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Spatial and temporal variability of rainfall distribution in hilly region of Nepal

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Abstract

The study provides information about the nature of rainfall regimes across hilly regions of Nepal. Hilly areas of Nepal are always vulnerable to frequent and more climate induced hazards, i.e., erratic rainfall, landslide erosion, flashflood, drought etc. In this study, 30 years rainfall data (from 1987 to 2016) from 17 field stations were analyzed using statistical parameters like Mean, Median, Standard Deviation, Coefficient of Skewness and Coefficient of Variation). Statistical parameters were used to check the rainfall variability. The study parameters indicated that rainfall varied significantly at all the stations. The total annual average rainfall in all station was 1818.093mm. The average maximum and minimum annual rainfall varied from 2233.13mm (during 1999) to 1543.47 mm (during 1992) respectively. Similarly, the highest and lowest average rainfall varied from 3015.04mm to 832.78mm respectively in Pansayakhola and Nepalthok station. The study area of Hill region receives 80.87% highest annual average in the monsoon rainfall and lowest in the winter rainfall (3.29%). Thus analysis of rainfall data helps in exploring problems related to rainfall that may be high intensity, low intensity, erratic or no rainfall. At the same time analysis of such historical rainfall data in hilly areas helps in understanding issues related to drought, landslides and floods. These estimates predict possible pathways and help policy makers in understanding the variability of rainfall distribution across hilly region which is important for future planning and management strategies.

Keywords: Hilly, regimes, rainfall, monsoon, statistical parameters.

Introduction

Water is one of our most valuable natural resource and crucial to all forms of life. As we know that rainfall is the basic input of hydrology that falls in the form of liquid droplets to the earth surface. Among all types of parameters, rainfall is the most important metrological parameter. The amount of rainfall received over an area is an important parameter to determine the availability of water where the most of the people is depend on rainfall for agriculture, irrigation and other human activities[1]. Knowledge of rainfall variability is important for judicious management of water resources which are under constant pressure because of its demand, population growth and economic development[2]. Analysis of rainfall is also an integral part of hydrological research[3]. Rainfall data provides the primary input to many hydrological studies which determine the quantity of runoff in a stream directly as overland flow and indirectly as subsurface and ground water flow. The intensity and frequency changes of rainfall are an important potential impact of climate change[4-5].

Recent studies show that the extreme rainfall events are intensifying due to global climate change[6-9]. In fact the global warming is changing the hydrological cycle. The study of the temporal hydrological trend is significant for the management of water resources and understanding the impact of climate change on water resources[10-13]. Variation of rainfall is responsible for many hydrological problems such as flood and droughts[14]. The extremity and reoccurrence of droughts can be predicted and upcoming problems arising due drought can be overcome by taking various precautionary measures through the proper and detailed study of various rainfall data which is analyzed. Analysis rainfall pattern of hilly areas is a practical interest because hilly region is prone to drought and flooding. Therefore, analysis of rainfall plays a vital role in planning and management strategies of the local government[15]. Hence this study was focused to know the variability and distribution of rainfall across the hilly region of Nepal.

Methodology

Study areas: Nepal is small country spread over an area 147,181sq. km lies between latitudes 26° and 31°N, and longitudes 80° and 89°E . It ranges 885 km from east to west and 145-248km from north to south which is dominated by the northwest to south east-trending Himalayan mountain range[16-17].

Nepal has been divided into three belts; i. Lowland (Terai), ii. Middle hills and iii. High Mountains. Hilly region lies in the central part of Nepal located between the Mountain and Terai regions. From hilly region of Nepal 17 station were selected randomly from different elevation (Figure-1).

