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Spatial distribution of annual rainfall in Himachal Pradesh and its implication in farming

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Abstract

Spatial distribution of annual rainfall and rainy days, dependable rainfall and rainfall trends in Himachal Pradesh was assessed using rainfall data(1971-2014) of 40 rain gauge stations. The normal annual rainfall of Himachal Pradesh was observed to be 1267 ± 375 mm spreading over 66 rainy days. Highest annual rainfall to the tune of 1000 mm at 75% probability was noticed in 16 (with 6 located alone in the Kangra district) out of 40 rain gauge stations. An expected annual rainfall in the range of 400-600 mm was observed in mid and high hill regions of the state comprising districts of Shimla with two stations and Mandi and Kinnaur each with single station. Ten observatories indicated significant decreasing trend in rainfall while seven showed increasing trend. Increasing trend in annual rainfall was observed mainly in Shimla (Kumarsain, Rohru and Shimla) and Mandi (Karsog, Chachiot and Sarkaghat) districts. Ten stations had an increasing trend in number of annual rainy days, whereas, six had decreasing trends. The heavy rainfall event trends were non- significant at most of the stations except Pachhad and Sundernagar where it was observed to be decreasing under 75-100 mm category. In more than 100 mm category, decreasing trend at Palampur, Nurpur, Nichar and Pachhad and increasing at Malan, Berthin and Sarkaghat was observed.

Key words: Annual rainfall, rainy days, rainfall variability, dependable rainfall, trends, Himachal Pradesh.

Rainfall is the key climatic variable affecting the spatial and temporal distribution of water availability for different uses including agriculture. Agriculture, food security, energy security and related sectors of India are mainly dependent on the timely availability of adequate amount of water (Jain and Kumar 2012). Being the primary source of water, any deficit or excess of rainfall during the critical crop growth stages determines productivity of that crop. According to the Inter-governmental Panel on Climate Change (IPCC 2014), future climate change is likely to affect water availability and so the agriculture leading to increased risk of hunger and water scarcity. Therefore, an important challenge posed by changing climate variability is the identification and quantification of trends in rainfall which may help in formulation of adaptation measures through appropriate strategies for the management of water resources (De Luis *et al.* 2000). Several recent studies have documented decreasing rainfall trend in Asia (Goswami *et al.* 2006; Dash *et al.* 2007; Sheikh *et al.* 2015). However, several studies (Lal 2001; Sinha Ray and De 2003; Kumar and Jain 2010) in India indicated no clear increasing or decreasing trend in rainfall in the country. Though the all India monsoon rainfall exhibited no significant trend over a long period of time, significant long-term rainfall changes on regional scale have been identified in some studies (Singh and Sen Roy 2002; Kumar *et al.* 2005; Goswami *et al.* 2006; Dash *et al.* 2007; Singh *et al.* 2008; Kumar and Jain 2010). The decreasing rainfall has been observed in the Indian Himalayas during last century suddenly rather than gradually (Basistha *et al.* 2009).Therefore, it was concluded from these studies that in the recent years there was significant impact of climate change in precipitation patterns on regional scale. Further, it has been well addressed that historical climatic observations at global or continental scale are of less importance than for local or regional scale (Raucher 2011).

A high-resolution dynamical model used to simulate a baseline run from 1970–2000 and for near future (2030s:2020–50) indicated the change in percentage precipitation for monsoon (June to September) months in the range of –8 to 12 %. The change for winter (December to February) months showed a much larger variation from less than –10 to over 30 % in some areas. The state showed a positive change for summer (March to May) rainfall in the range of 5 to 30 %. Post-monsoon (October- November) season also showed a variation in the changes of precipitation percentage in the range of less than–15 % in some areas to more than 30 per cent in others (Anonymous, 2015).

The state of Himachal Pradesh (H.P.) is principally a state with agricultural predominant economy. Wheat, maize and rice are the principal crops grown in the state. Contribution of agriculture towards state's economy is over 45% and is the main source of income. Over 93% of the population in the state directly or indirectly depends upon agriculture (Anonymous, 2015a). The state being mostly rain fed (about 80%), rainfall patterns become extremely important for continuous supply of water to carry out various agricultural and domestic activities (Prasad *et al.* 2016). An increasing trend in rainfall at some locations and a decreasing at others in HP has already been observed by Kumar *et al.* (2005). Decrease in rainy days for the period 1974-2004 at Palampur has also been observed (Prasad and Rana 2010). Annual rainfall trends for the period 1901–1984 showed increasing trend at 8 out of 11 stations in HP (Kumar *et al.* 2005). Decreasing trend in annual rainfall and rainy days by -4.58 mm/year and -0.13 days/year, respectively in HP have been observed by Jaswal *et al.* (2015). They have also observed decreasing trends in the daily heaviest rainfall in the southern parts of the state and increasing trends at the stations located in middle Himalayas. If the decreasing trends in rainfall and rainy days continue in future, it might impact agriculture and related sectors in the state.

