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RESEARCH ARTICLE

# STATISTICAL ANALYSIS OF RAINFALL TREND FOR THE NARI RIVER BASIN OF BALOCHISTAN

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ABSTRACT

Climatic variability for a region is referred to prolonged modification in precipitation, humidity, temperature, wind, evaporation and other parameters of metrology. Quantification of climate variability is essential to identify the change that has already occurred, as this will not only assist to make prediction but also lead to a better preparedness for natural disasters. The purpose of the present study was to examine the variability in rainfall occurred in the Nari River Basin of Balochistan, Pakistan from 1962 to 1993 by analyzing monthly and yearly precipitation data of 12 stations. The variability in monthly trends of the zones was represented through graph. Analysis of variance technique was used to determine any significant difference among the three sub-basins of both North and South zone of the basin. Significant differences were observed among the three sub-basins of both zones. Highest monthly precipitation recorded was 250.2 inches in the Northern zone and lowest 19.3 inches in the South zone. Linear regression analysis revealed no statistically significant trend for yearly and monthly rainfall data in both zones. The Mann-Kendall test revealed a statistically significant upward trend in some months in the South zone.



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## INTRODUCTION

Water, a limited resource on earth, is one of the most valuable, essential resources and is vital for human survival. The paramount origin of rain in any region is precipitation. Rainfall fluctuations, in intensity, quantity, frequency, and type (e.g. snow vs. rain), influence society and environment (Trenberth, 2011).The water resources system believes to be affected by the variation in rainfall over distinct time scale, as rainfall drives other hydrological processes such as groundwater, flow surface flow (De Lima *et al.*, 2010). Thus, it is essential to enquire the recent changes in rainfall patterns that are claimed by different studies. The quantity of water needed for distinct daily roles depends on the amount of precipitation in that specific region (Nyatuame *et al.*, 2014). Persistent absence or excess amount of precipitation will cause drought or flooding, respectively. Information on precipitation instability is therefore required for the better management of scant water resources that are under constant strain due to increases in population growth that are in turn responsible for increase in water demand. The amount of water in earth is always constant. Around 97% of the water in the world is in the oceans, with only 3% in fresh water in lakes, rivers and glaciers.

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Precipitation stores fresh water on the earth and therefore it is the vital segment of the water cycle. For decades Pakistan has experienced prolonged periods of rainfall fluctuation shifting between such periods in northern and Southern parts of the country (Burke *et al.*, 2013). Balochistan is the largest province of Pakistan, located in the South-Western region of the country and comprising of 44% of the country's total land mass. The province has confronted the issue of scant water resources for decades. In the past, Balochistan's economy has not done well. It has experienced the worst growth record and a terrible infrastructure, and an acute water crisis has been observed in the province. The woeful economic situation of the province results in poor living standards, the highest poverty and lowest progression indicators (Khan, 2011). The Nari River of Balochistan originates from district Zhob in the North province, comprising of streams (locally named as *Ruds*) that connect the Loralai tributary to become Beji tributary. Subsequently, at the joining of Beji and Khost tributaries to the East of Spera Ragha (in the Toba Kakar range, 6.5km), it is named as the Nari River. It outfall into Hammal Lake in Sindh and then ultimately into Manchar Lake which further flows into the Indus River as shown in Fig.1. The province of Balochistan suffers from water scarcity with immense temporal variability in precipitation. The average yearly rainfall in Nari River Basin (NRB) is 274 mm (Riaz *et al.*, 2008). The Nari River is a crucial river basin for Balochistan and it is a tributary of the Indus river system.