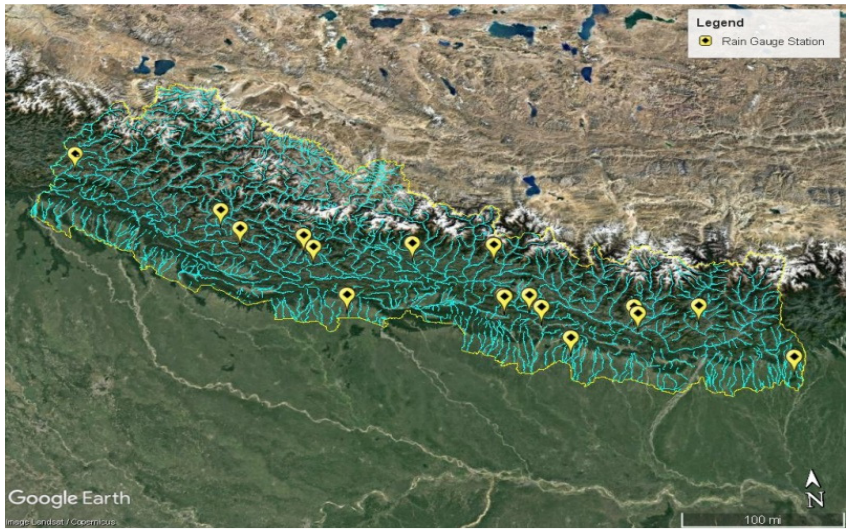

Figure-1: Different station location with water lines and water areas.

Methods: Several Statistical parameters (i.e. Mean, Median, Standard Deviation, Coefficient of Skewness and Coefficient of variation) was adopted for annual rainfall analysis, monthly rainfall analysis and seasonal of rainfall. It was applied for the rainfall data of 30 years during the period of 1987 to 2016 which were taken from seventeen weather station distribution over the hilly region studied with the statistical parameters.

Average: Mean is commonly known as average and best known measures of central tendency.

Median: Median refers to middle value in statistical distribution which provides the middle number of a group of numbers; that is, half the numbers have values that are greater than the median, and half the numbers have values that are less than the median. The middle position is obtained by the relation $(\frac{N+1}{2})^{th}$.

Standard deviation (σ): Standard deviation was calculated by using the following formula:

$$\sigma = \sqrt{\frac{\Sigma(x - \bar{x})^2}{n-1}}$$

Where x is the sample mean and n is the sample size.

Co-efficient of variation: Co-efficient of variation measures dispersion on standard deviation. A distribution having lesser C.V is considered less variable or more homogeneous or more consistent or more or more equitable or more stables etc. For comparing the variability between two or more than two sets of data, a distribution having more C.V is consider more variable or less heterogeneous or less consistent, less uniform or less equitable or less stable *etc*.

C.V= $\frac{\sigma}{x}\times 100$.

Coefficient of skewness (S_K): Coefficient of skewness is used in order to compare the sample and normal distribution. The larger the value, the larger the distribution differs from a normal distribution. Value of zero indicates no skewness. High negative value shows that the distribution is negatively skewed whereas; positive value highlightsa positively skewed distribution.

$$S_K = \frac{3(\text{MEAN} - \text{MEDIAN})}{\text{STANDARD DEVIATION}}$$

Results and discussion

Average rainfall: Year wise average rainfall (mm) during 1987-2016: The year wise average rainfall of 30 years during 1987- 2016 is plotted in Figure-6. Average rainfall of all 17 stations (during same year) was averaged to get annual rainfall (mm). The total rainfall varied significantly from year to year, as depicted below. The average annual rainfall was highest during 1999 (2233.13mm) and lowest in 1992 (1543.47 mm). The average rainfall of all 17 stations (during same year) of 30 years was 1818.19 (Figure-2).

Station wise average rainfall (mm) during 1987-2016: The station wise average rainfall of 30 years during 1987 to 2016 is given in the figure below (Figure-7). Thirty year station wise rainfall data was averaged to get average rainfall (mm) at each station during the mentioned period. The total rainfall received in respective station is highly variable. The station wise highest rainfall was observed in the Pansayakhola station with value of 3015.04mm and lowest was recorded in Nepalthok station with value of 832.78mm. The average rainfall of all 17 stations was also 1818.19mm (Figure-3).

Average Seasonal rainfall: The both average of seasonal rainfall of all 17 stations (during same year) and station wise rainfall of 30 years from1987 to 2016 shows that 80.87% highest contribution in the monsoon rainfall at Hill region and lowest in the winter rainfall (3.29%) of the total average rainfall. The total average annual rainfall of station and year wise was found 1818.093mm (Figure-4).

