Evaluation of Spatial Interpolation Methods for Total Dissolved Solids Zoning using GIS, Case Study, DEHGOLAN Aquifer, Iran

1 Loghman Sajjadi and 2Maaroof Siosemarde

1Department of Civil Engineering, Mahabad Branch, Islamic Azad University, Mahabad, IRAN.
2Department of Water Engineering, Mahabad Branch, Islamic Azad University, Mahabad, IRAN.

ABSTRACT

Total dissolved solids (TDS) comprise inorganic salts and small amounts of organic matter that are dissolved in water. Assessing the quality of groundwater is important to ensure sustainable safe use of these resources. Therefore, it is extremely important to qualitatively evaluate ground water resources. This paper aimed to evaluate of spatial interpolation methods for total dissolved solids zoning of DEHGOLAN aquifer of Kurdistan province, IRAN using the Geographical Information System (GIS). Garmin GPS has been used to collect the sampling point location. In this study, analysis of 35 Wells in DEHGOLAN plain during 1994, 1997, 2002, 2005 and 2011 is represented. Overall the value of TDS decreased 9 % at study area in 2011 compared to 1994. In order to interpolate TDS parameter used IDW, RBF and Ordinary Kriging methods. In order to evaluate interpolation methods and models used statistics of MAE and RMSE. The result showed that the exponential model among Ordinary kriging and Inverse multiquadric among RBF method had the good match. In addition, In order to interpolate TDS parameter, results showed that RBF with the highest accuracy in the first place followed by Ordinary kriging and IDW as the second place.

INTRODUCTION

Water is the basic element of social and economic infrastructure. Due to rapid increase in density of population, fast urbanization, industrialization and agricultural, use the demand of water is increasing day by day. As a result ground water level and quality water is decreasing and water pollution is increasing. Assessing the quality of groundwater is important to ensure sustainable safe use of these resources. Human activities can alter the natural composition of ground water through the disposal or dissemination of chemicals and microbial matter at the land surface and into soils, or through injection of wastes directly into ground water. Describing the overall water quality condition is difficult due to the spatial variability of multiple contaminants and the wide range of indicators (chemical, physical and biological) that could be measured. Groundwater quality comprises the physical, chemical, and biological qualities of ground water. Temperature, turbidity, color, taste, and odor make up the list of physical water quality parameters. Since most ground water is colorless, odorless, and without specific taste, we are typically most concerned with its chemical and biological qualities. Groundwater is a valuable natural resource that is essential for human health, socio-economic development, and functioning of ecosystems [6 & 15].

Salinity Sources including Agriculture, Municipal, Industrial and Natural. Salinity is a measure of the amount of dissolved particles and ions in water. There are several different ways to measure salinity; the two most frequently used analyses are described Total Dissolved Solids (TDS) and Electrical Conductivity (EC). The method most commonly used for the analysis of TDS in water supplies is the measurement of specific conductivity with a conductivity probe that detects the presence of ions in water. Conductivity measurements are converted to TDS values by a factor that varies with the type of water [11 & 13].

Total dissolved solids (TDS) comprise inorganic salts and small amounts of organic matter that are dissolved in water. The principal constituents are usually the cations calcium, magnesium, sodium and potassium and the anions carbonate, bicarbonate, chloride, sulphate and, particularly in groundwater, nitrate. At
a high TDS concentration, water becomes saline. Water with a TDS above 500 mg/l is not recommended for use as drinking water (EPA secondary drinking water guidelines). Water with a TDS above 1,500 to 2,600 mg/l is generally considered problematic for irrigation use on crops with low or medium salt tolerance. Total dissolved solids are not appreciably removed using conventional water treatment processes. In fact, the addition of chemicals during conventional water treatment generally increases the TDS concentration [5]. Certain treatment processes, such as lime-soda ash softening and sodium exchange zeolite softening, may slightly decrease or increase the TDS concentration, respectively [4].

Groundwater can become contaminated naturally or because of numerous types of human activities; residential, municipal, commercial, industrial, and agricultural activities can all affect groundwater quality [8, 9 & 14]. Groundwater can be optimally used and sustained only when the quantity and quality is properly assessed [7].

