THE SPATIAL AND TEMPORAL VARIATION IN THE GROUND WATER POTENTIAL DUE TO URBANIZATION IN THE PESHAWAR REGIME OF PAKISTAN.

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ABSTRACT: This paper attempts to indicate the effect on groundwater potential due to increase in urbanization. The population density in the study area of Peshawar is 2,894 persons per square kilometre in 1998 and it is increase up to 4,990 persons per square kilometre in 2013. The depth of water table was interpolated by using geo statistical method of ordinary Kriging. The results shows that the increase in the population of Peshawar region increase the depth of water table more than 8 meter up to 118 sq.km which is the 36% of total study area while in 1998 the depth of water table more than 8 meter was 17sq.km which is the 5% of total study area . The decline of water table in the Peshawar region indicates that the recharging of groundwater is not sufficient to fulfill the water demands of the people of Peshawar. The decline of water causes many secio- economic problems in the region.

Keywords: Groundwater potential; Union Council (UC); Population Density; Root mean square standardise error (RMSSE); Mean standardised error (MSE)

1. INTRODUCTION:

Ground water is the main source of water supply for dinking and irrigation. The growth of population effects on the extraction of groundwater and as a result the ground water potential decreases due to less recharging rate .It is observe that the areas where there is no or less rainfall like arid and semi-arid regions ground water is used for irrigation purpose[18]. As the population increasing, people in the arid regions uses more ground water for irrigation. In arid regions the water uptake by 1 kg of grain is 1.5-2.5 m^3 while in temperate regions it is 0.5 m3 that is why the fresh water scarcity is more in arid regions due to irrigation. The areas where ground water is used for irrigation aquifers are depleting and water table decreasing at alarming rate due to droughts and irrigation [17]. The water table is decreasing at alarming rate due to irrigation in the Indo-Genetic plains in India, the North China Plain and in the south-west of the USA [18]. The geo statistics to analyse the processes relating to conservation of water resources [15]. The use of geostatistical for the determination of long term trends of ground water and conservation of water resources for sustainable development of the area [7]. The performed statistical analysis on the two years data of groundwater level and then worked on spatial analysis of groundwater level for 31 wells by using kriging [20]. The spatial-temporal variation of regionalized variables by using interpolation methods and introduce the time is another spatial dimension and he treat time is an independent from the spatial dimensions [10]. The DEM can be used to estimate the depth of water table in aquifer systems and predict that the topography of earth effects the depth of water table and they are interrelated [4].Kriging method is use to estimate the water level and the cross validation can be used to evaluate the performance of kriging method and it is observe that the high standard deviation occurred in kriged points revealed low network density areas [14]. The non-linear kriging method and geo statistics can be used to determine the critical conditions of salinization of farmland [21]. The suitable sampling of ground water are required for the study of temporal variogram and the monitoring of groundwater well contamination [22].

STUDY AREA:

Peshawar is the metropolitan city and the provincial capital of Khyber Pakhtunkhwa (KPK). It is an old historical city and the hub for commercial, industrial, social and political activities in the north-western region of Pakistan. Peshawar is the largest city of the Khyber Pakhtunkhwa and it is situated close to the Pak-Afghan border at an altitude of 359 m (1,178 ft.) above mean sea level. Geographically Peshawar is located between 33° 44′ to 34° 15′ Northern Latitude and 71° 22′ to 71° 42′ East Longitude in the south western part of Peshawar valley. It is located about 160 km from Islamabad, the Federal capital of Pakistan and about 48 km from the historical Khyber Pass leading to Afghanistan border. Peshawar is linked with other parts of the country by roads, rail and air. This city has tremendous historical, military, economic and political importance. The study area for the Peshawar consists of 67 UCs with a total area of 330 sq.km Out of 67 UCs, 45 are located in the urban areas whereas 22 belong to the rural areas. The basis for distinguishing between the urban and rural UCs was the population density. A UC with population density of more than 50 persons per ha was classified as urban while the UCs having population density less or equal to 50 persons per ha were taken rural

