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Rainfall Characteristics Pattern and Distribution analysis at Tadong East Sikkim

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ABSTRACT

Sikkim is one of the highest rainfall-receiving states in India. Trends in monthly, seasonal, and annual rainfall on the meteorological station at Tadong, Gangtok were examined in this study. The year 2009 received lowest amount of annual rainfall (2458.8 mm), whereas the year 2003 received highest amount of annual rainfall (3740.6 mm) during the period 1983-2015. The year 2010 received highest number of rainy days (205 days) but its previous year 2009 received lowest number of rainy days (128 days) from 1983-2015. The average or mean annual rainfall was 3088.8 mm and the value of standard deviation was found to be 310.5 mm. The year 1986, 1988, 1989, 2006, 2007, 2009 and 2013) receiving rainfall less than 2778.3 mm should be drought years in Tadong. Thus, trend analysis of rainfall data series for 1983–2015 did showed a clear trend for the region as a whole.

1. Introduction

The change in weather condition is indicated by changes in temperature, rainfall, relative humidity, wind, *etc.* and any changes in their pattern, if any. A number of studies found that average global temperature is increasing and there is a shift in rainfall pattern. The number of extreme climatic events has gone up in recent years. The amount of rainfall at a particular place is important, an equally important factors is its temporal distribution. The importance of this distribution is realized in agriculture and allied sectors. The knowledge of distribution of dry spells and amount of rainfall during wet spells is very much essential for successful management of agriculture. The information of amount of rainfall during wet spell is useful for strong purpose based on the magnitude of dry spells and drought severity. Although climate change is a broad area of research, the changing pattern of precipitation deserves urgent and systematic attention as it will affect the availability of food supply. Changes in rainfall quantity and frequency would alter the pattern of stream flows and demands (particularly agricultural), spatial and temporal distribution of runoff, soil moisture, and groundwater reserves. Climate change in the Himalayas is already having a significant impact on biodiversity, hydrology, livelihoods and almost every other aspect of the environment and human enterprise (Xu *et al.,* 2009). A lot of work has been carried out in the past by various investigations on rainfall analysis (Chakraborty *et al.,* 2008.; Jakhar *et al.,* 2011; Mohanty *et al.,* 2001; Satapathy *et al.,* 1998.; Sharda, and Bhushan, 1985.; Verma, and Sharma. 1989). Climatically, Sikkim experiences variable temperature with summer in the foothills and freezing winter on the high mountains. For most of the period in a year, the climate is cold and humid as rainfall occurs in each month. The area experiences a heavy rainfall due to its proximity to the Bay of Bengal. Shrestha, Gautam and Bawa (2012) shown that between 1982 and 2006, temperatures in the Himalayas increased by 1.5°C (about three times the global average), and annual precipitation increased by 163 mm. Trend analysis of rainfall in different spatial scales will lead to a better understanding of the problems associated with floods, droughts, and the availability of water for various uses with respect to future climate scenarios. Thus, keeping the importance of rainfall in agriculture present investigation was carried out for rainfall characteristics, its pattern and distribution analysis at Gangtok of Sikkim state.

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2. Materials and Methods

The daily weather data such as rainfall recorded from 1983 to 2015 at the meteorological observatory located in the campus of ICAR Research Complex for North Eastern Hill Region, Sikkim Centre, Tadong was taken for this study. The observatory is located at 1350 m above the mean sea level (msl) and represents the mid-hill location (climate) of Sikkim and lies at 27˚20'N latitude and 88˚37'E longitude. The daily meteorological data were collected and verified for any error. Any month receiving precipitation less than 50% of the average monthly rainfall was used for calculating drought month. Any month receiving the precipitation more than twice the average monthly rainfall was used for calculating abnormal month. A day, when it receives rainfall equal to or more than 2mm, is called rainy day. On this basis monthly and yearly rainy days have been estimated from the rainfall data over 33 years from 1983 to 2015. The annual index of wetness has been calculated over the period of 33 years from 1983 to 2015 using the following equation as given below.

$$\text{Index of wetness} = \frac{Rainfall}{Normal\ rainfall}$$

3. Results and Discussion

The average monthly rainfall data are depicted in Figure 1. The bar diagram indicates that the month of June has received the maximum rainfall of 563.77 mm followed by the month of June which has received the second highest rainfall of 538.9 mm, August (500.93 mm), May (440.4 mm), September (375.04 mm), April (263.76 mm), October (164.82 mm) and March (114.37 mm).