In view of changing patterns of the rainfall in state, an analysis of rainfall trends is of utmost need for its impacts on different crops at regional/local level in the state. The information would help agricultural, horticultural and water resources planners in decision-making and advance arrangements to mitigate the effects of abnormal rainfall. Thus, an attempt has been made to analyse trends in annual rainfall, dependable rainfall and heavy rainfall events at 40 stations of HP during the recent time scale (1971-2014).

Materials and Methods

The observed daily data of 40 rain gauge stations in the state have been used to calculate mean, standard deviation and coefficient of variation of rainfall. The time period for which data of various stations were used for present investigation is given in Table 1. The historical data were subjected to data quality check before undertaking analyses through Weathercock 15 (Rao *et al.*2015).The RClimDex, a program script written in R language developed at the Meteorological Service of Canada was used for working out the indices and their trends (Venables and Smith 2012).

Station level daily (rainfall recorded in 24 hour period) rainfall data were segregated under two categories *viz.*, 75-100 mm and more than 100 mm. The significance of the trends were tested by trend/change detection software (Chiew and Siriwardena 2005). Average values of rainfall are simple indicators of rainfall over a period for a region. Dependable rainfall for agricultural purposes is generally taken as the expected amount of rainfall with 75% probability. In rain fed agriculture, dependable/assured rainfall helps in proper crop planning. Keeping its importance in view, expected rainfall at 75% probability was worked out using an incomplete gamma distribution method on annual basis for all the 40 stations of Himachal Pradesh. Preparation of GIS maps was carried out using ArcGIS9.3 version. Interpolation was done through Inverse Distance Weightage (IDW) Method. The shapes of frequency distribution curves which were unimodal and strongly asymmetrical like that of rainfall, departed far from symmetry and exhibited high degree of skewness. The mean was not representative of central tendency of such a strongly asymmetrical distributions. The median value, a middle of a cumulative frequency distribution; half the data were above the value and the other half below, was calculated by ordering the data and selecting the middle value. Extreme variation had less of influence on the median than on the mean because the median is a measure of position (WMO 2011). Since the median is based on the number of observations, the magnitude of extreme observations does not influence the median. The median is especially useful when observations tend to cluster around the centre but some of the observations were also very high or very low. As with the mean, data did not cluster towards a central value are not well represented by the median. Therefore, to assess the nature of distribution the rainfall characteristics of all these stations were analysed through descriptive analysis using Indian NARS Statistical Computing Portal.

Table 1. Geographical location, elevation and duration of data sets of different stations

District	Station	Data period	Latitude (°N)	Longitude (°E)	Elevation M (amsl)
Bilaspur	Ghumarwin	1982-2013	31.43	76.71	829
	Berthin	2004-2014	31.41	76.62	661
Chamba	Salooni	1991-2014	32.72	76.04	1766
Hamirpur	Bhoranj	2000-2014	31.68	76.52	933
	Hamirpur	1971-2014	31.70	76.50	782
	Nadaun	1991-2014	31.78	76.35	491
Kangra	Dehra	1973-2013	31.87	76.32	767
	Dharmashala	1972-2013	32.22	76.31	1246
	Nurpur	1974-2013	32.18	75.53	584
	Kangra	2003-2014	32.10	76.27	787
	Malan	2000-2014	32.11	76.41	1109
	Palampur	1974-2014	32.10	76.54	1253
Kinnaur	Nichar	1974-2010	31.55	77.96	2004
	Sangla	1970-2014	31.42	78.26	2649
Kullu	Banjar	1988-2014	31.63	77.34	1419
	Bajaura	1986-2014	31.84	77.16	1074
Lahaul&Spiti	Keylong	1972-2014	32.57	77.03	3098
	Udaipur	2001-2014	32.70	76.70	2617
Mandi	Chachiot	2001-2014	31.39	77.20	1055
	Jogindernagar	2001-2014	31.99	76.79	1207
	Karsog	1974-2014	31.38	77.20	1465
	Mandi	1970-2014	31.70	76.93	771
	Sarkaghat	1974-2014	31.70	76.74	1031
	Sundarnagar	1974-2014	31.53	76.90	849
Shimla	Shimla	1985-2014	31.09	77.17	2208
	Jubbal	1974-2014	31.10	77.70	1927
	Kothkhai	1974-2014	31.11	77.53	1640
	Kumarsain	1971-2014	31.31	77.44	1693
	Mashobra	1981-2014	31.13	77.22	2107
	Rohru	1972-2014	31.20	77.75	1553
	Theog	1974-2014	31.12	77.33	2033
Sirmaur	Dhaulakuan	1987-2014	30.56	77.30	411
	Nahan	1973-2014	30.55	77.28	677
	Pachhad	1972-2014	30.56	77.30	1567
	Paonta	1988-2014	30.44	77.60	388
Solan	Arki	1973-2014	31.15	76.97	1090
	Kandaghat	1972-2014	30.97	77.10	1484
	Kasauli	1975-2014	30.90	76.96	1783
Una	Akrot	1999-2014	31.37	76.10	430
	Una	1974-2014	31.48	76.28	389

