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REVIEW ARTICLE

EVALUATION OF CLIMATE CHANGE IMPACTS ON RAINFALL PATTERNS IN POTHOHAR REGION OF PAKISTAN

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ABSTRACT

Pakistan is a developing country whose economy mainly depends on agriculture which is more susceptible to the effects of climate changes. Due to lack of modern technical resources, Pakistan does not have adequate monitoring systems for the prediction of likelihood of occurrence of extreme events, or the assessment of possible changes in weather patterns, thus making the task of developing short term response or disaster mitigation strategies extremely difficult. Pothohar is a plateau in north-eastern Pakistan, forming the northern part of Punjab including Attock, Chakwal, Jhehlum, Rawalpindi districts and Islamabad Territory. Pothohar region is a prominent region in Pakistan and consists of important districts. Its agriculture is entirely based on rainfall and no canals are available for the irrigation in this area. Farmers in this area are adversely affected by the changing climate and abrupt changes in rainfall. They need to know the changing patterns of rainfall to adopt new techniques and schedules for their agriculture to cope the changing climate. Four districts were selected to cover this region and rainfall and temperature data of these districts and Mann-Kendall method was used to detect the trends. After that, kriging was used for interpolating the data between the stations. Monthly precipitation trends were identified here to achieve the objective which has been shown in the data. There are rising rates of precipitation in some months and decreasing trends in some other months obtained by these statistical tests suggesting overall insignificant changes in the area. From the results it is clear that the majority of the trends in the annual, seasonal and monthly T_{max} and T_{min} time series showed increasing tendency during the last decades, while the increasing trends in the T_{min} series were stronger than those in the T_{max} series. The T_{max} and T_{min} warming trends were more obvious in summer and winter than in autumn and spring.

KEYWORDS

Agriculture, weather patterns, Mann-Kendall method, precipitation

1. INTRODUCTION

Water resources are very significant aspect for the planning of flood reduction, food production as well as water management. Researchers concluded that the global warming is happening at a very high rate of 0.74 ± 0.18 °C during 1906–2005. It is also mentioned in the reports of IPCC that world will face a shortage of freshwater due to climate change issues. This has been discovered that up to the mid of twenty first century, the average runoff will be reduced, which will cause the reduction of accessibility of fresh water up to 30%. Many researchers worked on the issue of climate change with long term time series [1]. In case of rainfall and temperature, trend of many time series data has been increasing or decreasing in recent studies. Human intrusion is a major factor in the funding to climate change through altering land use due to irrigation and agricultural techniques [2].

During the previous century, an average annual surface air temperature has been increased by 2.9°C in Asia. Particularly, countries in Asian regions are pertained to the increase of greenhouse gases because of the possible consequence on the area due to climate change associated changes in forms of floods, storms and droughts along with the rising of sea level. Asian regions have always been penetrable to variations during the monsoons. Rainfall is the main element of hydrological cycle and atmosphere [3]. It is the only phenomena by which water comes to the earth. Pakistan mainly depends on agriculture and due to shortage of water a large area of fertile land is uncultivated. Pakistan is large agricultural producing country and is at 8th position throughout the world. There is a 30.46 MAF area in Pakistan which is irrigated through canal water and about 11.29 MAF area which is irrigated by other sources of water. It is estimated that the main source of surface water supply is through rainfall. Without rainfall water it is difficult to manage these resources.

Agriculture is main sector of Pothohar region as 47% of total area is under cultivation. Its contribution in_agriculture is depleting due to climate change. Most of the farmers in Pothohar plateau are not progressive. Due to high production cost and losses by climate change (i.e. either due to out-seasonal rainfall or extreme weather conditions) they are no longer interested in farming business. In this case scenario government should provide basic facilities and subsidy to promote agriculture in Pothohar region. Farmers in the Pothohar region are worried after the recent unexpected rains and hailstorms, coupled with gusty winds, damaged their crops. The crop in the Pothohar region mainly relies on rains. However, it has been seen that unexpected spell of rain has damaged the grains of the crop which had already grown and was being harvested by the farmers. This study was done to study the rainfall trends in the Pothohar region of Pakistan using Mann-Kendall method, where there is no other source of irrigation other than rainfall. This study will benefit farmers and policy makers as they will know the changing trends in rainfall and the effect of temperature on rainfall.