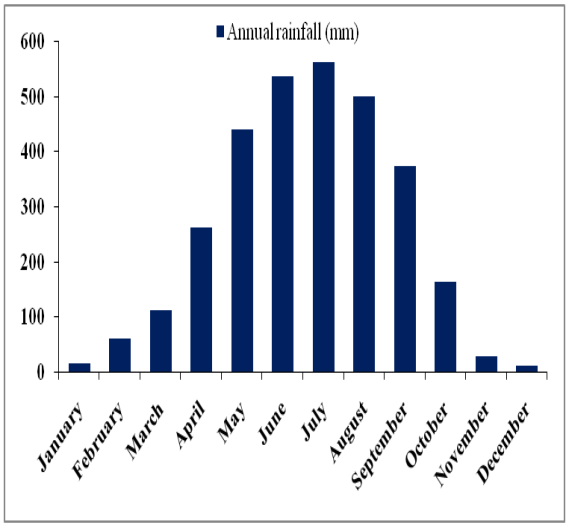

Figure 1. Average monthly variation of rainfall at Tadong (mid-hills of Sikkim) from 1983-2015

The month of December has received on an average the lowest rainfall of 13.91 mm followed by January which has received an amount of 17.3 mm. From the average values, it reveals that the dry spells have occurred during the months of January, February, November and December. Irrigation facilities should be available to provide irrigation to the winter crops grown during these four months. From the Figure 2 it is clearly shown that the year 2009 received lowest amount of annual rainfall (2458.8 mm), whereas the year 2003 received highest amount of annual rainfall (3740.6 mm) during the period 1983-2015.

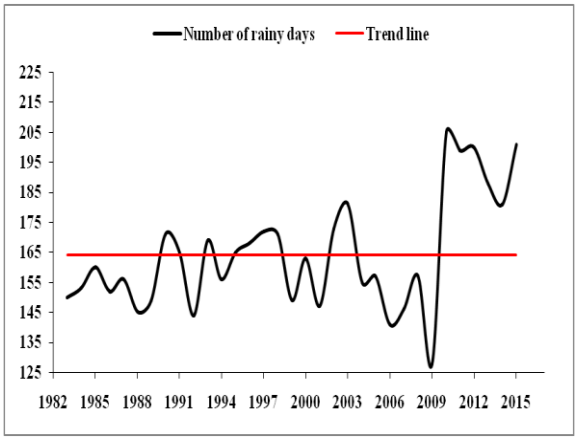

Figure 2. Annual variation of rainfall at Tadong (mid-hills of Sikkim) from 1983-2015

The normal rainfall was 3088.8 mm. Rainy days at Tadong over 33 years from 1983 to 2015 given in Table 1. The month of July has received daily rainfall equal to or more than 2mm on an average in 27 days followed by August (25 days) and June (24 days). December and January received lowest daily rainfall equal to or more than 2mm on an average in 1.7 and 2.4 days, respectively. Year-wise average number of rainy days at Tadong over 33 years from 1983 to 2015 given in Fig 3.Trend line shows that normal number of rainy days is 164.15 mm. The year 2010 received highest number of rainy days (205 days) but its previous year 2009 received lowest number of rainy days (128 days) from 1983-2015.