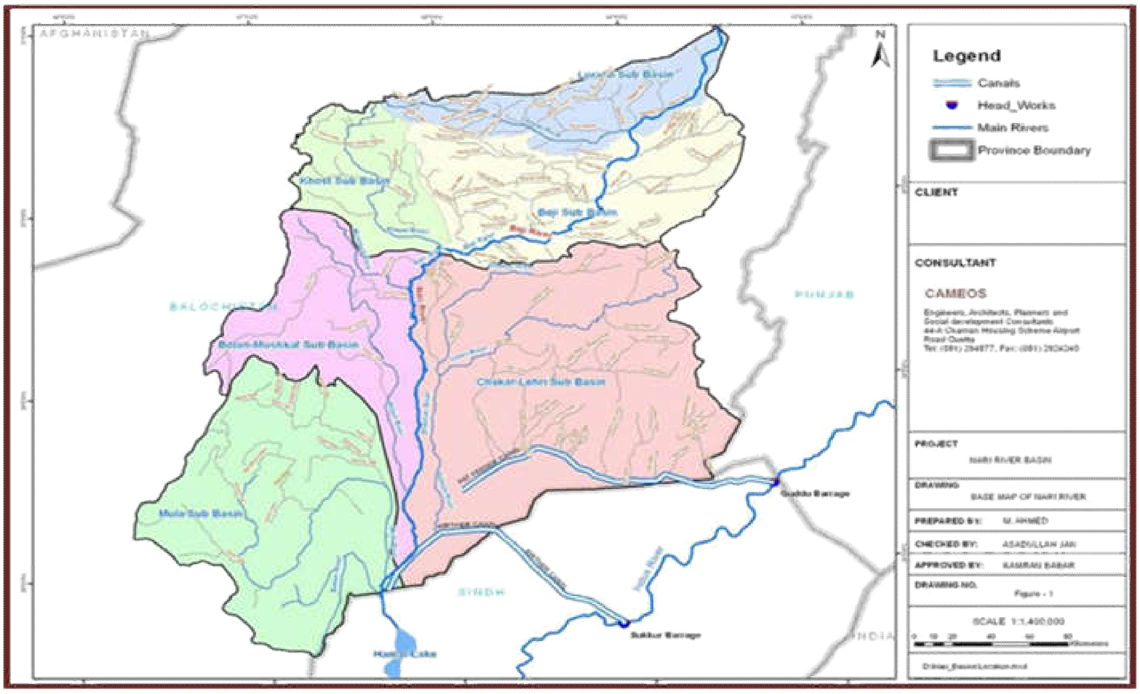


**Fig. 1. Map of Nari River Basin and the six sub-basins (Irrigation Department Government of Balochistan, Pakistan)**

The basin in the study is grouped into six sub-basins, namely the Loralai, Beji, Khost, ChakarLehri, Bolan Mushkaf and Mula. The first three sub-basins are linked with the Northern part of the province and the rest are associated with the Southern. The main source of water in the NRB is precipitation, both for surface and groundwater recharge. Due to a lack of snowfall data in the NRB, precipitation data would be used for the statistical analysisof the long-term historical data. In Balochistan and the NRB, droughts are a usual event. Precipitation is variable in the NRB and therefore it is province's vital basin, as it accrues rainfall from both the monsoonal climate and western disturbance. Jayawardene *et al*. (2005) carried out work on precipitations trend in Sri Lanka. The work was evaluated on 100 years' rainfall data recorded across 15 stations by using statistical methods such as the Mann-Kendall rank test, the least-square regression and the Spearman rank correlation.

Their results revealed an increasing statistically significant trend at the rate of 3.15 mm/year (perceived at Colombo and for Nuwara Eliya), while in Kandy stations a downward trend was noted at the rates of 4.87 mm/year and 2.88 mm/year. Kwarteng *et al*. (2009) studied 26 years' precipitation data of the Oman region. Different analysis techniques such as: Total rainfall, Number of rainy days, Maximum daily rainfall, Extreme rainfall events, and Rainfall intensities were used. Lazaro *et al*. (2001) also used a similar analytical approach. To evaluate the trend in data, the Mann- Kendall test was employed. Their study outcomes depicted huge variability in rainfall across the Oman region. Mann-Kendall statistics also revealed decreasing but insignificant trends in the data. Satyamurty *et al*. (2009) conducted a study on trend analysis of rainfall across the major rivers of the Brazilian Amazon Basin during the 1925-2007 periods. A simple linear regression line $y = a + bxwas$ used to determine trends in the basin. Their results revealed a significant positive trend in yearly precipitation at five stations out of the 18 stations under study. Kumar *et al*. (2009) carried out a precipitation trend study in India to observe trend modification in precipitation on both a seasonal and annual scale.