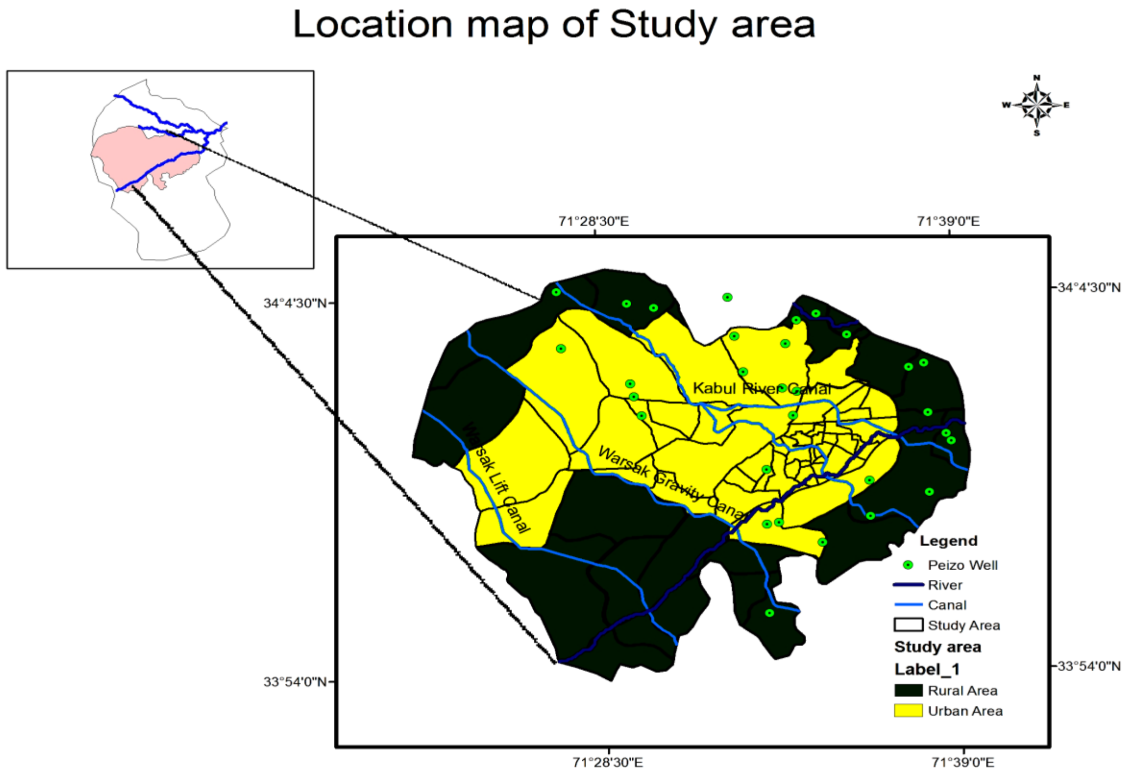

Figure1: Study area of Peshawar.

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2. MATERIALS AND METHODS

The data of ground water depth of 30 wells from 1998 to 2013 within the study area were used to study the Spatial and temporal variation in ground water table of Peshawar due to urbanization. The study was done by using geostatistical ordinary kriging method for interpolation of the depth of water table in ArcGIS 10.2. The geostatistical semivariogram is used to quantify the differences between sampled data values in the terms of separation distance h. In practice the semivariogram γ*(h), is calculated as follows:

$$\gamma^*(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [z(x_i) - z(x_i + h)]^2$$

Where $N_{(h)}$ is the number of sample pairs that are separated by a vector h, and z(x*i*) and $z(x_i+h)$ are the values of the variable z at locations x*i* and x_i+h, respectively. However, for kriging analysis, an appropriate theoretical model should be used to fit the experimental data.. The spherical model used in this study is defined as follows:

$$\gamma(h) = \begin{cases} C_o + C\left[\frac{3}{2}\frac{h}{a} - \frac{1}{2}\left(\frac{h}{a}\right)^3\right] & h \le a \\ C_o + C & h > a \end{cases}$$

Where C_0 is the y-axis intercept (the “nugget effect”), C_0+C is equal to “sill”, which represents the range of influence.

2.1 Ordinary Kriging:

Ordinary Kriging assumes that the mean is stationary but unknown. In addition, the Ordinary Kriging estimator is defined as follows:

$$z^*(x_o) = \sum_{i=1}^{n(u)} \lambda_i z(x_i)$$

With

$$\sum_{i=1}^{n(u)} \lambda_i = 1$$

Where z*(x*0*) is the Ordinary Kriging estimator at location x_0, z(x*i*) is the observed value of the variable at location x*i*, λ_i is the weight assigned to the known values near the location to be estimated and n(u) is the number of neighbouring observations. The values of λ_i are weighted to obtain a sum of unity, and the error variance is minimized as follows:

$$\begin{cases} \sum_{i=1}^{n(u)} \lambda_i \gamma(x_i, x_j) - \mu = \gamma(x_i, x_o) \\ \sum_{j=1}^{n(u)} \lambda_j = 1 \end{cases} \qquad j = 1, \dots, n(u)$$

Where μ is the Lagrange coefficient for minimizing the ordinary Kriging estimation variance, γ(xi, x_j) is the average semivariogram value between the observed values and $\gamma(x_i, x_0)$ represents the average semivariogram value between the location xi and the location to be estimated (i.e., x_0).The Ordinary Kriging estimation variance (or standard deviation) can be used as a measure of the estimation uncertainty as follows:

$$\sigma^{2*}(x_o) = \sum_{i=1}^{n(u)} \lambda_i \gamma(x_i, x_o) + u$$

2.2 PERFORMANCE OF MODEL:

The performance of model is evaluated by determining the mean standardized error and root mean square standardized.

