Universe International Journal of Interdisciplinary Research
(Peer Reviewed Refereed Journal)

© UIJIR | ISSN (O) – 2582-6417
JUNE 2021 | Vol. 2 Issue 1
www.uijir.com

APPLICATION OF NON PARAMETRIC TEST FOR TREND DETECTION OF RAINFALL IN CHAMKHARCHHU BASIN OF BUMTHANG, BHUTAN

Author's Name: Leki Dorji[1], Jamyang Seldon[2]

Affiliation: *[1]Lecturer, Civil Engineering and Engineering Geology Department, College of Science and Technology, Royal University of Bhutan, Bhutan.*

[2]Student, Civil Engineering Student, Royal University of Bhutan, Bhutan.

E-Mail: ldorjee6722@gmail.com

DOI No. – 08.2020-25662434

Abstract

Bhutan is one of the sensitive regions to climate variation particularly to temperature and precipitation changes as there is indication of melting Glaciers in the northern part of the country. This study attempts to an effort to analyze one of the most important climatic variable i.e., rainfall for analyzing its trend in Chamkhar area as the Royal Government of Bhutan is planning to come up with small hydropower in that region. Historical available data form 1996 to 2020 have been processed to determine the monthly variability of rainfall using Mann-Kendall test and Sen's Slope Estimator specially to observe trend and slope magnitude of rainfall. Correlation between rainfall and river discharge can be established, so as to achieve the objective of hydropower sustainability can be forecasted with the available of 25 years of data. The application of a trend detection framework resulted in the identification of insignificant trends from January to December. It has been observed with maximum decreasing rates of rainfall in some of the seasons particularly in summer season and autumn seasons of -2.003 and -0.754 respectively. However, june month indicates the maximum value of decreasing trend based in Sen's slope and Mandell Test. Mandell test and sen's slope obtained by these statistical tests suggesting overall insignificant changes in the area.

In contrast, most of the seasons represent slight precipitation either increase or decrease (which are not statistically significant) annually, spring, autumn and winter. However, summer is the most significant season of decreasing, followed by annul average decreasing trend and autumn indicated the least decreasing trend. The main objective of this study is to observe the rainfall trend so far in Chamkharchhu .Mann-Kendall's (MK) nonparametric test and Sen's slope estimation techniques were used to quantify the overall statistical significance of the results.

***Keywords**: Climate Variation, Precipitation, Mann-Kendall, Trend, nonparametric .*

INTRODUCTION

Changes of precipitation will be one of the most critical factors determining the overall impact of climate change altering the hydrological systems. Rainfall is much more difficult to predict than temperature but there are some statements that scientists can make with confidence about the future. It is likely that in a warmer climate heavy rainfall will increase and be produced by fewer more intense events. This could lead to longer dry spells and a higher risk of floods. Precipitation, especially rain, has a dramatic effect on agriculture and environmental system. All plants need at least water to survive; therefore rain play vital role in agriculture. A regular rain pattern is usually to know the health of the plants, too much or too little rainfall could be impeded for the regime of the river system, even devastating to crops and aquatic lives. The effects of rainfall are numerous such as damage to structures, including bridges, buildings, sewerage systems, roadways, and canals. Knowing the rainfall pattern would give the practical concept of the potentiality of hydropower and the hydrological systems of a river. For one of region in Bhutan, Phuntsholing, seasons represent slight precipitation increase (which are not statistically significant) annually, spring and autumn (Dorji, L. 2016)

Climatic variability can be described as the annual difference in values of specific climatic variables within averaging periods such as a 30-year period. These climatic variations will have unexpected consequences with respect to frequency and intensity of precipitation variability for many regions of the Earth. Although the subject of climate change is vast, the changing pattern of precipitation deserves urgent and systematic attention as it will affect the availability of food supply (Dore et al, 2005) and the occurrence of water related disasters triggered by extreme events.

In the Eastern Himalayas, a substantial proportion of the annual precipitation falls as snow and becomes ice later on. Therefore, the snow is like a natural form of storage, releasing water slowly into the ground or rivers, water is increasingly available only at the time of precipitation. Even in the Himalayan region, inclusive of Tibetan Plateau, has shown some constant warming trends during the past 100 years (Yao et al. 2006). However, little is known in detail about the climatic characteristics of the Eastern Himalayas both because of the paucity of observations and insufficient theoretical attention which has been given to the complex interaction of spatial scales in weather and climate phenomena in mountain areas. Long-term data sets are needed to determine properly the degree and rate of climate change, but there are none available for most of the region. A climate change signal that has been extracted from one single glacier will not a good representative of whole mountain areas as the variation between the mountains are very much. Freshwater availability in many river basins in Asia is likely to decrease due to climate change.