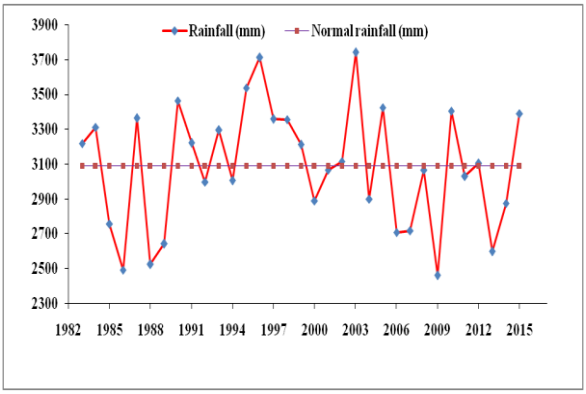

Figure 3. Year-wise average number of rainy days at Tadong from 1983 to 2015

The normal rainfall at Tadong was 3088.8 mm. The values of index of wetness are tabulated in the Table 2. Out of 33 years, the values of index of wetness were more than one in 33 years, which indicated that 48% of the period from 1983 to 2015 had experienced rainfall greater than normal and which might have caused larger runoff leading to more soil erosion and landslide. The year, 2009 had experienced the lowest rainfall of 2458.8 mm and thus, it had the lowest value of index of wetness as 0.8. Similarly the year 1996 had experienced highest rainfall of 3711.4 and thus, it had highest value of index of wetness as 1.2. The rainfall for a month to be a drought, abnormal or normal with the average rainfall has been shown in Table 3. The average or mean annual rainfall was 3088.8 mm and the value of standard deviation was found to be 310.5 mm. Therefore, any year receiving the rainfall less than or equal to 2778.3 mm will be the drought year. Thus as per the above definition 1986, 1988, 1989, 2006, 2007, 2009 and 2013) receiving rainfall less than 2778.3 mm should be drought years in Tadong.

During the period of past 33 years, drought has occurred in the months of October, November, December, January, February and March. December was the drought month, followed by January, November and February. Any year that has received rainfall $\geq$ 3399.3 mm (μ 3088.8.78 + σ310.5 mm) were sought to be an abnormal year, therefore the years 1990, 1995, 1996, 2003, 2005 and 2010 were considered as abnormal years. Years receiving rainfall between 2778.3 and 3399.3 mm were the normal years. Therefore, the remaining 20 years (60% of the total years) *i.e.* 1983, 1984, 1985, 1987, 1991, 1992, 1993, 1994, 1997, 1998, 1999, 2000, 2001, 2002, 2004, 2008, 2011, 2012, 2014 and 2015 were the normal years. Rahman *et al.* (2012) found that in Gangtok rainfall period has increased by 124 mm. He also mentioned that rainfall has decreased both in terms of number of rainy days (loss of 14.40 days) and total rainfall (355 mm). Seetharam (2012) found that rainfall has decreased between 1961 and 1990 in Gangtok. The results of Rahman *et al.* (2012) and Seetharam (2012) are not comparable because of the different periods involved.