- **Mean Error:** It is the averaged difference of observe and Estimated values.

$$\frac{\sum_{i=1}^{n}\left(\hat{Z}(\mathbf{s}_i) - z(\mathbf{s}_i)\right)}{n}$$

- **Root Mean Square Error:** it is shows how closely model predicts the measured values. The smaller this error, the better.

$$\sqrt{\frac{\sum_{i=1}^{n}\left(\hat{Z}(\mathbf{s}_i) - z(\mathbf{s}_i)\right)^2}{n}}$$

- **Average Standard Error:** The average of the prediction standard errors.

$$\sqrt{\frac{\sum_{i=1}^{n}\hat{\sigma}^2(\mathbf{s}_i)}{n}}$$

- **Mean Standardized Error: (MSE):** The value MSE should be closer to zero.

$$\frac{\sum_{i=1}^{n}\left(\hat{Z}(\mathbf{s}_i) - z(\mathbf{s}_i)\right)/\hat{\sigma}(\mathbf{s}_i)}{n}$$

- **Root Mean Square Standardized Error (RMSSE):** Its value should be close to one. If RMSSE is greater than one then there is underestimating. If RMSSE is less than one then there is overestimating.

$$\sqrt{\frac{\sum_{i=1}^{n}\left[\left(\hat{Z}(\mathbf{s}_i) - z(\mathbf{s}_i)\right)/\hat{\sigma}(\mathbf{s}_i)\right]^2}{n}}$$

3 Results and Discussion

The population of Peshawar region have increasing trend of urbanization in the KPK. The population of Peshawar is 1.1 million according to census report 1981 and it becomes 2 million in 1998. The increase in the population of Peshawar region increase demands of ground water .The average density of population in the study area of Peshawar region is 2,894 persons/Km^2 in 1998 and the average population density becomes 4,990 persons/Km^2 in 2013 as shown in table1. The population densities of the union councils were further classified into following 6 categories.

- Class1: Below 5,000 persons /km^2.
- Class2:5,000-10,000 persons /km^2.
- Class3:10,000-30,000 persons /km^2.
- Class4:30,000-60,000 persons /km^2.
- Class5:60,000-100,000 persons /km^2.
- Class 6: Above 100,000 persons /km^2.

The variation of population density in the study area from 1998 to 2013 is shown in figure2 and figure3. The population density in 2013 is nearly two times of 1998. In the central parts .In the study area the population density increased in the central part and it is expected to gradually expend more towards east. The union councils on the east side will become more populated compared to other sides. The growth in the population of Peshawar region from 1998 to 2013 demands the extraction of more ground water and it is observe that the ground water depth going to be decrease very rapidly in the urban region of Peshawar which will not sustain for future demand.

Table 1: Population Density of study area

UC's	1998		2013	
	Population (persons)	Density (Persons/km^2)	Population (persons)	Density (persons/km^2)
Urban	982,816	5,933	1,694,937	10,231
Rural	513,108	1,461	884,892	2,519
Total	1,495,924	-	2,579,829	-
Average Density	-	2,894	-	4,990