The Mann-Kendall test was employed to analyzed monthly, seasonal, and yearly precipitation trends by using a monthly data series of 135 years for 30 sub-divisions in India. The result revealed insignificant trends in yearly, monthly and seasonal precipitation data. Monsoon and yearly precipitation was found to be decreased whereas pre-monsoon, post-monsoon and winter precipitation was found to be increased at national scale. Naheed and Rasul (2011) evaluated a study on the rainfall variability in Pakistan by utilizing 50 years' data. The statistical method of variability coefficient was calculated. The result revealed a highest value of variability coefficient observed in Balochistan (251%), followed by Sindh (247%) and Punjab (208%), whereas the annual analysis revealed the increasing trend in variability coefficient from North to South respectively. Salma *et al*. (2012) carried out a study on the precipitation trends in various climatic regions of Pakistan. The study covered a period of 30 years. The statistical technique of Analysis of Variance along Dunnett's T3 test was used. The study depicted a downward trend in the whole country at the rate of -1.18mm/decade. Vyas *et al*. (2012) carried out a study on the trend analysis of rainfall for India's Junagadh District over a 25-year period. The method of least square was employed to observe the trends in precipitation of the period under study. The results revealed a series of periods between 1985-1989, 1990-1994, and 2000-2005 that signified upward trends, and a period between 1995-1999 that showed a downward trend. Babar *et al*. (2013) carried out a trend analysis of rainfall for India's Nethravathi Basin for the period of 40 years. Mann-Kendall and Sen Slope statistical techniques were employed to evaluate the trends in the data. The results disclosed an increasing trend for the month of September and a decreasing trend for the months of June, July and August. Hassan *et al*. (2014) carried out a study on yearly and seasonal precipitation trends in the coastal parts of South-East Bangladesh. The study covered a period of 32 years. Mann-Kendall and Sen Slope tests were employed in their study. The result indicated that yearly precipitation in South-East Bangladesh showed a statistically significant upward trend. Seasonal evaluations exhibits, i.e. pre-monsoon, rainy monsoon and post-monsoon, received a higher amount of precipitation than the winter season comparatively. Swain *et al*. (2015) carried out a study on trend analysis for monthly precipitation data for the Raipur district, Chhattisgarh. The study covered a period of 102 years. They used the methods of Mann-Kendall and Sen Slope estimation. The results disclosed a decreasing trend for almost all months in a year for the span of time under consideration. This paper presents statistical analysis of long term precipitation data for the NRB of Balochistan. This study aims to assess the variation in rainfall across the NRB. The analysis of the droughts conditions in the NRB is mainly based on the rainfall distribution in the basin thus, the major objective of this study is to determine and analyze the temporal variation in monthly and annual precipitation data of NRB by analyzing trend in monthly and yearly rainfall data.

## MATERIAL AND METHODS

Monthly and annual precipitation data for the period from 1962 to 1993 was obtained from the Meteorological and Irrigation Department of Balochistan on the six-sub basins of the Nari River Basin. To observe the characteristics of precipitation in the basin, statistical analysis of the precipitation in the NRB was conducted. The statistical analysis was used to determine the measure of central tendency (mean, median, etc.) and dispersion (range, S.D, etc.) and to evaluate any significant difference among the three sub-basins of North and South zones, the analysis of variance (ANOVA) was used. Graphs were constructed to determine the modification in trends within the months of the period under study. Linear regression and nonparametric method of Mann-Kendall was used to evaluate the trends in monthly precipitation. Linear regression is one of the easiest methods to evaluate trends in data. The model for linear regression line is given by where is the explanatory variable (time) and (rainfall) is the response variable. Negative and positive trend is described by the slope of regression line. Linear regression requires the assumption of normal distribution. The R-square $^2$ estimate or the coefficient of determination was employed to determine the goodness of fit of the regression model. The Mann-Kendall test was also used in the study to evaluate trends in the time series data for the six sub-basins. Thas *et al.* (2007) used the Mann-Kendall test statistics in their study of selection of nonparametric method for identification of monotonic trend in water quality. The test is as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn\left(x_j - x_i\right) \qquad (1)$$

where

$$sgn\left(x_j - x_i\right) \begin{cases} +1 & if\left(x_j - x_i\right) > 0 \\ 0 & if\left(x_j - x_i\right) = 0 \\ -1 & if\left(x_j - x_i\right) < 0 \end{cases} \qquad (2)$$

For the statistics S is approximately normally distributed with mean (Hirsch and Slack, 1984).

