Trend analysis in precipitation at individual and regional levels in Baluchistan, Pakistan.

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Abstract. Pakistan's largest province by area, is Baluchistan hosts deep sea Gawadar port and is playing a vital role in one belt one road (OBOR) plan. CPEC, a Regional route comes under OBOR which connect Pakistan's Gwadar port to Chinese Xinjiang Province. CPEC Corridor upon construction is expected to revolutionize the infrastructure, economy, trade, finance, demography, environment, culture, socio-economic conditions, of Pakistan. Much of western and central CPEC routes pass through it. However, Baluchistan, due to its topography and rugged terrain, is under constant risk of rainfall driven flash floods. Flash floods are responsible for colossal damages to the infrastructure, especially roads, bridges, trade, communication that ultimately badly affects the humans, economy and the environment. The intensity and frequency of rainfall are increasing due to climate change and flash floods put everything at high risk. In this view, the assessment of changes in rainfall has got significant importance. More or less no appreciable studies have been conducted on the precipitation trend analysis and in Baluchistan. This research is focused on assessment of trend analysis in precipitation of Baluchistan using 40 years (1977-2016) data of 13 stations in Baluchistan. The data has been obtained from the Pakistan Meteorological Department (PMD). Precipitation data sample is checked for normal distribution, abrupt changes, cycles, outliers and missing values. Normal distribution of precipitation data set is done by conducting tests for normality like the Shapiro-Wilk W test, Anderson–Darling, Lilliefors, and Jarque–Bera test. Statistical tests, being the most direct methods of detecting changes in extreme rainfall intensities were adopted. Two nonparametric tests Mann-Kendall (MK) and Spearman's rho (SR) have been used to find the trends in annual and seasonal precipitations. Nonparametric methods are selected as they are less sensitive to data gaps if it exists. Theil Sen slope estimator has been used to compute the magnitude of the trend. The seasonal and regional MK test has also been applied to test the seasonal and regional trends.
Keywords. Precipitation trend analysis, regional levels, Global Climate Risk Index, Baluchistan.

1. Introduction

Pakistan is ranked 18th of most vulnerable nations in 2011 by Global Climate Risk Index. The country is categorized as a 3rd most vulnerable country among 180 countries, impacted losses due to changing weather, [1]. Therefore, it is significant to analyses historical data, its changes, finding out variability in precipitation time series to predict probable future impacts of climate change, [2-4].

Parametric and non-parametric statistical techniques are employed to undertake trend and variability analysis for precipitation time series, [5-7]. The parametric analysis includes linear regression, which needs independent normally disputed data. Nevertheless, the required data scarcely exists for hydrometeorological variables, [8]. On the other hand, the non-parametric analysis is usually employed due to its simplicity as compared to the parametric technique. Generally, Mann Kendall (MK) and Sen's Slope Estimator (SSE) is used for non-parametric analysis, [9, 10]. The MK test has

IOP Conf. Series: Materials Science and Engineering **414** (2018) 012042 doi:10.1088/1757-899X/414/1/012042

been strongly recommended by the World Meteorological Organization to estimate the trends in hydrometeorological datasets, [3]. The MK test is very important because it does not require any hypothesis for the statistical distribution of the data and can be implemented to the datasets with inconsistent and uneven sampling intervals. Numerous researches have been performed in the recent past using non-parametric analysis to study frequency change of precipitation time series, [11-14].

Few studies have been carried out regarding precipitation and trend analysis in Pakistan. The frequency of extreme precipitation occurrence was studied by Maida and Ghulam, [15]. data gathered from 41 stations and analyzed through the non-parametric Kolmogorov-Smirnov test. The study noted a rise in extreme precipitation events in the country. Investigation of precipitation trends through Dunnett T3 test and Variance Analysis of 30 years showed a decrease in precipitation trends, [16]. Hussain and Lee [14], examined data of 15 stations for the seasonal variability of extreme precipitation events. MK test and simple linear regression was used. Decreasing and increasing seasonal trends in extreme precipitation was identified in southwestern and northeastern part of Pakistan respectively. Abbas et al. [2], explored the change in the extreme in precipitation events in Punjab through MK test using data from five stations. Nevertheless, no considerable trend was identified. Similarly, Ijaz Ahmad et al. [17], carried out a study regarding precipitation behavior in the Swat River Basin. MK and Spearman's rho test was employed on data from 13 stations and a mixture of increasing and decreasing trends were found.