2. STUDY AREA

Pothohar Plateau is circumscribed from south by Salt Range, from north by Margalla Hills and Kala Chitta Range, from west by Indus River and from east by Jhelum River. The Kala Chitta Range lunges towards east near Rawalpindi, Soan and Haro river valleys cross the plateau from the eastern foothills to the Indus. The Pothohar region lies from 32.5°N to 34.0°N Latitude and from 72°E to 74°E Longitude, having an area of about 22254 Km^2 and having a population of about 17,464,763.

Figure 1: Study Area

3. MATERIALS AND METHODS

In the present study, trend analysis has been done by using non-parametric Man- Kendall test. This is a statistical method which is being used for studying the spatial variation and temporal trends of hydro climatic series. A non-parametric test is taken into consideration over the parametric one since it can evade the problem roused by data skew. Man-Kendall test is preferred when various stations are tested in a single study [4]. Mann-Kendall test had been formulated by *Mann (1945)* as non-parametric test for trend detection and the test statistic distribution had been given by a scholar for testing non-linear trend and turning point [5].

3.1 Autocorrelation

Trend detection in a series is largely affected by the presence of a positive or negative autocorrelation [6-9]. With a positive autocorrelation in the series, possibility for a series of being detected as having trend is more, which may not be always true. On the other hand, this is reverse for negative autocorrelation in a series, where a trend is not detected. The coefficient of autocorrelation ρk of a discrete time series for lag k is projected as

$$\rho_k = \frac{\sum_{t=1}^{n-k}(x_t - \bar{x}_t)(x_{t+k} - \bar{x}_{t+k})}{[\sum_{t=1}^{n-k}(x_t - \bar{x}_t)^2 \times \sum_{t=1}^{n-k}(x_{t+k} - \bar{x}_{t+k})^2]^{1/2}} \quad (1)$$

Where, $\bar{x}_t$ and *Var* (x_t) are considered to be the sample variance and sample mean of the first $(n-k)$ terms, and *Var* (x_t+k) and $\bar{x}_{t+k}$ are sample variance and sample mean of the last $(n-k)$ terms respectively. Moreover, coefficient of autocorrelation was used for the testing of serial independence hypothesis as $H_0 : \rho 1 = 0$ versus $H_1 : |\rho 1| > 0$ using

$$t = |\rho| \sqrt{\frac{n-2}{1-\rho_1^2}} \quad (2)$$

Where the t test statistic has a Student's t-distribution with $(n-2)$ degrees of freedom. If $|t| \geq t\alpha_{/2}$, then null hypothesis of serial independence will be rejected at the significance level α.

3.2 Mann-Kendall Test

The Mann-Kendall statistic S is given as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(x_j - x_i) \quad (3)$$

The trend test is done for a time series x_i, i = 1,2,………n-1 and x_j, j = i+1,2,……….n. Both of the data point x_i is taken as a reference point which is compared with the remaining data pointsx_j,

$$Sgn(x_j - x_i) = \begin{cases} +1, > (x_j - x_i) \\ 0, = (x_j - x_i) \\ -1, < (x_j - x_i) \end{cases} \quad (4)$$

It has been attested that when n ≥ 8, the statistic S is about normally distributed with the mean.

$$E(S) = 0 \quad (5)$$

The variance can be calculated as

$$VAR(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(i)(i-1)(2i+5)}{18} \quad (6)$$

Test statistic Z_C can be calculated as

$$Z_c = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} \\ 0, S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, S < 0 \end{cases} \quad (7)$$

Zc here follows a standard normal distribution. A positive (negative) value of Z signifies an upward (downward) trend. A significance level α is also utilised for testing either an upward or downward monotone trend (a two-tailed test). If Zc appears greater than Zα/2 where α depicts the significance level, then the trend is considered as significant.

3.3 Modified Mann–Kendall test

Pre-whitening is being used for detecting a trend in a time series in the presence of autocorrelation. Nonetheless, pre-whitening is stated to reduce the rate of detection of significant trend in the MK test. Thus, the Modified MK test has been used for trend detection of an autocorrelated series [10-14]. In the present study, the autocorrelation between ranks of the observations ρk has been estimated after subtracting an estimate of a non-parametric trend such as Sen's median slope from the data. Significant values of ρk have only been used for calculating the variance correction factor n/n^* S, as the variance of S is underestimated for the positively autocorrelated data:

$$\frac{n}{n_s^*} = 1 + \frac{2}{n(n-1)(n-2)} \times \sum_{k=1}^{n-1}(n-k)(n-k-1)(n-k-2)\rho_k \quad (8)$$

Where n will represent the factual number of observations, n^* s will signify the effective number of interpretations to describe the autocorrelation and ρk will be measured as the autocorrelation function for the ranks of the observations. Variance after correction will be calculated as

$$V^*(S) = V(S) \times \frac{n}{n_s^*} \quad (9)$$

Where V (S) is taken from the equation 6. The remaining equation is similar as in the Mann-Kendall test.