$E(S)$=0

and the Variance.

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t(t-1)(2t+5)}{18} \qquad (3)$$

Where tiare the ties of sample time series. The test statistics is computed as in eq (4),

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t(t-1)(2t+5)}{18} \qquad (3)$$

where, the statistic$Z$ follows a normal distribution and used to evaluate the existence of a statistical trend, a positive value of $Z$signifies an upward trend and negative (downward trend). At significance level $\alpha$ (usally 5%), $H_0$ is rejected if the value of $Z \geq Z_{\alpha/2}$, than the trend of the data is considered to be significant. To test the significant trend, $P$-value (Probability value from Two-Tailed test using the $Z$-value can also be used. If $P$-value $>\alpha$ than the null hypothesis ($H_0$: there is no trend in the data is failed to reject).

## RESULTS AND DISCUSSION

For the Southern and Northern zone the highest mean monthly precipitation for the period under study as indicated in figure 2 recorded in July and the month of October received the minimum amount of precipitation. The figure also indicated that September, October and November were the driest months for both zones.

Table 1 represents the descriptive statistical properties of monthly precipitation for South zone. It can be seen from table 1 that July in the South zone is noted with the highest standard deviation value i.e. (5.5 inches) indicating that data points are spread out over a wider range of values and the lowest standard deviation recorded (0.5inches) for the month of October. The highest quantity of mean monthly precipitation was observed for the month of January (3.2 inches) and the maximum precipitation occurred in the month of July (28.3inches).

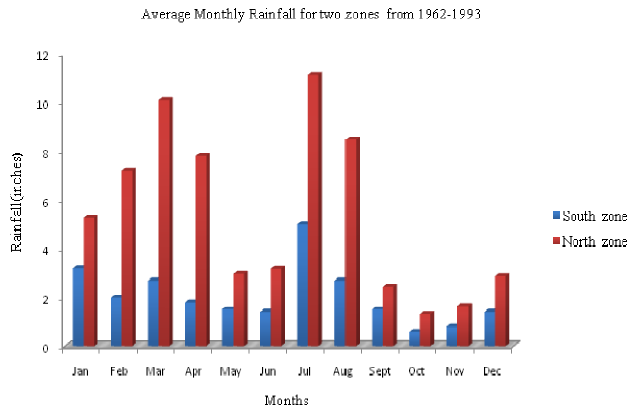


**Fig. 2. Mean Monthly Rainfall of Nari River Basin**

The month of April and June showed a negative coefficient of kurtosis indicating that distribution is more flat than normal distribution while the skewness coefficient for almost all months are positive indicating the occurrence of low precipitation. For some of the months the skewness coefficient is equal to or nearly equal to zero signifying the data follows a normal distribution. The trend of rainfall for the period of 32 years from January to December for the South zone has been analyzed for each month using linear regression analysis, and the results are reported in Table 2. The linear trend lines of the monthly rainfall revealed a downward trend for the months of July, November and December, and an upward trend for the other months.

**Table 1. Descriptive statistics of monthly rainfall (inches) of South zone**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 3.2 | 2.0 | 2.7 | 1.8 | 1.5 | 1.4 | 5.0 | 2.7 | 1.5 | 0.6 | 0.8 | 1.4 |
| S.D | 2.9 | 2.1 | 3.2 | 1.3 | 1.3 | 1.0 | 5.5 | 2.7 | 1.4 | 0.5 | 0.7 | 1.7 |
| Kurtosis | 2.7 | 5.0 | 9.3 | -0.4 | 4.2 | -0.8 | 10.3 | 4.1 | 9.2 | 0.2 | 0.6 | 15.8 |
| Skewness | 1.5 | 2.2 | 2.7 | 0.7 | 1.8 | 0.5 | 2.8 | 1.9 | 2.6 | 0.6 | 1.0 | 3.6 |
| Range | 13.0 | 8.8 | 16.1 | 4.9 | 5.6 | 3.6 | 28.3 | 10.9 | 7.5 | 1.8 | 2.7 | 9.4 |
| Minimum | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Maximum | 13.0 | 9.0 | 16.1 | 4.9 | 5.6 | 3.6 | 28.3 | 10.9 | 7.5 | 1.8 | 2.7 | 9.4 |
| Total | 102.4 | 62.7 | 86.7 | 58.3 | 46.5 | 44.7 | 158.8 | 85.4 | 48.5 | 19.3 | 26.5 | 43.2 |