2. Study Area

Balochistan is the biggest province of Pakistan in terms of the area out of the four provinces. It has an area of 347,190 square kilometers comprising nearly 44 % of Pakistan's totals land area, figure-1. It encompasses the southwestern part of the country. Quetta is the provincial capital and largest city having 1 million population. Punjab and the Khyber Pakhtunkhwa lie on the northeast of Balochistan, Sindh to the east and southeast, it has 800 km long coast with the Arabian Sea to the south. Neighboring countries are Iran to the west and Afghanistan to the north and northwest.

The major economic and financial source of growth of Balochistan is Gwadar Port on the Arabian Sea, and renewable resources like natural gas, coal, precious stones, gems, marble, zinc, lead, copper in found Khuzdar area etc.

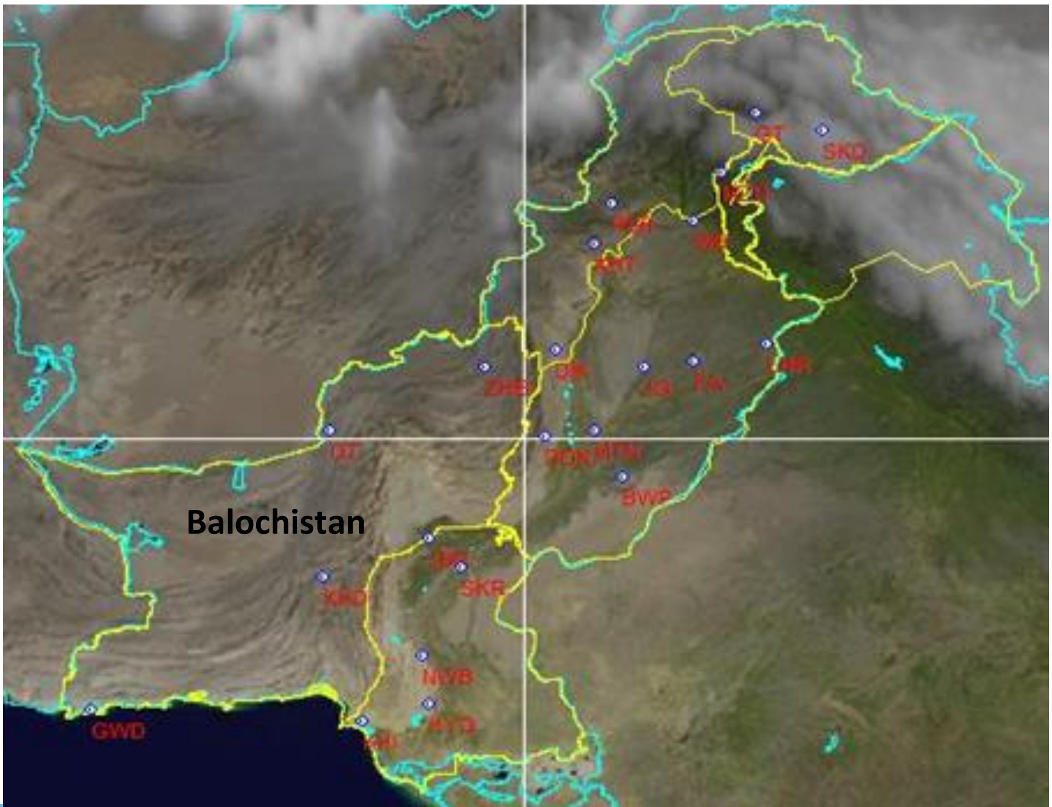

Figure 1. Baluchistan Province, the study area, (PMD).

3. Data Preparation
This research was carried out on monthly and annual precipitation data in mm/day from 15 different stations all over Balochistan. Stations were selected and scrutinized on the basis of 3 parameters (i) 40 years Data from (1977-2016) (ii) Authentic data (iii) Reliable source i.e. Pakistan Meteorological Department (PMD). Locations of all PMD weather stations in Baluchistan are shown in figure 2.

Figure 2. PMD Weather Stations of Baluchistan, (PMD).

Out of the total 15 weather stations in Balochistan, 13 weather stations were selected for the study because of their accurate, consistent, continuous data i.e. 40 years of data. Table no 1 show all 13 stations along with their longitude, latitude, mean sea level, and Mean annual precipitation and Max annual precipitation.

