Spatiotemporal Variability of Groundwater Depth in Urmia Plain, Iran

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Abstract: More often scientists and researchers should be able to expand their measured point's data set to the desirable entire study area. Therefore, on the basis of available data set, a systematized method for estimating information at unmeasured locations is needed. Kriging is an interpolation method to calculate values at such mentioned points. Currently, Urmia plain with continuous depression in its groundwater depth are encountered. In this article, groundwater table depth variation at unmeasured locations were estimated on the basis of data set available from 57 observation wells during the years 2006, 2008 and 2010 using a kriging model. The results showed that in application of ordinary kriging, experimental semivariogram with the spherical model was suitable, and correlation coefficient for the fitted model was calculated to be 0.938. Also it should be mentioned that the depth of groundwater is at a deeper position in the Eastern parts and gradually decreasing to the Western part of the study area. Surface land area during the same four years that the groundwater level was decreased between 2 and 3 meters, has increased about 2800 hectares. For which in 1360 hectares of land in the mentioned plain, groundwater level declined about 28 to 30 meters, this condition did not exist previously.
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1. Introduction

Kriging is an interpolation method to calculate value at unmeasured locations. In this method we use the fitted mathematical model to the experimental semivariogram to find the optimum set of related data. kriging method is based on the intrinsic assumption (Cho and Kang, 1997). Akbari et al. (2009), used Geographic Information System (GIS), with the interpolation method for preparation of the equipotential lines and zoning maps of declined groundwater level for some aquifer in Khorasan province, the results showed that groundwater level has declined in Central and Western parts of the study area. Dehghani et al. (2009), based on their study in the Qazvin plain concluded that the Neuro-Fuzzy Inference System resulted a correlation coefficient of 98 percent with least mean square error, which was more accurate to estimate the groundwater level, than the other methods such as Geostatistics and Neural Networks. Izadi et al. (2008), showed that the Panel Data model with the combined effects had the best result to predict water level variation. In the mentioned study the performance criteria (R2=0.99 and RMSE=0.05) indicates the validity and efficiency of the used model. Moreover, according to the gained results using the Artificial Neural Network were compared and its relative superiority was confirmed. Pourtabari et al. (2010), reported that the results obtained by making use of the Intelligent Model for simulation as well as predication the behavior of groundwater level variation in compared with the Static Nervous Network models was more efficient and accurate. Zehtabyan et al. (2004), showed that the use of groundwater for irrigation in Varamin plain should be done more carefully and in an area of about 9354 hectares, depth of groundwater level was less than three meters, which in practice agricultural operations are faced with limitations if special care is not done. Kelin et al. (2005), studied the groundwater level of North China Plain, using kriging method for preparation water level zones' maps as well. Bardossy and Molnar (2004), in order to visualize the spatial distribution of the groundwater level information on the groundwater resources of Northwest Hungary, applied the interpolation methods too. Hamad (2009), applied Geostatistical analysis for groundwater level predication in the south Aljab Alakhdar area using GIS as well. As it is obvious from aforementioned case studies, applicatoin of Geostatistical methods is suitable for such water table fluctuation prediction if adequate measured data are available.

Water resources are renewable but their capacity is rather stable. The demand for water has increased rapidly. According to World Meteorological Organization, during recent decades, global demand for water becomes more than six times, while the population has been tripled (Starosolszky, 2011). As there are serious limitations in available water resources in Iran, continuing the current trend of water utilization, reduces the per capita of renewable water to less than about 1300 m3 per year up to the next 20 years, which represents the country's entry to the water stress conditions. Currently over 90 percent of West Azarbaijan province’s groundwater potential is exploited and six major plains are encountered with water deficit of 44 million m3, also continuous decline in groundwater level is reported (Anon, Water news network of Iran, 2007).

In the present study, with the aim of simulating and predicting the behavior of groundwater level changes in Urmia Plain, during three mentioned period interval was done, using Geostatistical models and comparison of the obtained results have been performed.

2. Material and Methods

Study Area

Urmia Plain is located at Northwest part of Iran, with an area of about 114317 hectares and covered the lands along the Western side of Urmia Lake. The plain is situated in coastal and low slope lands, between 44°55′ - 45°18′ east longitude and 37°20′ - 37°49′ north latitudes, in which the rivers namely: Nazloochaei, Rozehchaei, Shahrchay and Barandozchay after crossing Western highlands emerge into Urmia lake. Figure (1) shows the location map of the region in the country, province and distribution of the observation wells network.