**Table 2. Statistical result for monthly rainfall of South zone 1962-1993**

| Months | Regression Equation | R-Square | P-Value | Statistically Significant |
|---|---|---|---|---|
| Jan | | 0.07 | 0.13 | No |
| Feb | | 0.08 | 0.09 | No |
| Mar | | 0.00 | 0.87 | No |
| Apr | | 0.00 | 0.99 | No |
| May | | 0.06 | 0.17 | No |
| Jun | | 0.02 | 0.37 | No |
| Jul | | 0.00 | 0.75 | No |
| Aug | | 0.00 | 0.79 | No |
| Sept | | 0.06 | 0.16 | No |
| Oct | | 0.00 | 0.81 | No |
| Nov | | 0.05 | 0.21 | No |
| Dec | | 0.03 | 0.30 | No |

**Table 3. Analysis of variance of mean annual rainfall among the three Sub Basins of the South zone of the Nari River Basin from 1962-1993**

| | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 0.469 | 2 | 0.235 | 5.666* | 0.005 |
| Within Groups | 3.85 | 93 | 0.041 | | |
| Total | 4.319 | 95 | | | |

Df=Degrees of freedom, *=0.05 level of significant, Sig.=Significance

**Table 3.1. LSD multiple comparison of average yearly precipitation of the three sub-basins of South zone from 1962 to 1993**

| (I) Sub Basin | (J) Sub Basin | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| Bolan Mushkaf | Mula | .14094* | 0.05087 | 0.007 | 0.0399 | 0.2419 |
| | ChakarLehri | -0.01375 | 0.05087 | 0.788 | -0.1148 | 0.0873 |
| Mula | Bolan Mushkaf | -.14094* | 0.05087 | 0.007 | -0.2419 | -0.0399 |
| | ChakarLehri | -.15469* | 0.05087 | 0.003 | -0.2557 | -0.0537 |
| ChakarLehri | Bolan Mushkaf | 0.01375 | 0.05087 | 0.788 | -0.0873 | 0.1148 |
| | Mula | .15469* | 0.05087 | 0.003 | 0.0537 | 0.2557 |

*. The mean difference is significant at the 0.05 level.

**Table 4. Mann-Kendall trend analysis for South zone**

| Time series | First year | Last Year | Test Z | Statistically Significant. |
|---|---|---|---|---|
| Jan | 1962 | 1993 | 1.84 | + |
| Feb | 1962 | 1993 | 1.38 | No |
| Mar | 1962 | 1993 | 2.92 | ** |
| Apr | 1962 | 1993 | 2.93 | ** |
| May | 1962 | 1993 | 2.76 | ** |
| Jun | 1962 | 1993 | 0.18 | No |
| Jul | 1962 | 1993 | 2.69 | ** |
| Aug | 1962 | 1993 | 2.38 | * |
| Sept | 1962 | 1993 | 1.64 | No |
| Oct | 1962 | 1993 | 1.61 | No |
| Nov | 1962 | 1993 | 2.23 | * |
| Dec | 1962 | 1993 | 1.08 | No |

** = 0.01 level of significance; * = 0.05 level of significance; +=0.1 level of significance

Since the probability value from the regression analysis for the slopes of the monthly trend lines was greater than the significant level, the null hypothesis ($H_o$: there is no trend in the data, is accepted, meaning there by, monthly rainfall data trends are not statistically significant for Southern zone. The R-squared statistic also indicated a very weak relationship between the explanatory and response variables. Statistical analysis was performed to assess any significant difference among the three sub-basins of the South zone within the years of data under study.

