THE GEO STATISTICAL APPROACH TO ASSESS THE GROUNDWATER DROUGHT BY USING STANDARDIZED WATER LEVEL INDEX (SWI) AND STANDARDISED PRECIPITATION INDEX (SPI) IN THE PESHAWAR REGIME OF PAKISTAN.

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ABSTRACT: *Groundwater resources are the major source of water during periods of drought. Indiscriminate exploitation of groundwater during drought periods will lead to a lowering of water tables beyond replenish able limits. Groundwater resources can be used effectively if their sustainability is planned long before drought periods. This paper attempts to indicate the drought condition of groundwater by using Standardized water level index (SWI) and the main source of ground water recharge is precipitation therefore the drought condition of precipitation is estimated by using Standardize precipitation index SPI. The depth of water table was interpolated by using geo statistical method of ordinary Kriging. The results shows that in 1990 the depth of water table more than 10 meter increase from 0.2% to 17.5 % of total study area during pre-monsoon and in 2013 the depth of water table more than 10 meter increase from 0.74 % to 23% of total study area during post monsoon. The mild drought condition is observed only in 6 wells out of 30 wells in 1990 during pre-monsoon but the severe drought hit to the 15 wells out of 30 wells in 2013 during pre-monsoon. The SPI value shows that the drought condition of precipitation decrease in the study area from 1990 to 2013 during pre-monsoon while the precipitation drought increases from 1990 to 2013 during post-monsoon in the 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; Standardized Water-Level Index (SWI); Standardised Precipitation Index (SPI); Drought;

1. INTRODUCTION:

One of the major natural hazard that impacts the environment and economy is a drought. It disturb major parameters of hydrological cycle including precipitation, runoff and most importantly the storage of ground water aquifers. We elect that parameter of hydrological cycle on which we perform our analysis [2].We can classify the droughts based on meteorology, hydrology and agriculturally which include less precipitation, stream flow, ground water recharge and soil moisture and high evapotranspiration [18].Variables of drought are intensity, frequency and duration. Less precipitation, more evapotranspiration and over use of water resources or combination of all these cause water shortage that results drought. For the classification, identification and measurement of drought causative and responsive parameters the drought indices are used. It is difficult to correlate the parameters of different types of drought. There are many drought indices are developed to study the drought condition such as Palmer's Drought Severity Index [21], Palmer's hydrological drought index [20], surface water supply index [3] Standardized runoff index [16].

Study Area:

Peshawar is provincial capital of Khyber Pakhtunkhwa (KPK). It is an old city which is the hub for commercial, industrial, social and political activities in the north-western region of Pakistan. 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. The study area for the Peshawar a total area of 330 sq.km. Peshawar features a semi-arid-climate, with very hot summers (May to September) and mild winter (November to March). The maximum summer temperature is over 40°C during the hottest months of May and June and the mean minimum temperature is 25°C. The mean minimum temperature during winter is 4°C and maximum is 18.5°C. The average annual rainfall in Peshawar area is 340 mm, while the mean annual evapotranspiration is approximately 1500 mm. The spring comes around the end of February which is the most pleasant period of the year. The average humidity is not high over the region. Under the influence of western disturbances and monsoon rainfall it rises locally. The mean relative humidity ranges from 42 to 69 percent during the year. The water supply for Peshawar is mainly from groundwater which prevails over an area of 5000 sq .km. Groundwater flows from Southwest to Northeast direction towards Kabul River. Peshawar valley is mostly comprised of alluvial deposits having variable depths eroded from the surrounding mountainous. The alluvial deposits that fill the valley make up the aquifer that provides groundwater for Peshawar.

2. MATERIALS AND METHODS:

In order to monitor hydrological drought in study area the pre-monsoon and post-monsoon ground water levels of 30 observation wells of the region have been analysed. Standardized Water Level Index (SWI) has been Use to estimate the groundwater recharge deficit both for the pre-monsoon and the post-monsoon seasons. The pointwise SWI values are then spatially interpolated in GIS environment using the ordinary kriging method and ArcGIS 10.2 software to find out the areal extent of drought in the study area. The data of ground water depth of 30 wells from 1990 to 2013 within the study area were used to study the drought condition of ground water table in Peshawar. The study was done by using geostatistical ordinary kriging method for interpolation of the depth of water table in ArcGIS 10.2. The ordinary kriging method with spherical model is best for interpolation in the study area [1].The geostatistical semivariogram is used to quantify the differences between sampled data values in the