Results and Discussion

The knowledge of rainfall variability for the state at local/regional level is necessary to understand the impacts of climate change and also for the management of water. Fig 1 presents map showing weather stations and districts boundaries in HP. The key rainfall statistics and its spatial distribution for 40 rain gauge stations of the state have been presented in Fig 2 &3.

Rainfall

The annual normal rainfall of HP is 1267 ± 375 mm with a coefficient of variation (CV) of 30%. Himachal Pradesh constitutes only single meteorological sub-division. During the period 2006-2014, highest rainfall (1242.8 mm) was received in 2010 and lowest (792.3 mm) during 2009, the year incidentally was also declared as an All-India drought year (Rathore *et al.* 2014). During this period, all the years received below normal rainfall and majority of the years witnessed more than 20% less rainfall than annual normal rainfall. There was a large variability in rainfall across the stations with Dharamshala topping the list (2679 mm) followed by Palampur (2332 mm), Jogindernagar (1939 mm), Malan (1838 mm) and Kangra (1674 mm). Lowest rainfall was recorded at Keylong station (564 mm) which is one of the dry temperate stations of the state. This was closely followed by Udaipur (604 mm) and Sangla (698 mm). The annual rainfall was highly variable at Salooni (54%) followed by Udaipur (48%), Mandi, Keylong and Chachiot each having coefficient of variation 44%. Least variability in annual rainfall was observed at Banjar (15%) and Akrot (16%).

Rainy days

A rainy day is defined as a day when cumulative rainfall received in a period of 24 hours is ≥ 2.5 mm. As a first approximation, the temporal distribution of rainfall can be understood from the number of rainy days. Fig. 4 shows the temporal variation of annual rainy days for all the stations. The mean annual rainfall of 1267 mm is received over 66 rainy days with a variability of 21% in the state. The annual variability in rainy days was low. Numbers of annual rainy days were high at Dharamshala (103) and Palampur (96) followed by Jogindernagar (85) and Mashobra (84 days) and lowest at Keylong (44 days) followed by Chachiot (48 days) and Udaipur (50 days).

Characteristics of annual rainfall

The distribution characteristics of rainfall over 40 rain gauge stations have been presented in Table 2. The distribution of rainfall at 58% stations, majority of which lie in southern districts viz., Solan, Sirmaur, Shimla and Bilaspur of the state was either approximately symmetric or symmetric and platykurtic indicating that mean could represent the rainfall distribution equally good as that of the median at these stations. Distribution was either moderately or highly (positive/ negative) skewed and platykurtic at 30% of the stations, majority of which are located in Una, Bilaspur, Sirmaur, Shimla, Solan, Mandi and Kangra districts. The remaining 12% stations, were positively highly skewed and laptokurtic. For these 42% stations, mode was better representative than that of the mean or median.

Rainfall at 75% probability

Highest annual rainfall at 75% probability to the tune of more than 1000 mm was noticed at 16 out of 40 stations out of which 6 (Dehra, Dharamshala, Malan, Kangra, Nurpur and Palampur) were located in the Kangra district, followed by Sirmaur district (3 stations *viz*., Paonta, Nahan and Dhaulakuan), two each (Jogindernagar and Sarkaghat) in Mandi and Bhoranj and Hamirpur in Hamirpur districts and one each in Shimla (Mashobra), Chamba (Salooni) and Solan (Kasauli) districts. Hence, it is evident that at these stations there is high potential for cultivation of high value / long duration / high water demanding crops / double cropping systems with 50 to 83 weeks LGP in addition to considerable amount of harvestable rain water. Expected annual rainfall ranges between 800 and 1000 mm at the nine stations representing seven districts *viz.*, 2 (Mandi and Sundernagar) stations in Mandi, 2 (Arki and Kandaghat) in Solan and one each in Bilaspur (Ghumarwin), Hamirpur (Nadaun), Shimla (Shimla), Kullu (Bajaura) and Una (Una) (Fig. 5). Cultivation of high value / long or medium duration crops with 57 to 83 weeks LGP at these stations is very much possible with less risk.

