation method as deterministic method and the Kriging interpolation method as stochastic method is done to determine the best performance for measuring levels of ground water in Baghdad Governorate. Spatial raster surface surfaces as ground water prediction maps are generated from each method by using average ground water level measured at 206 wells in the study area. These maps are shown spatial variation in the ground water levels and they have complete different. The IDW method results a refined map and lesser error than the Kriging method. Thus, the analysis shows that the IDW gives better real performance of measuring levels of ground water in Baghdad Governorate.*

Keywords- *Baghdad, Inverse Distance Weighting, Kriging, Spatial interpolation.*

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1. Introduction

Interpolation can be defined as a mathematical function that predicts the values at positions according to the observed values in other locations. Spatial interpolation supposes that the values of attribute are uninterrupted throughout space. This assumption permits to predict the value of attribute at any position within the boundary of space. Another assumption assumes that the attribute data are more like than the values further apart. The objective of spatial interpolations is to make raster surface that gives the topper representation for empirical fact. Thus, the selected method should be assessed for accuracy [2]. There isn't unique favoured method for interpolating data. Requirements of the algorithmic selected facts need to base on actual data, level of required accuracy, time, and computer software availability. Selecting an appropriate method of spatial interpolation is essential for analysis of surface because different interpolation methods can give different surfaces and completely different results.

2. Description of the Study Area

Baghdad Governorate lies in the middle of Iraq within the Mesopotamians Plain. It is the capital of Iraq. Tigris river passes through Baghdad city dividing it into two parts; Karkh on the west of river and Rusafa on the east of river. Baghdad city is bounded from the east by Diyala river which joins Tigris river at the southeast of Baghdad city. The Army Canal, 24 km long, recharges from Tigris river in the northern part of Baghdad city and terminates in the southern part of Diyala river [1]. The information mentioned before is shown in Figure 1.The information of two hundred six wells that were drilled by the General Commission of Ground Waters and the National Center for Water Resources Management in Iraq are used in this study; the distribution of these wells are shown in Figure 2. Most of these wells lie within Baghdad Governorate and few little lie on the border of it and nearby it. Forty-nine of 206 wells lie within Baghdad city. The static ground water level recorded at these wells are used to draw ground water contour map by using the IDW method and the NN method for Baghdad Governorate.

3. The Kriging Interpolation Method

Kriging is a local interpolation method and one of the geostatistical methods. Georges Matheron (French geostatistician) and D.G. Krige (South African mining engineer) were developed this method. This method is also known as local, exact, and stochastic method. Kriging recognizes that the simple smooth mathematical function can not be used in modelling the spatial variation of any continuous attribute value. Hence, it can be modelled as stochastic surface or random field.

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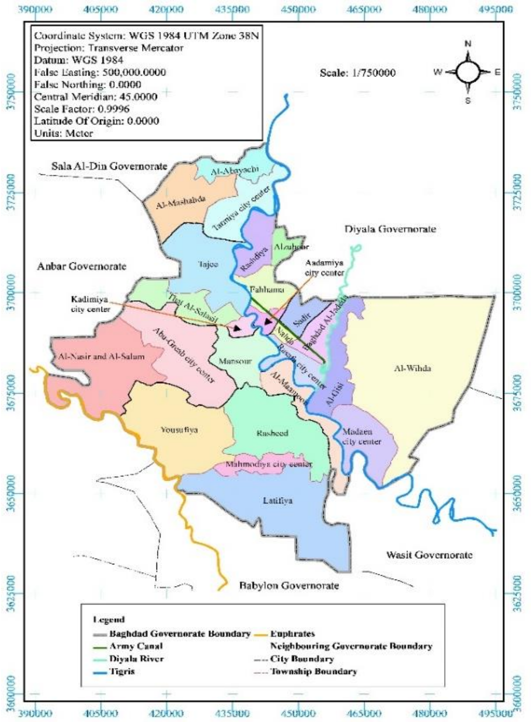

Figure 1: Map of Baghdad Governorate with its administrative regions

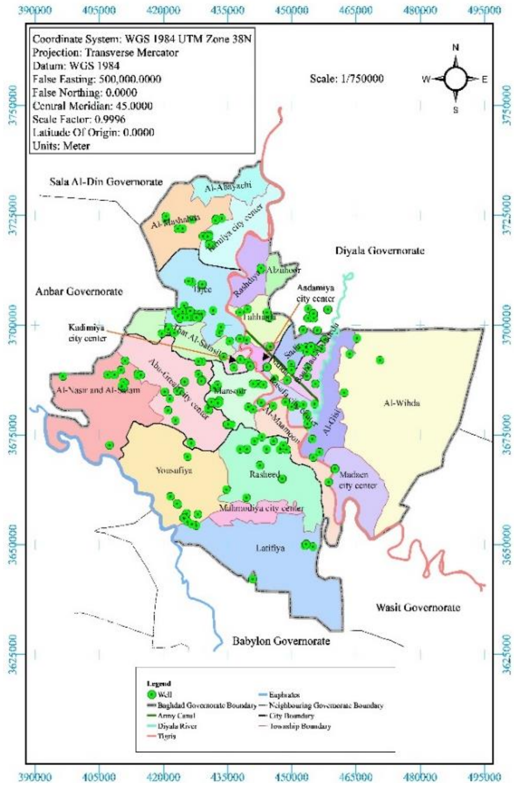

Figure 2: Distribution of wells within Baghdad Governorate

Theory of localized variable supposes that the spatial variation of any variable is expressed as a summmation of structural (having constant mean or trend), random (regionalized variable), and remainder component. Therefore, the value of random variable (Z) at x can be stated as follows [5]:

$$Z(x) = m(x) + \varepsilon'(x) + \varepsilon'' \qquad (1)$$

where Z(x) is the value of random variable at x, m(x) is a function describing the structural component, ε''(x) is the stochastic autocorrelated residuals obtained from m(x) (i.e. it is the regenerralized variable), and ε'' is a random noise component following normal distribution. Determinationof m(x) is achieved as the first step. The flat surface having no trend is decided in the simplest case where the value of mean of m(x) is within the sample area; i.e. the expected difference between the two points (x and x+h; where h is the distance between these points) is equal to zero. Thus,

$$E[Z(x)-Z(x+h)]=0 \qquad (2)$$

The variance of the differences is also assumed to be function of the distance between the points as shown in the following eqaution

$$E[\{Z(x)-Z(x+h)\}^2] = E[\{\varepsilon'(x)-\varepsilon''(x+h)\}^2] = 2\gamma(h) \qquad (3)$$

where γ(h) is the semivariance.
The original model under those two assupmtions (statianarity of difference and stationarity in the variance of differences), can be given as follows:

$$Z(x)=m(x)+\gamma(h)+\varepsilon'' \qquad (4)$$

The semi-variance can be computed from the following equation:

$$\hat{\gamma}(h) = \frac{1}{2n}\sum_{i=1}^{n}\{z(x_i)-z(x_i+h)\}^2 \qquad (5)$$

where n is the number of pairs of sample points separated by distance h.

4. Inverse Distance Weighted Interpolation (IDW)

This method is classified as one of the most readily available and simplest interpolation methods. In this method, it is assumed that the value of attribute at any point laid within the chosen area is taken equal to a weighted average values of the attributes at points over a certain distance of cut-off or from a specified number (m) of the nearest points (distinctively ranging from 10 to 30).Inverse proportional values to the power of those distances are usually having for the weights which is leading to the following estimator [4; 9]:

$$F(r) = \sum_{i=1}^{m} w_i z(r_i) = \frac{\sum_{i=1}^{m} z(r_i)/\left|r-r_i\right|^p}{\sum_{j=1}^{m} 1/\left|r-r_j\right|^p} \qquad (6)$$

where p is a parameter typically equalt to 2.Despite the fact that, this method is easy in implementing and availabale in almost GIS software, it has some well-known defects leading to reduce its practical applications [4; 6; 9]. Frequently, this method gives local extrema at the extreme points and the the local shape involved by the data does not reproduced. Many enhancements were proposed leading to type of multivariate blended IDW surfaces and volumes [6; 8; 9]. However, most of these enhancements are note implemented in GIS sotware.

5. Comparison between Ground Water Prediction Map

In this section, the interpolation methods (IDW and Kriging) are adopted by using the GIS software package ArcGIS 10.5 and ArcToolbox/ Spatial Analyst tools. The average static water level observed at 206 wells within Baghdad Governorate are used to produce the maps with the ArcMap module of the ArcGIS. The differences between predicted and observed data are computed by using root mean square error (RMSE) which is computed from the following equation [7]:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\hat{Z}(x_i) - z(x_i))^2} \quad (7)$$

where $\hat{z}(x_i)$ is the predicted value, $z(x_i)$ is the observed value, and N is the total number of data.

The raster surface generated from each IDW and Kriging interpolation method is used to predict ground water level for 206 well. Then, the RMSE is computed for each raster and the raster that gives smaller RMSE is considered as the best one in predicting static ground water level (static) in Baghdad Governorate.Figure 3 and 4 shows the spatial distribution of ground water level in the study area obtained by the Kriging (ordinary with spherical semivariogram model) Interpolation and Inverse Distance Weighting Interpolation (with power parameter p=2). It is noted that there are different between the prediction map provided by two interpolation methods (Figure 2 and Figure 3). It is indicated that the IDW method gives smoother map with lowest RMSE. RMSE statistics shown in Table 1 gives quantitative comparison of these two techniques. The best model is selected depending on the smallest root mean square prediction error (RMSE). For Kriging method RMSE is equal to 1.667 m while IDW gives RMSE equal to 0.496 m. Graphical comparisons between the actual and the predicted values for each interpolation method are also given as Figure 5 and 6.

Table 1: RMSE for ground water level for Kriging and IDW interpolation methods.