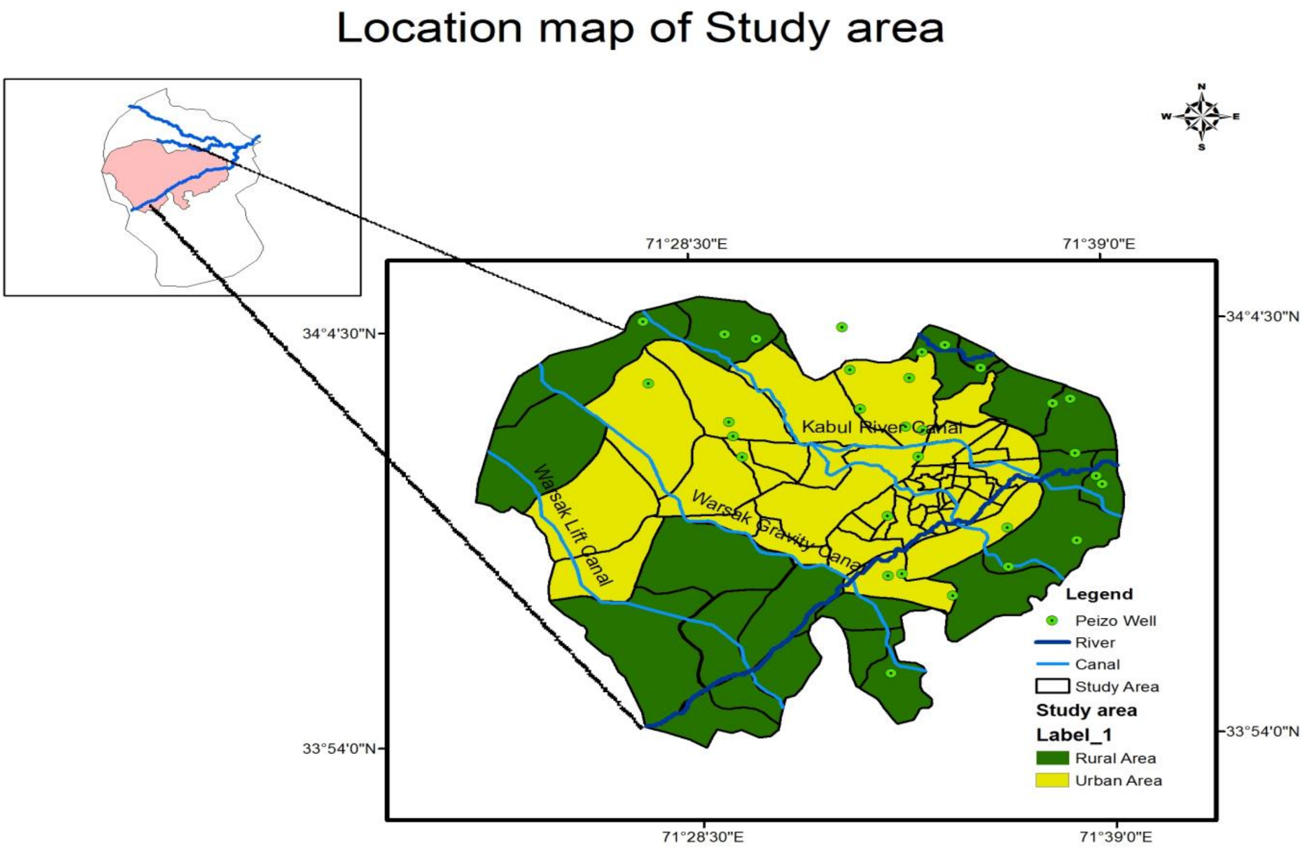

Figure1: Study area of Peshawar.

terms of separation distance h. In practice the semivariogram $\gamma^*(h)$, 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 of 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 $z^*(x0)$ 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:

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

Where μ is the Lagrange coefficient for minimizing the ordinary Kriging estimation variance, $\gamma(xi, x_j)$ 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 Standardized Water-Level Index (SWI):

The Standardized Water-Level Index (SWI) was proposed in order to monitor anomalies in ground water levels [29]. The SWI is computed by normalizing seasonal groundwater levels and dividing the difference between the seasonal water level and its long-term seasonal mean by the standard deviation. SWI is an indicator of water-table decline and an indirect measure of recharge, and thus an indirect reference to drought

SWI = (Wij –Wim) / σ

where Wij is the seasonal water level for the ith well and jth observation, Wim is the seasonal mean and σ is the standard deviation. Since groundwater levels are measured from the ground surface to the bottom of the observation wells, positive anomalies correspond to water stress while negative anomalies represent a 'no drought' condition. The drought conditions on the basis of SWI is given in table 1.

Table1: SWI drought Conditions

SWI value	Condition
SWI > 2.0	Extreme drought
SWI > 1.5	Severe drought
SWI > 1.0	Moderately drought
SWI > 0.0	Mild drought
SWI < 0.0	No drought

2.3 Standardised Precipitation Index (SPI):

The SPI is use to analyse the impact of rainfall deficiency on drought development in the study area, The Six month SPI analysis has been used to quantify the precipitation deficit in the monsoon and the non-monsoon periods since 19990 up to 2013. The SPI is calculated using the following equation, written as

Table2: SPI drought Conditions

SPI value	Conditions
2.0+	Extremely Wet
1.5 to 1.99	Very Wet
1 to 1.49	Moderately Wet
-0.99 to 0.99	Near Normal
-1 to -1.49	Moderately Dry
-1.5 to -1.99	Severely Dry
-2 and less	Extremely Dry

SPI = (Xij –Xim) / σ

where, Xij is the seasonal precipitation at the ith rain-gauge station and jth observation, Xim is its long-term seasonal mean and σ is its standard deviation.The drought condition corresponding to SPI value is shown in table2.

