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The Precipitation Trend in Baglung District: A Statistical Analysis

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ABSTRACT
The climate pattern of Nepal is uncertain regarding the precipitation but the extreme events such as floods and drought are increasing. Due to an increase in uncertain precipitation, the extreme rainfall and its intensity are also increased. Baglung District elevated from 650m to 4300m has a diverse climatic zone from upper tropical to alpine, almost similar to the whole Nepal. The data were taken from the Department of Hydrology and Meteorology from 1970 to 2018 (on monthly basis) are used for analyzing the precipitation trends in Baglung District based on five stations by taking the secondary data. To analyze the data, Mann- Kendall, and Sen's Slope are used to find trend and magnitude. SPSS and R softwere are used to draw graph and other statistical calculations. The analysis shows that there is a positive trend in precipitation in the Baglung district. This is contradictory to national trends of precipitation, which is slightly negative. The maximum value of precipitation is 271.892mm in 1998, followed by 263.070mm in 2000, and the minimum value is 27.217mm in 1973, followed by 86.10 mm in 1972. There is a wide variation in average monthly rainfall in different stations ranging from 158.326mm (Baglung station) to 235.828mm (Rangkhani station) with standard deviations 199.342mm and 310.196mm respectively. The analysis indicates that the trend of precipitation is slightly positive but insignificant which shows that the intensity of rainfall is increased, but the number of rainy days is decreased. Similarly, the results indicate that the average rainfall in Baglung (190.400mm) is higher than the national level (150mm app.).

KEYWORDS: Climate change, precipitation, precipitation trend, rainfall

INTRODUCTION

Nepal is a fragile country with an elevation of 60m to 8848m. It has a tropical to tundra and alpine climate. It is an agricultural country and its productivity is mainly based on monsoon and precipitation. The records show that about 80% of the annual precipitation occurs during the monsoon among the four seasons. But, the amount of rainfall generally declines from east to west (UNEP, 2002). As a mountainous country, Nepal is the most susceptible to precipitation extremes and related hazards, including severe floods, landslides, and droughts that cause huge losses of life and property, impact the Himalayan environment and hinder the socioeconomic development of the country (Karki et al., 2017). It is significantly affected by the south-easterly monsoon, which provides most of the precipitation during the rainy summer months (June to September)

(Shrestha & Aryal, 2011). Monsoonal precipitation is the most important climatic element for agriculture as well as water resources of the country (Malla, 2009). Additionally, the non-uniform rugged terrain has a greater influence on variation in the amount of precipitation from the south to the north in Nepal (Chalise et al., 2006). The consequences of climate change have seemed global to specifically in developing and mountainous countries like Nepal such that precipitation is becoming unpredictable and more erratic than ever, with more droughts and shorter periods of heavy rainfall (Shrestha & Aryal, 2011). The effects of climate change on both drought and flooding events have been found, including severe winter drought and excessive monsoon flooding (Yu et al., 2013). High altitude glaciers are thinning retreating at an alarming rate, faster than the world average in Nepal (Maharjan et al., 2018). From the report of the Department of Hydrology And Meteorology, no significant trend is observed in precipitation in any season in Nepal(DHM, 2017).

The Intergovernmental Panel on Climate Change (IPCC)'s fifth assessment has concluded that global climate change is an imminent threat to many communities as there is clear scientific evidence of increasing greenhouse gasses, warming atmosphere and oceans, diminishing amount of snow and ice, and rising sea level (IPCC, 2014). Some researchers are indicated that the magnitude, frequency, and intensity of these disasters have been increasing and can be partially attributed to global climate change (Confalonieri et al., 2009; Hallegatte, 2015). The estimation of precipitation (rainfall and snowfall) across the Earth's surface is important for both science and user applications, ranging from understanding and improving our knowledge of the global energy and water cycle, to water resources and hydrological modeling, and societal applications such as water availability and monitoring of waterborne diseases (Levizzani et al., n.d.). The territory of Nepal covers the annual total amounts of precipitation of 267 km^3, out of which about 10% occur as snowfall and 90% as rainfall (UNEP, 2002).

The rainfall in Nepal varies greatly from place to place due to sharp topographical variations. As rain-bearing winds approach Nepal from the south-east in the summer monsoon season, most rain falls over the foothills of the lower Himalayas, increasing with altitude on the windward side, and sharply decreasing on the leeward side of each successive range (Nayava, 1974). Most of the reviewed work has largely dealt with the summer monsoon period and annual precipitation in total. Therefore, there is a need to consider the seasonal behavior of precipitation over the year i.e. the form and magnitude of the precipitation regime (Kansakar et al., 2004).

Changes in rainfall and other forms of precipitation will be one of the most critical factors determining the overall impact of climate change. Rainfall is much more difficult to predict than temperature but there are some statements that scientists can make it with confidence about the future. A warmer atmosphere can hold more moisture, and globally water vapour increases by 7% for every degree centigrade of warming. How this will translate into changes in global precipitation is less clear-cut but the total volume of precipitation is likely to increase by 1-2% per degree of warming. Kansakar et al.(2004) used data gathered from 222 stations over Nepal to derive climatological patterns of monthly precipitation, classifying regimes by the shape and magnitude of monthly precipitation. They found that precipitation patterns were controlled by the summer monsoon and by orographic effects induced by the mountain ranges.