3.4 Sen's Slope Estimator Test

The scale of trend can be projected with the Sen's slope estimator.
The slope (Ti) of the data can be calculated as (Sen*, 1968)*

$$T_i = \frac{x_j - x_k}{j - k} \qquad \text{For i = 1, 2, 3..., N} \quad (10)$$

Where x_j and x_k are taken as data values at time j and k (j>k) respectively. The median of these values of T_i is shown as Sen's estimator of slope and can be given as:

$$Q_i = \begin{cases} T_{\frac{N+1}{2}} \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) \end{cases} \quad (11)$$

Sen's slope estimator can be calculated as Q_{med}=T(N+1)/2 if N seems odd, and it is conceived as Q_{med}= [$T_{N/2}$+$T_{(N+2)/2}$]/2 if N seems even. In the end, Q_{med} can be calculated by a two-sided test at 100 percent confidence interval and after that a true slope can be generated by the non-parametric test.

4. RESULTS AND DISCUSSION

Trend analysis of rainfall in Pothohar region has been done with 40 years of rainfall data from 1976 to 2015. Trend of the data was detected by the use of Sen's slope estimator and Mann-Kendall test. Figure 2 shows the annual rainfall for the period of 40 years having maximum rainfall during the year 2006 with an overall precipitation of 4794.8 mm approximately and 2009 was the year with minimum rainfall having just 1825 mm precipitation. Average rainfall found to be 3436.8 mm for these 40 years.

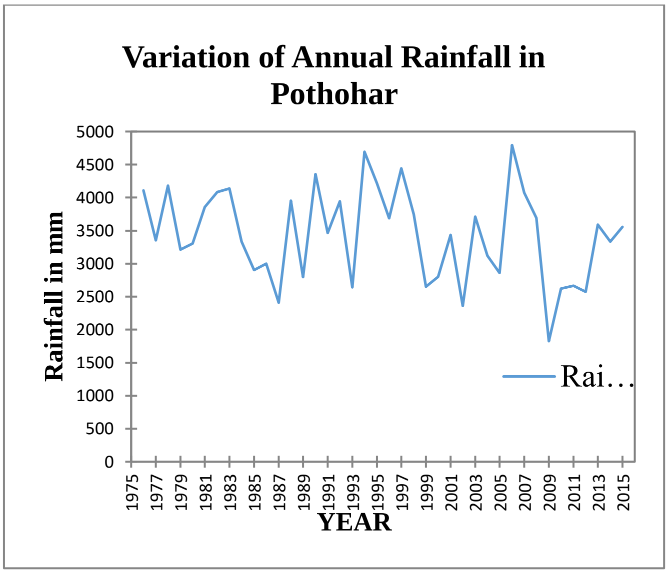


Figure 2: Annual rainfall of 40 years

Annual average is least for the month of November for all these 40 years (62.98 mm) followed by October (89.33 mm) and December (102.18 mm) while maximum rainfall occurs in the month of July (911.64 mm) followed by August (873.10 mm) and September (337.50 mm). Fig.3, 4, 5 and 6 shows the rainfall distribution of 40 years of individual months.