Table 1. Details of Selected Stations

S/n	Stations	Longitude	Latitude	Mean Sea Level	Mean Annual Precipitation	Max. Annual Precipitation
1	Dalbandin	28.88	64.39	843 m	83.30	203.7
2	Jewani	35.77	64.68	57 m	101.39	386.4
3	Kalat	29.05	66.58	2,007 m	207.49	976.9
4	Lasbella	25.87	66.71	46m	181.73	481.6
5	Nokkundi	28.82	62.75	679 m	34.44	187.6
6	Ormara	25.26	64.60	7 m	71.96	505.0
7	Panjgur	26.73	64.14	980 m	96.33	304.3
8	Pasni	25.25	63.41	10 m	102.39	356.2
9	Quetta	30.17	66.97	1,680 m	270.67	949.8
10	Sibbi	29.55	67.88	130 m	181.18	371.0
11	Zohb	31.34	69.46	1,426 m	284.00	495.0
12	Khuzdar	27.18	66.60	1,237 m	267.33	594.7
13	Barakhan	29.89	69.52	1,098 m	422.96	784.0

The precipitation data of Turbat and Gawadar weather stations do not spread over the entire study period from 1977 to 2016 and thus are not considered for the analysis.

3.1 Monthly and Annual Precipitation Data
The data, for this research obtained from PMD, was on monthly basis, which was converted to annual precipitation data for analysis. The Study period is from 1977-2016 (40 years) for the selected 13 stations all over Baluchistan.

3.2 Seasonal Data
To conduct seasonal analysis, the data is prepared by summing three to two months into 5 most common seasons namely winter, spring, summer, monsoon, and autumn. The monthly values were added to prepare the seasonal data. Table-2 illustrates the seasons being considered and the months included in each of the seasons.

Table 2. Seasonal Data

S. No	Seasons	Months
1	Winter	December, January, February
2	Spring	March, April
3	Summer	May, June
4	Monsoon	July, August, September
5	Autumn	October, November

Pakistan has been divided into 5 zones based on temperature by PMD namely zone A to Zone E. Figure-3 shows the zoning of Pakistan on the basis of temperature as defined by PMD. This research follows the temperature zoning of PMD and the study area consisting of Baluchistan province falls into three temperature-based Zones, namely: zone C, zone E primarily and some portion zone D.

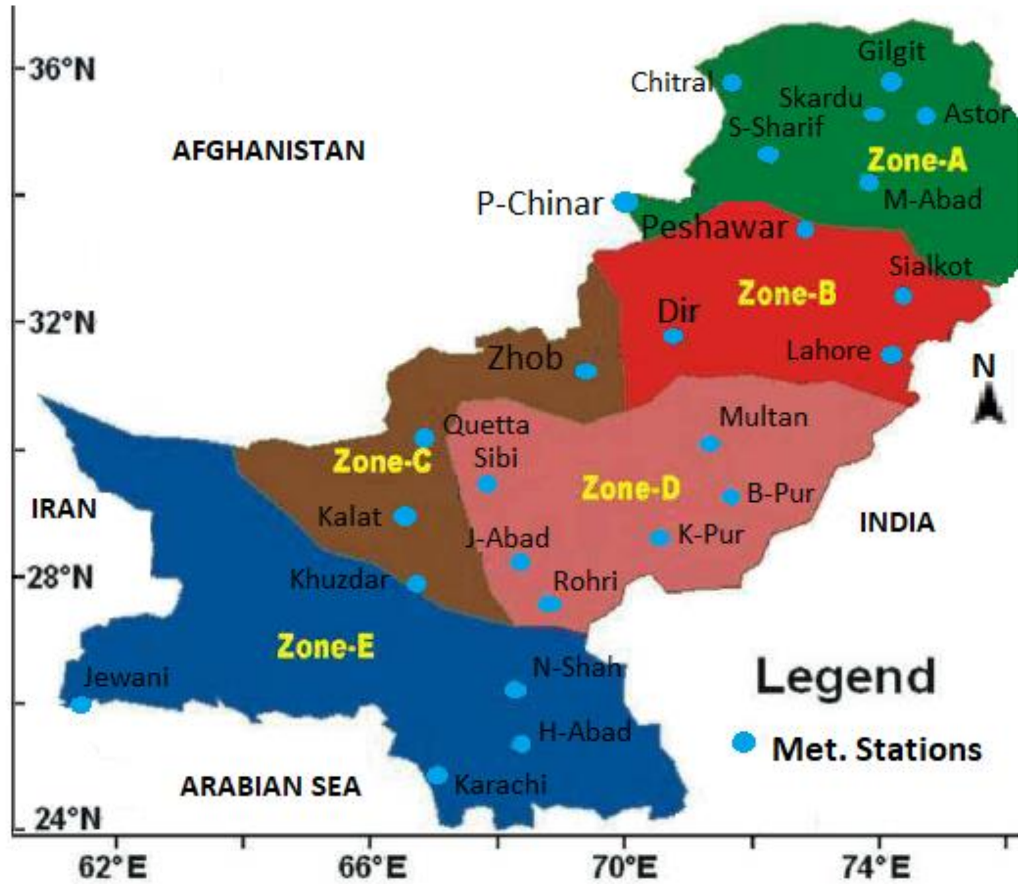

Figure 3: The temperature-based zoning map of Pakistan, [4, 11, 13, 14, 16].