The timing and amount of precipitation and its distribution across Nepal are controlled fundamentally by the annual monsoon system. Four climatological seasons can be identified, for which (Nayava, 1974) details the associated synoptic weather patterns. The pre-monsoon season (March-May) is characterized by hot-dry weather with scattered rainfall with moderate to strong westerlies prevailing; toward the end of this period, it becomes more humid with thunderstorms. The summer monsoon season (June–September) is governed by the southeasterly moisture-laden air-mass moving from the Bay of Bengal. The monsoon reaches eastern Nepal with a modal onset date of 10 June and advances westwards covering the whole country within a week. The post-monsoon season (October–November) has a modal onset date of 21 September. Rainfall activity is substantially reduced, with November typically the driest month. The winter season (December–February) is generally dry although westerly weather systems may bring cold air and winter precipitation to northwestern areas (Shrestha, 2000). Therefore, the major objective of this study is to find out the temporal and spatial trend of precipitation in the Baglung district

DATA AND METHODS

Study Area

Baglung District, also known as the district of suspension bridge elevated from 650m (Kharbang) to 4300m (Dhorpatan) with an area 1784km^2, is diverse in temperature, altitude, culture, ethnicity, etc, like Nepal and the geographical map is approximately similar to Nepal. It is surrounded by Parbat, Myagdi, Rukum, Rolpa, Pyuthan, and Gulmi districts. Rainfall is heavily affected by the monsoon and most of it occurs from June through September. The rest of the year is mostly dry and sunny. Snowfall is extremely rare in the city core; however, higher elevations within the city limits see occasional snow during the winter months. Due to a large topographic variation climate ranging from hot subtropical to temperate mountain climate can be experienced within the city limits. There are five meteorological stations established by DHM for keeping the record of temperature and precipitations. Among five stations the records of precipitation were available in all five stations but temperature data were available only for Baglung-station.

Rationale

Agriculture is the main backbone of the national economy and rainfall (precipitation) plays a vital role in agricultural production in Nepal. The heterogeneous pattern of rainfall is found according to the variation of geographical location. Baglung District has been chosen for the study because according to the Climate Change Vulnerability Mapping of Nepal published by Ministry of Environment, Nepal (2010), the district lies on very high risk (0.557-1.0) for landslide, high risk (0.442-0.579) for rainfall, and temperature, high risk (0.38-0.61) for ecological sensitivity and high (0.5-0.681) in combine exposure risk. Apart from this, there is lacking studies to give the actual trend of precipitation by using all available secondary data obtained from the Department of Hydrology and Meteorology.

Data Collection

The monthly rainfall data are collected from the record of Stations of the Department of Hydrology and Meteorology from the years 1970 to 2018 of the Baglung station, Bhimgithhe, Bobang, Galkot, and Rangkhani stations. These monthly data are grouping into four seasons namely pre-monsoon (March to May), Monsoon (June to September), Post-monsoon (October to November), and Winter (December to February). The data is analyzed with descriptive and inferential statistical tools and models like Mann-Kendall, Sen's slope, by using SPSS and R software.

Data Analysis

The Mann-Kendall Test

The rank-based nonparametric Mann-Kendall method was applied to the long term data in this study to detect statistically significant trends. In this test, the null and alternative hypothesis is set as the Null hypothesis (H0): There has been no trend in precipitation over time. The alternate hypothesis (H1): There has been a trend (increasing or decreasing) over time. The mathematical equations for calculating Mann-Kendall Statistics S, (S) and standardized test statistics Z are as follows:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \text{sign}(x_j - x_k) \quad \ldots\ldots(1)$$

Where, x_j and x_k are annual values in years j and k, j>k respectively, n is the number of data points and $\text{sign}(x_j - x_k)$ is calculated by using the following equation

$$\text{sign}(x_j - x_k) = \begin{cases} 1 & \text{if } (x_j - x_k) > 0 \\ 0 & \text{if } (x_j - x_k) = 0 \\ -1 & \text{if } (x_j - x_k) < 0 \end{cases} \quad \ldots\ldots(2)$$

A positive value of S indicates an upward (increasing) trend and a negative value indicates a downward (decreasing) trend. If the number of data values is 10 or more, the S- statistic approximately behave as normally distributed with mean E=0 and variation is given by

$$V(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5)\right] \quad \ldots\ldots(3)$$

Where, n=no of data points, q=no of tied groups, t_p=no of data points in the p^{th} group. Then the trend value (Z) is calculated by using the relation:

$$Z = \begin{cases} (S-1)/\sqrt{(Var.S)} & \text{if } S>0 \\ 0 & \text{if } S=0 \\ (S+1)/\sqrt{(Var.S)} & \text{if } S<0 \end{cases} \quad \ldots\ldots(4)$$

Positive Z values indicate an upward trend in the hydrologic time series; negative Z values indicate a negative trend. If $|Z| > Z_{1-\alpha/2}$, (H_o) is rejected and a statistically significant trend exists in the hydrologic time series. The critical value of $Z_{1-\alpha/2}$ for a p value of 0.05 from the standard normal table is 1.96.