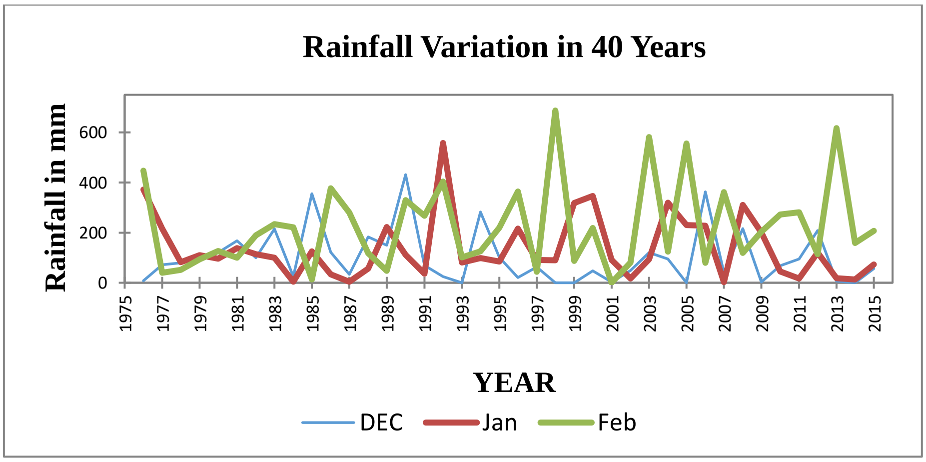


Figure 3: Rainfall of Winter Season for 40 Years

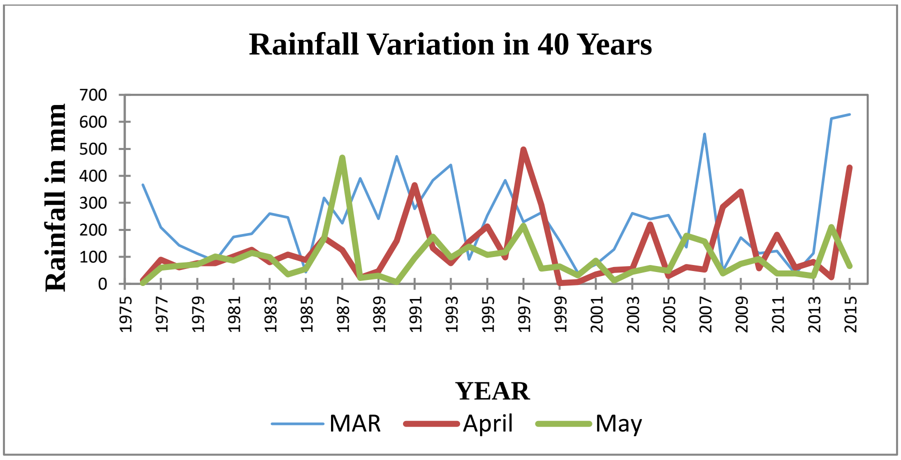


Figure 4: Rainfall of Spring Season for 40 Years

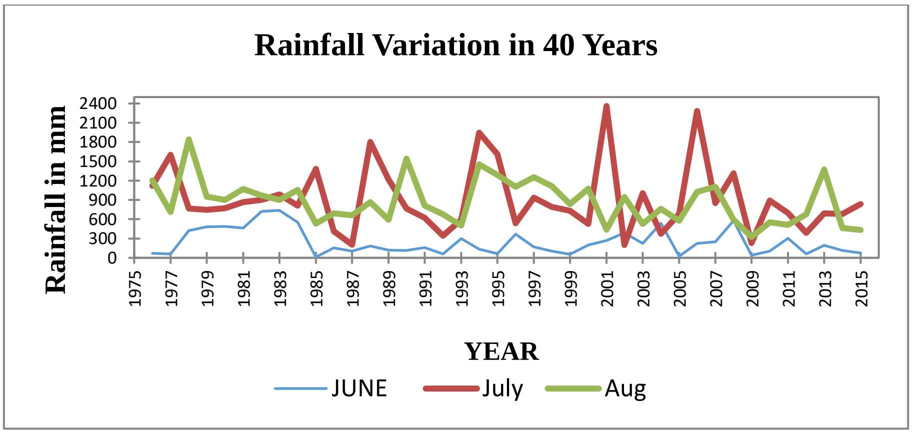