3.3 Regions and Regional Data

For regional trend analysis (Table 9) Baluchistan is divided into four regions: region-1 represent province Balochistan which includes all 13 stations, regions-2 includes 5 stations which fall in zone C, region-3 includes 2 stations which fall in zone D and Region-4 includes remaining 6 stations which falls within zones E. Table-3 provides the details of regions and the stations included in each region.

Table 3. Details of Regions

Region-1	Region-2		Region-3		Region-4	
All 13 stations in Baluchistan	Dalbundin Kalat Quetta Zhob Khuzdar	Zone C	Sibi Barakhan	Zone D	Jewani Lasbella Nokkundi Ormara Panjgur Pasni	Zone E

4. Methodology

The two major methods to evaluate significant trends in precipitation time series data sets are; parametric and nonparametric trend methods. The data should be continuous independent, normally distributed and have the same standard distribution in parametric trend analysis, where as in the nonparametric method; the only condition is that the data should be independent.

Normality tests were used to check whether the time series data for each of the 13 locations are normally distributed or not. Parametric Test such as simple linear regression utilized to calculate the trend slope, its significance and validity to detect the trend in the time series precipitation data. Validity is determined by checking the normal distribution of residuals obtained from simple linear regression.

Test such as simple linear regression utilized to calculate the trend slope, its significance and validity to detect the trend in the time series precipitation data. Validity is determined by checking the normal distribution of residuals obtained from simple linear regression.

Non-parametric test such as Mann-Kendall (MK) test and Spearman's rho (SR) were used to evaluate the trends in the annual and seasonal rainfall. The reasons for adopting these tests is that they are robust and non-sensitive if the data has some gaps and do not follow the normal distribution. The magnitude of the trend estimated by Theil and Sen slope estimator (TSA). The MK and SR were applied on annual and seasonal data to evaluate the trend on annually, monthly and seasonally at each of the 13 selected stations.

The regional MK test was applied to test the regional trends on four regions: Baluchistan as a whole, temperature-based Zone C, D, and E.

4.1 Normality Tests

Precipitation data sample is checked for the characteristics such as Normal Distribution, Abrupt Changes, Cycles, Outliers and Missing Values. Normal distribution of precipitation data set is done by conducting four tests for normality like the Shapiro-Wilk W test, Anderson–Darling, Lilliefors, and Jarque–Bera test. A 2011 study concluded that Shapiro–Wilk has the best power for a given significance, followed closely by Anderson–Darling when comparing. Some research proposes this test has weaknesses. Like, the test has low power for distributions with short tails, especially for bimodal distributions. Some researchers have not included its results in their researches because of its low overall performance.

4.2 Linear Regression Analysis (Parametric Tests)

The linear regression, a parametric test and utilized to estimate linear trends in time series data. The least squares regression utilized to fit "best" straight line. The linear trend observed when slope of regression line statistically different from zero by using t-test. The positive and negative slope indicating increasing and decreasing trends respectively.

Simple linear method of least squares was used to detect the significant trend and for the comparison of trend slope. Simple linear regression calculates (1) the coefficient of variation (R^2), which is an estimate of the degree of co-variation between AR and time (1=perfect correlation, 0=zero correlation) and (2) the p-value representing the appropriateness of rejecting the null hypothesis of no trend with time. If p-values are less than 0.05, then there is a 95 percent probability that data indicate an increasing or decreasing trend, depending on the sign of the slope. The validity of linear regression results depends on whether or not the regression residuals are normally distributed.

4.3 Mann-Kendall (MK) test

The Mann-Kendall (MK) test analysis technique was widely used in detecting trends in climate variables, [18-24]. The MK test is a robust method of detecting a trend in precipitation data with a strength being its application in skewed data. The MK test is a rank-based procedure and has a low sensitivity to abrupt breaks, which may be caused by discontinuous data.

The MK test is a nonparametric test for monotonic trends where data is either consistently increasing or decreasing over time. Therefore, the MK test is not suitable when the cyclic trend observed, where data is alternatively increasing and then decreasing.