Sen's slope Estimator

If a linear trend is present in a time series then the true slope (changed per unit time) can be estimated by using a simple nonparametric procedure developed by Sen (Sen PK) that is the linear model f(t) can be described as f(t) =Qt +B. Where Q is the slope and B is a constant.

The procedure developed by Sen is used to estimate the slope present in the trend. Positive and negative slope signifies increasing and decreasing slope respectively.

Zero slopes signify that no trend exists in the data for the study period. The slope Q of all data pairs are calculated using the relation

$$Q_{i=} (X_j-X_k)/ (j-k), \text{ for all, } i=1,2,3,\ldots\ldots N, j>k..$$

The Sen's estimator of the slope is the median of these N values of Q_i. The N values of Q_i are ranked from the smallest to the largest and the Sen's estimator is

$$Q= \begin{cases} Q_{(N+1)/2} \text{ if N is odd}\} & \ldots\ldots\ldots\ldots(5) \\ \{\tfrac{1}{2}(Q_{N/2}+Q_{(N+2)/2}\} \text{if N is even} \end{cases}$$

A 100(1-α)% two-sided confidence interval about the slope estimate is obtained by the nonparametric technique based on the normal distribution. This method is valid for N as small as ten unless there are many ties. Next $M_1=(N-C\alpha)/2$ and $M_{2=}(N+C\alpha)/2$ are computed. The lower and upper limits of the confidence interval, $Q_{min,}$ and Q_{max} are the M_1^{th} largest and the $(M_2+1)^{th}$ largest of the N ordered slope estimates $Q_{i.}$.

The data for precipitation were obtained from the meteorological station situated in five different places Baglung station, Babong, Rangkhani, Bhimgithhe, and Galkot station ranging from elevation 650m to 4300m. The monthly and annual data about rainfall-sum since 1970 have been analyzed in respect of seasonal basis (pre-monsoon, monsoon, post-monsoon, and winter).

Table 1

Monthly Rainfall-sum of Baglung district from 1970-2018

Month	Mean	N	Std. Deviation
1	24.62	50	21.658
2	29.76	50	31.330
3	34.78	50	28.700
4	59.34	50	39.894
5	149.61	50	56.795
6	387.44	50	167.024
7	630.27	50	183.841
8	557.00	50	169.027
9	320.96	50	128.681
10	66.78	50	51.487
11	10.82	50	19.189
12	13.45	50	19.735
Total	190.40	600	237.179

The graph of monthly rainfall-sum of Baglung District

Figure 1

Simple Bar Diagram: Monthly Precipitation of Baglung District from 1970-2018

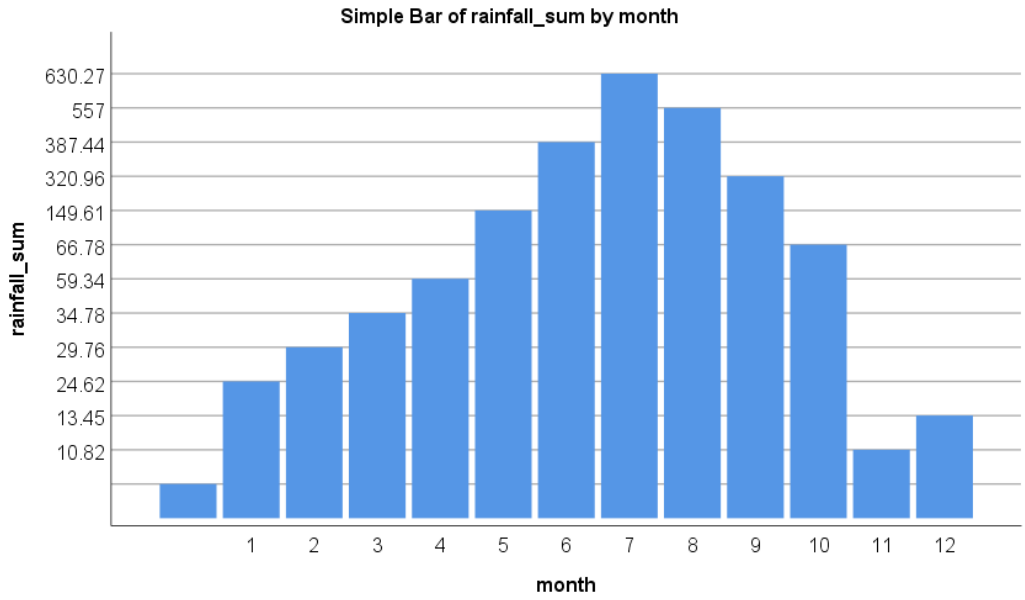


Table 2

The Area Covered by Various Climates Zones of Baglung District

Climate zone	Elevation range	Percentage of area
Upper tropical	300 to 1000m	2.8%
Sub-tropical	1000 to 2000m	37.1%
Temperate	2000 to 3000m	39.4%
Subalpine	3000 to 4000m	18.6%
Alpine	4000 to 5000m	2.1%