RESULTS AND DISCUSSION

The standardized water level index was calculated from the pre-monsoon and post-monsoon groundwater level data for the period 1990-2013. The temporal assessment of hydrological drought indicated abrupt change in SWI values for the period 1990-2013. The results shows that 6 wells have a mild drought out of 30 wells in pre monsoon 1990 but the drought condition increase from mild to moderate drought for 15wells in pre monsoon 2013 shown in the figure1. The analysis revealed that droughts of mild to moderate category occurred in the study area in a frequent manner during the pre-monsoon seasons. The standardized precipitation index shows that there is no drought condition of precipitation in 1990 but the drought condition occurred in 2013 in pre monsoon but the precipitation drought during post monsoon is not occurred in 2013 shown in figure 2.

The depth of ground water table was interpolated by using geostatistical method of ordinary kriging Method during the period of 1990 to 2013 for premonsoon and postmonsoon.The result indicate that the depth of water table more than 10 meter is extented upto 11 sqkm to 94 sqkm of study area during 1990 to 2013 in premonsoon but in post monsoon the depth of water table more than 10 meter is increses upto 4 sqkm to 125 sqkm. The trend of the depth of ground water table is decline in the east part of the study area shown in the figure 3.

The value of SWI is interpolated by using geostatistcal method of ordiary krigging. The maps of SWI shows that during the pre-monsoon in 1990 few discrete pockets of moderate drought found in the central part of the study area and the major parts of the study area were free from drought in all other years. but the drought conditon is increacses from central part of the study area to east part during pre monsoon in 2013. The drought condition becomes mild to Extreme drouhght during premonsoon 2013 as shown in figure 4 and figure 5.