Out of nine stations which received annual rainfall in the range of 600 - 800 mm in the state, 3 stations *viz.*, Jubbal, Theog and Rohru were in Shimla district and one station each in Una, Kullu, Bilaspur, Mandi, Kinnaur and Sirmaur districts.

An expected annual rainfall in the range from 400 - 600 mm was observed majorly in mid and high hill region of the state comprising districts of Shimla (2), Mandi (1) and Kinnaur (1). Lowest annual rainfall (< 400 mm) was expected at two stations of Lahaul & Spiti district where the rain related risk in agriculture is ruled out due to adequate irrigation facilities available from snow melt water in the district.

Table 2. Distribution of annual rainfall of different stations in Himachal Pradesh

Station	Range	Mean	Median	Skewness	Kurtosis	Type of distribution
Akrot	582.3	1053.8	1058.4	0.8	-0.1	PMS & P
Arki	1166.8	1065.8	1006.5	0.2	-0.8	AS & P
Bajaura	661.0	942.6	948.1	0.4	0.2	AS & P
Banjar	556.4	970.5	1005.0	0.3	-0.1	AS & P
Berthin	947.0	1093.6	1040.8	1.0	0.9	PMS & P
Bhoranj	667.4	1315.0	1279.1	-0.2	-0.7	NAS & P
Chachiot	1352.2	1019.4	1141.5	-0.9	-0.4	NMS & P
Dehra	1993.6	1332.8	1318.1	0.7	2.1	PMS & P
Dharamshala	2636.6	2678.8	2616.3	0.5	-0.3	AS & P
Dhaulakuan	1767.0	1649.1	1592.6	0.5	0.2	AS & P
Ghumarwin	1626.2	1192.0	1058.9	1.0	0.1	PMS & P
Hamirpur	1445.3	1313.2	1322.4	0.2	1.4	AS & P
Jogindernagar	1975.0	1939.3	1858.3	0.3	-1.0	AS & P
Jubbal	1129.4	1030.3	995.1	-0.1	-0.4	AS & P
Kandaghat	1634.4	1078.9	1078.2	0.9	2.0	PMS & P
Kangra	1176.7	1724.9	1643.1	0.4	-1.4	AS & P
Karsog	1009.1	942.5	937.4	0.0	-0.4	Normal & P
Kasauli	2655.0	1578.2	1444.3	1.1	2.3	PHS & P
Keylong	1126.0	564.2	527.0	0.9	0.8	PMS & P
Kothkhai	1360.4	714.2	661.0	0.8	1.3	PMS & P
Kumarsain	1093.0	750.7	789.8	-0.1	-1.1	AS & P
Malan	2719.3	1859.6	1877.2	0.8	2.6	PMS & P
Mandi	3138.7	1459.5	1268.7	1.3	1.9	PHS & P
Mashobra	1204.7	1348.6	1324.6	0.5	0.5	AS & P
Nadaun	1023.8	1157.6	1091.3	0.4	-0.7	AS & P
Nahan	1722.7	1499.6	1425.1	0.4	-0.4	AS & P
Nichar	1436.6	925.8	923.2	0.2	-0.7	AS & P
Nurpur	2517.9	1545.4	1432.7	2.0	6.2	PHS & L
Pachhad	1922.6	1134.3	1143.9	0.5	0.0	AS & P
Palampur	2356.6	2339.7	2327.8	0.0	-0.5	AS & P
Ponta	1661.0	1447.3	1457.0	0.2	-0.2	AS & P
Rohru	1033.2	864.6	853.5	0.5	-0.5	AS & P
Salooni	4857.7	1803.3	1494.0	2.0	5.2	PHS & L
Sangla	1834.5	697.9	634.9	1.9	6.2	PHS & L
Sarkaghat	1634.6	1540.3	1497.0	0.5	0.0	AS & P
Shimla	1380.8	1310.8	1356.5	-0.9	0.5	NMS & P
Sundarnagar	1334.3	1278.6	1302.9	-0.1	0.0	AS & P
Theog	1147.8	992.8	928.7	0.3	-0.5	AS & P
Udaipur	1225.0	603.6	548.3	2.7	8.7	PHS & L
Una	1886.2	1065.9	1025.0	1.3	3.7	PHS & L

P- Platykurtic; L-Leptokurtic; PMS- Positively moderately skewed; AS- Approximately skewed; PHS- Positively highly skewed; NMS- Negatively moderately skewed; NAS - Negatively approximately skewed

It is seen from the above that around 62% of the stations in the state received adequate annual rainfall >800 mm at 75% probability. But large chunk of shallow coarse textured soils with undulating topography of the state gives poor soil moisture and storage capacity leading to poor moisture availability for rainfed crops (Prasad *et al.* 2016). Moreover, inadequate sowing rains during *kharif* (mid- May to mid- June) and *rabi* (mid- October to mid- December) seasons results in poor soil moisture leading to poor germination and seedling growth of principal crops. Meticulous planning and with adequate adoption of rain fed technology in 80% rain fed area of the state, productivity of various crops/farming systems can certainly be improved.

