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# Trends in climate variability over Himachal Pradesh

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## ABSTRACT

The study indicates warming signals in all the study sites except Shimla during 1969 to 87. The study indicated of higher than average signals of warming in Himachal Pradesh upland than lowland regions viz. Fatehpur and Palam Valley in recent decades. The data analyzed in terms of day and night temperature indicated that the warming was predominantly due to an increase in maximum temperature. The annual rainfall in all the regions experienced decreasing trends. The rainfall during rabi season found to be increased by 1.0 to 7.44 mm y-1in the regions receiving snowfall during winter months.. The Palam and Kullu valley experienced decreasing trends in evaporation whereas relative humidity showed increasing trends at all elevations.

***Key Words :*** Climate change indicators, temperature, rainfall, future scenarios, Himachal Pradesh

Climate is the major determinant responsible for fluctuations in agricultural productivity and largely determines the suitability of vegetation in a particular area. It may alter the distribution and quality of natural resources and adverse-ly affect the livelihood of people of any region. With an econo-my closely tied to its natural resource base and cli-mate-sensitive sectors such as agriculture, the region may face a major threat because of the projected changes in climate. Climate change and agriculture are interrelated process, both of which take place on global and regional scales with varying magnitude. Agriculture is not only affected by climate change but also contributes to it. Ten to twelve per cent of global greenhouse gas emissions are due to human food production (Barker *et al*., 2007). The changes in climate, which are likely to occur during future decades, may have significant consequences (positive or negative) on the development, growth and yields of various crops (Patel *et al*., 2008). According to the findings of adaptation studies in agriculture, the degree of benefits for adaptation are greater with moderate warming (<20C) than with greater warming and scenarios under increased rainfall than those with decreased rainfall (Howden *et al*., 2007). Mountains have been identified as the regions more prone to climatic changes and assessment of climate related impacts than plain areas. Climate changes rapidly with elevation over relatively short horizontal distances, so does vegetations and hydrology. The low hill to high hill offers unique geography which produces a spectrum of climates over the State of Himachal Pradesh. It is a mountainous state having more than 56 per cent area above 3251 m amsl (Bhagat *et al.*, 2007). The north eastern part of the State houses high mountains more than 3251 m amsl whereas south western part is relatively plain having less elevation than 1000 m amsl. Therefore, this study attempts to estimate the change in climatic parameters in different elevations in the State.

## MATERIALS AND METHODS

### *Study sites*

Four study sites were selected in the State which represents different elevations. These study sites are located in four districts each representing the different agro ecological situations spread all over the State.

The database of weather parameters for these four sites i.e. Dhaulakuan for Fatehpur valley in district Sirmour (<700 m amsl), Palampur for Palam valley in district Kangra (700-1500 m amsl), Bajaura and Bhuntar for Kullu Valley in district Kullu (1100-2000 m amsl) and Shimla Mall Road and Central Potato Research Institute (CPRI) Shimla for Shimla region in district Shimla (>2000 m amsl) respectively varies from three to four decades (1974 to 2009).The trends in temperature, rainfall, evaporation and relative humidity were analyzed using the statistical tools.

### *Future climate scenarios*

The projected climate change scenarios HadCM3 GCM were extracted from IPCC-2004 (Inter-governmental

**Table 1:** Future climate Scenarios (IPCC-2004) for Himachal Pradesh

| Scenarios | Maximum Temperature ( $^{O}$K) | | | Minimum Temperature ( $^{O}$K) | | | Rainfall (mm) per rainy day ( $^{O}$K) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2020 | 2050 | 2080 | 2020 | 2050 | 2080 | 2020 | 2050 | 2080 |
| A2a | 0.74 | 1.71 | 3.95 | 1.72 | 3.17 | 5.1 | 0.17 | 0.37 | - |
| A2b | 0.076 | - | 3.83 | 1.61 | - | 5.15 | 0.19 | 0.21 | 0.44 |
| A2c | 1.3 | 2.12 | 3.98 | 1.63 | 3.19 | 5.18 | 0.08 | 0.13 | 0.26 |
| B2a | 0.69 | 1.76 | 2.52 | 1.58 | 2.94 | 3.74 | 0.14 | 0.23 | 0.28 |
| B2b | 0.87 | 1.13 | 1.9 | 1.35 | 2.54 | - | 0.12 | 0.41 | 0.68 |

Panel on Climate Change,) for Himachal Pradesh using the geographic grids of H.P. The grid size was 3.75 degree in longitude and 2.5 degree in latitude for extraction of climate scenarios. In the scenarios, the base data were used from 1961-1990. The data between two grids were averaged for Himachal Pradesh. The mean monthly climatic parameters viz. temperatures in 0 Kelvin and rainfall deviations (mm) per day were extracted for all the months and also averaged over the crops seasons. The change in temperatures in Kelvin can directly be read as degree centigrade for normal calculations.