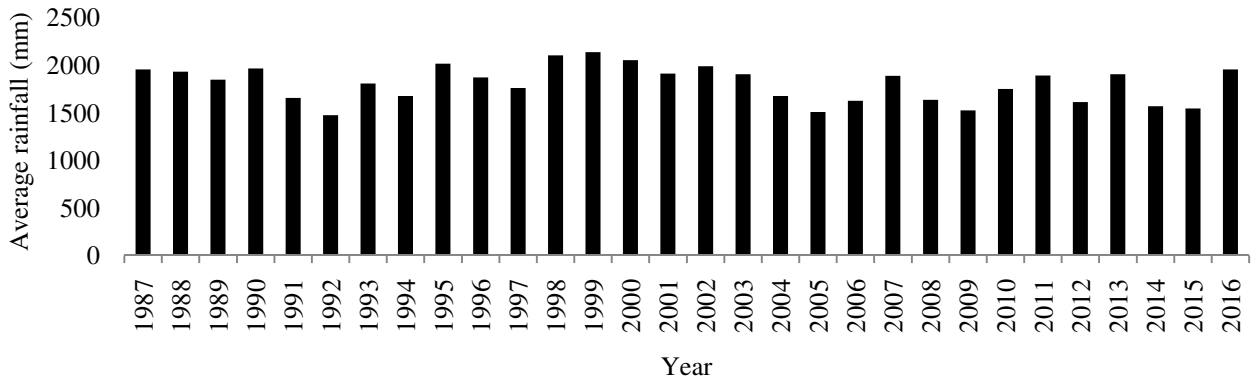

Figure-2: Year wise average rainfall, mm (during 1987-2016).

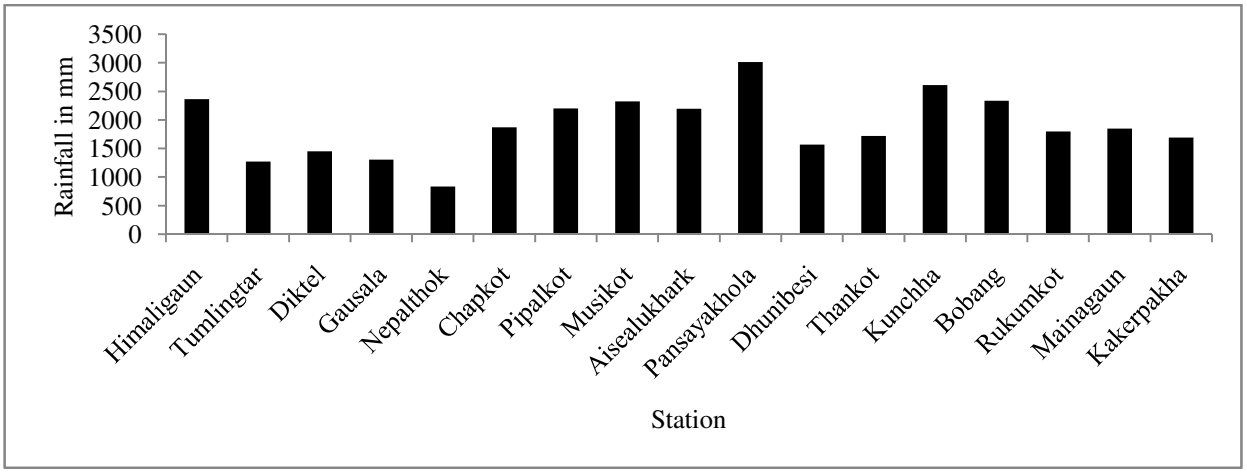

Figure-3: Station wise average rainfall (mm).