GIS and remote sensing has been used extensively to assess the water quality all over the world [12]. GIS has been used in the map classification of groundwater quality, based on correlating total dissolved solids (TDS) values with some aquifer characteristics [3] or land use and land cover [1]. Nas and Berktay (2010) have mapped urban groundwater quality in Koyna, Turkey, using GIS [10]. Ground water quality analysis was carried out for Coonoor Taluk in Nilgiris District water samples were collected all around the taluk the strategically analyzed results are presented in a GIS based water quality mapping [16]. Other studies have used GIS as a database system in order to prepare maps of water quality according to concentration values of different chemical constituents [17]. Spatial variations in ground water quality in the corporation area of Gulbarga City located in the northern part of Karnataka State, India, have been studied using geographic information system (GIS) technique. The spatial database established in GIS will be helpful for monitoring and managing ground water pollution in the study area. Mapping was coded for potable zones, in the absence of better alternate source and non-potable zones, in terms of water quality [2].

The objectives of the present study including evaluate of spatial interpolation methods for total dissolved solids zoning of DEHGOLAN aquifer of Kurdistan province, IRAN using the Geographical Information System (GIS).

MATERIALS AND METHODS

The DEHGOLAN plain is situated in the east of Kurdistan province of IRAN. Total geographical area is 983 sq.km. The main sources of irrigation are wells. Ground water plays a major role for Irrigation as well as Domestic uses. DEHGOLAN plain lies between North Latitudes 38°22' and 39°25' East Longitudes 69°40’ and 74°00’. The elevation in this area is 1740 m to 2110 m. The mean annual rainfall in this area is about 332 mm and the max of annual rainfall is 634 mm and the min of annual rainfall is 83 mm. The mean annual potential evaporation in this area is about 1870 mm. The values of TDS were tested in the laboratory. The TDS parameter is given in the database to GIS. The DEHGOLAN map was scanned and digitized. The spatial variation was done. Finally, integrated ground water quality map was created using ARC GIS 9.3. Garmin GPS has been used to collect the sampling point location. In this study, analysis of 35 Wells in DEHGOLAN plain during 1994, 1997, 2002, 2005 and 2011 is represented. In order to interpolate TDS parameter, used IDW, RBF and Ordinary Kriging methods. In order to evaluate interpolation methods and models used statistics of MAE and RMSE.

The results were analyzed with statistics of Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) that calculated using equation (1) and (5) respectively, where \( O_i \) and \( P_i \) represents measured and predicted, and \( O_{ave} \) and \( P_{ave} \) represents mean values of measured and predicted respectively, and \( n \) represents the number of instances presented to the model that it is total number of training and testing pattern for training and testing step, respectively.

The RMSE statistic indicates only the model’s ability to predict away from the mean. RMSE gives more weight to high values because it involves square of the difference between observed and predicted values. The MAE provides an unbiased error estimate because it gives appropriate weight to all magnitudes of the predicted variable. The best model should be the smallest MAE and RMSE.

\[
\text{RMSE} = \left( \frac{\sum_{i=1}^{n} (P_i - O_i)^2}{n} \right)^{1/2}
\]

\[
\text{MAE} = \frac{\sum_{i=1}^{n} |P_i - O_i|}{n}
\]

Results:

Overall the value of TDS decreased 9 % at study area in 2011 compared to 1994. In order to assess the ground water quality 35 sampling points are identified throughout the DEHGOLAN plain and water samples
have been collected (Figure 1). The major water quality parameter TDS have been estimated. The tested data have been converted into spatial variation using GIS.

Fig. 1: Location of sampling wells in DEHGOLAN plain at Kurdistan province of IRAN.

The total mass of dissolved constituents is referred to as the total dissolved solids (TDS) concentration. In water, all of the dissolved solids are either positively charged ions (cations) or negatively charged ions (anions). TDS in groundwater can also be due to natural sources such as sewage, urban runoff and industrial waste. An aesthetic objective of less than 500 mg/L has been established for total dissolved solids (TDS) in drinking water. According to physical and chemical specifications of drinking water as specified by the Institute of Standards and Industrial Research of Iran (ISIRI 1053) the desirable limit of TDS is 1000 mg/L. To ascertain the suitability of ground water for any purposes, Total Dissolved Solids is essential to classify the ground water depending upon their hydro chemical properties based on their TDS Values. The average of TDS values ranges from 271.07 - 309.13 mg/l in 2002/10 and 1997/10 respectively (Fig. 2). Overall the value of TDS decreased 9 % at study area in 2011 compared to 1994.