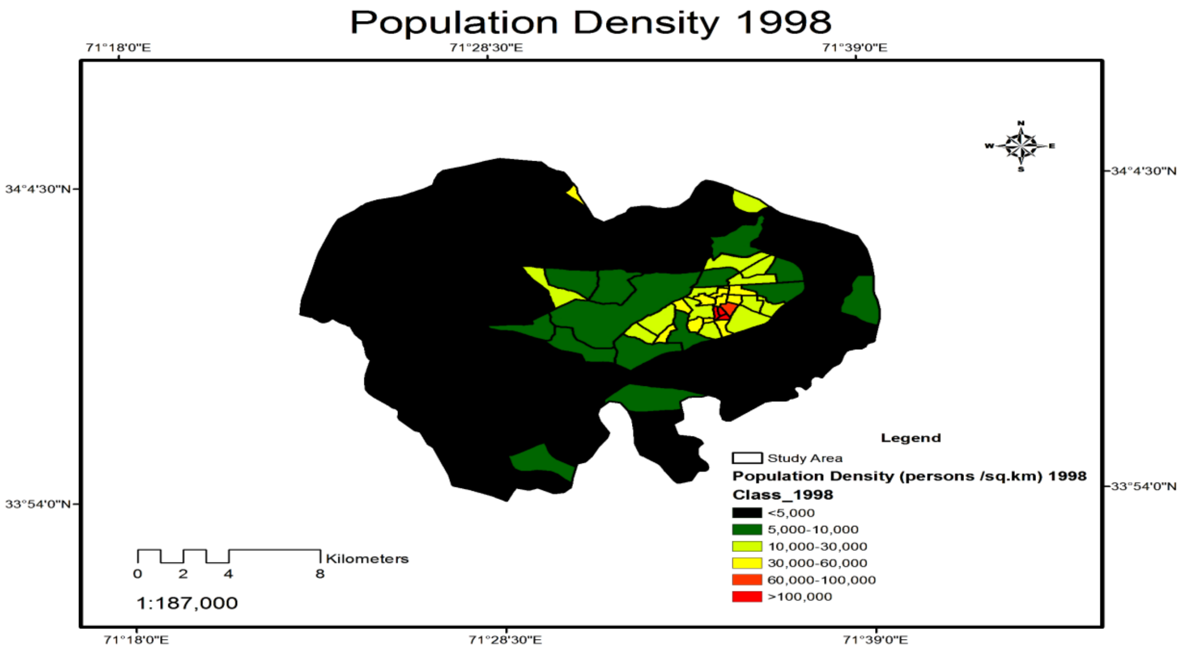


Figure2: Population Density of study area in 1998