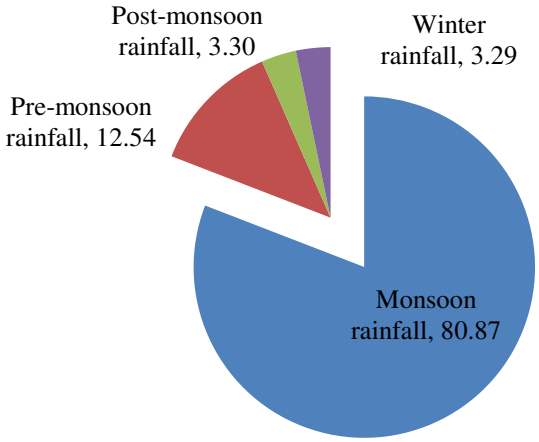

Figure-4: Average Seasonal rainfall.

Statistical characteristics for average rainfall analysis: Station wise: Table-1 represents maximum average rainfall (3015.04 mm) and maximum median rainfall (3061.40 mm), which was observed at Pansaykhola station whereas the lowest average rainfall (832.79mm) and lowest median rainfall (240.59mm) was observed in Nepalthok. The highest standard deviation (717.03mm) of rainfall occurred at Gausala station and lowest standard deviation (240.59mm) of rainfall occurred in Nepalthok. Gausala station had the highest co-efficient (54.88%) of variation and subsequently the lowest coefficient of variation was observed at Pipalkot (15.57%). Skewness shows both positive and negative value at different stations. Negative values for the skewness indicate that data are skewed towards left and positive values for the skewness indicate that data are skewed to the right.

Year wise: Table-2 shows that maximum average rainfall is received in the year 1999 (2233.14 mm) lowest average rainfall 1992(1472.83mm). The highest median value of rainfall was in the year 1988(2290.2 mm) and lowest median value rainfall 2009(1392.4mm). The year with the highest values standard deviation was 1989(834.64mm) and lowest standard values was at 1994 (492.97 mm). Skewness shows both (16) data positive and (14) data negative value. The highest coefficient variation was at 2004(43.2%) whereas lowest coefficient variation was at 1987(26.39%).

Discussion: The study area of Hill region receives 80.87% highest annual average in the monsoon rainfall and lowest in the winter rainfall (3.29%). The average maximum and minimum annual rainfall varied from 2233.13mm (during 1999) to 1543.47mm (during 1992) respectively. Similarly, the highest and lowest average rainfall varied from 3015.04mm to 832.78mm respectively in Pansayakhola and Nepalthok station. Our study parameters indicated that rainfall varied significantly at all the stations. The characteristics monthly rainfall was peak on July during average of 30 years which was similar to the study of Kansakar et al.[16]. Understanding the rainfall distribution of year to year variability helps to determine recent and future water resource stress which is useful for water resources management and regional development[18]. The most time-series of regional rainfall have experienced fluctuations at different time-scales which have shown by the several studies[19-20]. On the similar study it was found 78% of annual precipitation was in the monsoon season, and the contribution of monsoon precipitation was the highest in Hill and Mountain while according to Shrestha, 2000 shows that Nepal receives 80% of the total annual precipitation in monsoon season[21-22]. Hilly regions are prone to soil erosion and landslides due to its fragile geology. The frequency of floods and drought are affected due to the change in the intensity of rainfall, as rainfall influences the distribution of runoff, soil moisture and groundwater reserves[23-28]. Variation of rainfall and change in the intensity of rainfall is responsible to increases many hydrological problems such as floods, drought landslides in the hilly region[29,14]. There is a huge research gap in defining temporal variability both in annual, seasonal and monthly rainfall regimes across hilly region of Nepal[30]. Knowing of rainfall pattern is a subject of ongoing concern which is critical for making policies and plans[31]. Thus understanding the status annual, seasonal and monthly rainfall pattern across the hilly region helps in planning and management strategies.

Table-1: Statistical Parameters for Station wise rainfall Analysis.