The advantage with a non-parametric test is that it only requires data to be independent and can tolerate outliers in the data (Hameed and Rao, 1998). One of the popular non-parametric tests widely used for detecting trends in the time series is the Mann-Kendall test (Mann, 1945) The two important parameters of this test are the significance level that indicates the trend strength and the slope magnitude that indicates the direction as well as the magnitude of the trend (Burn and Elnur, 2002). The advantage of the test is that it is distribution-free, robust against outliers and has a higher power than many other commonly used tests (Hess et al., 2001)

DATA AND METHODOLOGY

Trend analysis of rainfall is determined by the historical data records of 25 years from 1996 to 2020 using the method of Mann-kendall (MK) test of non-parametric test.

Mann-kendall (MK) test.

The magnitude of the trend in the seasonal and annual series were determined using the Sen's estimator (Sen, 1968) and statistical significance of the trend in the time series were analysed using Mann-Kendall (MK) test (Mann, 1945; Kendall, 1975).

Magnitude of trend

The magnitude of trend in a time series was determined using a non-parametric method known as Sen's estimator (Sen, 1968). This method assumes a linear trend in the time series. In this method, the slopes (T_i) of all data pairs are first calculated by

$$T_i = \frac{x_j - x_k}{j - k} \quad \text{for } i = 1,2,\ldots\ldots,N \qquad (1)$$

where x_j and x_k are data values at time j and k (j>k) respectively. The median of these N values of T_i is Sen's estimator of slope which is calculated as

$$Qi = \begin{cases} T_{\frac{N+1}{2}} & N \text{ is odd} \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+2}{2}}\right) & N \text{ is even} \end{cases} \qquad (2)$$

A positive value of Q_i indicates an upward (increasing) trend and a negative value indicates a downward (decreasing) trend in the time series.

Significance of trend

To ascertain the presence of statistically significant trend in hydrologic climatic variables such as temperature, precipitation and stream flow with reference to climate change, nonparametric Mann-Kendall (MK) test has been employed by a number of researchers (Douglas et al.2000; Yue et al., 2003; Burn et al., 2004; Singh et al., 2008a, b; Kumar et al., 2009). The MK method searches for a trend in a time series without specifying whether the trend is linear or non-linear. In the present study the MK test was also applied. MK test checks the null hypothesis of no trend versus the alternative hypothesis of the existence of increasing or decreasing trend. The statistics (S) is defined as (Salas et al, 1980)

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

where N is number of data points. Assuming (x_j-x_i) = θ, the value of *sgn(θ)* is computed as follows:

$$\operatorname{sgn}(\theta) = \begin{cases} 1 & if \quad \theta > 0 \\ 0 & if \quad \theta = 0 \\ -1 & if \quad \theta < 0 \end{cases} \qquad (4)$$

This statistics represents the number of positive differences minus the number of negative differences for all the differences considered. For large samples (N>10), the test is conducted using a normal distribution (Helsel and Hirsch, 1992) with the mean and the variance as follows:

$$E[S] = 0 \qquad (5)$$

$$Var(S) = \frac{N(N-1)(2N+5) - \sum_{k=1}^{n} t_k(t_k-1)(2t_k+5)}{18} \qquad (6)$$

Where n is the number of tied (zero difference between compared values) groups, and t_k is the number of data points in the k_{th} tied group. The standard normal deviate (Z-statistics) is then computed as (Hirsch et al., 1993):

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & if \quad S > 0 \\ 0 & if \quad S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & if \quad S < 0 \end{cases} \qquad (7)$$

If the computed value of $|Z| > z_{\alpha/2}$, the null hypothesis (H_o) is rejected at α level of significance in a two-sided test. In this analysis, the null hypothesis was tested at 95% confidence level.
Temperature and rainfall record data of Chamkhar Chhu Basin for 25 years are shown graphically in the following graphs.