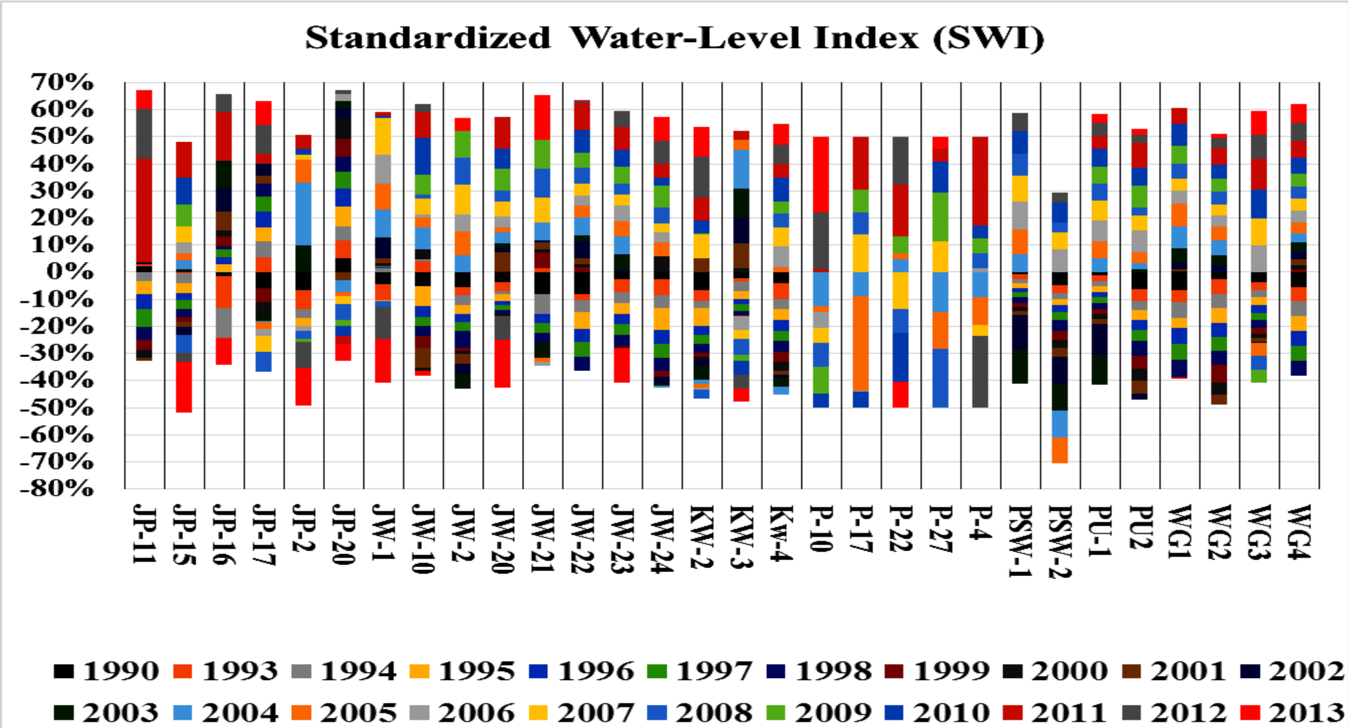

Figure 1: Standardized water level index of pre Monsoon

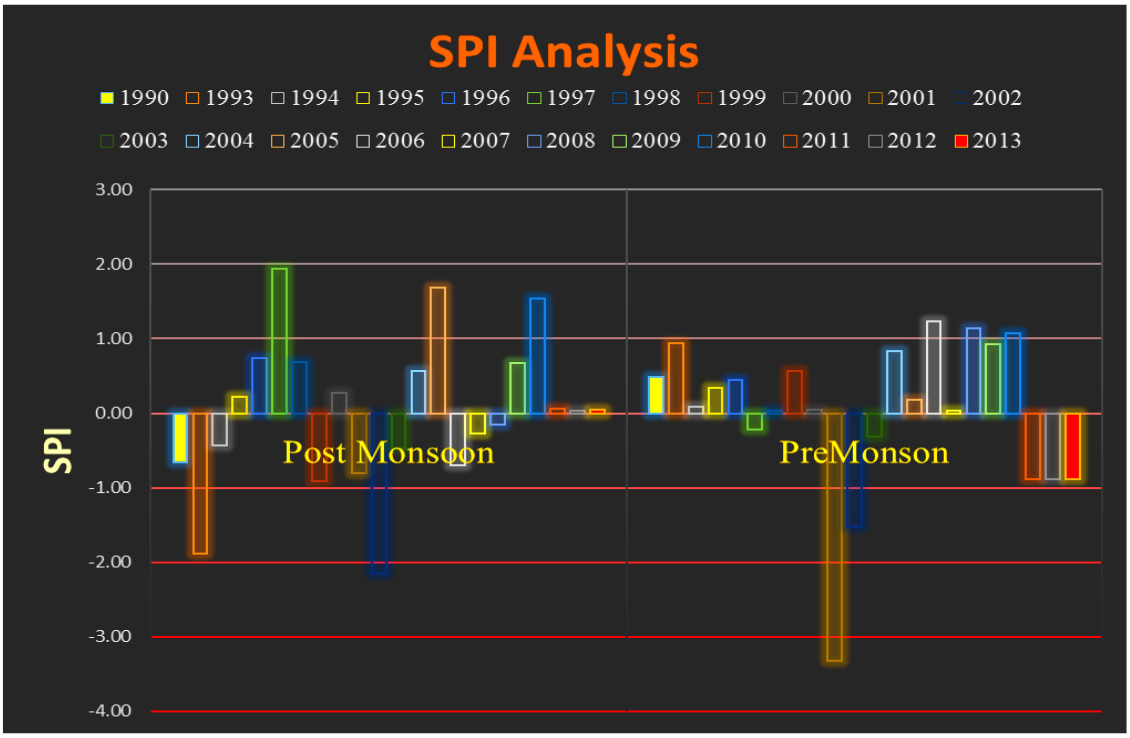

Figure 2: Standardized Precipitation index of pre Monsoon and post Monsoon.