Name of station	Average rainfall (mm)	Standard deviation(mm)	Median (mm)	Co-efficient of Variation (%)	Coefficient of skewness
Himaligaun	2362.44	371.85	2389.95	15.74	-0.22
Tumlingtar	1270.05	285.43	1252.20	22.47	0.19
Diktel	1451.13	311.66	1442.25	21.48	0.09
Gausala	1306.64	717.03	1184.40	54.88	0.51
Nepalthok	832.79	240.59	803.85	28.89	0.36
Chapkot	1869.83	390.37	1874.95	20.88	-0.04
Pipalkot	2203.07	342.92	2205.95	15.57	-0.03
Musikot	2321.77	403.93	2383.70	17.40	-0.46
Aisealukhark	2193.52	429.31	2255.30	19.57	-0.43
Pansayakhola	3015.04	517.10	3061.40	17.15	-0.27
Dhunibesi	1568.11	402.14	1507.10	25.64	0.46
Thankot	1716.70	368.33	1660.75	21.46	0.46
Kunchha	2607.52	497.81	2533.70	19.09	0.44
Bobang	2333.34	365.54	2353.35	15.67	-0.16
Rukumkot	1798.85	283.87	1778.25	15.78	0.22
Mainagaun	1848.86	473.24	1702.70	25.60	0.93
Kakerpakha	1688.41	308.30	1621.90	18.26	0.65

Table-2: Statistical Parameters for year wise rainfall.

Year	Average (mm)	Standard deviation(mm)	Median (mm)	Co-efficient of Variation (%)	Coefficient of skewness
1987	2055.88	542.54	2064.60	26.39	-0.05
1988	2052.79	701.73	2024.40	34.18	0.12
1989	1980.74	834.64	2029.60	42.14	-0.18
1990	2065.19	663.01	1954.00	32.10	0.50
1991	1770.84	661.70	1949.50	37.37	-0.81
1992	1543.47	630.54	1617.90	40.85	-0.35
1993	1905.38	585.50	1997.90	30.73	-0.47
1994	1756.39	492.97	1733.30	28.07	0.14
1995	2122.96	647.41	2076.50	30.50	0.22
1996	1984.38	590.66	1913.40	29.77	0.36
1997	1870.87	726.29	1720.70	38.82	0.62
1998	2224.65	757.89	2290.20	34.07	-0.26
1999	2233.14	790.33	2234.90	35.39	-0.01
2000	2173.32	829.35	2281.90	38.16	-0.39
2001	2030.24	702.26	2121.60	34.59	-0.39
2002	2080.64	657.92	2061.60	31.62	0.09
2003	2017.79	705.77	2119.80	34.98	-0.43
2004	1758.33	759.54	1764.80	43.20	-0.03
2005	1573.21	514.82	1442.60	32.72	0.76
2006	1684.94	596.51	1472.00	35.40	1.07
2007	1999.06	528.89	2076.70	26.46	-0.44
2008	1728.15	501.03	1729.90	28.99	-0.01
2009	1618.12	586.05	1407.10	36.22	1.08
2010	1866.98	749.14	1836.50	40.13	0.12
2011	1973.62	589.98	1986.30	29.89	-0.06
2012	1723.52	599.90	1624.30	34.81	0.50
2013	2050.78	676.95	1821.50	33.01	1.02
2014	1663.52	561.59	1577.10	33.76	0.46
2015	1605.43	597.82	1532.60	37.24	0.37
2016	2041.08	698.02	2011.20	34.20	0.13

Conclusion

Thirty years rainfall data from 17 field stations were analyzed by means of statistical parameter like Mean, Median, Standard Deviation, Coefficient of Skewness and Coefficient of variation. The results implied that rainfall varied significantly in all the stations. The total annual average rainfall in all station was 1818.093mm. The average maximum and minimum annual rainfall varied from 2233.13mm (during 1999) to 1543.47 mm (during 1992) respectively. Similarly, the highest and lowest average rainfall varied from 3015.04mm to 832.78mm respectively in Pansayakhola and Nepalthok station. The study area of Hill region receives 80.87% highest annual average in the monsoon rainfall and lowest in the winter rainfall (3.29%).

Thus analysis of rainfall data helps in exploring problems related to rainfall that may be high intensity, low intensity, erratic or no rainfall. At the same time analysis of such historical rainfall data in hilly areas helps in understanding issues related to drought, landslides and floods. These estimates predict possible pathways and help policy makers in understanding spatial and temporal variability of rainfall distribution of hilly areas in Nepal which is important for future planning and management strategies.

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