Fig. 2: The annual average of TDS values.

In order to interpolate TDS parameter used IDW, RBF and Ordinary Kriging methods. In order to evaluate interpolation methods and models used statistics of MAE and RMSE. Table 1 showed the selected optimal models in RBF and Ordinary Kriging methods using RMSE statistic.

The result showed that the exponential model among Ordinary kriging and Inverse multiquadric among RBF method had the good match.

In addition, Table 2 showed the values of RMSE and MAE statistics of IDW, RBF and Ordinary Kriging methods.

Table 1: Selected optimal models in RBF and Ordinary Kriging methods using RMSE statistic.

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<tr>
<th>Month and Year</th>
<th>Ordinary kriging</th>
<th>RBF</th>
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<tbody>
<tr>
<td>1994 March</td>
<td>Gaussian</td>
<td>*</td>
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<td>1994 July</td>
<td>*</td>
<td>Inverse Multiquadric</td>
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<td>1997 March</td>
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<td>Inverse Multiquadric</td>
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<td>1997 July</td>
<td>Gaussian</td>
<td>Thin Plate Spline</td>
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<td>2002 March</td>
<td>Exponential</td>
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<tr>
<td>2002 July</td>
<td>Exponential</td>
<td>Inverse Multiquadric</td>
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<tr>
<td>2005 March</td>
<td>*</td>
<td>Inverse Multiquadric</td>
</tr>
<tr>
<td>2005 July</td>
<td>Exponential</td>
<td>Inverse Multiquadric</td>
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<tr>
<td>2011 March</td>
<td>Exponential</td>
<td>*</td>
</tr>
<tr>
<td>2011 July</td>
<td>Exponential</td>
<td>Inverse Multiquadric</td>
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Also Table 3 showed selected optimal interpolation methods using MAE statistic among IDW, RBF and Ordinary Kriging methods.

Table 2: the values of RMSE and MAE statistics of IDW, RBF and Ordinary Kriging methods.

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<td>IDW</td>
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<td>RBF</td>
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<td>Ordinary Kriging</td>
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Table 3: selected optimal interpolation methods using MAE statistic.

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<tbody>
<tr>
<td>IDW</td>
<td>66.97</td>
<td>47.06</td>
<td>61.61</td>
<td>39.22</td>
<td>63.02</td>
<td>44.86</td>
<td>66.73</td>
<td>50.71</td>
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<tr>
<td>RBF</td>
<td>61.74</td>
<td>44.24</td>
<td>57.21</td>
<td>37.16</td>
<td>55.57</td>
<td>41.01</td>
<td>65.01</td>
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<td>OK</td>
<td>65.99</td>
<td>47.44</td>
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<td>67.98</td>
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Results showed that RBF with the highest accuracy in the first place followed by Ordinary kriging and IDW as the second place. Figures 3 - 12 show the spatial distribution of TDS in the study area in 1994 - 2011.

Fig. 3: Spatial variation map of TDS in 1994/6.

Fig. 4: Spatial variation map of TDS in 1997/6.

Fig. 5: Spatial variation map of TDS in 2002/6.
Fig. 6: Spatial variation map of TDS in 2005/6.

Fig. 7: Spatial variation map of TDS in 2011/6.

Fig. 8: Spatial variation map of TDS, 1994/10.

Fig. 9: Spatial variation map of TDS, 1997/10.
Discussion:
Total dissolved solids (TDS) comprise inorganic salts and small amounts of organic matter that are dissolved in water. This paper aimed to evaluate of spatial interpolation methods for total dissolved solids zoning of DEHGOLAN aquifer of Kurdistan province, IRAN using the Geographical Information System. In order to interpolate TDS parameter used IDW, RBF and Ordinary Kriging methods. The result showed that the exponential model among Ordinary kriging and Inverse multiquadric among RBF method had the good match. In addition, results showed that RBF method had the highest accuracy.

REFERENCES