In the MK test, it is assumed that the rainfall data (X1, X2,.. ., Xn) represent "n" independent and equally distributed among random variables. The series x of Mann-Kendall statistic S by Mann [10], and Kendall [9], is written as:

$$S = \sum_{i-l}^{n-1} \sum_{j=i+1}^{n} sgn(X_j - X_i)$$

$$sgn(X_j - X_i) = \begin{cases} +1 & (X_j - X_i) > 0 \\ 0 & \text{if } (X_j - X_i) = 0 \\ -1 & (X_j - X_i) < 0 \end{cases}$$

Where i and j are observations of the xi and xj of time series and sign is a function of signum. The S is computed as a variance;

$$Var = \frac{n(n-1)(2n+5) - \sum_{i=1}^{g} t_i(t_i - 1)(2t_i + 5)}{18}$$

Where number of groups g is the tied rank and number of ties t in the group. For a sample size of n>10 or larger, the statistics Z is computed by

$$Z = \begin{cases} \frac{S-1}{\sigma} & for\ S > 0 \\ \frac{S+1}{\sigma} & for\ S < 0 \\ 0 & for\ S = 0 \end{cases}$$

The positive and negative Z values indicate increasing and decreasing trends respectively. The trends are significant if |Z| values are comparatively larger than standard normal deviate $Z_{1-\alpha/2}$ for the value of significance level (α).

When $|Z| > Z_{1-\alpha/2}$ or the p-value is smaller than the significance level (α), the null hypothesis of no trend is rejected. The alternative hypothesis that there is a significance trend in the time series is accepted. The $Z_{1-\alpha/2}$ and p-value are attained from table of standard normal distribution. For significance level of α=0.05 null hypothesis of no trend is rejected while |Z|>1.96.

4.4 Theil and Sen Slope (TSA) Estimator

The Theil and Sen's median slope estimator [25, 26], used for computing magnitude of the trends in time series data. The method as compared to simple linear regression gives a better estimate of trends because it is not affected by outliers. The Theil-Sen approach (TSA), a frequently-used to assess the significant linear trends in time series, employed in research. The TSA is powerful as compared to least-squares method because of relative insensitivity to extreme presentation, [27]. The slope Q between two points of time series x estimated by the relationship;

$$Q = \frac{x_k - x_j}{k - j}, k \neq j$$

The time series x with n point observations, N = n (n - 1)/2 and Q may evaluate. Sen's method used to estimate slope as median N values of Q. The Q* as slope estimator can be calculated by;

$$Q^* = \begin{cases} Q_{(N+1)/2}, N\ odd \\ \frac{Q_{N-2} + Q_{(N+2)/2}}{2}, N\ even \end{cases}$$

If the significant trends are 95% confidence intervals by means of non-parametric techniques as defined Salmi, et.al [28]. The quantity α is first calculated as;

$$C_\alpha = Z_{1-\alpha/2}\sqrt{V(S)}$$

The standard normal deviate Z, and α is 0.05. M_1 and M_2 indices calculated by;

$$M_1 = \frac{N - C\alpha}{2}$$
$$M_2 = \frac{N + C\alpha}{2}$$

The limits of confidence M1th and (M2+1) are the major among estimates of Q, with interpolation of non-integer figures of M_1 and M_2.

4.5 Spearman's Rho (SR) test

The SR test is a simple with uniform power for linear and non-linear trends utilized to verify the absence of trends [29, 30]. The null hypothesis (H_0) in the test of time series are independent and identically distributed, while alternative hypothesis (H_1) is that increasing or decreasing trends exist, [31]. The SR test statistic D and the standardized test statistic ZSR are gives as;

$$D = 1 - \frac{6\sum_{i=1}^{n}(R_i - i)^2}{n(n^2 - 1)}$$

The variance associated with SR test statistic D is computed as

$$Z_{SR} = D\sqrt{\frac{n-2}{1-D^2}}$$

Where Ri is the "ith" observation, Xi time series and n is the length in time series. Positive and negative values of Z_{SR} indicate upward trends and downward trends in the time series respectively. When $|Z_{SR}|>$ Z-crit for t(n-2,1-α/2), rejected null hypothesis, the significant trend occurs in time series. The t(n-2,1-α/2) is a critical value of t from the t-student table, for 5% significant level. The value of t(n-2,1-α/2) for n=40, the sample size in this study is 2.024.