Trends in rainfall and rainy days

Trend analysis of a time series consists of the magnitude of trend and its statistical significance. Around 43% of the stations (17 out of 40) in the state showed significant trend in annual rainfall. Ten stations out of 17 *viz.*, Kotkhai in Shimla, Nichar in Kinnaur, Sundernagar in Mandi, Udaipur in Lahaul & Spiti, Nurpur and Palampur in Kangra, Arki and Kasauli in Solan and Pachhad and Poanta in Sirmaur district showed declining trend in annual rainfall (Fig. 6). On the other hand, increasing trend in annual rainfall was observed at 7 stations, three each in Shimla (Kumarsain, Rohru and Shimla) and Mandi (Karsog, Chachiot and Sarkaghat) and one in Kangra (Malan) district. Stations, Chachiot and Sarkaghat in Mandi district showed steep (significant at 99%) increase in rainfall and Kotkhai in Shimla, Nichar in Kinnaur and Pachhad in Sirmaur showed steep decreasing trend. Decreasing trend at Arki, Sundernagar and Pachhad based on 1951-2005 data has also been observed by Jaswal *et al*. (2015).The results for Shimla, are contrary to Jaswal *et al*. (2015) and Kumar *et al.* (2005). However, in these studies,numbers of stations and data periods were different which might be the reason for the contrary results. Kumar *et al.* (2005) have also reported increasing trends at more number of station (8) out of 11 stations studied in the state for the period 1901–1984.

The number of annual rainy days showed significant increasing /decreasing trends at 40% (16 out of 40) of stations. 25% (10 out of 40) stations showed an increasing trend whereas Kotkhai (Shimla), Pachhad (Sirmaur), Udaipur (Lahaul & Spiti), Palampur (Kangra) and Hamirpur and Nadaun (Hamirpur) showed decreasing trend (Fig. 7). On the contrary Jaswal *et al*. (2015) has not observed increase in number of rainy days in the state out of the above stations.

Trends in receipt of heavy rainfall events in various districts of Himachal Pradesh

In general, no significant trend has been observed at most of the stations in 75-100 mm and more than 100 mm rainfall events except few stations. Significant decreasing trend in annual rainfall events is noted at two rain gauge stations (5%), Pachhad (slope; -2.292) in Sirmaur and Sundernagar (slope; -2.011) in Mandi district under 75-100 mm category (Fig. 8 & 9). Under >100 mm category, a decreasing trend is observed at 4 (10%) stations, 2 in Kangra [Palampur (slope; -2.078) and Nurpur (slope; -2.19)] and one each in Kinnaur (Nichar, slope; -1.91) and Sirmaur districts (Pachhad, slope; -1.852) whereas it was observed to be increasing at 3 (8%) stations, one each in Kangra (Malan, slope; +1.93), Bilaspur (Berthin, slope; +0.856) and Mandi (Sarkaghat, slope; +1.853). Jain and Kumar (2012) have also observed deceasing trend in extreme rainfall indices at Shimla. Jaswal *et al.* (2015) have also observed that the daily heaviest rainfall is showing significantly decreasing trends at Hamirpur, Kotkhai, Nahan, Nurpur and Pachhad whereas increasing trend was noted at Palampur for the period of 1951-2005. Increase in heavy rainfall events and decrease in rainy days at Palampur during monsoon for the period 1974 -2004 have also been observed (Prasad and Rana 2010).

Analysis of rainfall and rainy days at 40 stations of the state showed that trends at more than 50% of the stations were not significant. There was a general decline in rainfall and increase in rainy days at more number of stations. Heavy rainfall events were also showing decreasing trend. The popular belief that more rainfall is occurring in fewer events was not corroborated through the present analysis. The state exhibits considerable variation in the distribution of rainfall due to the various aspects like topography and altitudes (Anonymous, 2012). Since, hilly regions are more sensitive to any change; they have a special role in showing the effects of climate change. If the decline in rainfall persists in future also it will certainly affect agriculture and food security in the state.