## RESULTS AND DISCUSSION

***Minimum temperature***

The minimum temperature showed increasing trends in all study sites except kharif season in Kullu valley at Bajaura and rabi season in Shimla region. The increase in minimum temperature was more for the lower elevation areas (below 700 m amsl) as compared to higher elevation areas. The increase in minimum temperature at Fatehpur valley (Fig.1) was 0.04 $^{0}$C y$^{-1}$ during *kharif* season compared to 0.024 $^{0}$C y$^{-1}$ during rabi season. In mid hill regions in Palam valley (Fig. 1) the rise in temperature was 0.003 to 0.04 $^{0}$C y$^{-1}$ during post monsoon period and early winter months except *kharif* season. Trends in Kullu valley analysed from data recorded at Bhuntar and Bajaura revealed warming trends (Fig. 1). In Shimla region minimum temperature showed decreasing trends up 1987 and whereas CPRI data from 1990 to 2009 also showed decreasing trends for October to May.

***Maximum temperature***

The maximum temperature at different elevations depicted increasing trends (Fig.2). The magnitude of increase in maximum temperature was more at higher elevations. The increase in maximum temperature varied between 0.002 to 0.01 $^{0}$C y$^{-1}$ at lower elevations areas at Fatehpur valley. The rate of rise in temperature was 0.025 $^{0}$C per year for rabi compared to a decrease of 0.011 $^{0}$C y$^{-1}$ for *kharif*. The Palam valley showed increasing trends of maximum temperature in all the months (Fig.2). The rise was more in rabi (0.064 $^{0}$C y$^{-1}$) compared to kharif (0.029$^{0}$C). In Kullu valley at Bajaura (Fig. 8) the rate of increase was higher in rabi (0.095 $^{0}$C y$^{-1}$) than kharif (-0.015 $^{0}$C y$^{-1}$). The monthly maximum temperature at Bhuntar in Kullu valley (Fig. 2) also showed increasing trends during December to April (0.0027 to 0.15 $^{0}$C y$^{-1}$) and July to August. In Shimla region during 1967 to 87 (Fig. 2) the maximum increase was observed during June to September. Decreasing trends in maximum temperature were observed during October to May ranging from 0.015 to 0.10 $^{0}$C y$^{-1}$. The pattern from 1990 to 2009 showed similar decreasing trends during October to May. *Kharif* season showed increase in maximum temperature. Rao *et al*., (2010) studied annual maximum and minimum temperature recorded across different regions in India which revealed the increasing trend in maximum temperature lowest in 20 percent stations in north zone and highest in 75 percent of the stations in south zone. The increase in minimum temperature was observed in more than 60 percent of stations over all zones of India.

***Rainfall***

The rainfall showed decreasing trends in all the study sites. The decrease in rainfall varied from -0.09 to -28.6 mm y$^{-1}$. In Fatehpur valley (Fig.3) a decreasing trend in kharif season (-1.94 mm y$^{-1}$) was more significant than rabi (-0.95 mm y$^{-1}$). Palam valley (Fig.3) also showed decrease of rainfall in all months with significant decrease in July (-16.8 mm y$^{-1}$) and August (-3.4 mm y$^{-1}$). The decreasing trends of total