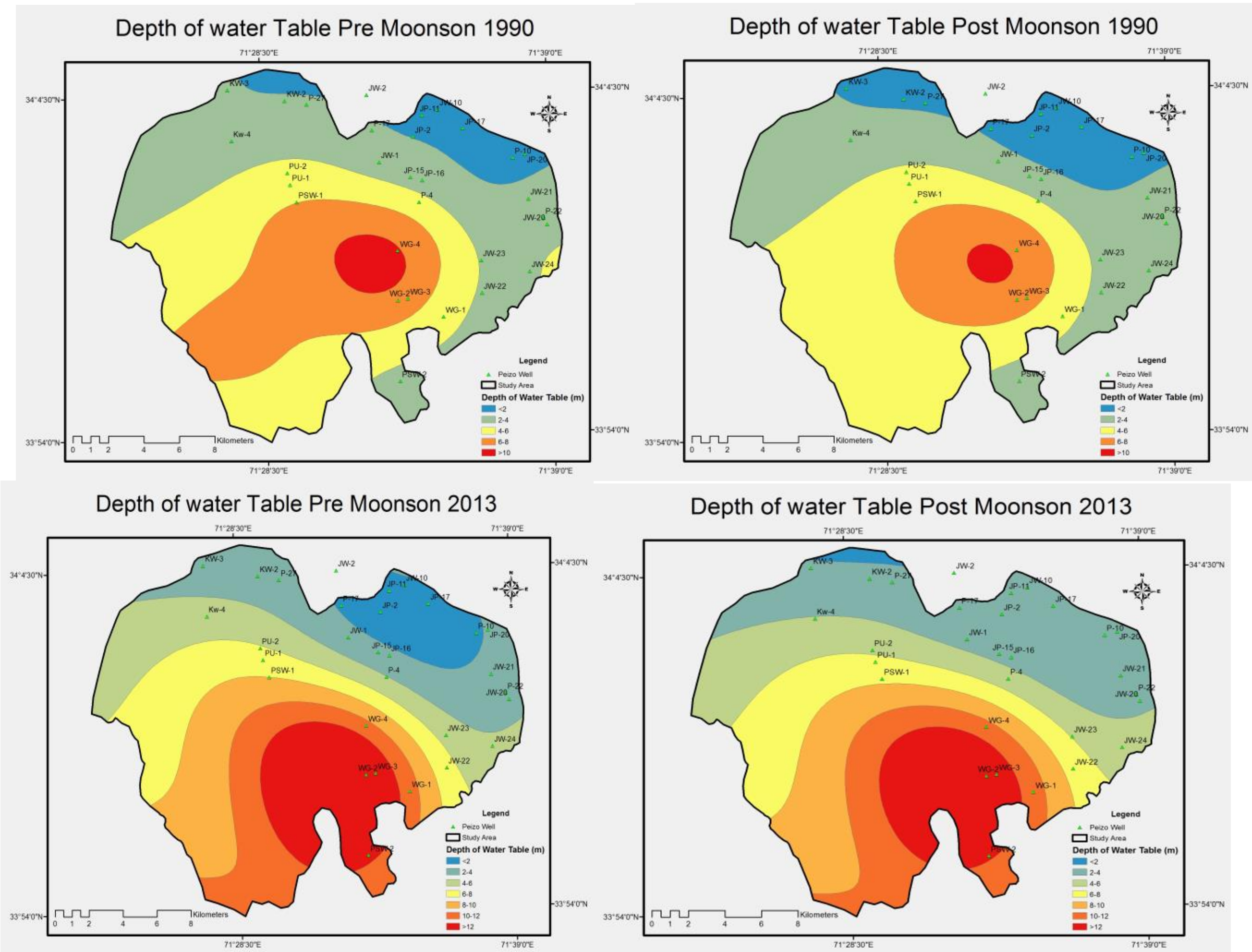

Figure 3: Depth of water table in premonsoon and Post monsson.