Agricultural scenario of Himachal Pradesh

Amongst cereals, wheat, maize and rice are the principal crops of the state. The area under wheat is about 3.5 lakh ha with a production of 6.97 lakh tonnes and productivity of 1926.65 kg/ha. Maize is the second largest crop with an area of about 2.93 lakh ha, production of 2.89 lakh tonnes and productivity of 2549.8 kg/ha. Rice which occupied an area of 0.99 lakh ha in the 1980s, is now grown on about 0.74 lakh ha with production of 1.28 lakh tonnes and 1728 kg/ha of productivity. The area under barley has also declined from 0.35 lakh ha in 1980s to 0.20 lakh ha with production of 0.20 lakh tonnes. Among major oilseed crops, area under rapeseed mustard has been increased from 0.63 lakh ha in 1980s to 0.9 lakh ha with production of 0.47 lakh tonnes and productivity of 516 kg/ha. A decline has been observed in the area under sesame from 0.65 lakh ha in 1980s to 0.27 lakh ha with production 0.1 lakh tonnes with marginal increase in productivity 338 kg/ha to 370 kg/ha. Agricultural scenario of 4 major cereals viz., wheat, maize, rice & barley and 2 important oilseed crops viz., rapeseed-mustard & sesame out of 24 field crops grown in Himachal Pradesh indicate that in addition to inter-annual fluctuations in the area, there was also overall reduction in area in five out of the six crops except rapeseed-mustard. The impact of weather parameter and technology trend in productivity of wheat crop, which is one of the major cereal crops of the state, has been bifurcated for all the districts and it was found that there was decreasing trend in the productivity of three (Kangra, Una and Sirmaur) out of five major wheat growing districts of the state.

Spatial distribution of annual rainfall and rainy days, dependable rainfall and rainfall trends in the state was assessed for the first time using rainfall data of 30 years of 40 rain gauge stations. The normal annual rainfall of state was observed to be 1267 ± 375 mm spreading over 66 rainy days. Highest annual rainfall to the tune of 1000 mm at 75% probability was noticed mainly in Kangra district. Largely no increase/decrease in rainfall was observed in the state however increasing trend in annual rainfall was observed mainly in Shimla and Mandi districts. Significant increase/decrease in extreme rainfall events (75-100 mm & >100 mm) was also observed at fewer stations. The state exhibits considerable variation in the distribution of rainfall due to the various aspects like topography and altitudes. These finding are extremely important background climatic information which could be used as resource in developmental planning in general and in agriculture in particular.