Interpolation method	RMSE (m^2)
The ordinary Kriging	1.667
Inverse distance weighting	0.496

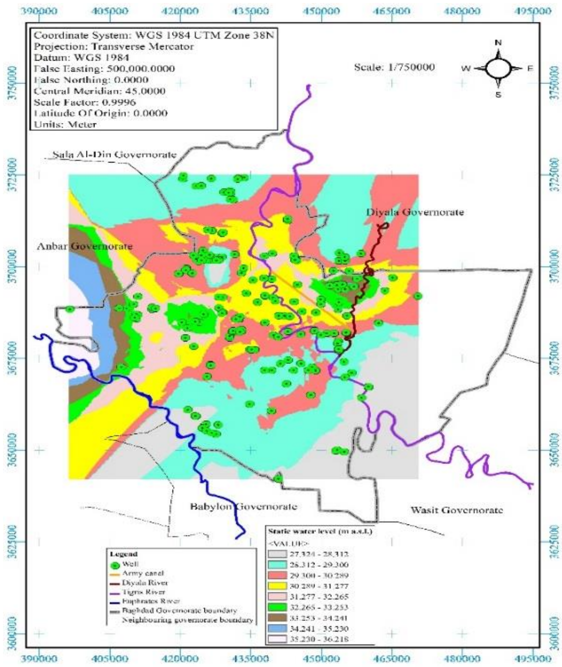

Figure 3: Prediction map of ground water level for Baghdad Governorate generated by the Ordinary Kriging Interpolation method

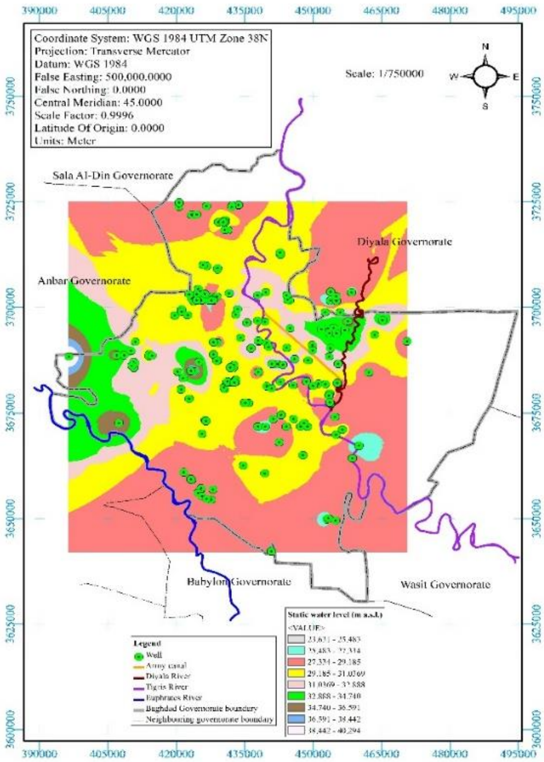

Figure 4: Prediction map of ground water level for Baghdad Governorate generated by the Inverse Distance Weighting Interpolation method

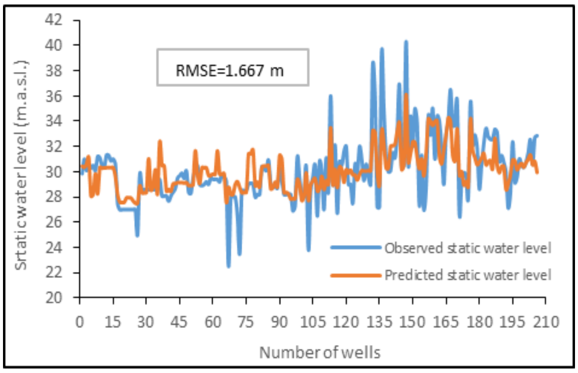

Figure 5: Comparison of predicted ground water level (SWL) in Baghdad Governorate as obtained from the ordinary Kriging method with the observed ground water level at 206 wells

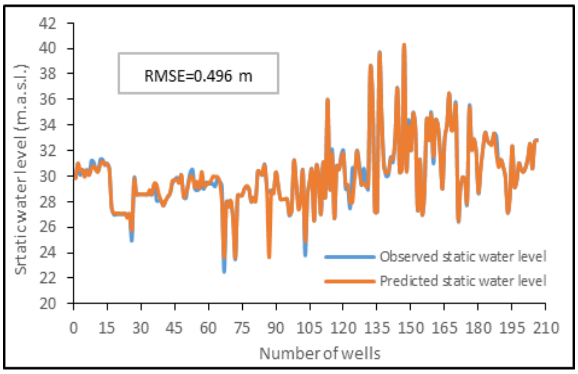

Figure 6: Comparison of predicted ground water level (SWL) in Baghdad Governorate as obtained from the IDW method with the observed ground water level at 206 wells

6. Conclusion

Ground water maps which are obtained from ground water level (static water level) data measured at 206 wells for the Inverse Distance Weighting (IDW) and the Ordinary Kriging interpolation method shows the spatial variation of level of ground water in the area of study and there are complete different. IDW interpolation method gives a smoother map. It is found that the root mean square error (RMSE) between predicted and observed ground water level (SWL) for all wells is 1.667 when using the Ordinary Kriging interpolation method and 0.496 when using the IDW interpolation method. Therefore, the IDW is considered the best method for predicting ground water level in Baghdad Governorate.

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