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Analysis of total precipitation and snowfall pattern over Shimla

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ABSTRACT

The study conducted using 20 years total winter precipitation and snowfall data of Shimla (Himachal Pradesh) for winter season (December to March) shows that the total precipitation and snowfall for all the months have a decreasing tendency, the highest being for the month of January. The total precipitation and snowfall for different months were found to have decreased in the second decade under study by 6 to 36% and 16 to 86%, respectively. The beginning of snowfall season did not show any delay. However the season is tending to end earlier by about 12 days per decade. The decadal analysis shows that the average date of ending of the snowfall season has advanced by two weeks in the second decade compared to the first decade. The analysis indicates a potential adverse impact on the river flow and agricultural/horticultural production in Himachal Pradesh and other states down stream.

Key words: Winter precipitation, snowfall, snowfall days

The amount, intensity and type of precipitation vary in time and space. The variation is more marked in the mountainous regions because of the large variation in the physiographic features over short distances. Besides the variation caused by physiographic features, the trends in temperature and precipitation need to be investigated in details for assessing their impacts on the hydrological cycle and agricultural/horticultural production. According to the fourth assessment report of the Inter-governmental Panel on Climate Change (Anonymous, 2007), the global average temperatures have increased by 0.74 ± 0.18^{O} C during the twentieth century and also the northern hemisphere snow cover is decreasing. The report also says that the precipitations have declined in south Asia. According to a study by the India Meteorological Department (Guhathakurta and Rajeevan, 2006), the monsoon rainfall in the two hilly states of India - H.P and Uttarakhand has decreased by 61 and 79 mm, respectively over past 100 years.

The type of precipitation at a station (rain/snow) depends on the temperatures. The relationship, however, varies with latitude and altitude of the place. According to Singh and Bhan (2008) any precipitation during a day at Shimla is most likely to be in the form of snow if the minimum temperature in the morning is one degree Celsius or less; and in the form of rain if the minimum temperature is four degree Celsius or more. Mixed precipitation is received with temperatures between one and four degree Celsius. Duan and Yao (2003) have reported that variability of precipitation in the Himalayas is closely related to the variation in temperature with precipitation decreasing with increase in temperatures. Previous studies for the Western Himalayan region suggest that the temperatures in the region are showing an increasing trend (Lal *et al*., 1995 and Murty *et al*., 2008). This emplies that warming temperatures in the hilly regions can lead to reduction in proportion of snowfall to total precipitation. The decreasing precipitation in the form of snow in the hilly regions has its imacts on the river flow as most of the perennial rivers originating from the Himalayas are dependent on the snowmelt during the non-monsoon months. Jindal *et al*. (2001) reported that winter precipitation especially in form of snow is very crucial for induction of dormancy, bud break and ensuring flowering in apples. They also reported that the decrease in snowfall and early withdrawal of snowfall is reflected in decrease in apple yields over past two decades.

In view of above, an analysis of total precipitation, snowfall and duration of snowfall season over a hilly station in western Himalayas - Shimla, is being presented here as both rainfall and snowfall data are available for the station.

DATA AND METHODOLOGY

Winter season in Shimla is considered from November to March. Though precipitation data of the meteorological observatory at Shimla are available for longer period, snowfall data are available only from early 1990s. Therfore, the total precipitation and snowfall data of Shimla for 20 winter seasons from 1991-92 to 2010-11 were considered for the study. Snowfall at the station is measured by adding a known quanity of warm water in snow collected on the rain gauge every three hours. One cm of snowfall is considred equal to one mm of liquid precipitation and hence the snowfall in the text, wherever mentioned, be taken as mm equivalent of liquid water. As the snowfall in the month of November has occurred only once during the study period, November