Fig. 1: Map showing stations and districts boundaries

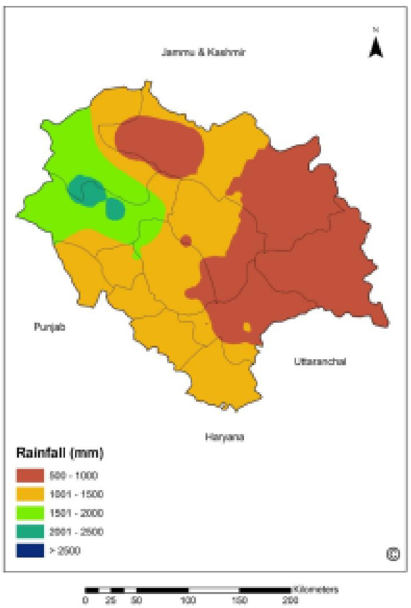

Fig. 2: Annual rain (mm) over Himachal Pradesh

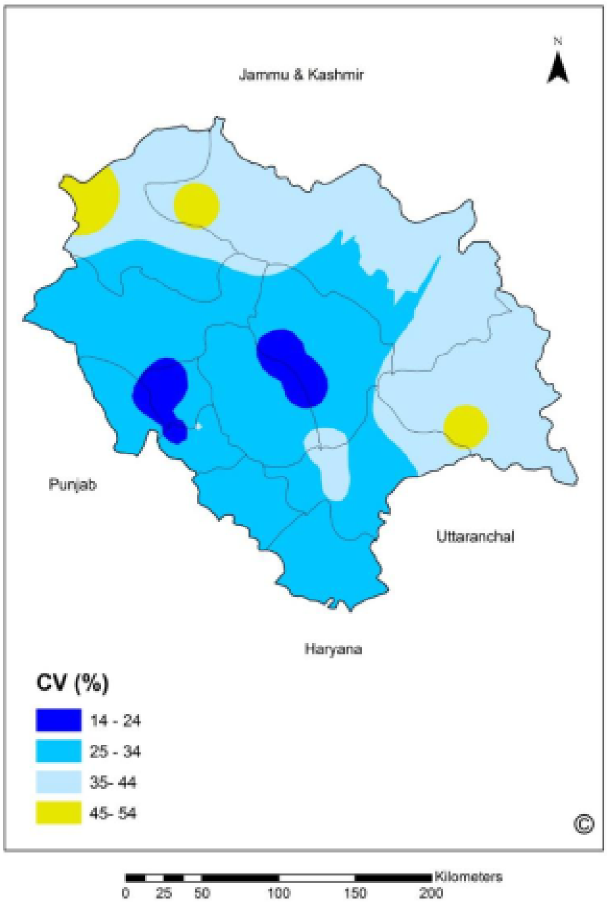

Fig 3. Variability of annual rain in Himachal Pradesh

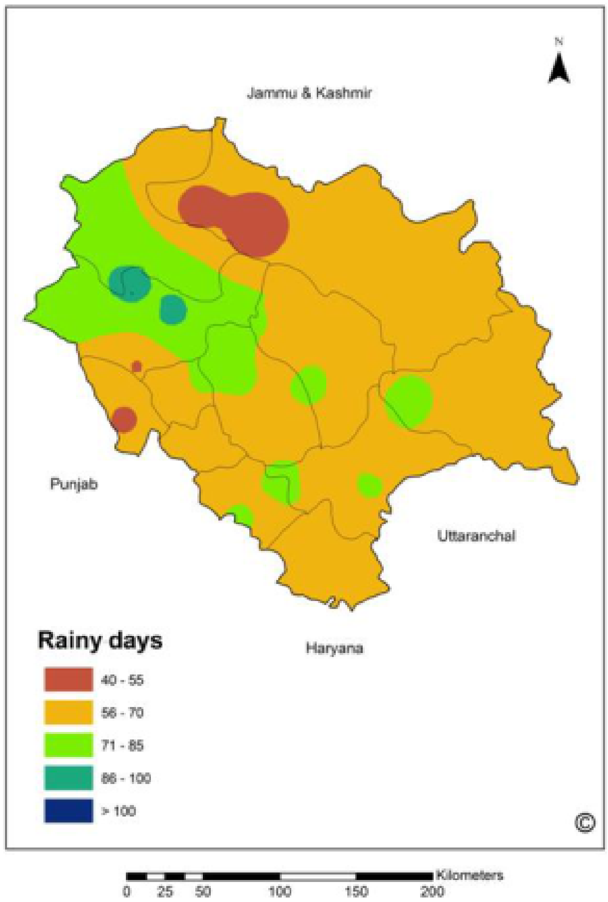

Fig 4. Annual number of rainy days in Himachal Pradesh

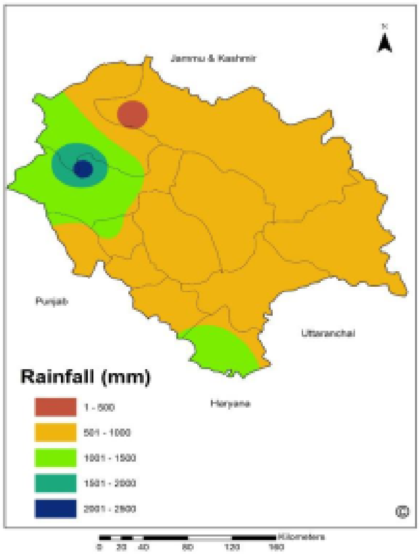

Fig 5. Station with ≥ 75% probable annual rain in Himachal Pradesh

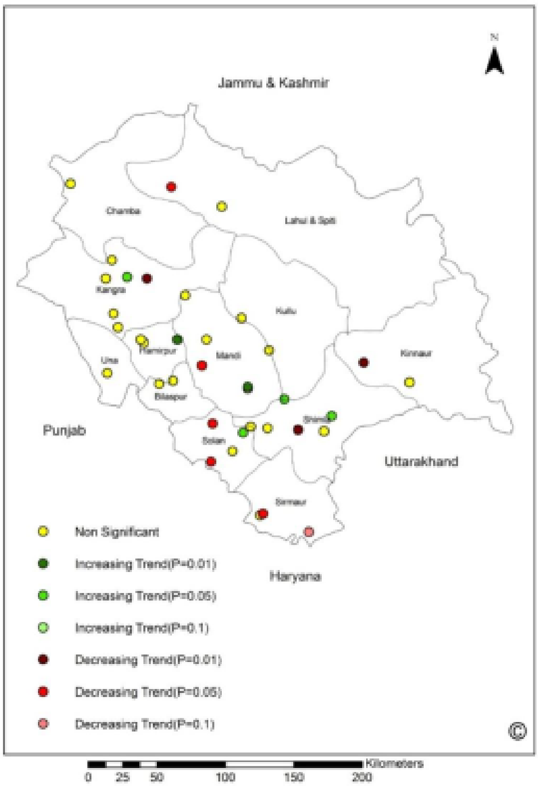