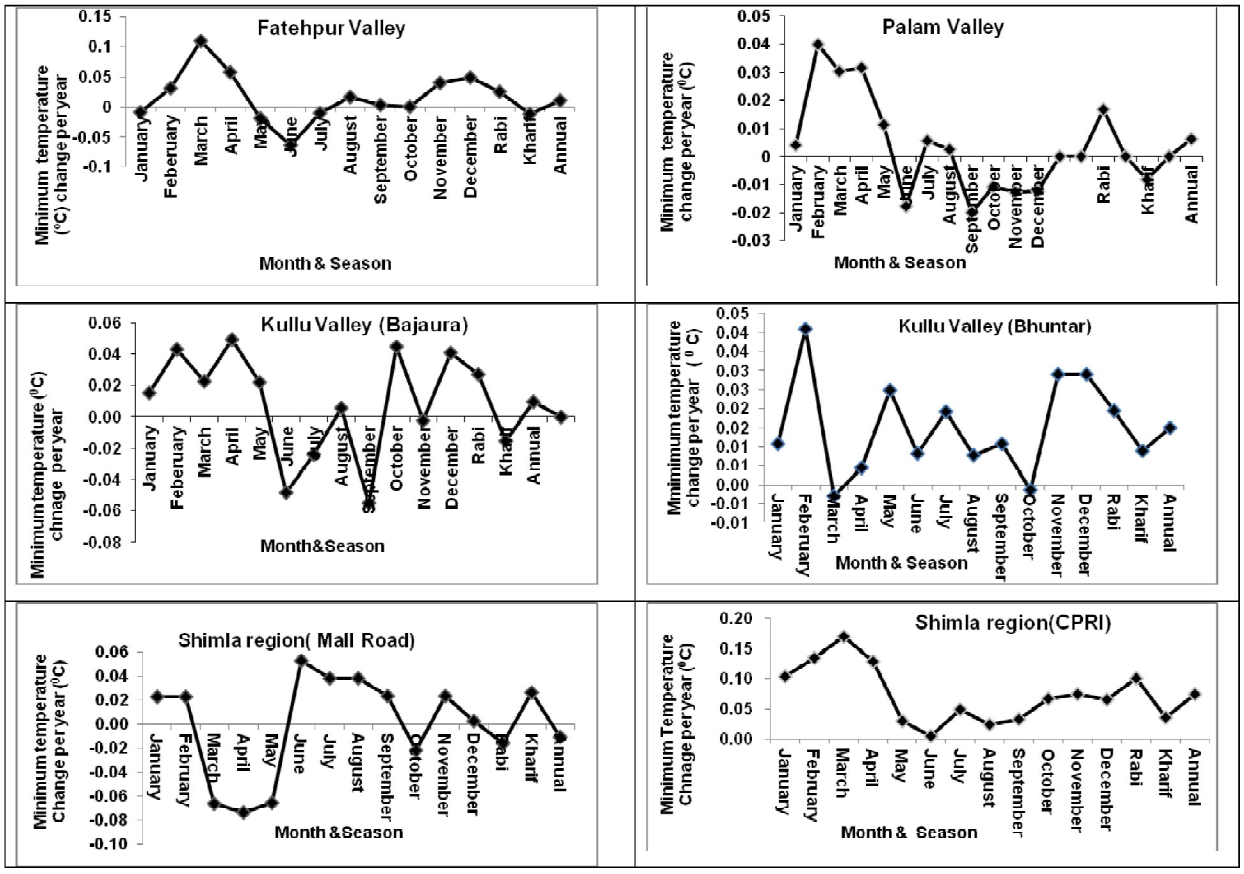


**Fig. 1 :** Minimum temperature change per year ($^0$C) at different locations

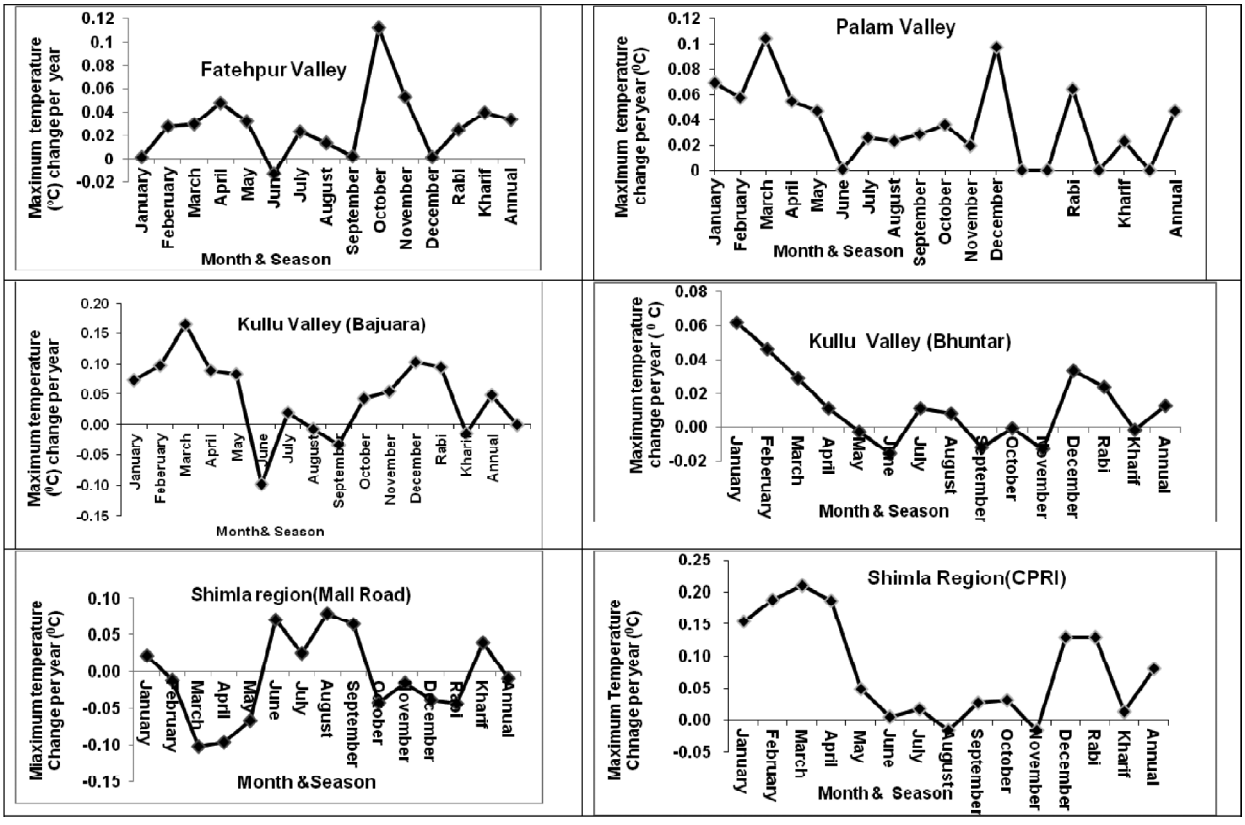