Table 1: Decade wise monthly and seasonal precipitation over Shimla

Month	Decade period	Total precicitation	Snowfall	% of snowfall to total precipitation
December	1991-92 to 00-01	28.3	9.9	35
	2001-02 to 10-11	25.8	1.4	5
	Mean	27.0	5.7	20
January	1991-92 to 00-01	85.9	49.5	58
	2001-02 to 10-11	54.9	26.1	48
	Mean	70.4	37.8	54
February	1991-92 to 2000-01	87.2	8.2	48
	2001-02 to 2010-11	82.0	5.3	43
	Mean	84.6	38.6	46
March	1991-92 to 2000-01	82.5	8.2	10
	2001-02 to 2010-11	72.4	5.3	7
	Mean	77.5	6.8	9
Season	1991-92 to 2000-01	283.9	109.4	39
	2001-02 to 2010-11	235.1	68.1	30
	Mean	259.5	88.8	34

month is ignored while analysing the data. An analysis of precipitation in form of rain or snow and the contribution of snowfall towards total precipation has been done for the winter season. The snowfall days also have been calculated and analysed. A day was considered as snowfall day if the precipitation had occurred in form of either only snow or a mix of rain and snow. First day of snowfall during the season and last day of the snowfall during the season at Shimla were also analysed to examine the length of snowfall season.

RESULTS AND DISCUSSION

Total precipitation and snowfall

The analysis revealed that the highest average preciptation of 85 mm is received during the month of February; and the lowest of 27 mm in December. Precipitation in form of snow was found to be nearly equal for the months of January and February (38 and 39 mm, respectively), and for December and March (6 and 7 mm, respectively). The contribution of snowfall towards total precipitation was highest during January (54%) and lowest during March (9%). About one third of the total seasonal precipitation during the study period has been received in form of snowfall. According to Singh *et al*. (1995) also about 30% of the winter precipitation at an altitude of 2000 m in the western Himalayas is in form of snow.

Decadal precipitation and its trend

The period under study was divided into two decades (1991-92 to 2000-01 and 2001-02 to 2010-11) to analyse the precipitation trend over the two decades. The results presented in Table 1 show that both the total precipitation and snowfall have decreased (2001-02 to 2010-11) compared to 1st decade. (1991-92 to 2000-01) The decrease in snowfall was found to be maximum during beginning of the season (86% for December and 47% for January). The decrease was minimum for February (16%) followed by March (35%). Thus it can be said that the total precipitation and snowfall in middle part of winter season remained relatively stable whereas a considerable decrease occurred during the beginning and end of the season.

The seasonal total precipitation and snowfall alongwith their trend analysis are presented in Fig. 1 and 2, respectively. Both these parameters registered a decreasing trend during the study period. The seasonal total precipitation and snowfall showed a decreasing trend of about 90 and 57 mm per decade, respectively. The trend analysis for individual months presented in Table 2 show that the month of January has registered the highest decreasing trends of 46.0 mm and 29.6 mm per decade in total precipitation and snowfall, respectively. The lowest decreasing trend for total precipitation was found in December (3.8 mm per decade)

Table 2: : Trends in total precipitation and snowfall

Month	Trend (mm per decade)	
	Total precipitation	Snowfall
December	-3.8	-8.4
January	-46.0	-29.6
February	-20.9	-14.5
March	-19.2	-4.3
Season	-89.9	-56.9

Table 3: : Number of days with snowfall

	Average number of days with snowfall	Maximum number of days with snowfall (year/s)
December	0.8	3 (1995)
January	3.1	8 (1995)
February	3.9	12 (2000)
March	0.4	2 (1993 ,2007)
Season	8.2	20 (1994-95)