Table 1. Rainy days at Tadong, Sikkim from 1983 to 2015

Year	Month												Annual Total
	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	
1983	00	02	05	06	17	20	27	23	27	07	01	02	150
1984	06	01	05	15	26	20	27	25	19	06	01	02	153
1985	01	11	09	15	21	20	25	22	21	06	06	02	160
1986	00	02	09	18	13	24	25	22	21	14	02	02	152
1987	01	03	12	15	21	22	27	23	22	10	01	01	156
1988	01	05	13	12	17	21	28	28	11	04	01	02	145
1989	02	04	05	06	17	27	27	22	27	07	08	01	149
1990	03	13	10	19	23	25	29	21	20	06	00	00	171
1991	04	01	11	17	26	21	27	27	24	03	00	05	165
1992	03	09	03	12	19	21	27	24	14	10	01	02	144
1993	04	07	08	14	18	26	28	26	22	14	03	01	169
1994	03	05	13	17	17	26	23	27	18	08	04	02	156
1995	03	09	06	11	19	26	28	26	23	09	03	04	165
1996	06	02	11	11	27	23	29	28	23	10	00	00	168
1997	02	14	10	17	20	26	26	25	21	07	00	05	172
1998	02	03	16	15	16	29	30	28	19	12	00	00	171
1999	01	00	04	13	19	19	29	26	21	12	03	01	149
2000	03	03	16	17	17	20	27	23	23	10	05	00	163
2001	00	04	06	21	21	22	27	24	20	12	03	01	147
2002	07	02	14	21	21	23	29	28	18	08	02	03	173
2003	04	11	12	22	21	25	22	24	22	12	02	03	181
2004	02	09	11	23	23	21	27	20	21	08	00	00	155
2005	02	05	12	14	25	26	26	23	13	08	02	01	157
2006	00	02	06	13	17	25	25	26	19	06	01	00	141
2007	00	00	07	15	19	25	25	22	22	09	02	01	146
2008	01	01	09	18	18	28	27	25	20	06	02	01	157
2009	4	2	10	21	21	26	29	28	16	8	2	1	128
2010	0	4	12	20	25	28	30	29	27	20	10	0	205
2011	6	6	9	20	24	24	29	29	24	11	14	3	199
2012	5	6	10	24	17	28	31	30	25	20	1	3	200
2013	0	5	14	23	29	26	31	31	5	17	3	4	188
2014	0	0	13	15	27	27	29	30	27	7	3	3	181
2015	6	6	7	27	28	28	30	29	23	9	6	2	201
Total	82	157	318	547	689	798	906	844	678	316	92	58	5417
Average	2.4	4.7	9.6	16.5	20.8	24.18	27.4	25.5	20.5	9.5	2.7	1.7	164.15

Table 2. Index of wetness at Tadong from 1983 to 2015

Sl. No	Year	Annual rainfall (mm)	Index of wetness
1	1983	3219.1	1.04
2	1984	3310.2	1.07
3	1985	2756.3	0.89
4	1986	2490.3	0.81
5	1987	3363.7	1.09
6	1988	2522.9	0.82
7	1989	2640.8	0.85
8	1990	3462.6	1.12
9	1991	3220.1	1.04
10	1992	2996.8	0.97
11	1993	3294	1.07
12	1994	3003.9	0.97
13	1995	3537.8	1.15
14	1996	3711.4	1.20
15	1997	3357.3	1.09
16	1998	3356.3	1.09
17	1999	3210.3	1.04
18	2000	2888.9	0.94
19	2001	3065.5	0.99
20	2002	3115.2	1.01
21	2003	3740.6	1.21
22	2004	2897.9	0.94
23	2005	3424.2	1.11
24	2006	2707.7	0.88
25	2007	2718.3	0.88
26	2008	3066.8	0.99
27	2009	2458.8	0.80
28	2010	3405	1.10
29	2011	3029	0.98
30	2012	3102.5	1.00
31	2013	2596.6	0.84
32	2014	2873.6	0.93
33	2015	3388.7	1.10

Table 3. Rainfall for a month to be normal, abnormal, drought and average rainfall

Sl. No.	Months	Average rainfall, mm	Normal, mm (in between)	Abnormal, mm (more than)	Drought, mm (less than)
1	January	17.9	8.5-35.8	35.8	8.5
2	February	63.03	31.52-126.06	126.06	31.52
3	March	114.37	57.19-228.74	228.74	57.19
4	April	263.76	131.88-527.52	527.52	131.88
5	May	434.4	217.2-868.8	868.8	217.2
6	June	538.9	269.45-1077.8	1077.8	269.45
7	July	523.77	261.89-1047.54	1047.54	261.89
8	August	481.93	240.97-963.86	963.86	240.97
9	September	375.04	187.52-570.08	570.08	187.52
10	October	164.82	82.41-329.64	329.64	82.41
11	November	30.82	15.41-61.64	61.64	15.41
12	December	13.91	6.96-27.82	27.82	6.96

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