4.6 Regional Mann-Kendall (RMK) test

In order to assess trends at a regional scale, the regional MK test was employed by Hirsch, Slack, the Smith and Douglas et al. [32, 33, 34], to quantitatively combine results of the MK test for individual stations and to evaluate the regional trends. In the regional MK test, the Sr of regional data is calculated as:

$$S_r = \sum_{i=1}^{n} S_i$$

Where Sr is Kendall's S for the "ith" station in a region with m stations within the region. If Sr is estimated using independent identically distributed data, Sr is approximately normally distributed for large m with mean equal to 0 and the variance as noted below

$$var\,(S_r) = \sum_{i=1}^{n} Var = \sigma^2$$

$$Z_r = \begin{cases} \dfrac{S_r - 1}{\sigma} & for\ S_r > 0 \\ \dfrac{S_r + 1}{\sigma} & for\ S_r < 0 \\ 0 & for\ S_r = 0 \end{cases}$$

To determine whether to reject or not the null hypothesis of no trend, and test statistic Z_r is assessed against the critical value Zcrit corresponding to the specific significance level α of the test. For the two-tailed test, the critical value is defined as $\Phi^{-1}(1-\alpha/2)$, where Φ is cumulative distribution function of standard normal distribution, [35]. The null hypothesis is rejected and the trend is considered significant statistically if the value of |Zr|≥ Zcrit.

5. Results and Discussions

The MK, SR and RMK tests were run on the time series data with significance levels of 10% and 5% for annual, monthly and seasonal time series whereas with 5% on regional time series and the results are presented in the three sub-sections as discussed below.

The first section discusses the applicability and validity of linear regression test. The second section discusses the presence of significant trends detected through non-parametric tests including MK and SR at each of the selected 13 stations at the local level on the annual, monthly and seasonal time series data. The third section discusses the annual and seasonal trends at the regional level using RMK test.

5.1 Assessing normality of time series data

The normality tests including Shapiro-Wilk W test, Anderson–Darling, Lilliefors, and Jarque–Bera test were run on the annual time series to evaluate the normal distribution of time series data and the results are given in Table-4.

Table 4. Normality Test on Annual Time Series

S.No	Stations	Shapiro-Wilk	Anderson-Darling	Lilliefors	Jarque-Bera
1	Dalbandin	passed	passed	passed	passed
2	Jewani	failed	failed	failed	failed
3	Kalat	failed	failed	failed	failed
4	Lasbella	failed	failed	failed	failed
5	Nokkundi	failed	failed	failed	failed
6	Ormara	failed	failed	failed	failed
7	Panjgur	failed	failed	failed	failed
8	Pasni	failed	failed	failed	failed
9	Quetta	failed	failed	failed	failed
10	Sibi	passed	passed	passed	passed
11	Zhob	passed	passed	passed	passed
12	Khuzdar	failed	failed	Passed	failed
13	Barakhan	passed	passed	passed	passed

Normality test runs on annual precipitation time series data shows that the time series data of only four stations namely Dalbandin, Sibbi, Zhob, and Barakhan are normally distributed and mostly the data is not normally distributed.

5.2 Trend using Linear Regression and its validity

Parametric tests - Linear regression analysis with least square fit test were run on all the time series data for detecting of the trends and the results are presented in Table-5.

Table 5. Linear Regression on Annual Time Series

S.No	Stations	R^2	Regression Slope	P-value	Result	Residual normality
1	Dalbandin	0.0499	-0.9179	0.166	No trend	passed
2	Jewani	0.07532	-2.0969	0.087	No trend	failed
3	Kalat	0.0015	0.5609	0.811	No trend	failed
4	Lasbella	0.0541	-2.3279	0.149	No trend	failed
5	Nokkundi	0.015	0.403	0.451	No trend	failed
6	Ormara	0.003	0.4423	0.736	No trend	failed
7	Panjgur	0.062	-1.2097	0.121	No trend	failed
8	Pasni	0.0357	-1.3075	0.243	No trend	failed
9	Quetta	0.1264	-4.707	0.024	Decreasing	failed
10	Sibbi	0.038	1.509	0.228	No trend	passed
11	Zhob	0.0534	-1.8367	0.151	No trend	passed
12	Khuzdar	0.0302	-1.7735	0.283	No trend	failed
13	Barakhan	0.017	-1.590	0.419	No trend	passed

Linear Regression failed in all stations except Quetta. The conclusion drawn is that the parametric tests are not suited for trend analysis on the annual precipitation because the data is not normally distributed and doesn't have the same standard distribution. Non-parametric MK and SR tests should be adopted to evaluate the significant trends in the precipitation time series data and TSA should be used for calculating the magnitude of the slope.

5.3 Annual, Monthly, and Seasonal Trends

5.3.1 Annual Trends

MK annual precipitation analysis shows that only two stations namely Panjgur and Quetta out of thirteen has 5% significant trend, which is also decreasing in nature. Sen's Slope result shows decreasing trend in nine (9) stations and increasing trend in two (2) stations and no trend in the remaining two (2) stations, however, Sen's Slope is not recommended for trend analysis, it is used mainly to determine the trend. Results of MK analysis on the annual precipitation data for the thirteen (13) stations are shown in Table-6.