Source: DHM

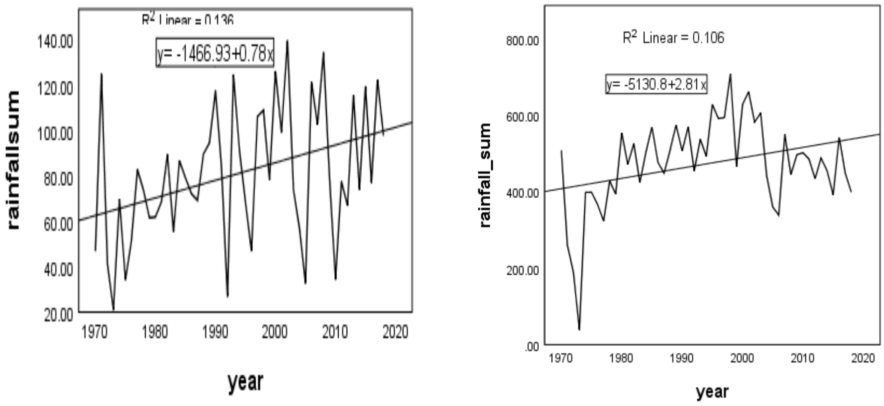
RESULTS AND DISCUSSION

The precipitation pattern of Baglung District is found to be in positive trend (0.072mm/year), but highly insignificant (p-value=0.638), which is the contradictory results for the national insignificant trend and is slightly decreasing in order. For the whole Baglung district, the trend of average rainfall sum is positive for three seasons namely pre-monsoon, monsoon, and winter season while negative in post-monsoon, but the value is highly significant only in pre-monsoon with a p-value 0.0054. The values of other seasons are insignificant at 5%level of significance. The pattern of rainfall sum is also heterogeneous on different seasons which can be described as follows in Figure 3. The Mann-Kendall test and Sen’s slope indicate that the trend of rainfall-sum on Baglung district is positive and significant in the pre-monsoon season, positive and insignificant in monsoon and winter whereas negative and insignificant in the post-monsoon season.

Figure 2

Graph and Trend Line of Baglung District for Rainfall_sum on Different Seasons

a) Premonsoon b) Monsoon



c)Post monsoon d) Winter

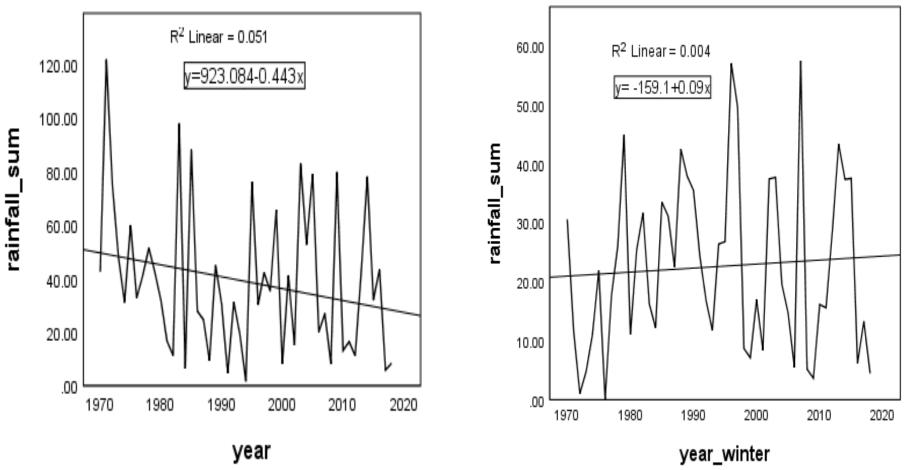


Table 3

Mann-Kendall Tau-Value and Sen's Slope for Baglung District

Rainfall-sum/Season	Tau-value	p-value	Sen's slope	p-value	Trend	Result
Pre-monsoon	0.2760	0.0054	0.9114	0.0054	Positive	Significant
Monsoon	0.1680	0.0895	2.0583	0.0895	Positive	Insignificant
Post-monsoon	-0.1520	0.1249	-0.4013	0.1249	Negative	Insignificant
Winter	0.0451	0.6540	0.0720	0.6540	Positive	Insignificant

The pattern of rainfall sum by Stations

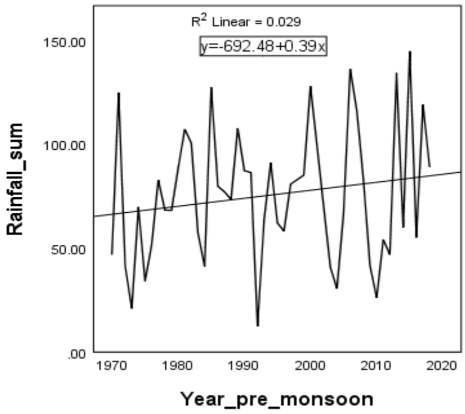
Precipitation pattern in Baglung station

The precipitation pattern and the trend of rainfall-sum in different seasons in Baglung station are given in Figure 3 and the Mann-Kendall and Sen's slope for Baglung station is given in Table 4.