Figure 5: Rainfall of Summer Season for 40 Years

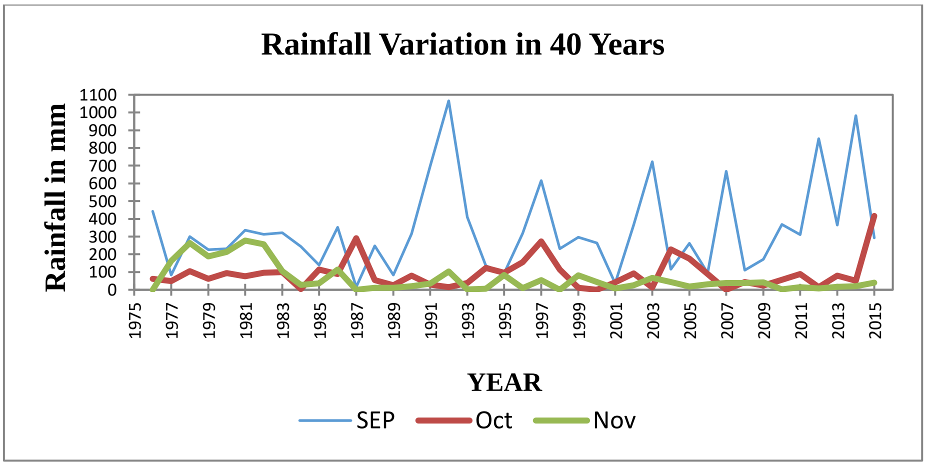
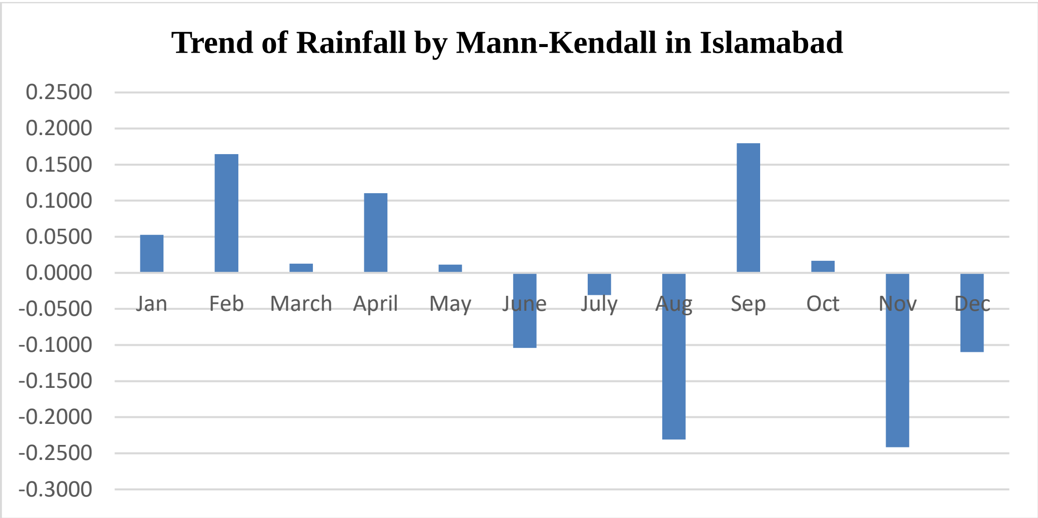


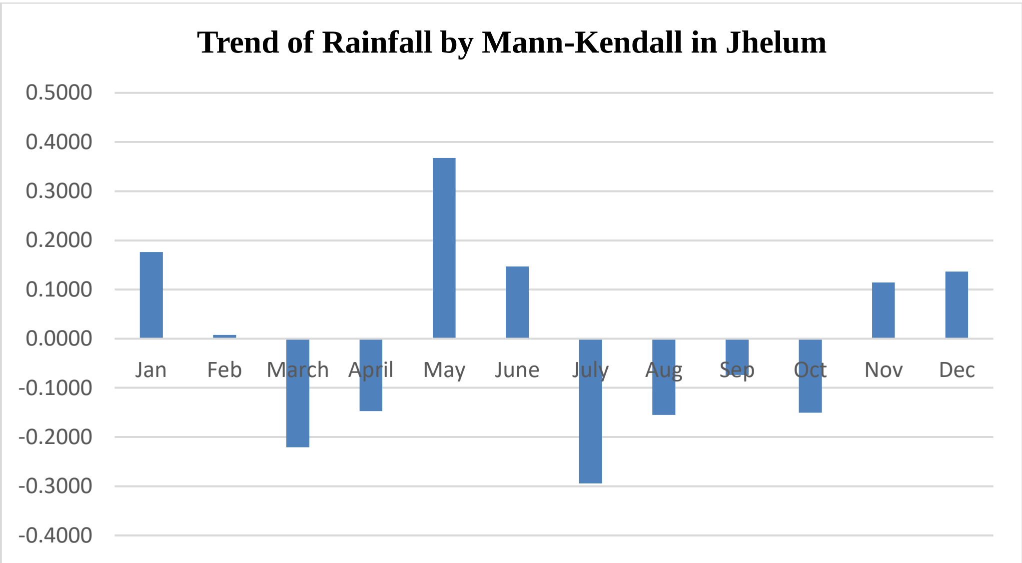
Figure 6: Rainfall of Autumn Season for 40 Years