STUDY AREA:
The princely Kingdom of Bhutan is a landlocked country, about 300 km long and 150 km wide encompassing an area of 38,394 square kilometers. Located between longitude $88^0 45'$ and $92^0 10'$ East and latitudes $26^0 40'$ and $28^0 15'$ North in the Eastern Himalayas, it is bounded by India in South and South-West and Tibetan autonomous region of China in the North and North-West respectively.
Almost the entire country is mountainous, and elevation ranges from 100m along the Indian border to the 7,554m Kulha Gangri peak on the Tibetan border. These two extremes frame a landscape which stretches from sub-tropical to arctic like conditions hat makes a huge variation of rainfall all over the country. The maximum East-West stretch of the country is approximately 300 km and north-South about 150 km.

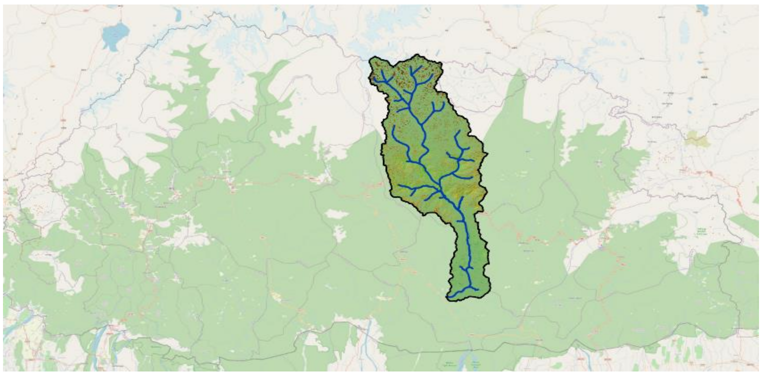


Fig 1: Bhutan showing Chamkharchhu Basin

© UIJIR | ISSN (O) – 2582-6417
JUNE 2021 | Vol. 2 Issue 1
www.uijir.com

Chamkharchhu Basin is situated at the latitude of 27°35’13’’ N and longitude of 90° 44’13” E in the northern part of country at the 2600 m above m.s.l. (mean sea level) and approximately area of 1350 square km.This basin is studied to be feasible for the construction of Hydropower project in future.

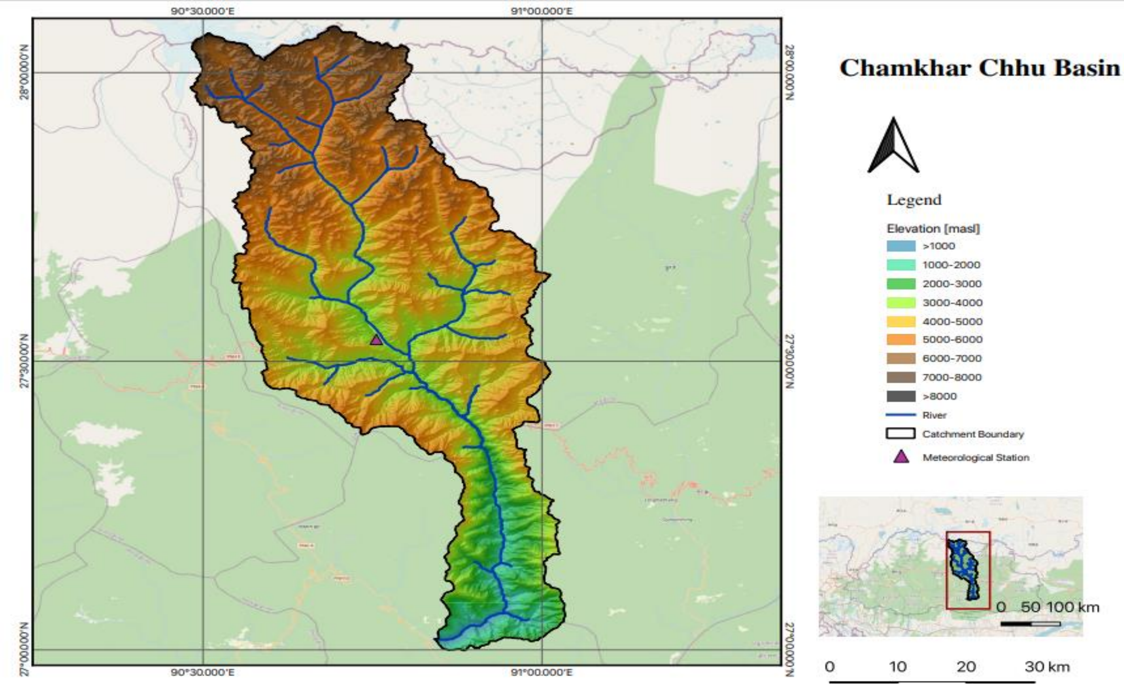
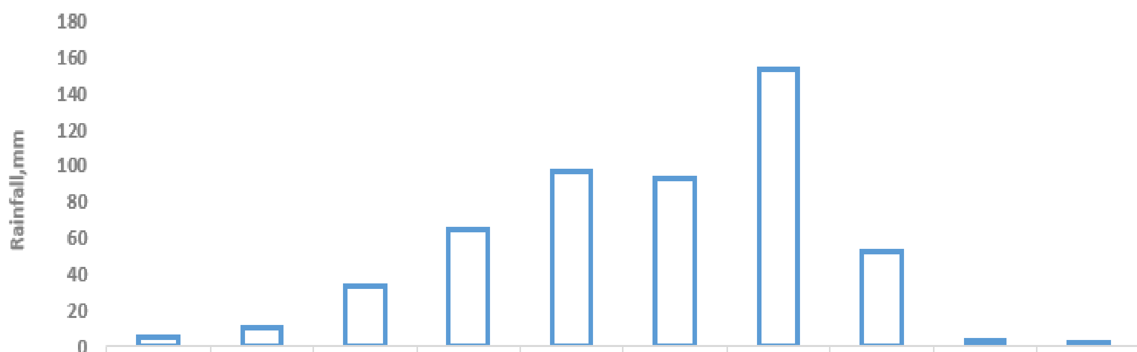