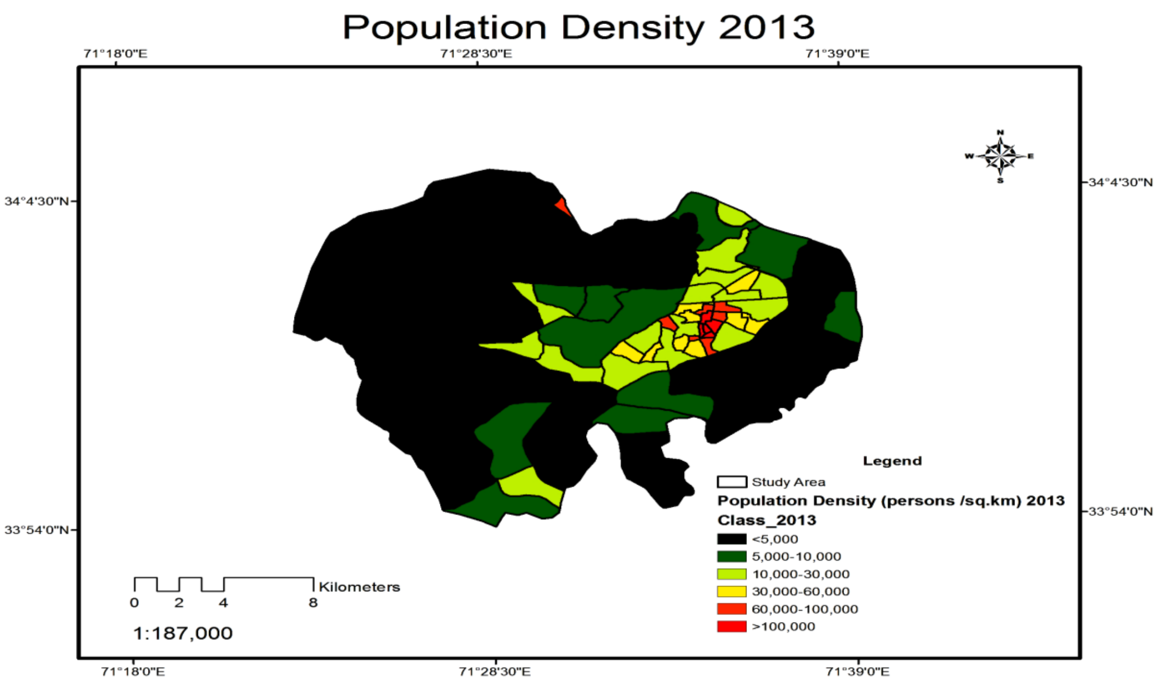
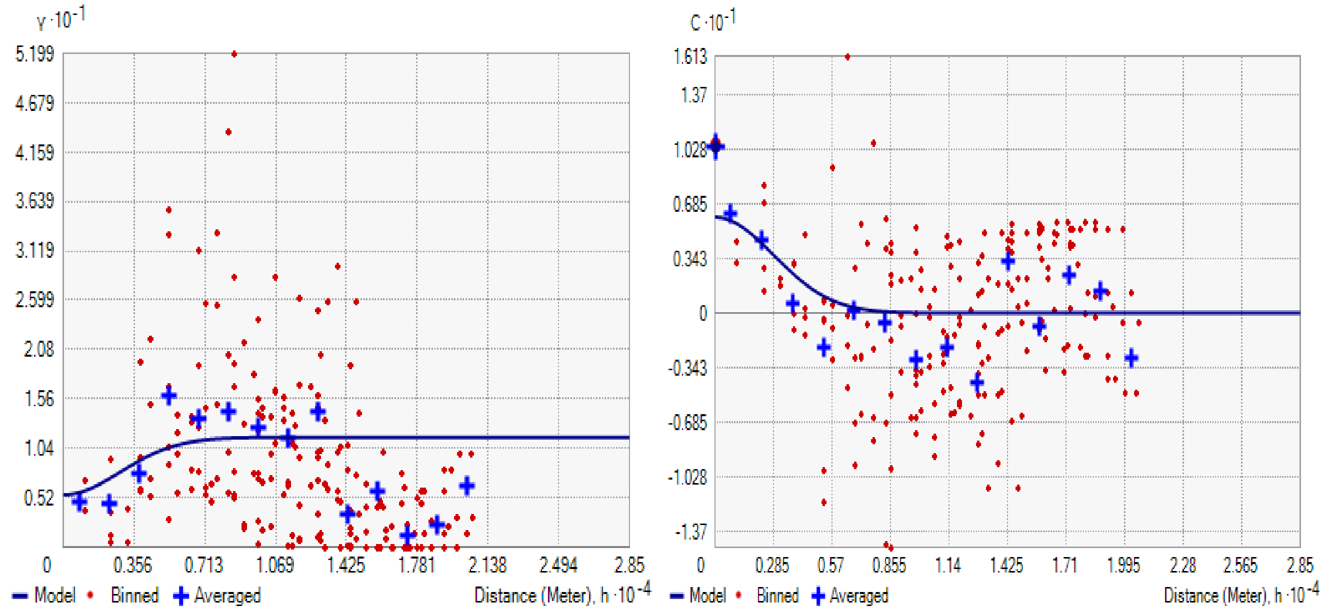