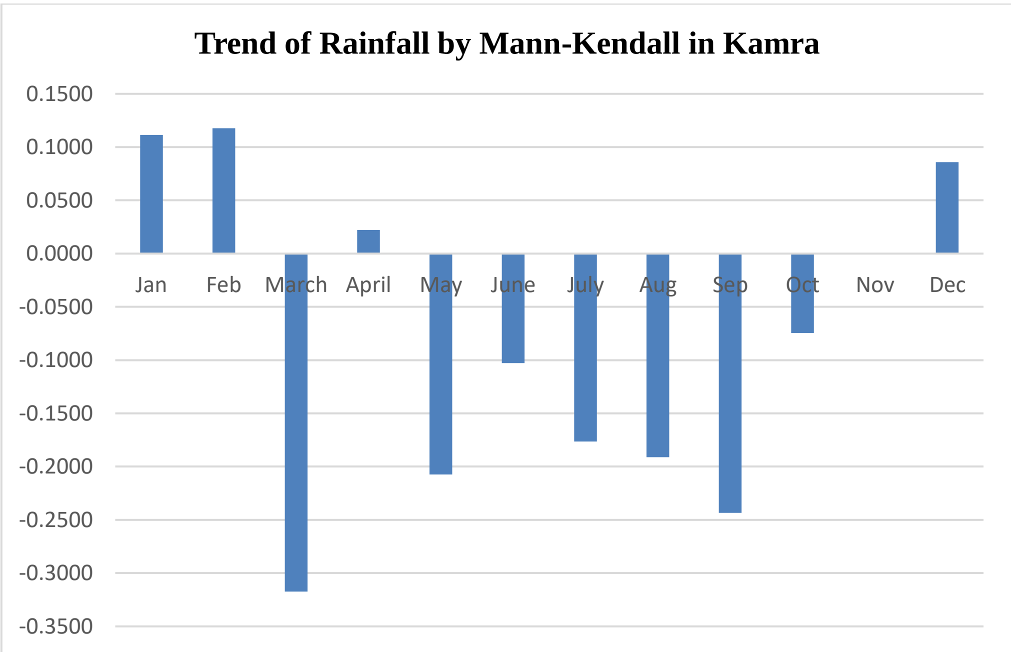
Table 1: Estimated Sen's Slope from 1976-2015 in Porhohar

Month	Variance	Mean	Standard Deviation	Sen's Slope	Kendall's Tau
Jan	7365.67	52.5475	46.8750	-0.2564	0.0526
Feb	7362.00	87.5100	71.0715	1.3000	0.1645
March	7366.67	92.6475	64.1006	0.1143	0.0128
April	7366.67	50.1275	47.1141	0.4853	0.1103
May	7365.67	35.6500	32.6715	0.0298	0.0115
June	7365.67	92.5975	72.3177	-0.8395	-0.1039
July	7366.67	357.2475	219.8958	-0.3600	-0.0308
Aug	7366.67	337.0975	133.4127	-3.1919	-0.2308
Sep	7366.67	132.2650	102.3684	1.2835	0.1795

Oct	7363.67	35.4650	36.5615	0.0543	0.0167
Nov	7362.00	23.3600	27.7480	-0.8000	-0.2416
Dec	7347.00	39.6550	42.7296	-0.3586	-0.1099







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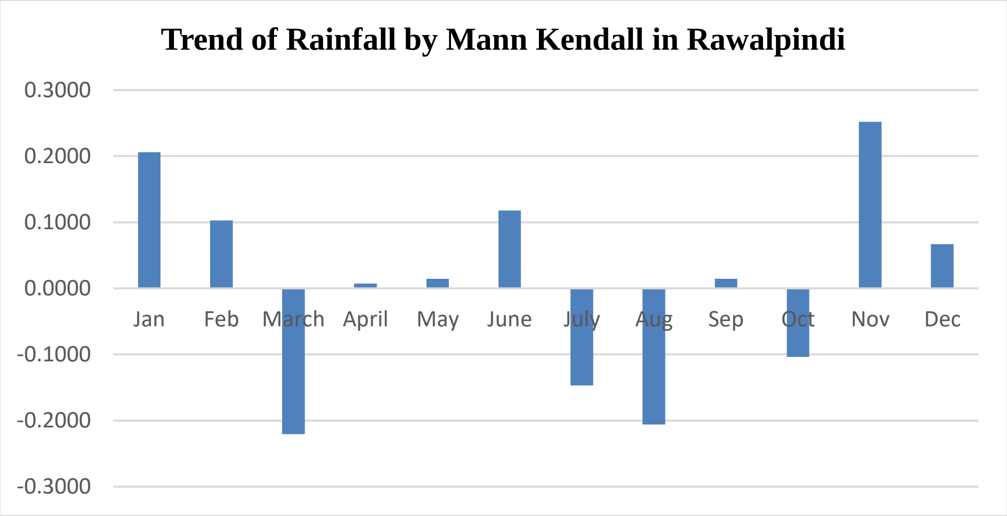