Fig 2: Chamkharchu Basin

RESULT AND DISCUSSION:

Trend analysis of Chamkharchhu has been done in the present study with precipitation data only. The majority of the monthly series in the data set appear to have no significant correlation coefficient so all the statistical tests described above are applied to the original time series. Mann-Kendall and Sen’s Slope Estimator has been used for the determination of the trend. Figure-2 represents the annual with mean rainfall occurrence from 1996-2020 at a period of 25 years.



	January	February	March	April	May	June	July	October	November	December
Mean Rainfall	5.324	10.336	33.668	64.26	97.024	92.404	153.248	52.272	3.296	2.672

Fig 3: Mean rainfall data record (1996-2020)

The threat of global warming as of now is real and the resultant of its impact are an alarming as it has observed in and around world. The data availability of high altitude stations is almost negligible and only one meteorology station nearby study area. The values of Mann Kendall statistic (Z_{mk}) and Sen's slope (Q) for temperature from 1996 to 2020 are tested at 95% confidence level as indicated table 1. There are four season in Bhutan and it has been analyzed by the statistical method.

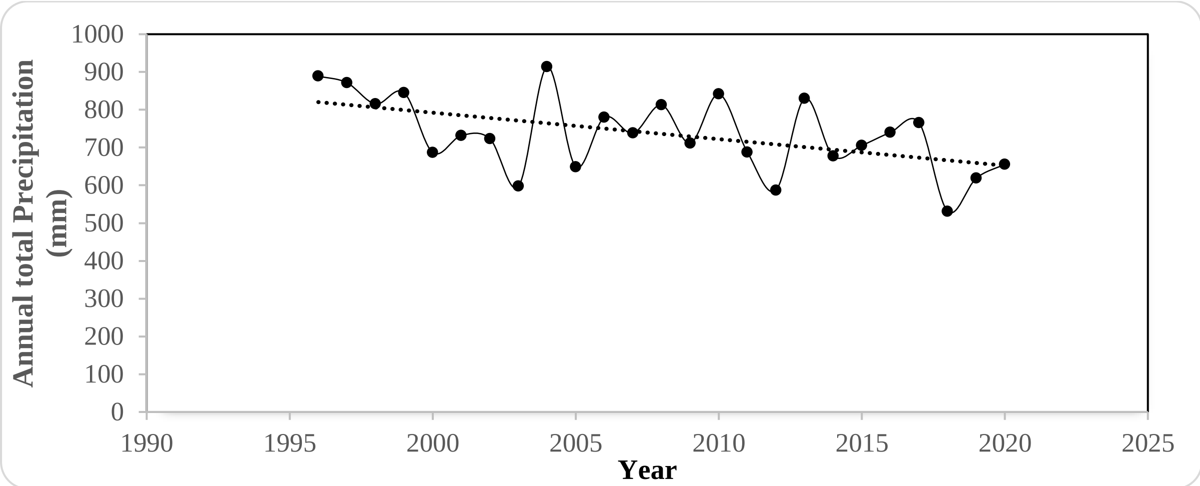


Fig 4: Annual mean rainfall from 1996 to 2020

Annual average is least for the month of December for all these 25 years (2.67 mm) followed by January (3.29 mm) while maximum rainfall occurs in the month of July (153 mm) followed by August (135 mm) and May (97.12 mm). Figures 3, 4 and 5 show the rainfall distribution of 25 years of individual seasons of 25 years.