Figure3: Population Density of study area in 1998

Table 2: The statistical analysis of Ordinary Kriging

Model statistics										
Year	Nugget	Sill	Range	Lag size	Lag distance	Mean	Root mean square	Mean Stander error	MSE	RMSSE
1998	1.65	8.86	5567	1500	19	0.05	2.8	2.85	0.019	1
2013	19	26.93	6017	1410	14	0.02	5.66	5.61	0.003	0.98

Semivarigram 1998 Covariance



Semivarigram 2013 Covariance

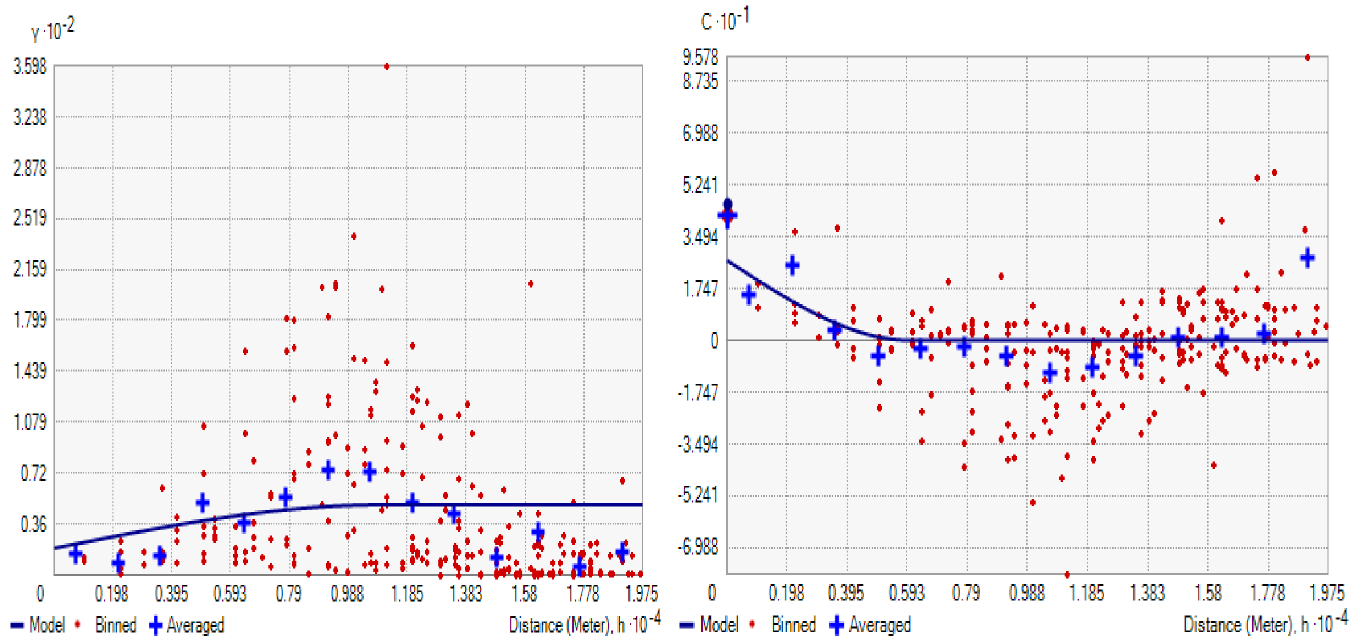
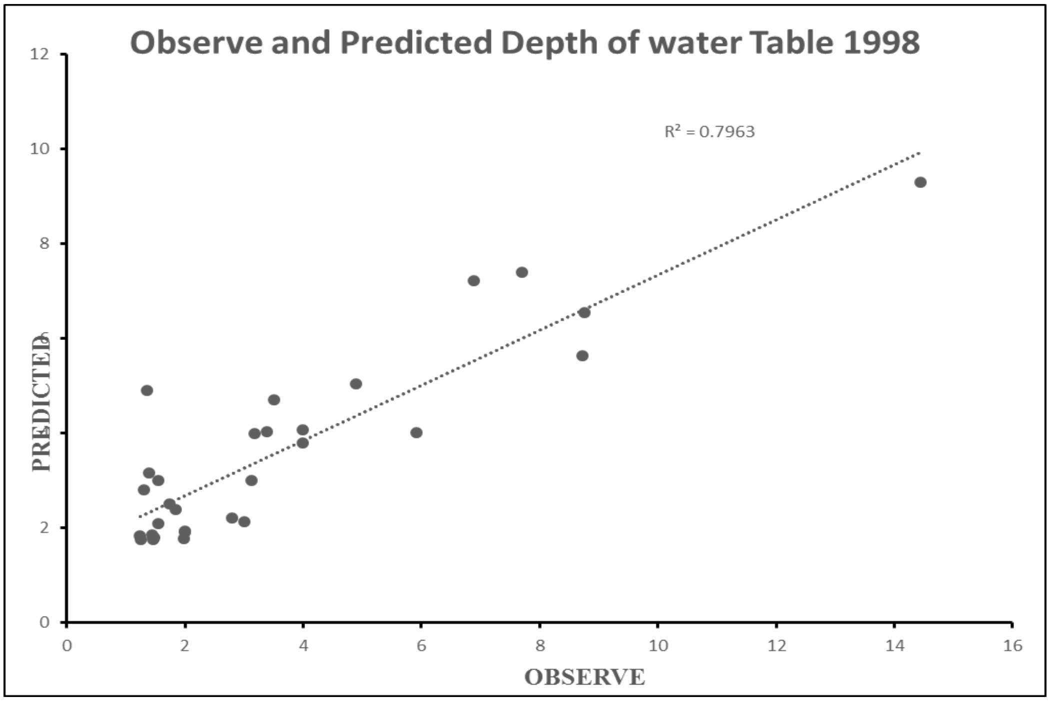


Figure4: Semivariogram and Covariance of Ordinary Kriging.

Model (1998) = 1.6539×Nugget+8.8644×Spherical(5567.7)…………(1)

Model (2013) =19.021×Nugget+26.981×Spherical(6017.2) …………(2)