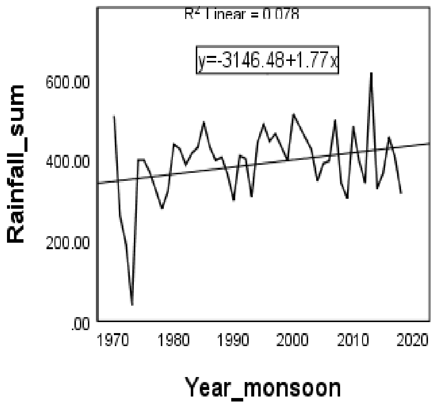
Figure 3

Precipitation trends in Baglung station on different seasons

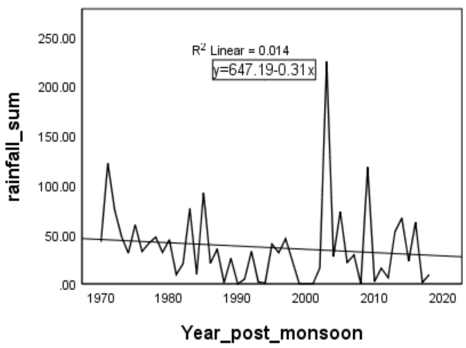
a) Pre-monsoon



b) Monsoon



a) Post-monsoon



d) Winter

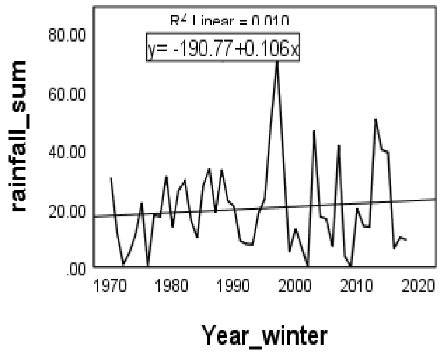


Table 4

Mann Kendall and Sen Slope Test for Precipitation Trend of Seasons on Baglung Station

Rainfall-sum /Season	Tau value	P value	Sen slope	P value	Trend	Results
Pre-monsoon	0.1050	0.3065	0.4247	0.3156	Positive	Insignificant
Monsoon	0.1030	0.3156	1.1350	0.3156	Positive	Insignificant
Post-monsoon	-0.1960	0.0514	-0.547	0.0514	Negative	Insignificant
Winter	0.0037	0.9780	0.0000	0.9780	Null	Insignificant

The precipitation data obtained from the Baglung station showed that there is a decreasing trend of rainfall in the post-monsoon season but an increasing trend in pre-monsoon and monsoon season whereas neither increasing nor decreasing (stationary) in the winter season. The Mann-Kendall test and Sen's slope estimator indicate that the trend of rainfall-sum on Baglung station in all four seasons is insignificant.

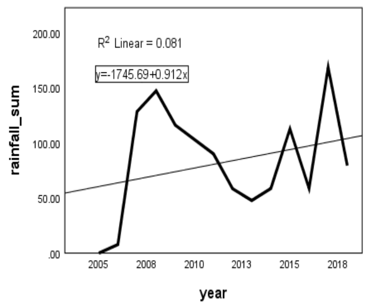
Precipitation Pattern in Bhimgithhe Station

The precipitation pattern and the trend of rainfall-sum in different seasons in Bhimgithhe station are given in Figure 4 and the Mann-Kendall and Sen's slope for Bhimgithhe station is given in Table 5.