Fig. 6: Stations in Himachal Pradesh showing a change in annual rainfall

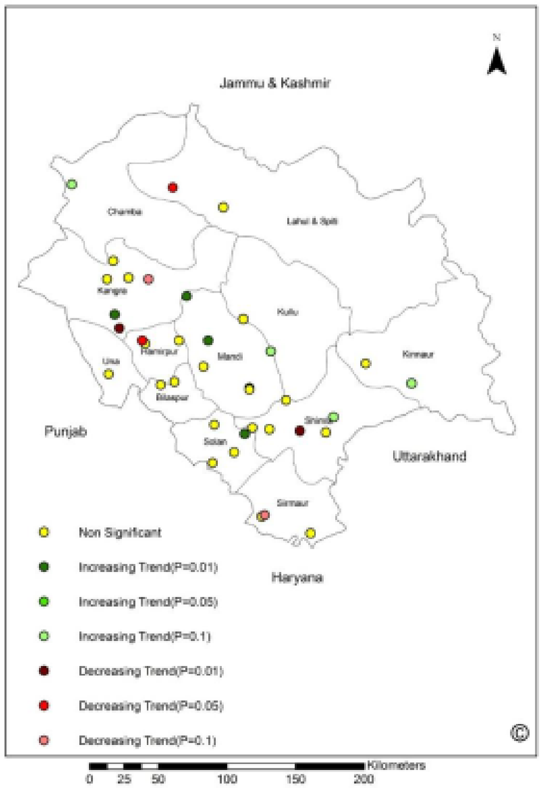

Fig. 7: Stations in Himachal Pradesh showing a change in annual rainy days

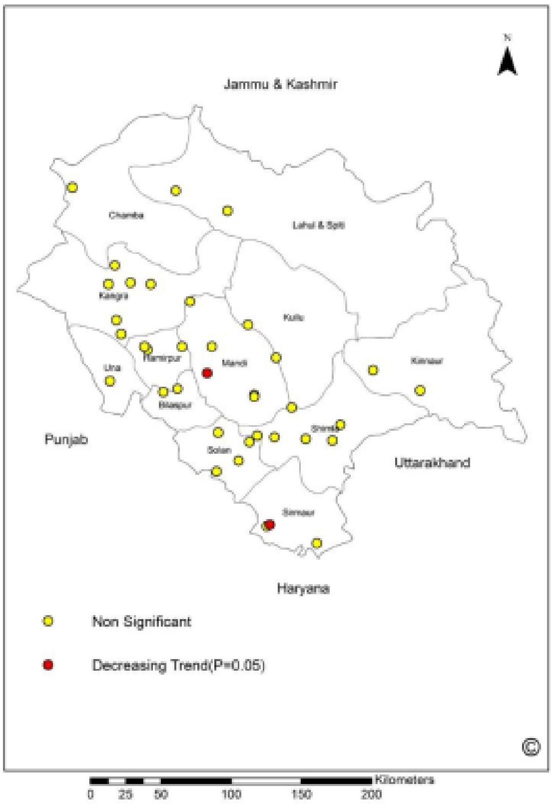

Fig. 8: Stations showing a change in annual rainfall events in 75-100 mm category

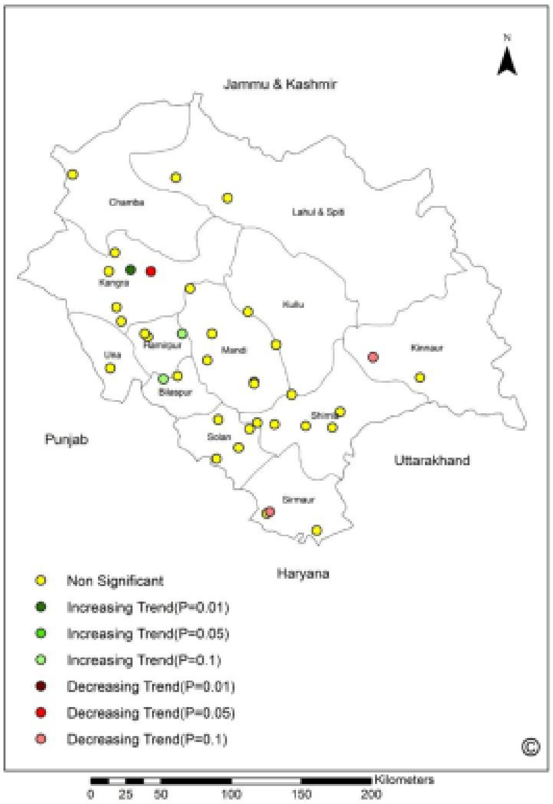

Fig. 9: Stations showing a change in annual rainfall events in >100 mm category

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