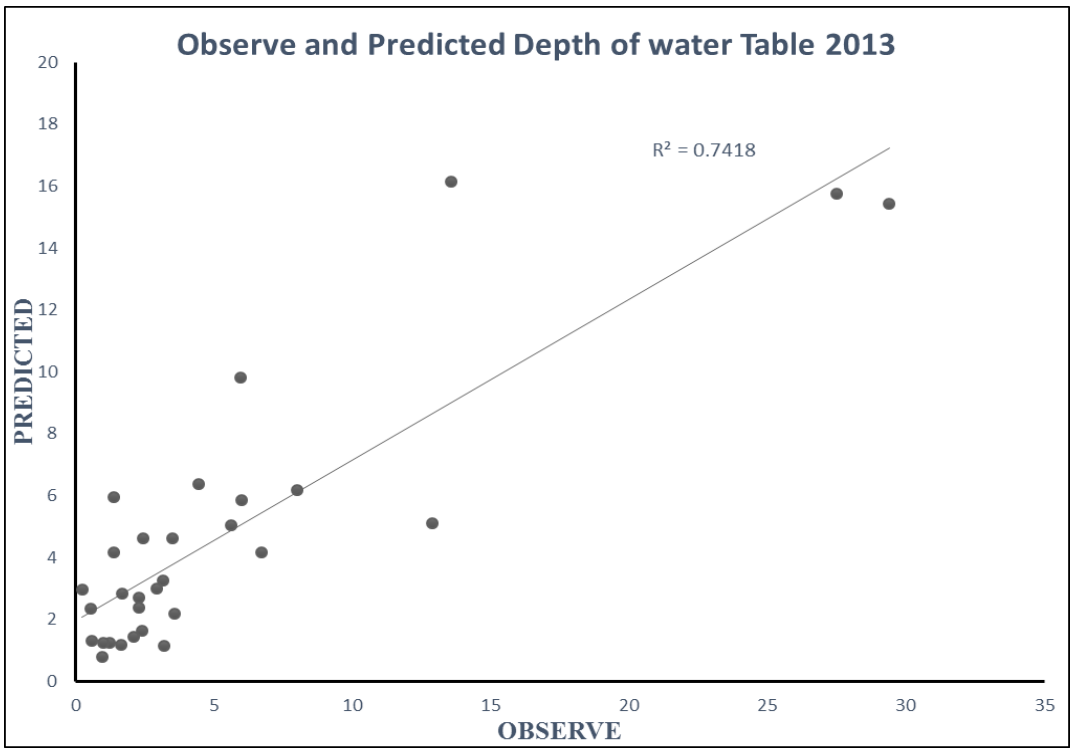


Figure5: Comperison Observe and Predicted Depth of water Table of 1998 and 2013

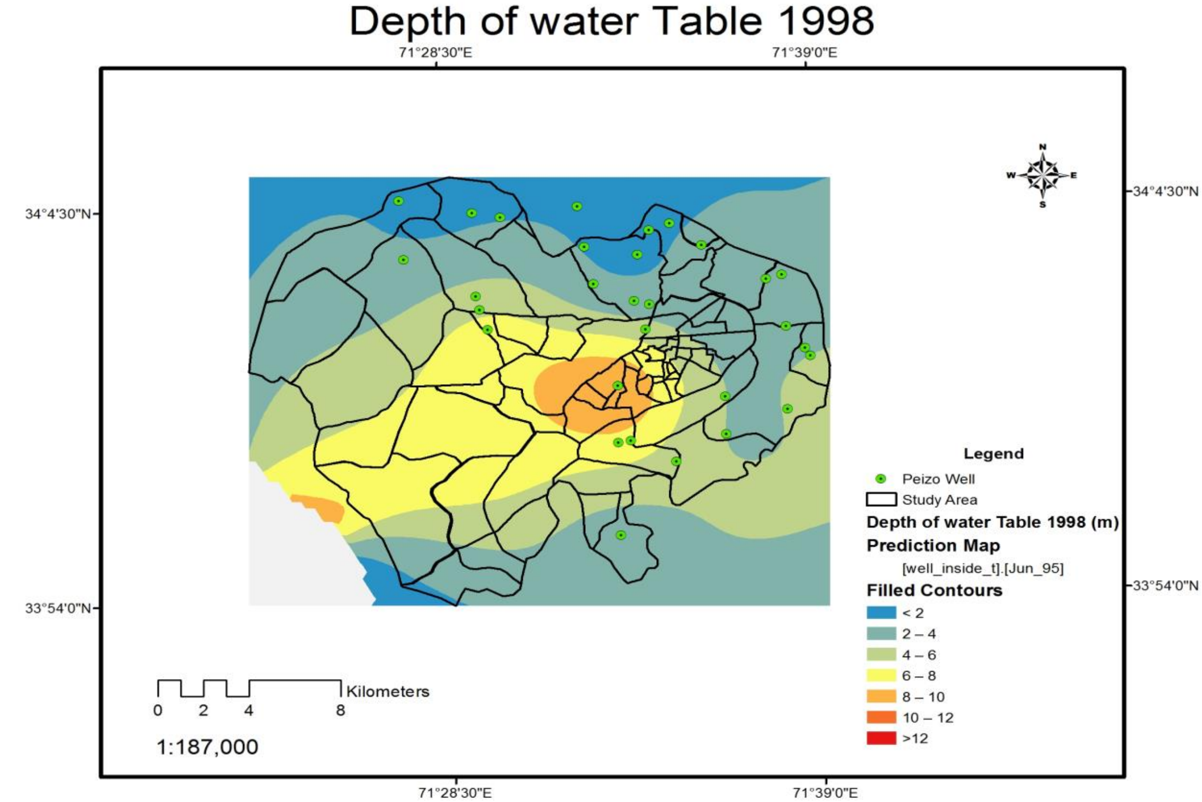


Figure6: Depth of water Table, 1998.