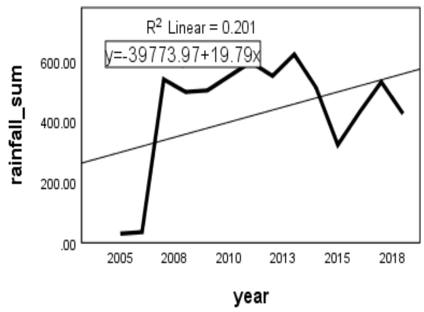
Figure 4

Precipitation Trends in a Different Season of Bhimgithhe Station

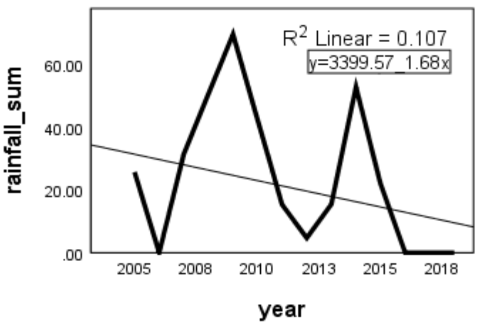
a) Pre-monsoon



b)Monsoon



b) Post-monsoon



d) Winter

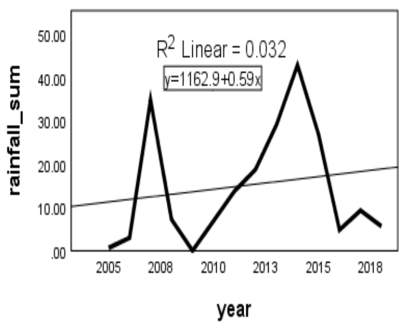


Table 5

Mann-Kendall and Sen's Slope Test for Precipitation Trend of Seasons on Bhimgithhe Station

Rainfall-sum/season	Tau value	P value	Sen slope	P value	Trend	Result
Pre-monsoon	0.0303	0.9453	0.1000	0.9453	Positive	Insignificant
Monsoon	0.1280	0.5829	4.5125	0.5830	Positive	Insignificant
Post-monsoon	-0.3180	0.1834	-2.2575	0.1834	Negative	Insignificant
Winter	0.1790	0.4277	0.6708	0.4277	Positive	Insignificant

The precipitation data obtained from Bhimgithhe station showed that there is an increasing trend of rainfall in pre-monsoon, monsoon, and winter season while the decreasing trend in the post-monsoon season. The Mann-Kendall test and Sen's slope indicate that the trend of rainfall-sum in all four seasons is insignificant in this station.

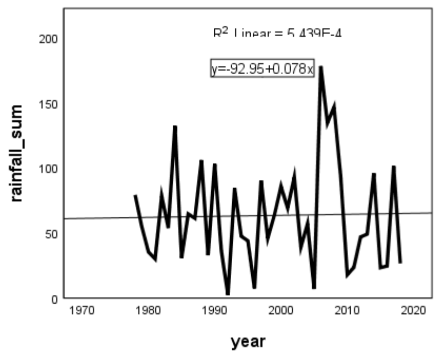
Precipitation Pattern in Bobang Station

The precipitation pattern and the trend of rainfall-sum in different seasons in Bobang station are given in ~~F~~igure 5 and the Mann-Kendall and Sen's slope for Bobang station is given in Table 6.

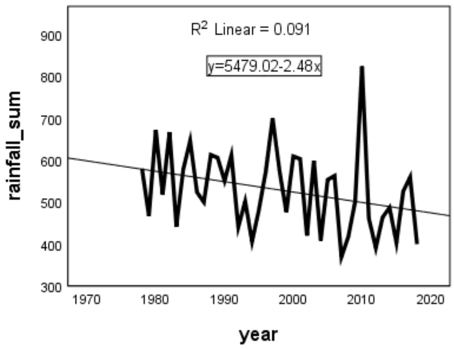
Figure 5

Precipitation Trend and Graph of Different Seasons of Bobang Station

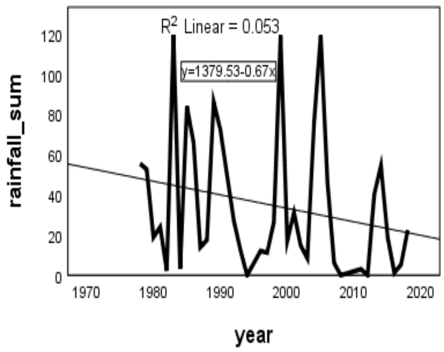
a) Pre-monsoon



b) Monsoon



c) Post-monsoon



d) Winter

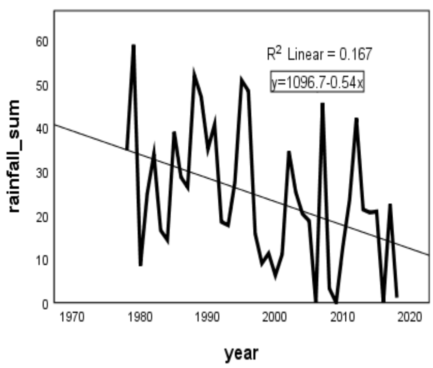


Table 6

Mann-Kendall and Sen's Slope Test for Precipitation Trend of Seasons on Bobang Station

Rainfall-sum/Season	Tau value	P value	Sen slope	P value	Trend	Result
Pre-monsoon	-0.0024	0.9910	-0.0426	0.9910	Negative	Insignificant
Monsoon	-0.2730	0.0123	-2.9359	0.0123	Negative	Significant
Post-monsoon	-0.1910	0.0992	-0.5491	0.0992	Negative	Insignificant
Winter	-0.2600	0.0172	-0.5334	0.0172	Negative	Significant

The precipitation data obtained from the Bobang station showed that there is a decreasing trend of rainfall in all seasons. The Mann-Kendall test and Sen's slope indicate that the trend of rainfall-sum in monsoon and winter seasons is significant but insignificant in pre-monsoon and post-monsoon seasons.