Table 6. MK Test Results Increasing (Decreasing) on Annual Time Series with 5% Significance

S/n	Stations	Mann-Kendall					Sen's nonparametric estimator of slope			
		Kendall's tau	S	Z	Prob (%)	Result	Sen Slope	Lower Limit	Upper Limit	Result
1	Dalbandin	-0.137	-107.00	-1.235	21.25%	no trend	-1.035	-1.258	-0.623	(trend)
2	Jewani	-0.209	-163.00	-1.887	5.75%	no trend	-1.347	-1.75	-0.95	(trend)
3	Kalat	0.068	53.00	0.605	53.69%	no trend	0.814	0.22	1.56	(trend)
4	Lasbella	-0.121	-94.00	-1.083	28.08%	no trend	-1.754	-2.42	-1.06	(trend)
5	Nokkundi	-0.209	-163.00	-1.887	5.75%	no trend	-1.358	-1.75	-0.95	(trend)
6	Ormara	-0.040	-31.00	-0.349	71.79%	no trend	-0.205	-0.53	0.04	no trend
7	Panjgur	-0.236	-184.00	-2.132	3.24%	(trend)	-1.198	-1.38	-0.95	no trend
8	Pasni	-0.122	-95.00	-1.095	26.83%	no trend	-1.039	-1.39	-0.62	(trend)
9	Quetta	-0.241	-188.00	-2.178	2.88%	(trend)	-2.968	-3.50	-2.24	(trend)
10	Sibbi	0.144	112.00	1.293	19.75%	no trend	1.712	1.23	2.42	(trend)
11	Zhob	-0.203	-158.00	-1.829	6.7%	no trend	-2.121	-2.64	-1.65	(trend)
12	Khuzdar	-0.172	-134.00	-1.549	12.19%	no trend	-2.288	-2.81	-1.52	(trend)
13	Barakhan	-0.079	-62.00	-0.710	47.99%	no trend	-1.584	-2.46	-0.66	(trend)

Spearman's rho also showed trends in two (2) stations namely Panjgur and Quetta out of thirteen (13) stations, which validates findings of MK results. The results are presented in Table-7.

Table 7. SR Increasing (Decreasing) Test Results on Annual Time Series with 5% Significance

S.No	Stations	Spearman's Rho		
		Abs.Z_{SR}	**t-crit(df,1-alpha/2)**	**Result**
1	Dalbandin	1.19517	2.024394164	no trend
2	Jewani	1.91667	2.024394164	no trend
3	Kalat	0.71783	2.024394164	no trend
4	Lasbella	0.95980	2.024394164	no trend
5	Nokkundi	1.91667	2.024394164	no trend
6	Ormara	0.17876	2.024394164	no trend
7	Panjgur	2.31238	2.024394164	(trend)
8	Pasni	1.04218	2.024394164	no trend
9	Quetta	2.42614	2.024394164	(trend)
10	Sibbi	1.17868	2.024394164	no trend
11	Zhob	1.92531	2.024394164	no trend
12	Khuzdar	1.63060	2.024394164	no trend
13	Barakhan	0.82972	2.024394164	no trend

5.3.2 Monthly Trends

MK tests were run on the monthly data to evaluate the increasing (decreasing) trends in the monthly time series data for the significance levels of 10% and 5%. Minimum of 16 observations are considered as a threshold for detecting the monthly trends. Increasing (decreasing) trend results are presented in Table-8.

Table 8. MK Test Results Increasing (Decreasing) on Monthly Time series on 10% and 5% Significance

Months	1	2	3	4	5	6	7	8	9	10	11	12	13
	Dalbandin	Jewani	Kalat	Lasbella	Nokkundi	Ormara	Panjgur	Pasni	Quetta	Sibbi	Zhob	Khuzdar	Barakhan
Jan	-10%	-	-	-	-	-	-	-	-5%		-5%	-	-5%
Feb	-	-	-	-	-	-	-	-	-			-	-
Mar	-	-	-	-	-	-	-	-	-10%			-	-
April	-	-	-	-	-	-	-	-	-			-	-
May	-	-	-	-	-	-	-	-	10%	10%		-	-
Jun	-	-	-	-	-	-	-	-	5%	10%	5%	-	-
July	-	-	-10%	-	-	-	-5%	-	-	-	-	-	-
Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
Sept	-	-	-	-	-	-	-	-	-	-	-	-	-
Oct	-	-	-	-	-	-5%	-	-	-	-	-	-	-
Nov	-	-	-	-	-	-	-	-	-	-	-	10%	5%
Dec	- 5%	-5%	-	-	-	-	10%	-	-10%	-	-	-10%	-

5.3.3 Seasonal Trends

Similarly, MK and SR tests were run on prepared seasonal data on the five (5) seasons namely winter, spring, summer, monsoon and autumn for 13 stations. Results of the seasonal trends are further scrutinized with respect to the strength of trend and depth of observations. Minimum of 16 observations are considered as a threshold for detecting the monthly trends. Increasing (decreasing) trend results are presented in Table-9.