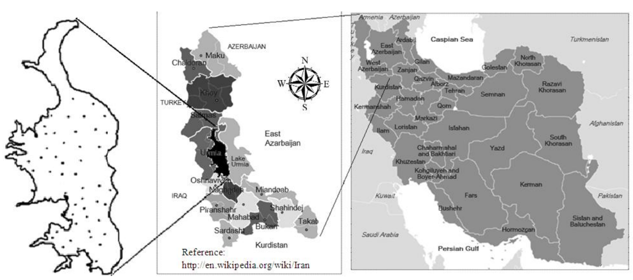

Figure 1. Location map of the region and the observation wells network in West Azerbaijan province, Iran.

Methodology

In order to estimate the variation of the groundwater behavior, the data of groundwater depths measurements taken from 57 observation wells, which are distributed in Urmia plain were used. The normality of data was tested with Shapiro-Wilk test (Shapiro and Wilk, 1965) using SPSS software, and then daily observed data were converted to annual set and treated with Geostatistical method, to evaluate the spatial distribution of groundwater depth changes. For evaluating groundwater depth, data taken from 57 observation wells during three period years, 2006, 2008 and 2010 were analyzed. Ordinary Kriging technique in GS+ software was applied to calculate the spatial changes and the assessment of groundwater depth variation. The general relationship of the mentioned method is according to following equation:

$$\hat{f}(x^*) = \sum_{i=1}^{n} \lambda i(x^*)\ f(xi)$$

In which:

$\hat{f}(x^*)$: Estimated value,

(xi) : Position of the observed points,

$f(x_i)$: The observed value,

λi : Weighting factor for the i th point, and

n : The number of measured points.

To verify the accuracy of interpolation method, Cross Validation Technique (Moore, 2007), was used. Afterwards, based on Geostatistical interpolation mathematical model for the obtained data, the groundwater depth maps for Urmia plain were provided by ARCGIS.

3. Results

The primary results indicated that the observed data set were normal. Statistical specifications of the groundwater table depth of Urmia plains are presented in Table 1.

Table 1. Statistical specifications of the groundwater depth in Urmia plain.

year	groundwater depth(meter)			Standard deviation
	Min	Max	Average	
2006	1.14	53.2	7.98	10.5
2008	1.11	53.66	8.11	10.42
2010	1.01	54.19	8.19	10.71

The result of a fitting spherical model on experimental semivariogram in ordinary kriging method of groundwater depth for Urmia plain, is shown in the Figure (2). The effect radiance of this semivariogram was determined to be 26860 meters, the nugget effect was calculated as 1 and its sill was obtained as 704.8 m2. The correlation coefficient for the fitted model was calculated equal to 0.938 (Figure 2).

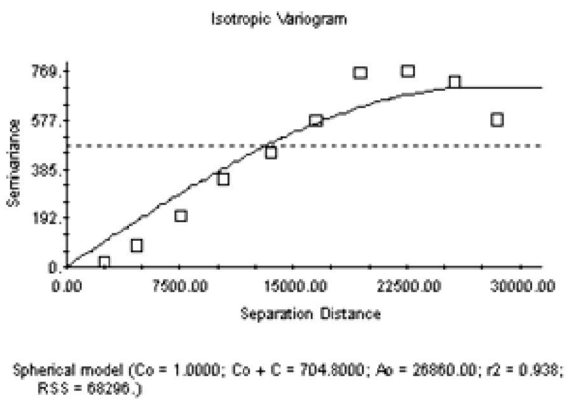

Figure 2. Experimental semivariogram of groundwater depth obtained on the basis of ordinary kriging for study area.

Cross Validation method with a correlation coefficient of 0.942 was obtained and comparing to the actual values match fairly with the predicted values, that represents the accuracy of the mathematical model to estimate the groundwater depth in unmeasured points. Based on the obtained mathematical model, the zoning map of the groundwater depth for Urmia plain during the years 2006, 2008 and 2010 were prepared (Figures 3, 4 and 5). The prepared Figures shows the spatial variations in the groundwater depth change in the study area, in which the groundwater is at a deeper position in the Eastern parts, and decreasing gradually to the Western part of the study area.