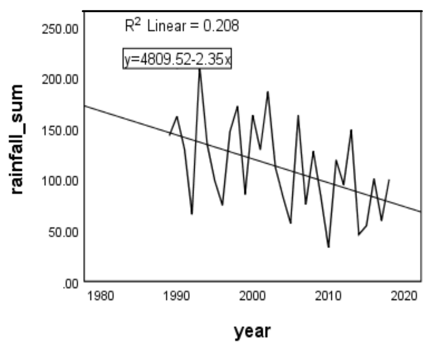
Precipitation Pattern in Rangkhani Station

The precipitation pattern and the trend of rainfall-sum in different seasons in the Rangkhani station are given in Figure 6 and the Mann-Kendall and Sen's slope for Rangkhani station is given in Table 7.

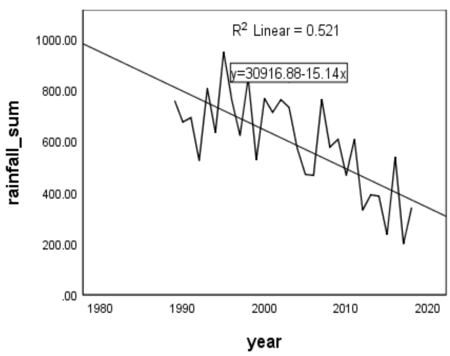
Figure 6

Precipitation Trend and Graph of Different Seasons of Rangkhani Station

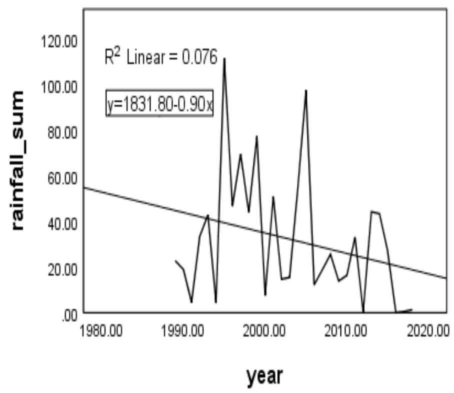
a) Pre-monsoon



b) Monsoon



c) Post-monsoon



d) Winter

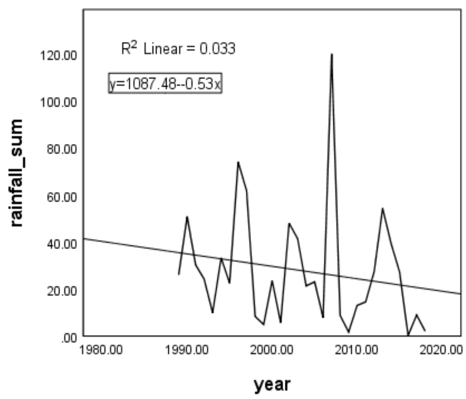


Table 7

Mann-Kendall and Sen's Slope Test for Precipitation Trend of Different Seasons on Rangkhani Station

Rainfall-sum/Season	Tau value	P value	Sen slope	P value	Trend	Result
Pre-monsoon	-0.3010	0.0204	-2.2476	0.0204	Negative	Significant
Monsoon	-0.5080	<0.0001	-15.2517	<0.0001	Negative	Significant
Post-monsoon	-0.1820	0.1640	-0.6833	0.1640	Negative	Insignificant
Winter	-0.2050	0.1164	-0.6057	0.1164	Negative	Insignificant

The precipitation data obtained from the Rangkhani station showed that there is a decreasing trend of rainfall in all seasons. The Mann-Kendall test and Sen's slope indicates that the trend of rainfall-sum in pre-monsoon and monsoon is significant but insignificant in post-monsoon and winter seasons.

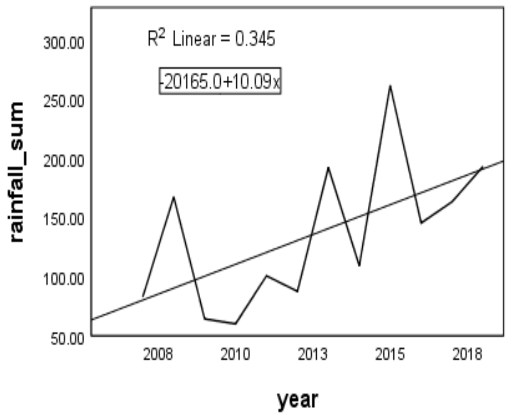
Precipitation Pattern in Galkot Station

The precipitation pattern and the trend of rainfall-sum in different seasons in the Galkot station are given in Figure 7 and the Mann-Kendall and Sen's slope for Galkot station is given in Table 8.