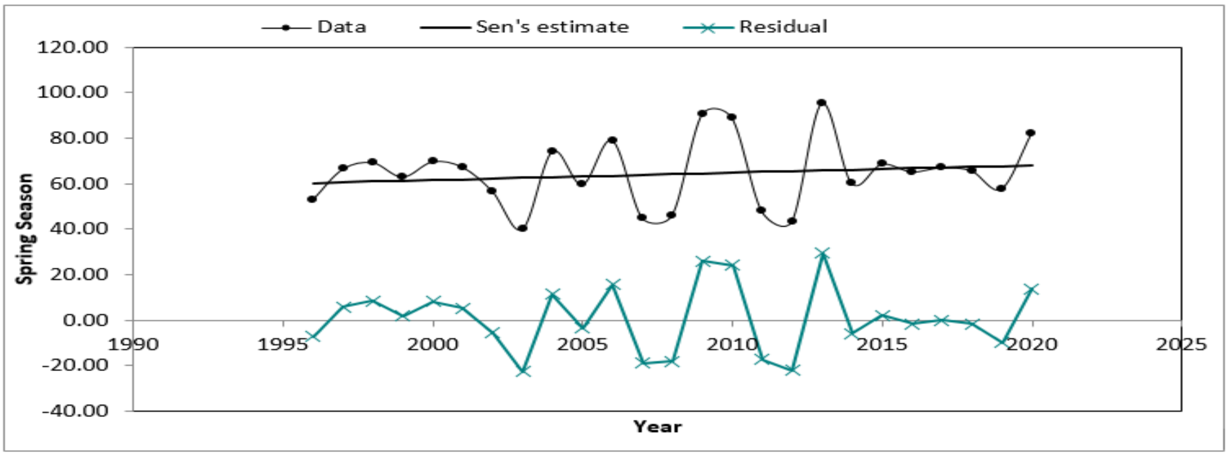


Fig 5: Spring season rainfall of March to May months from 1996 to 2020

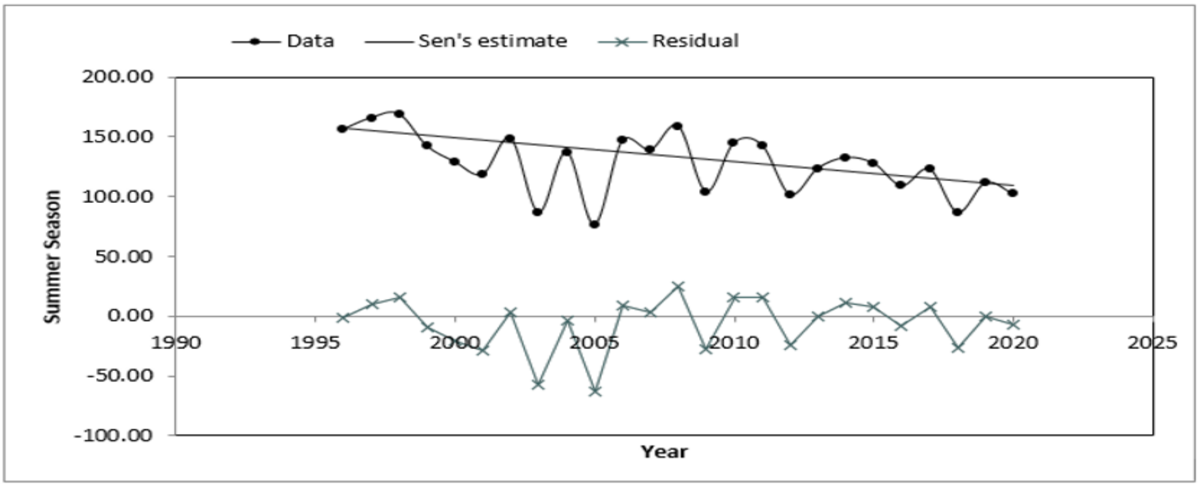


Fig 6: Summer season rainfall of June to August months from 1996 to 2020

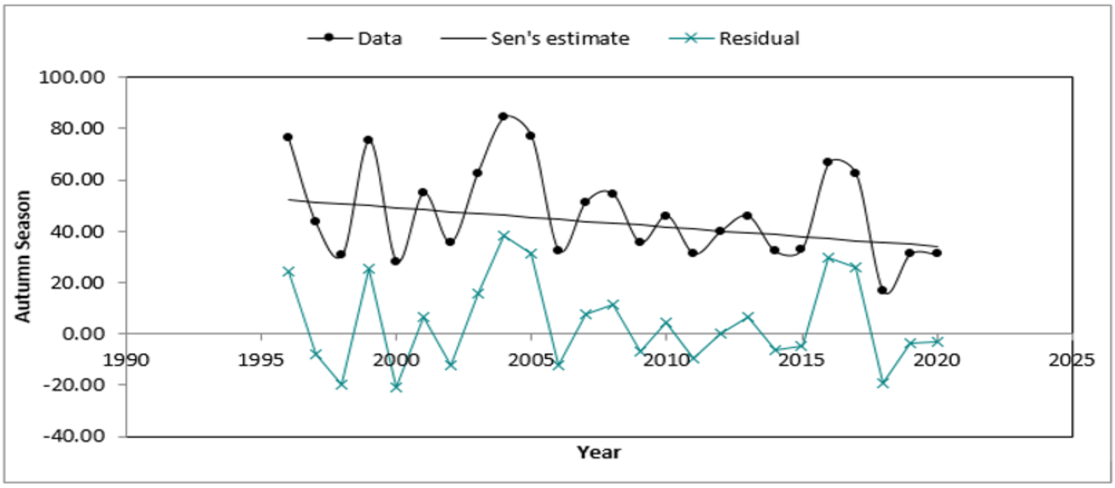


Fig 7: Autumn season rainfall of September to November months from 1996 to 2020

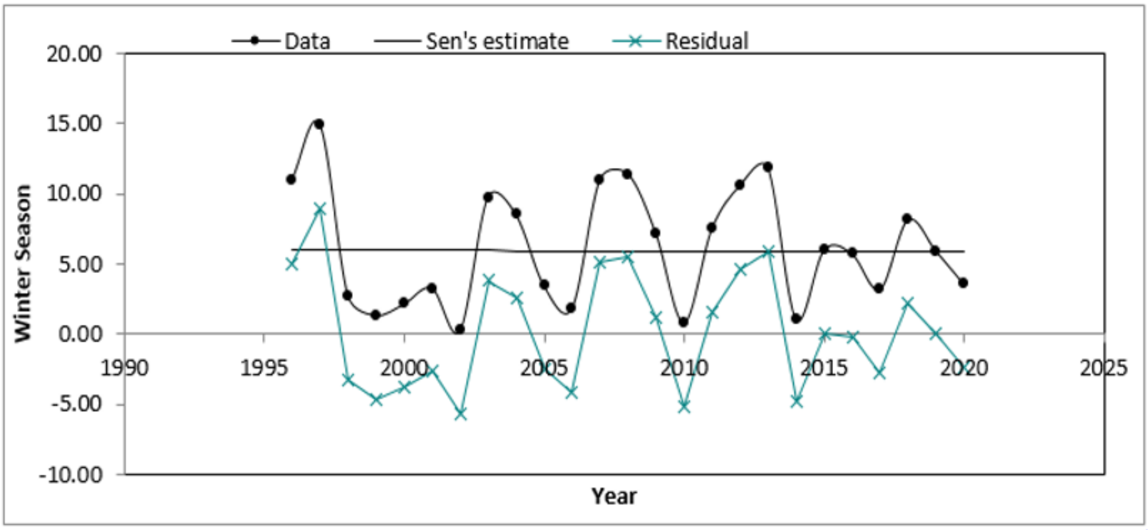


Fig 8: Winter season rainfall of December to February months from 1996 to 2020

In the non-parametric Mann-Kendall test, trend of rainfall for 25 years from January to December has been calculated for each month individually together with the Sen's magnitude of slope. In the Mann-Kendall test describes the trend of the series for individual 12 months from January to December which are 0.414, 0.397, 0.631, 0.280, 0.210, -2.220, -0.724, -1.611, -0.701, -1.121, 0.455, 1.641, respectively. For January, February, March, April, May, November and December, there is an evidence of rising trend while test value is showing negative trend in June, July, August, September, October. Thus test values for summer season shows a negative trend and for other seasons show positive trend representing almost non-significant condition (Table-2)