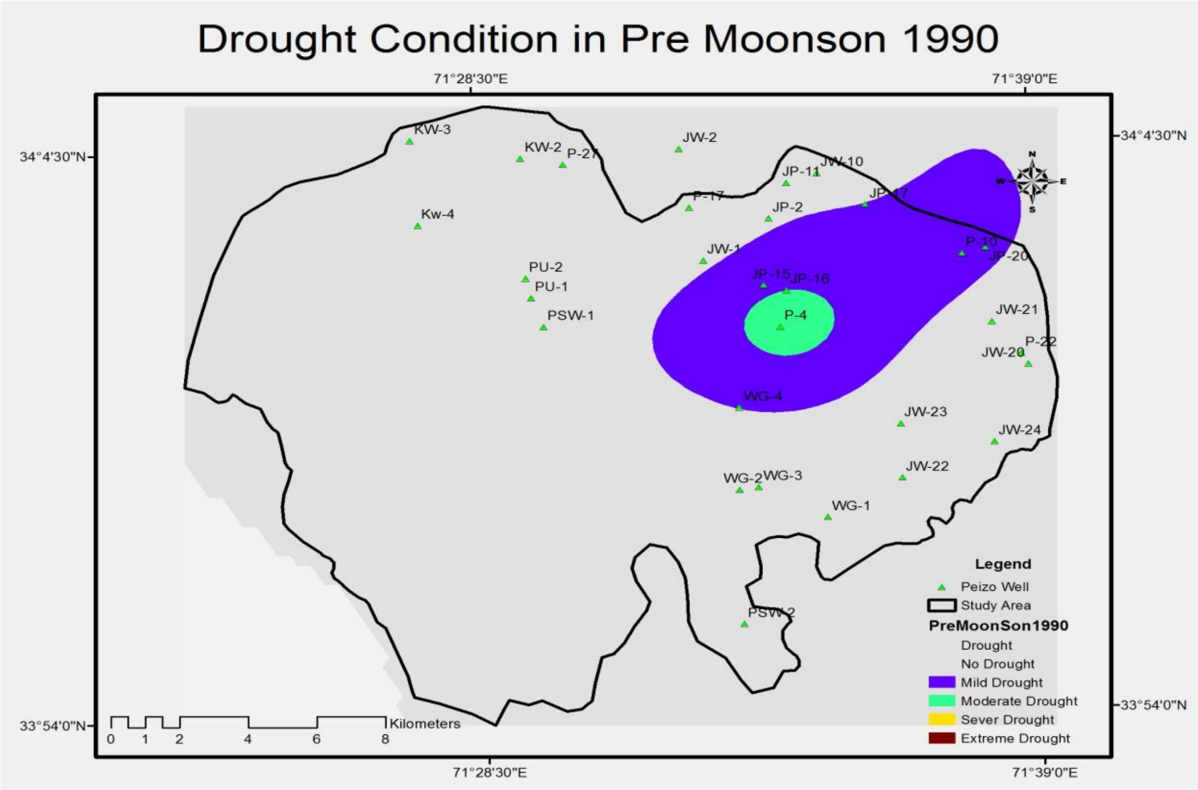

Figure 4: Drought condition premonsoon1990

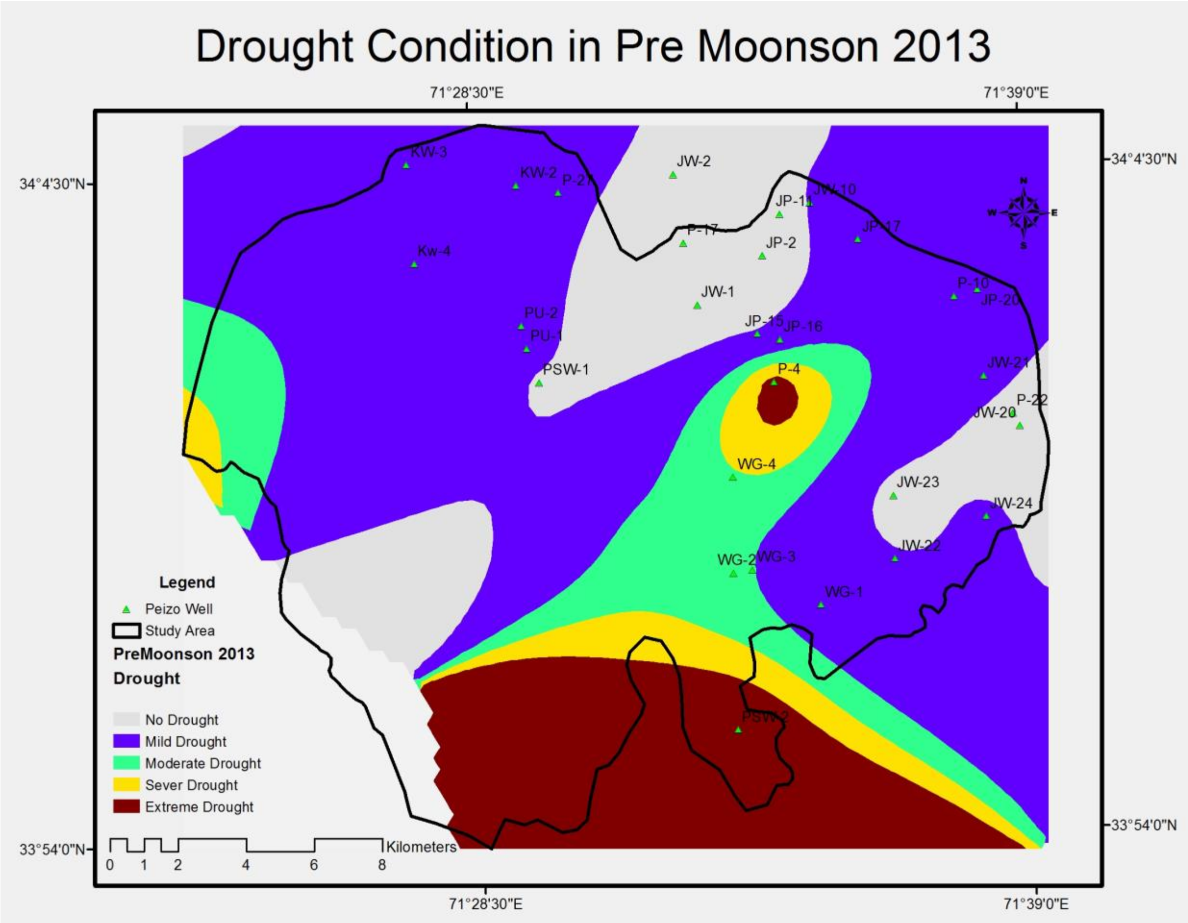

Figure 5: Drought condition premonsoon1990.