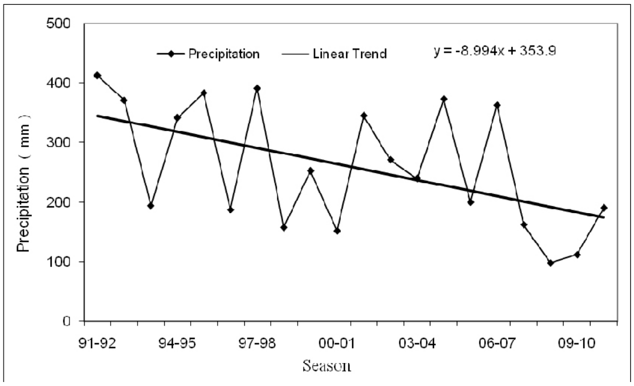

Fig. 1: Total seasonal precipitation over Shimla

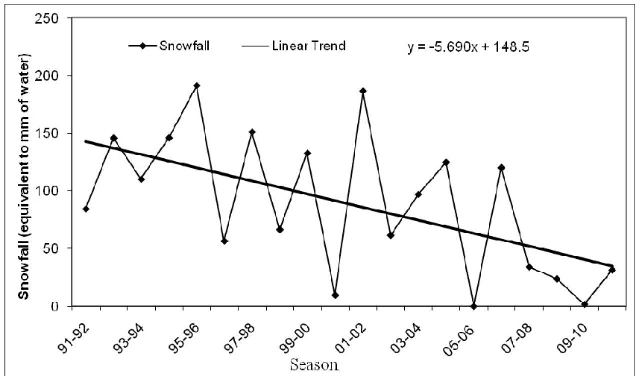

Fig. 2: Total seasonal snowfall (equivalent to mm of water) over Shimla

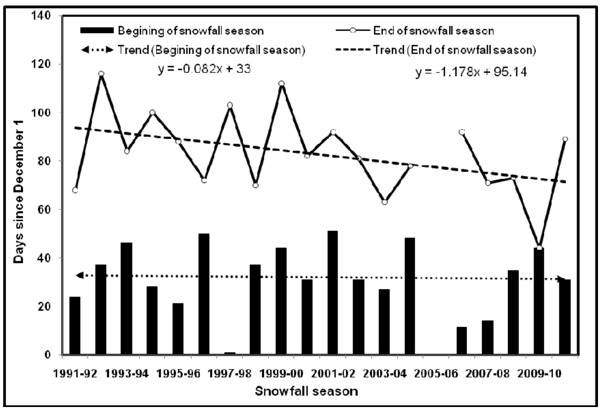

Fig. 3: Beginning and end of snowfall season at Shimla

and that for snowfall in March (4.3 mm per decade). The decreasing trends, though, are clearly discernible. Giri *et al*. (2008) have shown that the annual precipitation in the state of Jammu and Kashmir recorded a decreasing trend between 1990 and 2004. Rana *et al*. (2009) have also reported a decrease in winter snowfall in Himachal Pradesh.

Number of days with snowfall and duration of snowall season

The analysis of the number of days with snowfall for individual months and for the season as a whole (Table 3) shows that on an average, the highest number of days with snowfall are in the month of February (3.9) and the lowest in March (0.4) with the seasonal total being 8.2. The highest number of days with snowfall during a season have been 20 during the winter season of 1994-95. For individual months, the highest number of days with snowfall have been 3 in December (1995), 8 in January (1995), 12 in February (2000) and 2 in March (1993 and 2007).

Beginning, end and duration of snowfall season

The average date of beginning of snowfall season was found to be 01 January. However, the season began as early as on 01 December in 1997-98 and as late as on 20 January in 2001-02. Similarly, there is a large spread in cessation of the season. The average date for end of the season was found to be 21 February. The most delayed end of the season was on 26 March in 1992-93 whereas the season ended as early as on 13 January in 2009-10.

The average duration of snowfall season (number of days between first and last snowfall days at the station) was found to be 52 days for the entire period. There is difference of two weeks in average duration of the season between the two decades (58.6 days for first and 44.4 days for second decade). The above analysis shows that the duration of snowfall season has decreased between the two decades by about two weeks. This decrease has been because the season ended earlier during most of the years of the second decade.

The year to year days of beginning and end of the snowfall season (Fig. 3) shows that there has been no trend in the dates of beginning of the snowfall season. The ending of the season, however, shows a decreasing trend of about 12 days per decade indicating a shortening of the season. The trend analysis for duration of snowfall season shows a decreasing trend of about 11 days per decade. This early ending of the snowfall season may have adverse impact on the river flow during summer season and thus adversely affecting the agriculture/horticulture in the region. Rana *et al*. (2009) have reported that early termination of snowfall is reflected in decrease in apple yields over past two decades.

CONCLUSIONS

The study of the 20 years' total winter precipitation and snowfall data of Shimla shows that the month of February has the highest contribution towards the total seasonal precipitation whereas the contribution of snowfall towards the total seasonal snowfall is nearly equal for the months of January and February. The total precipitation and snowfall for all the months showed a decreasing tendency, the highest being for the month of January. The beginning of snowfall season does not show any delay. However, the season is tending to end earlier by about 12 days per decade. The analysis indicates a potential adverse impact on the river flow and agricultural/horticultural production in the state. However, extensive studies need to be carried out before arriving at final conclusions regarding the impacts.

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