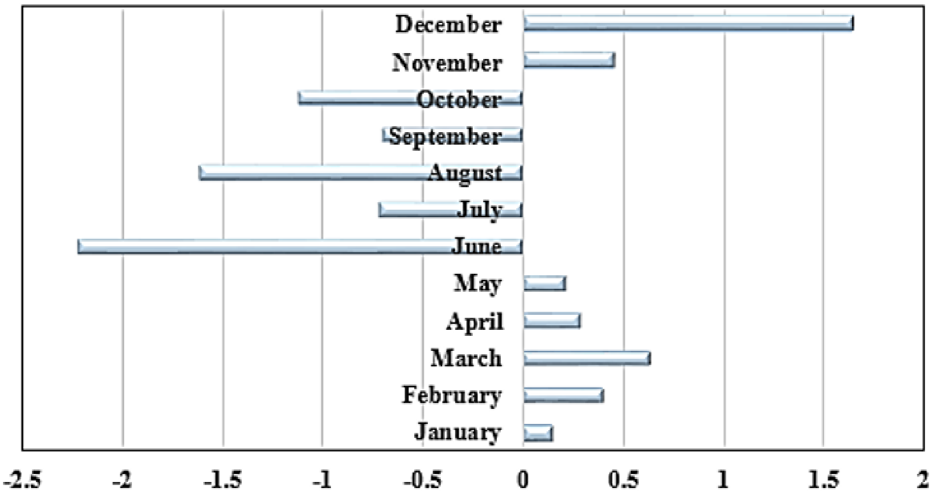


Fig 9: Trend for individual months by Mann-Kendall test.

According to the Sen's slope summer and autumn indicated decreasing trend and of all, summer indicates maximum decreasing trend. The spring and winter seasons indicate positive values insignificantly and overall annual slope is a negative value (Table 1).
Similarly, the values of Mann-Kendall statistic Z_{mk} and Sen's slope for short term period for the precipitation are shown below. Annual and summer indicates the most negative value of decreasing trend with significant at 95% confidence levels (Table 2).

Table 1: Estimated non parametric results and significance test.

Months	Mann- Kendall Trend Test	Sen's slope estimate
January	0.14	0.00
February	0.40	0.05
March	0.63	0.34
April	0.28	0.08
May	0.21	0.19
June	-2.22	-1.63
July	-0.72	-0.83
August	-1.61	-1.94
September	-0.70	-0.59
October	-1.12	-0.98
November	0.46	0.00
December	1.64	0.00

Table 2: Mk test value and Sen's slope for precipitation

Time series	Test Z	Sig.	Q (Sen's Slope)	Qmin95	Qmax95
Annual Average	-2.45	*	-0.692	-1.05	-0.16
Spring Season	0.63		0.324	-0.57	1.40
Summer Season	-2.83	**	-2.003	-3.14	-0.80
Autumn Season	-1.73	+	-0.754	-2.14	0.04
Winter Season	0		0.003	-0.29	0.25

Table 3: Basic statistics of rainfall data of Chamkharchhu from 1996 to 2020.

Year	Maximum Rainfall	Minimum Rainfall	Mean	Median	Standard Deviation
January	30.20	0.00	5.32	0.80	8.72
February	34.70	0.00	10.34	6.60	9.63
March	81.50	7.00	33.67	29.40	17.25
April	130.40	37.30	64.26	60.30	22.86
May	175.70	42.00	97.02	95.10	35.36
June	156.60	35.60	92.40	101.50	33.31
July	277.30	71.20	153.25	151.40	41.94
August	238.40	38.10	135.81	129.70	43.99
September	179.00	39.00	85.97	74.70	33.71
October	190.80	5.60	52.27	31.60	47.38
November	21.70	0.00	3.30	1.40	5.62
December	30.50	0.00	2.67	0.00	7.58

The following figure indicates all the four season of rainfall from 1996 to 2020. The summer season indicates the maximum rainfall of 152 mm. The winter season indicates the lowest rainfall of 0.2mm