Table 3 shows the result of ANOVA to ascertain the existence of significant differences in the average Yearly precipitation among the three sub-basins of the South zone. The results revealed a statistically significant difference in yearly precipitation among the three sub-basins at (F=5.66, *P-value*=0.005). Thus the hypothesis that the existence of significant differences in the average Yearly precipitation among the three sub-basins over the period of 32 years is accepted. To ascertain the actual difference in the average yearly precipitation, the multiple mean comparison test was

**Table 5. Statistical results for Monthly rainfall of North zone between 1962-1993**

| Months | Regression Equation | R-Square | P-Value | Statistically Significant |
|---|---|---|---|---|
| Jan | | 0.03 | 0.34 | No |
| Feb | | 0.00 | 0.71 | No |
| Mar | | 0.09 | 0.08 | No |
| Apr | | 0.03 | 0.30 | No |
| May | | 0.00 | 0.96 | No |
| Jun | | 0.02 | 0.50 | No |
| Jul | | 0.00 | 0.81 | No |
| Aug | | 0.00 | 0.87 | No |
| Sept | | 0.00 | 0.86 | No |
| Oct | | 0.00 | 0.91 | No |
| Nov | | 0.02 | 0.45 | No |
| Dec | | 0.00 | 0.78 | No |

Significant at $p<0.05$

**Table 6. Descriptive summary of monthly rainfall data of North zone**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 5.3 | 7.2 | 10.1 | 7.8 | 3.0 | 3.2 | 11.1 | 8.5 | 2.4 | 1.3 | 1.6 | 2.9 |
| Median | 4.6 | 6.3 | 7.5 | 6.4 | 2.2 | 2.5 | 10.0 | 6.4 | 1.4 | 0.6 | 1.3 | 2.0 |
| S.D | 3.4 | 5.7 | 7.5 | 6.2 | 2.7 | 2.5 | 6.4 | 6.7 | 2.8 | 1.9 | 1.4 | 3.0 |
| Kurtosis | -0.4 | 1.6 | -0.3 | 1.7 | 2.8 | 4.3 | -0.9 | 3.0 | 12.5 | 5.4 | 0.6 | 2.8 |
| Skewness | 0.5 | 1.3 | 0.8 | 1.4 | 1.7 | 1.8 | 0.5 | 1.6 | 3.2 | 2.3 | 1.0 | 1.5 |
| Minimum | 0.0 | 0.6 | 1.9 | 1.4 | 0.4 | 0.2 | 1.6 | 1.4 | 0.1 | 0.0 | 0.0 | 0.0 |
| Maximum | 12.2 | 24.8 | 28.3 | 26.7 | 11.1 | 12.3 | 23.1 | 29.0 | 14.9 | 8.1 | 5.7 | 12.9 |
| Sum | 168.6 | 230.3 | 323.0 | 250.2 | 95.0 | 101.7 | 356.6 | 271.6 | 77.5 | 42.2 | 52.5 | 91.7 |

**Table 7. Analysis of variance of mean annual rainfall among three sub-basins of North zones of Nari River Basin of from 1962 to 1993**

| | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 6.313 | 2 | 3.157 | 13.074* | 0 |
| Within Groups | 22.453 | 93 | 0.241 | | |
| Total | 28.766 | 95 | | | |

Df=Degrees of freedom, *=0.05 level of significant, Sig.=Significance

**Table 7.1. LSD multiple comparisons of average yearly precipitation of the three Sub Basins in the North zone from 1962 to 1993**

| (I) Sub Basin | (J) Sub Basin | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| Khost | Beji | .62813* | 0.12284 | 0 | 0.3842 | 0.8721 |
| | Loralai | .31875* | 0.12284 | 0.011 | 0.0748 | 0.5627 |
| Beji | Khost | -.62813* | 0.12284 | 0 | -0.8721 | -0.3842 |
| | Loralai | -.30937* | 0.12284 | 0.013 | -0.5533 | -0.0654 |
| Loralai | Khost | -.31875* | 0.12284 | 0.011 | -0.5627 | -0.0748 |
| | Beji | .30937* | 0.12284 | 0.013 | 0.0654 | 0.5533 |

* The mean difference is significant at the 0.05 level

**Table 8. Mann-Kendall trend analysis for North zone**

| Time series | First year | Last Year | Z Test | Statistically Significant |
|---|---|---|---|---|
| Jan | 1962 | 1993 | 1.02 | No |
| Feb | 1962 | 1993 | 0.57 | No |
| Mar | 1962 | 1993 | 1.51 | No |
| Apr | 1962 | 1993 | -0.65 | No |
| May | 1962 | 1993 | -0.42 | No |
| Jun | 1962 | 1993 | 0.00 | No |
| Jul | 1962 | 1993 | -0.32 | No |
| Aug | 1962 | 1993 | -0.05 | No |
| Sept | 1962 | 1993 | 0.11 | No |
| Oct | 1962 | 1993 | -1.07 | No |
| Nov | 1962 | 1993 | 1.17 | No |
| Dec | 1962 | 1993 | -0.55 | No |