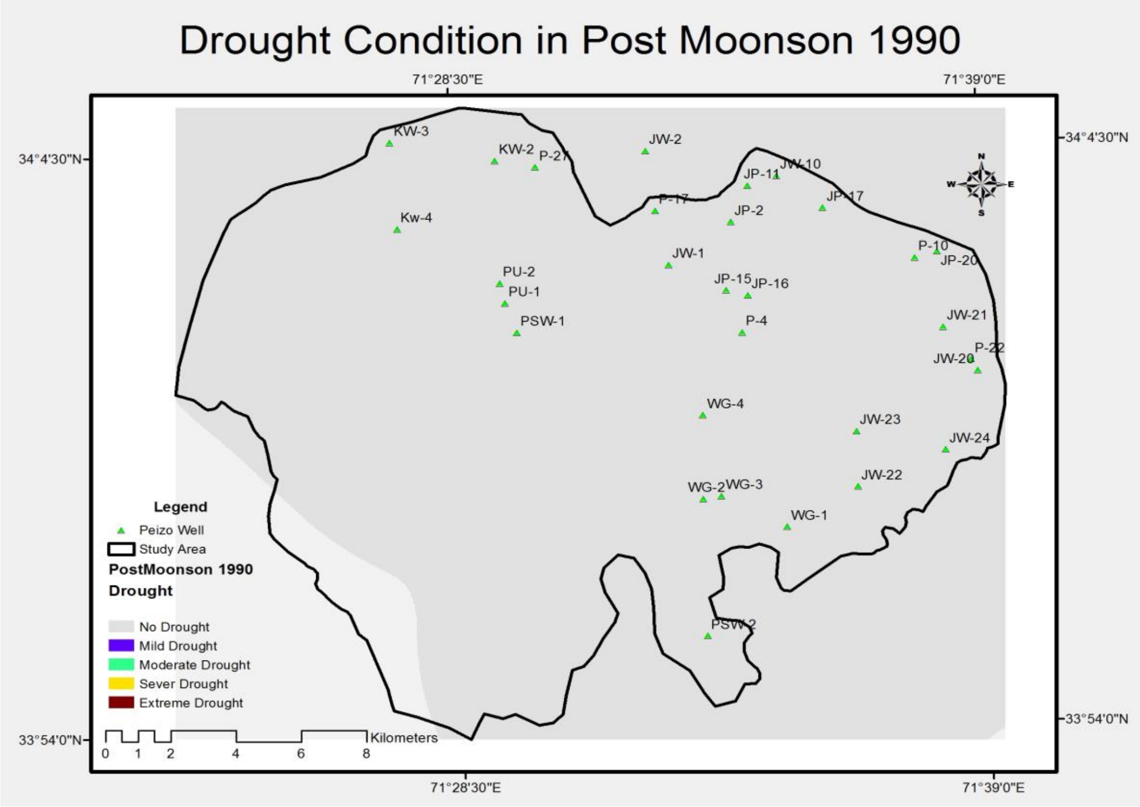

Figure 6 : Drought condition in 1990 Post monsoon.

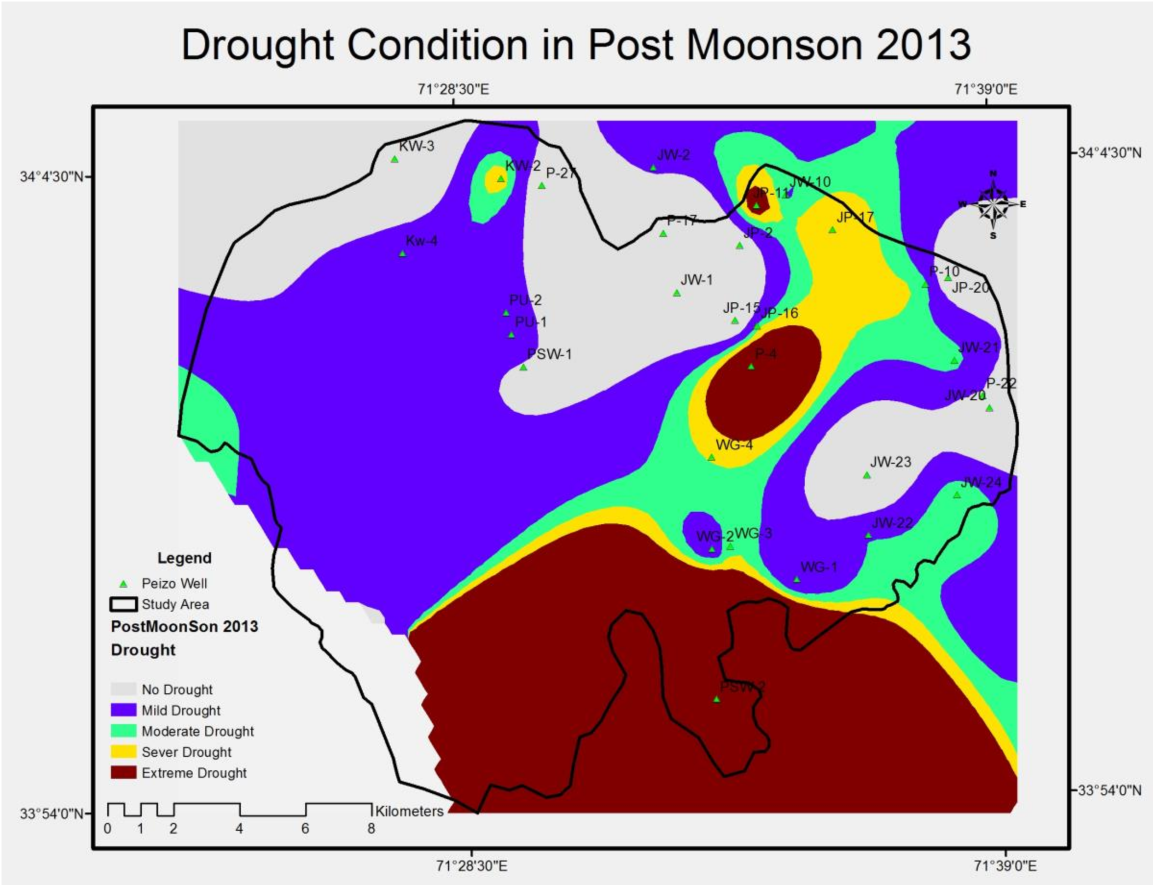

Figure 7: Drought condition in 2013 Post monsoon.

In the year1990, post-monsoon water level was normal or near-normal in major parts of the study area and there is no drought found in the study area but in 2013, post monsoon, many parts all over the study area were hit by extreme drought .The drought situation was aggravated in the post-monsoon period of 2013 with moderate and severe droughts in some parts of the study area shown in the figure 6 and figure 7.