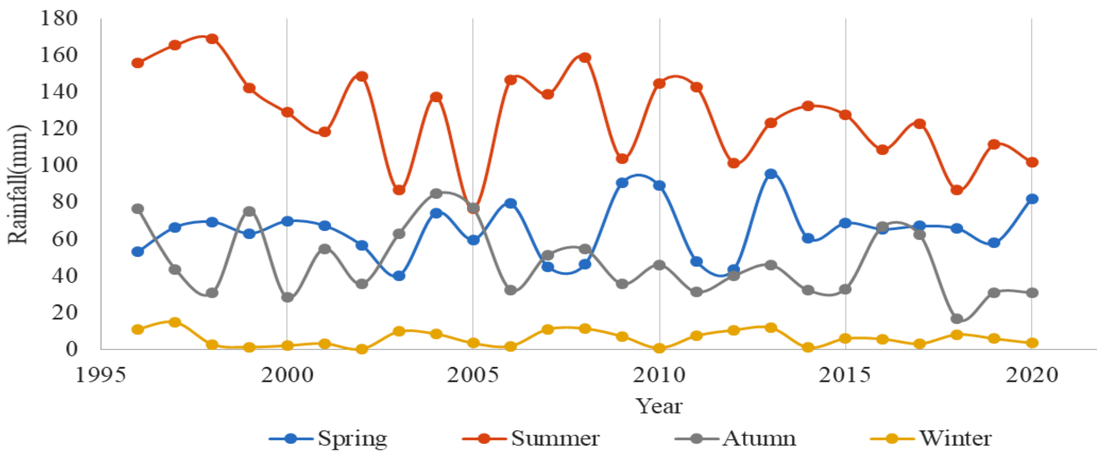


Fig 10: Four Seasons rainfall from 1996 to 2020

CONCLUSION

The application of this trend analysis indicates an overall increasing and decreasing trend even though no statistically significant. Furthermore, Chamkharchhu Basin is a rural area and thus represents more of agricultural land and forest zones which exhibits both the characteristic of run off and infiltration capacity. In this study, the Mann-Kendall Test represents both positive and negative trend in the area although not much significant. For January, February, March, April, May, November and December, there is an evidence of rising trend while test value is showing negative trend in June, July, August, September, and October. According to the Sen's slope summer and autumn indicated decreasing trend and of all, summer indicates maximum decreasing trend with significant value. The spring and winter seasons indicate positive values insignificantly and overall annual slope is the second maximum negative value.

Sen's Slope is also indicating increasing and decreasing magnitude of slope in correspondence with the Mann-Kendall Test values. There are four months with decreasing trend value along with the decreasing slope magnitude, and three months indicates positive with no Sen's slope. However, rest four months indicates positive value and Sen's Slope. However, study of the area may reveal other aspects which will be helpful in controlling flood causing havoc in this particular area.

REFFERENCES

- Burn, D. H., and Elnur, M. A. H., (2002). Detection of hydrological trends and variability, Journal of Hydrology, Vol. 255, pp. 107-122
- Dore, M.H.I., (2005). *Climate change and changes in global precipitation patterns*: Environmental International. **31**, 1167-1181.
- Dorji, L. (2016). *Seasonal and annual variation of Temperature and Precipitation in Phuntsholing,* International Journal of Advanced Scientific Research and Management, Vol. 1 Issue 10.
- Douglas, E. M., Vogel, R. M. and Kroll, C. N. (2000).'Trends in floods and low flows in the United States: impact of spatial correlation', J. Hydrol. 240, 90-105}.
- Hamed, K. H., and Rao, A. R., (1998). *A modified Mann-Kendall trend test for autocorrelated data*. Journal of Hydrology, Vol. 204, pp. 182 196
- Helsel and Hirsch, (1992). *Appropriate method to estimate the mean and variance of the data*.
- Hess, A., Iyer, H., Malm, W., (2001). *Linear trend analysis: a comparison of methods*, Atmos. Environment, Vol. 35, pp. 5211–5222
- Kendall, M.G. (1975). *Rank Correlation Methods*. Charles Griffin, London, UK.
- Mann, H.B. (1945). Nonparametric tests against trend. Econometrica, **13**,245-259.
- Salas, J. D., Delleur, J. W., Yevjevich, V. and Lane, W. L.: (1980). *Applied Modelling of Hydrologic Time Series,* Water Resources Publications, Littleton, Co., USA.
- Sen, P.K. (1968). *Estimates of the regression coefficient based on Kendall's tau*. Journal of the American Statistical Association 63:1379-1389
- Yao, TD., (2006), *temperature change over the past 100 years in ice cores on the Tibetan Plateau*. Science in China: Series D Earth Science 49(1): 1-9.