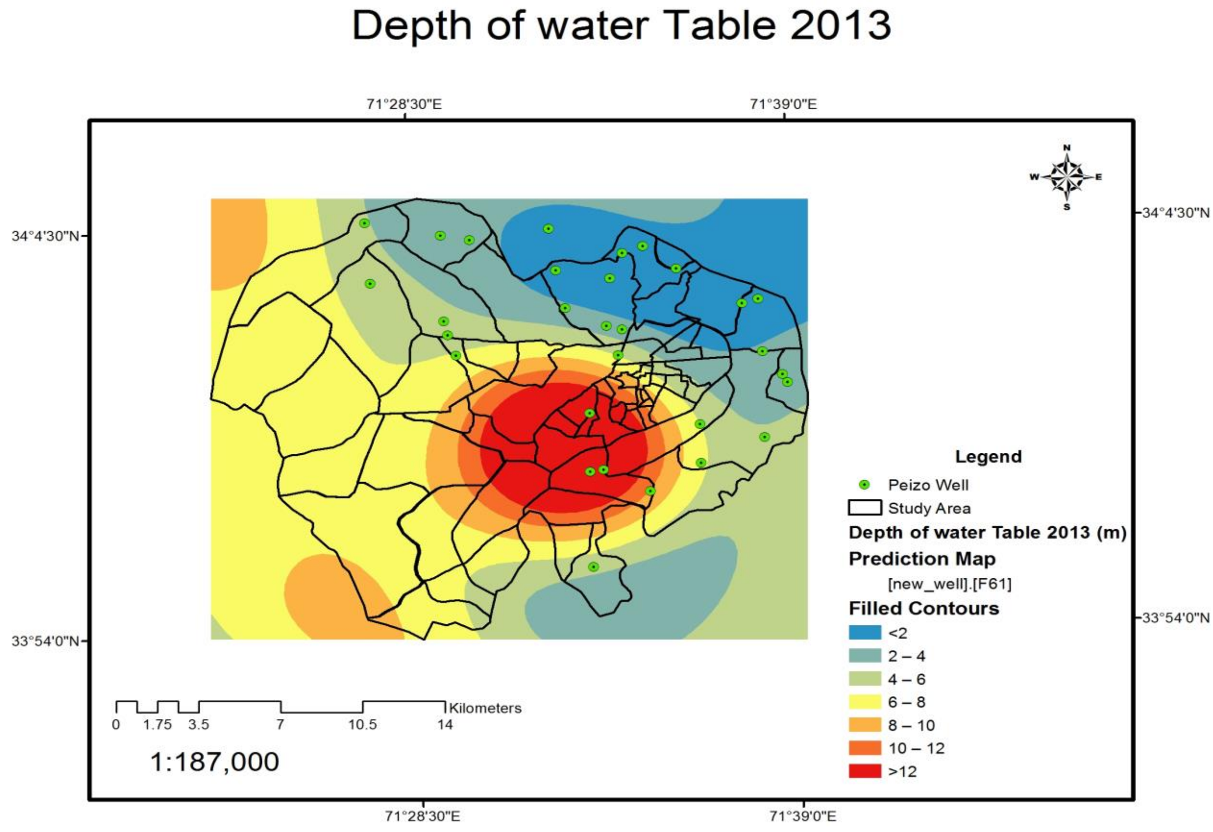


Figure7: Depth of water Table 2013.

The Depth of water table in 1998 and 2013 are interpolated for pre monsoon by using Kriging method the statistical results of kriging method with spherical model shown in Table 2. The RMSSE is very close to 1 and the mean standard error is near to zero. The performance of the predicted model is verify by cross validation

The semivariogram and covariance of ordinary kriging for 1998 and 2013 are shown in figure 4. Which shows that the data sets are very close to the variogram line.

The interpolating model of kriging for 1998 and 2013 represented in equation 1 and 2 respctively.The predicted groundwater table for 1998 and 2013 from ordinary kriging method is shown in the figure 5.The observed and predicted grounwater table are very closed to each other.

The results of water depth from ordinary krgging shows that the depth of water table going to increases very sharply from 1998 to 2013 . The area of the urban region where depth of water table more then 8 meter is 17 squre kilometer in 1998 which is the 5.15% of the total study area and the depth of water table increse upto 118 square kilometer in 2013 which is the 35.7% of the total study area shown in figure 6 and figure 7. This is indicated that the volume of ground water is continuse decrease with the increases of urbanization and the depresional zone having trend to moves towords the south part of the sudy area.

CONCLUSION AND RECOMMENDATION:

The average population density in 2013 of the study area is increase four times the population density in1998. Union councils located in the south of the study area are expected to be less populated in the near future. Therefore provision of infrastructure and municipal services would be more urgently needed in the north east parts of the study area. The depth of groundwater table more than 8 meter in the study area increase from 5% to 36% in the last 15 years. The population of the Peshawar region continually increases and it is expected that the population becomes two times of the present population of Peshawar in next ten years and availability of water from underground becomes in sufficient to meets the water demands of people and in order to sustain the depth of ground water the pumping well installed near to Kabul River and Surface Water facilities should be avail to minimize use of groundwater.

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