3. CONCLUSION AND RECOMMENDATION:

The present study concerned the assessment of hydrological drought and the spatio-temporal behavior of SWI in a chronically drought prone region of Peshawar region of Pakistan. The depth of groundwater table more than 10 meter in the is increases from 0.2% to 17% of the total study area of in the last 23 years in pre monsoon and during post monsoon the depth of water table more than 10 meter increases from 0.74% to 23% of the total study area in post monsoon from 1990 to 2013. The 20% wells of the study area having mild drought during pre-monsoon in 1990 and in 2013 the 30% of wells hit by extreme drought during pre-monsoon. The mostly drought is facing on the east part of study area in 2013. The SPI values indicate that the precipitation drought in the study area is decreases in post monsoon but during pre-monsoon the precipitation drought increases in the study area .Therefore 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.

REFERENCES:

1. Akif Rahim, Dr Khalida Khan, Amina akif (2015). The Spatial and Temporal Variation in the Ground water Potential due to Urbanization in the Peshawar Regime of Pakistan. Journal of science international Vol 8 issue 3 May-June 2015. http://www.sci-int.com/searchpage.php?cat_id=50
2. Bogaert, P. (1996). Comparison of kriging techniques in a space-time context. Mathematical Geology, 28, pp73–86.
3. Bordi I, Sutera A (2008). Drought over Europe in recent years, In: López-Francos A (ed) Drought management: Scientific and technological innovations. CIHEAM, Options Méditerranéennes: Série A Séminaires Méditerranéens; n 80, Zaragoza, pp 63–68.
4. Cambardella, C. A., Moorman, T. (1994). Field scale variability of soil properties in Central Iowa soils. Soil Science Society of America Journal, 58, pp 1501–1511.
5. C. Bhuiyan (2004), "Various Drought Indices for Monitoring Drought Condition in Aravalli Terrain of India," Proceedings of the XXth ISPRS Conference, Istanbul, 12-23. pp. 907-912.
6. Desbarats, A. J., Logan, C. E., Hinton, M. L., & Sharpe, D. R. (2002). On the kriging of water elevations using collateral information from a digital elevation model. Journal of Hydrology, 225, pp25–38.
7. Govt. of Pakistan. 1998-99. Pakistan Integrated Household Survey (PIHS). Round 3, Federal Bureau of Statistics, Islamabad.
8. Khan, A.N. and A. Rahman. (1999/2000). Urbanization Trends and Prospects in Pakistan, Pakistan journal of Geography, 9, 31-44.
9. Kumar, D., & Ahmed, Sh. (2003). Seasonal behaviour of spatial variability of groundwater level in a granitic aquifer in monsoon climate. Current Science, 84, pp.188–196.
10. Kumar, S., Sondhi, S. K., & Phogat, V. (2005). Network design for groundwater level monitoring in upper Bari Doab canal tract, Punjab, India. Irrigation and Drainage, 54, pp 431–442.
11. Leuangthong, O., McLennan, J. A., & Deutsch, C. V. (2004). Minimum acceptance criteria for geostatistical realizations. Natural Resources Research, 13, pp131–141.
12. Li, L., & Revesz, P. (2004). Interpolation methods for spatio– temporal geographic data. Computers, Environment and Urban Systems, 28, pp201–227.
13. Liu, D., Wang, Z., Zhang, B., Song, K., Li, X., Li, J., et al. (2006). Spatial distribution of soil organic carbon and analysis of related factors in croplands of the black soil region, northeast China. Agriculture, Ecosystems and Environment, 113, pp 73–81.
14. Ma, T. Sh., Sophocleous, M., & Yu, Y. Sh. (1999). Geostatistical applications in ground water modeling in south-central Kansas. Journal of Hydrologic Engineering, 4, pp 57–64.
15. Smedema, L. K., & Shiati, K. (2002). Irrigation and salinity: A perspective review of the salinity hazards of irrigation development in the arid zone. Irrigation and Drainage Systems, 16, 161–174.
16. S. Shukla, and A.W. Wood, "Use of a standardized runoff index for characterizing hydrologic drought," Geophys. Res. Lett, 2008. pp. 35, L02405. doi:10.1029/ 2007GL032487.
17. Tabinda Masud , Amjad Ali (2013), Estimation of groundwater balance for the Pabbi region, Khyber Pakhtunkhwa , Journal of Himalayan Earth Sciences,46,2, pp113-119.
18. Theodossiou N., & Latinopoulos, P. (2006). Evaluation and optimization of groundwater observation networks using the kriging methodology. Environmental Modelling and Software, 21, 991–1000. Tonkin, M. J., & Larson, S. P. (2001). Kriging water levels with a regional-linear and point-logarithmic drift. Ground Water, 40, pp185–193.
19. Triantafilis, J., Odeh, I. O. A., Warr, B., & Ahmed, M. F. (2004). Mapping of salinity risk in the lower Namoi valley using non-linear kriging methods. Agricultural Water Management, 69, pp.203–231.
20. T.R. Karl (1986), The sensitivity of the Palmer drought severity index and Palmer's Z index to their calibration coefficients including potential evapotranspiration. J. Climate. Appl. Meteorology, 25, pp. 77–86.
21. W.C. Palmer (1965), Meteorological Drought," US Department of Commerce, Weather Bureau. Research Paper No. 45, pp. 58