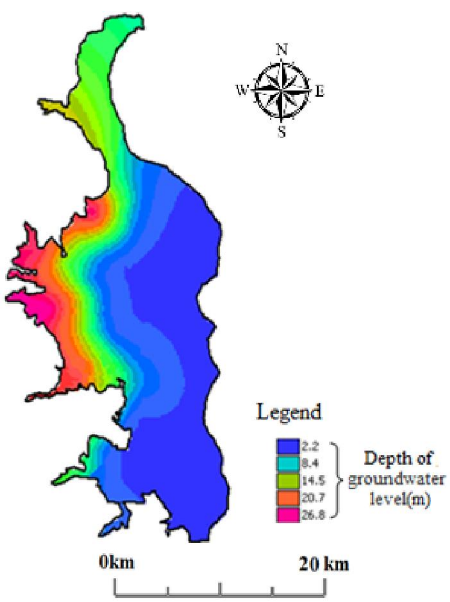

Figure 3. Zoning map of groundwater depth in Urmia plain in 2006.

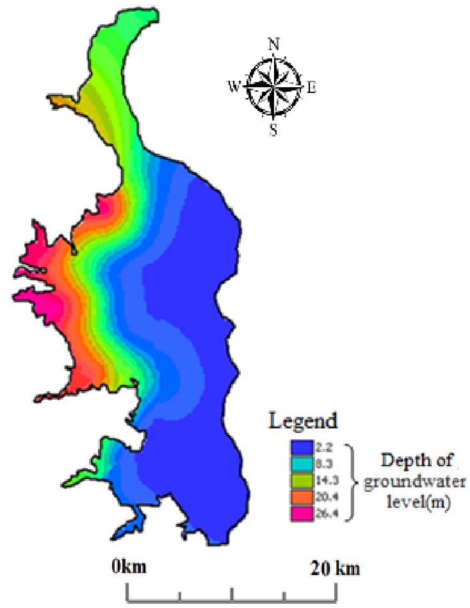

Figure 4. Zoning map of groundwater depth in Urmia plain in 2008.

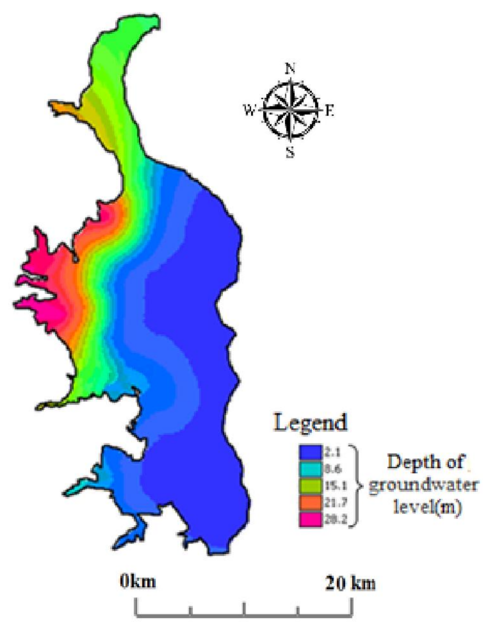

Figure 5. Zoning map of groundwater depth in Urmia plain in 2010.

Distribution histogram of covered zones of groundwater depths in Urmia plain is presented in Figure (6) and Table (2).