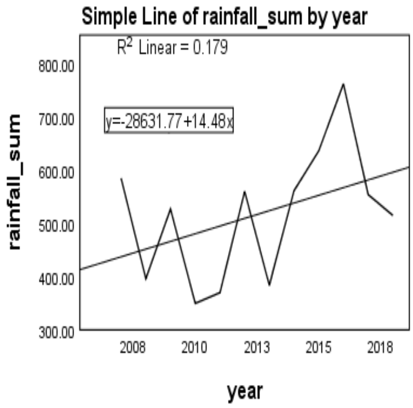
Figure 7

Precipitation Trend and Graph of Different Seasons of Galkot Station

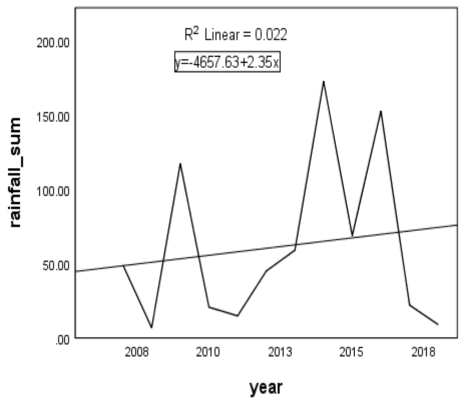
a) Pre-monsoon



b) Monsoon



c) Post-monsoon



d) Winter

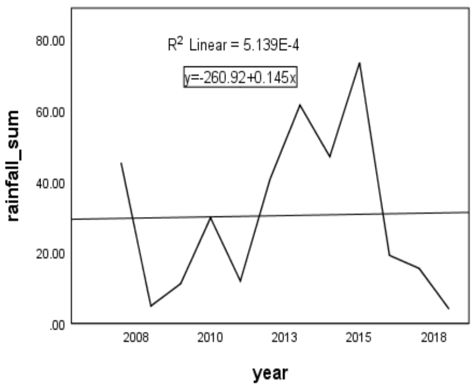


Table 8

Mann-Kendall and Sen Slope Test for Precipitation Trend of Seasons on Galkot Station

Rainfall-sum/Season	Tau value	P-value	Sen slope	P-value	Trend	Results
Pre-monsoon	0.4850	0.0335	11.9495	0.0335	Positive	Significant
Monsoon	0.2120	0.3727	11.6471	0.3727	Positive	Insignificant
Post-monsoon	0.1210	0.6312	1.6833	0.6312	Positive	Insignificant
Winter	0.0606	0.8370	0.4584	0.8370	Positive	Insignificant

The precipitation data obtained from the Galkot station showed that there is an increasing trend of rainfall in all seasons. The Mann-Kendall test and Sen's slope indicates that the trend of rainfall-sum in pre-monsoon is significant but insignificant in all other seasons.

DISCUSSION

The rainfall in Nepal varies greatly from place to place due to sharp topographical variations. As rain-bearing winds approach Nepal from the south-east in the summer monsoon season, most rain falls over the foothills of the lower Himalayas, increasing with altitude on the windward side and sharply decreasing on the leeward side of each successive range (Nayava, 1974). In Baglung District the trend of precipitation is varied and inconsistent both temporally and spatially. The trend is increasing for monsoon season and decreasing for the post-monsoon season in most of the stations while other seasons are inconsistent. Climate plays a large role in the water resources of the country. Changes in precipitation and temperature brought by climate change could affect run-off (Shrestha & Aryal, 2011). The annual total rainfall was increased. Driest months (November and December) total monthly rainfall is decreasing while two wettest months (July and August) total monthly rainfall is increasing. Such a pattern of rainfall changes affects the communities' water resource availability and increases the climatic, uncertainties in the region(Sharma, 2015). In Nepal, no significant trend is observed in precipitation in any season. Only pre-monsoon precipitation shows a significant negative trend in the High-Himalayan region. In other seasons, precipitation trends are insignificant in all physiographic regions (DHM, 2017). The influence of Southern Oscillation (SO) in Nepal monsoon rainfall is found to be very significant. The years with significant negative (positive) Southern Oscillation Index (SOI) have less (more) rainfall in most of the cases during the 32 years. This relationship is also found to vary with time (Shrestha, 2000).

CONCLUSION

Though Baglung District had a positive trend of average rainfall sum (0.072mm/year) with an insignificant p-value (0.638), the average rainfall sum was a positive trend in three seasons having highly significant value in the pre-monsoon season while the negative trend in the post-monsoon season. The pattern of average rainfall was not similar among five stations, but the post-monsoon season was prohibited by the negative trend in four stations (except Galkot station). This will indicate the possibility of drought problems in the coming future. The erratic rainfall in monsoon season may promote the possibility of landslide in Baglung District.

LIMITATIONS

This study is conducted based on the secondary data obtained from the Department of Hydrology and Meteorology through five stations of Baglung District which may not represent the complete geographical scenario. No stations except the Baglung station had a complete record of monthly average rainfall. Also, the temperature records of four stations except for the Baglung station for climate variability were not available. Temperature and precipitation are the interdependent inputs of climate change. Due to the lack of complete data of temperature the actual relations and other statistical measures related to climate change could not be computed. In the Baglung station, the data of maximum and minimum temperatures were available from the period 1978-2018 incomplete and inadequate for statistical analysis.

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