evaluated using Least Square Difference (LSD) test was employed as ANOVA indicated the mean difference among the three sub-basins). Table 3.1 revealed that average difference in yearly precipitation among the three sub-basins of South zone was significant except Bolan Mushkaf and Chakar Lehri. Here the average difference in yearly rainfall noted over the period in the two sub basins was not statistically significant (mean diff. = 0.1375 inches and *P-value*=.788). Trend direction, magnitude and significance for Southern zone is given in Table 4, as it can be seen from the table seven out of 12 months revealed a statistically significant positive trend at level of confidence. The month of January revealed a statistically significant trend at 90% level of confidence. Four months (March, April, May and July) accounted for a 99%

level of confidence while August and November reported a 95% level of confidence and five months i.e. (February, June, September, October and December) showed statistically significant upward trends. The results of the linear regression trend analysis for the North zone are presented in Table 5. The trend of rainfall for the period of 32 years from January to December has been calculated for each month separately. The results indicated a downward trend for the months of April, June and December and the rest of the months revealed an upward trend. These trends are statistically insignificant as indicated by the P-values. The R-squared statistic signified weak relationship between the variables of rainfall and year. Statistical summary of each precipitation month of North zone is presented in Table 6. It can be seen from the table that the highest average monthly rainfalls over the period of 32 years occurred in July (11.1 inches) followed by March with (10.1inches). Incidentally the month of the March usually records with less amounts of precipitation and falls within the minor season. Variability in the precipitation season could be associated with the so-called climate change (Nyatuame *et al.*, 2014). The month with the lowest rainfall is September (1.3inches) followed by November (1.6inches). The skewness co-efficient for almost all months throughout the period of 32 years were found positive, revealing the usual occurrence of scarce precipitation. Table 7 showed whether there is a significant difference in the mean annual rainfall among the three sub-basins in the North zone.

The outcomes revealed the existence of significant difference in the average annual rainfall among the three sub-basins in the North zone at (F=13.074, P=0.00). The null hypothesis that there is no significant difference in the average annual rainfall among the three sub-basins in the North zone over the period of 32 years is therefore rejected in favor of alternative hypothesis. To identify the actual difference in the three sub-basin of North zone in terms of average yearly precipitation, the multiple mean comparison was calculated using LSD (LSD was employed as ANOVA disclosed the difference in the three sub-basin of the North zone). The results are exhibited in table 7.1 revealed that mean differences in yearly precipitation were all statistically significant among the three sub-basins of the North zone. Table 8: represented the results of the Mann-Kendall test for the North zone. The results revealed that in North Bain there is no statistically significant trend neither at 0.1, 0.01 nor 0.05 significant level, for all months over the period of 32 years. The month of January, February, March, June, September and November indicated a positive trend whereas the month of April, May, July, August, October and December are found with insignificant negative trend.

**Conclusion**

This study was concerned with identifying trends in precipitation and seasonal rainfall sequences on the selected stations by employing different statistical techniques.

**Conclusions that have been abstracted from the study are given as below**

For the South zone of NRB, a negative coefficient of kurtosis was found for the month of April and June, revealing more flat distribution than normal distribution whereas the skewness coefficient was found positive for all months, indicating the occurrence of repeatedly low precipitation. For the North zone, the months of June, September and October were found to have a kurtosis value of more than four, revealing more peaked distribution than normal distribution.

The South zone recorded a lowest maximum and minimum yearly precipitation of 58.5 inches and 6.7 inches, respectively followed by the Northern zone with 133.4 inches and 28.3 inches. Results of linear regression analysis for monthly precipitation data disclosed that both zones showed statistically insignificant increasing trends in some months and decreasing trends in others, as well as revealed very weak correlations between rainfall and period. The significance of trends was determined by employing the Mann-Kendal rank statistic. For the South zone, the months of August and November revealed an increasing statistically significant trend at 95% level of significance, and the rate of increase was observed in the range of 0.021-0.026 inches/year, whereas both increasing and decreasing statistically insignificant trends were demonstrated by the North zone.

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