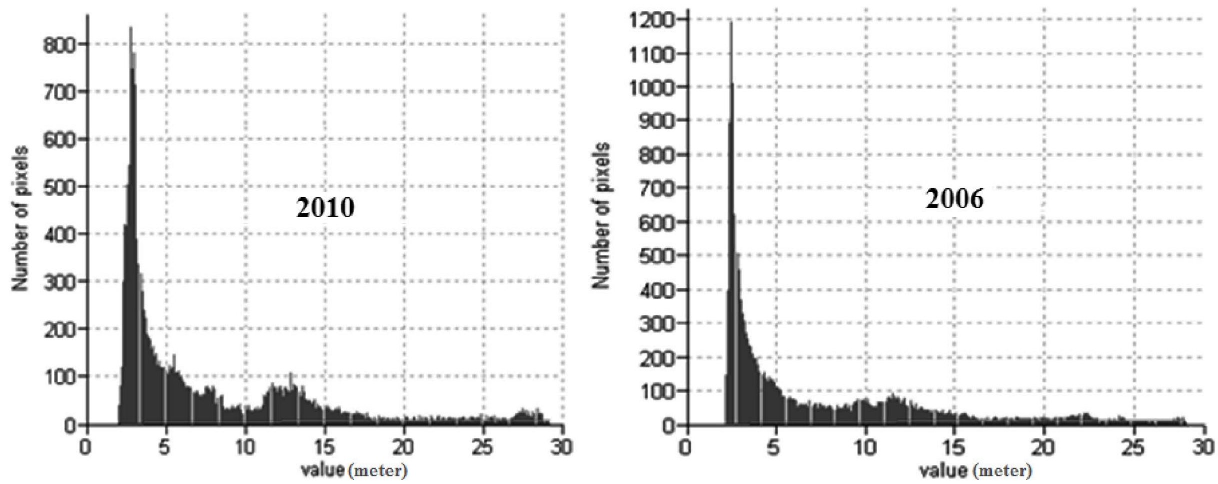

Figure 6. Distribution histogram of covered zones of groundwater depths during 2006 and 2010.

Based on the obtained results, justified lines of groundwater depth for Urmia plain is from North to South, and minimum water depth was observed in the Western part and maximum depth was in the Eastern parts of the plain as well. Total area in which during four years, groundwater depth of it declined between 2 or 3 m has increased about 2,800 hectares. Also, in 1360 hectare of lands mentioned above, water depth declined between 28 to 30 meters, which previously did not exist.

4. Discussions

Statistical and Geostatistical methods were used to investigate the variation of groundwater depths and their dynamics condition in the Urmia plain. Using statistical interpolation techniques can be reconstructed and quantified groundwater depth. Speed in calculating and avoid from the unexpected errors are the advantages of Geostatistical methods applications such as kriging. Ordinary kriging were used to interpolate different groundwater levels in three different time period interval at years 2006, 2008 and 2010. The results show that mean groundwater depths are significantly different in each time period intervals and decrease from years 2006 to 2010. On the other hand, groundwater fluctuations changed considerably. Bardossy and Molnar (2004), in order to visualize the spatial distribution of the groundwater levels information on the groundwater resources of Northwest Hungary, applied the Interpolation Methods. For this purpose, they used external-drift kriging. Subsequently we produced groundwater depth maps, which show the

Table 2. Difference between covered zones area of groundwater depth during 2006 and 2010.

water depth (m)	Area(hectare)		differences	water depth (m)	Area(hectare)		differences
	2006	2010	2006-2010		2006	2010	2006-2010
2--3	32869	30075	2794	16--17	1219	1625	-406
3--4	17488	19206	-1718	17--18	1306	1250	56
4--5	8756	8538	218	18--19	1256	863	393
5--6	5669	7263	-1594	19--20	1313	788	525
6--7	3900	4931	-1031	20--21	1338	850	488
7--8	3713	4519	-806	21--22	1588	813	775
8--9	3388	3038	350	22--23	1725	925	800
9--10	4156	2344	1812	23--24	925	894	31
10--11	4063	2169	1894	24--25	1119	956	163
11--12	5063	4400	663	25--26	819	900	-81
12--13	3869	4881	-1012	26--27	675	869	-194
13--14	2900	4300	-1400	27--28	975	1675	-700
14--15	2319	2688	-369	28--29	-	1269	-1269
15--16	1906	2194	-288	29--30	-	94	-94
				total	114317	114317	

groundwater is at a deeper depth in the Western parts of the study area. Hamad (2009), carried on a similar study and observed that deeper water level located in the Northern part of the study area and it gradually becomes shallower in the South. The main goal of this study was to investigate the pattern of a spatial distribution of groundwater depths in Urmia plain, using Geostatistical techniques. Akbari et al. (2009), using GIS, showed that groundwater depth has declined in Central and Western parts of Khorasan province up to 30 meters during the past 20 years, the average water level has declined 0.6 meters per year. Finally we obtained in our study that, Urmia plain groundwater depth has been decreased about three meters during four years from 2006 to 2010. In addition, it should be noted that in Urmia Plain groundwater level in most of the area is more than three meters which is a serious problem for the agricultural water demand in study area.

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