Table 9. MK Test Results Increasing (Decreasing) on Monthly Time Series with 10% and 5% Significance

Seasons	1	2	3	4	5	6	7	8	9	10	11	12	13
	Dalbandin	Jewani	Kalat	Lasbella	Nokkundi	Ormara	Panjgur	Pasni	Quetta	Sibbi	Zhob	Khuzdar	Barakhan
Winter	-	-5%	-	-	-	-	-	-	- 5%	-	-	-	-5%
Spring	-	-	-	-	-	-	-	-	-	-	-	-	-
Summer	-	-	-	-	-	-	-	-	10%	10%	-	-	-
Monsoon	-	-	-	-	-	-	-5%	-	-	-	-	-	-
Autumn	-	-	-	-	-	-5%	-	-	-	10%	-	-5%	-

5.3.4 Regional Trends

MK tests were run at the regional level for the four regions i-e province, Zones C, D & E on the annual, seasonal and monthly time series. The results from the regional MK test as a single region (for the four regions) for the study periods are shown in Tables-9. The regional trend analysis for all the cases shows that there is a significant positive or (negative trend) in the AR intensity data at the 10% and 5% significance levels for 4 regions as a single region.

Table 10. RMK Test Results Increasing (Decreasing) on Annual, Seasonal and Monthly Time Series with 10% and 5% Significance

REGIONS	Annual	Winter	Spring	Summer	Monsoon	Autumn	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PROVINCE	-5%	-5%	-5%	-5%	-5%	-	-5%	-	-5%	-	-	5%	-10%	-5%	5%	-5%	-	5%
ZONE C	-5%	-5%	-5%	-	-5%	-	-5%	-	-	-	-	5%	-5%	-10%	10%	-	-	-5%
ZONE D	-	-	-	5%	-	-5%	-5%	-	-	-	-	5%	-5%	-	-	-	-5%	-
ZONE E	-5%	-5%	-5%	-	-5%	-5%	-5%	-10%	-5%	-	-	10%	-	-	-	-5%	-	-5%

6. Conclusion and recommendations

A study is conducted to find out trends of rainfall intensity in Pakistan. The selected study area for the study is Baluchistan-the largest province of Pakistan based on land area. Data for the study is collected from 13 different stations throughout the province. The time span of the data is four decades, from 1977 to 2016. The data is analyzed on the annual, seasonal and monthly basis to observe trends in rainfall intensity. Non-parametric test namely Mann-Kendall (MK) and Spearman's rho (SR) tests for trend analysis is conducted at 5% and 10% significance levels to monthly rainfall time series data on annual, monthly and seasonal basis. Theil and Sen's (TSA) slope approach applied for quantify slope trend. The Regional Mann Kendall test (RMK) test is employed to evaluate trends at a regional scale for the four regions.

The results of MK and SR tests for annual time series on individual stations at local level show that the number of statistically significant negative trends was greater than the statistically significant positive trends, thus, indicating the decreasing trend in rainfall. Similar trends are observed when the MK test is applied to monthly and seasonal time series, which confirms the findings of the MK tests on annual rainfall time series on individual stations. Whereas, in the case of regional tests the number of negative trends are significantly increased that depicts the decrease in precipitation on overall Baluchistan on a large scale.

As discussed earlier in this research paper regarding the significance of the study and the study area, Baluchistan: not only the largest province of Pakistan according to land mass but also a significant portion of CPEC is passing through Baluchistan. Moreover, Gawadar port is also situated in the same province, which will play a pivotal role in socio-economic development of Pakistan. The study will be a baseline study to compare the effect of CPEC and other anthropogenic activity on precipitation trend once it is completed. The analysis and results can be employed as an input for infrastructure planning of the area, which is going to be the financial hub of the country.

It is recommended that the MK test should also be conducted on annual maximum rainfall intensity data and annual maximum rainfall temperature data. Additionally, it is also highly recommended to study the potential effects of large-scale climatic indices to know the long-term precipitation trend of Baluchistan. The author is undertaking this study as a next task. Such in-depth studies will help in identification and adaptation of alternate solutions and mitigation strategies for Baluchistan, Pakistan.

Acknowledgment
The authors would like to thank the PMD for sharing precipitation data, to reviewers for their valuable comments and review to enhance the research excellence.

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