5. CONCLUSION

Occurrence of extreme events have been increased in the past two decades. It has been seen that these extreme events are occurring after an interval of every 3-4 years. From the results it is clear that the majority of the trends in the annual, seasonal and monthly T_{max} and T_{min} time series showed increasing tendency during the last decades, while the increasing trends in the T_{min} series were stronger than those in the T_{max} series. The T_{max} and T_{min} warming trends were more obvious in summer and winter than in autumn and spring. Study of annual rainfall trends showed that trends are non-significant and no prominent trend was found annually. Study of monthly trends concluded that months in monsoon season showed significant trends while other seasons have no significant trends. The estimated Sen's slope for the given years in Islamabad showed an increasing trend for seven months and decreasing trend for five months. In Jhelum, Sen's slope showed a trend for five months while decreasing trend for seven months. In Kamra, Sen's slope showed an increasing trend for just four months while decreasing trend for eight months.

REFERENCES

[1] Parry, M., Cox. B.S. 2007. Technical summary. In Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

[2] Dessens, J., Bücher, A. 1995. Changes in minimum and maximum temperatures at the Pic du Midi in relation with humidity and cloudiness, 1882–1984. Atmospheric Research, 37(1), 147-162.

[3] Serra, C., Burgueno, A., Lana, X. 2001. Analysis of maximum and minimum daily temperatures recorded at Fabra Observatory (Barcelona, NE Spain) in the period 1917-1998. International Journal of Climatology, 21(5), 617-636.

[4] Kalnay, E., Cai, M. 2003. Impact of urbanization and land-use change on climate. Nature, 423(6939), 528-531.

[5] Marengo, J.A. 2004. Interdecadal variability and trends of rainfall across the Amazon basin. Theoretical and applied climatology, 78(1-3), 79-96.

[6] Gul, M., Qazi, S.A., Qureshi, W.A. 2011, November. Incorporating economic and demographic variables for forecasting electricity consumption in Pakistan. In Electric Power and Energy Conversion Systems (EPECS), 2011 2nd International Conference on IEEE, 1-5.

[7] Salma, S., Rehman, S., Shah, M.A. 2012. Rainfall trends in different climate zones of Pakistan. Pakistan Journal of Meteorology, 9.

[8] Kendall, M. 1975. Multivariate analysis. Charles Griffin.

[9] Hamed, K.H., Rao, A.R. 1998. A modified Mann-Kendall trend test for autocorrelated data. Journal of Hydrology, 204(1), 182-196.

[10] Mann, H.B. 1945. Nonparametric tests against trend. Econometrica: Journal of the Econometric Society, 245-259.

[11] Hirsch, R.M., Slack, J. R. 1984. A nonparametric trend test for seasonal data with serial dependence. Water Resources Research, 20(6), 727-732.

[12] Hirsch, R.M., Slack, J. R., Smith, R.A. 1982. Techniques of trend analysis for monthly water quality data. Water resources research, 18(1), 107-121.

[13] Serrano, A., Mateos, V.L., Garcia, V.L. 1999. Trend analysis of monthly precipitation over the Iberian Peninsula for the period 1921–1995. Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere, 24(1), 85-90.

[14] Yue, S., Pilon, P., Phinney, B.O.B. 2003. Canadian streamflow trend detection: impacts of serial and cross-correlation. Hydrological Sciences Journal, 48(1), 51-63.

Cite The Article: Gohar Gulshan Mahmood, Haroon Rashid, Shafiq Anwar, Abdul Nasir (2019). Evaluation Of Climate Change Impacts On Rainfall Patterns In Pothohar Region Of Pakistan. *Water Conservation and Management*, 3(1): 01-06.