**Fig. 2 :** Maximum temperature change per year ($^0$C) at different locations

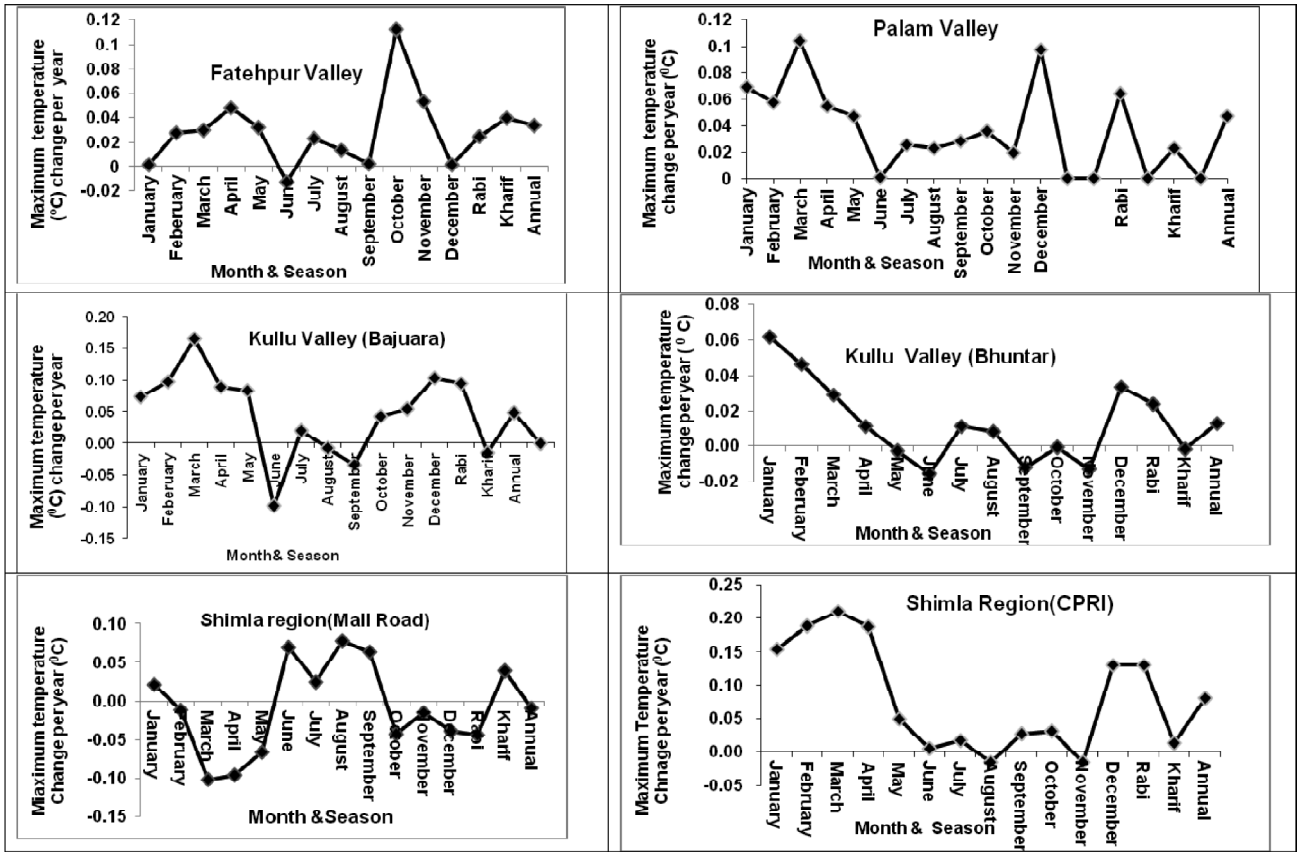


**Fig. 3 :** Rainfall change per year (mm) at different locations

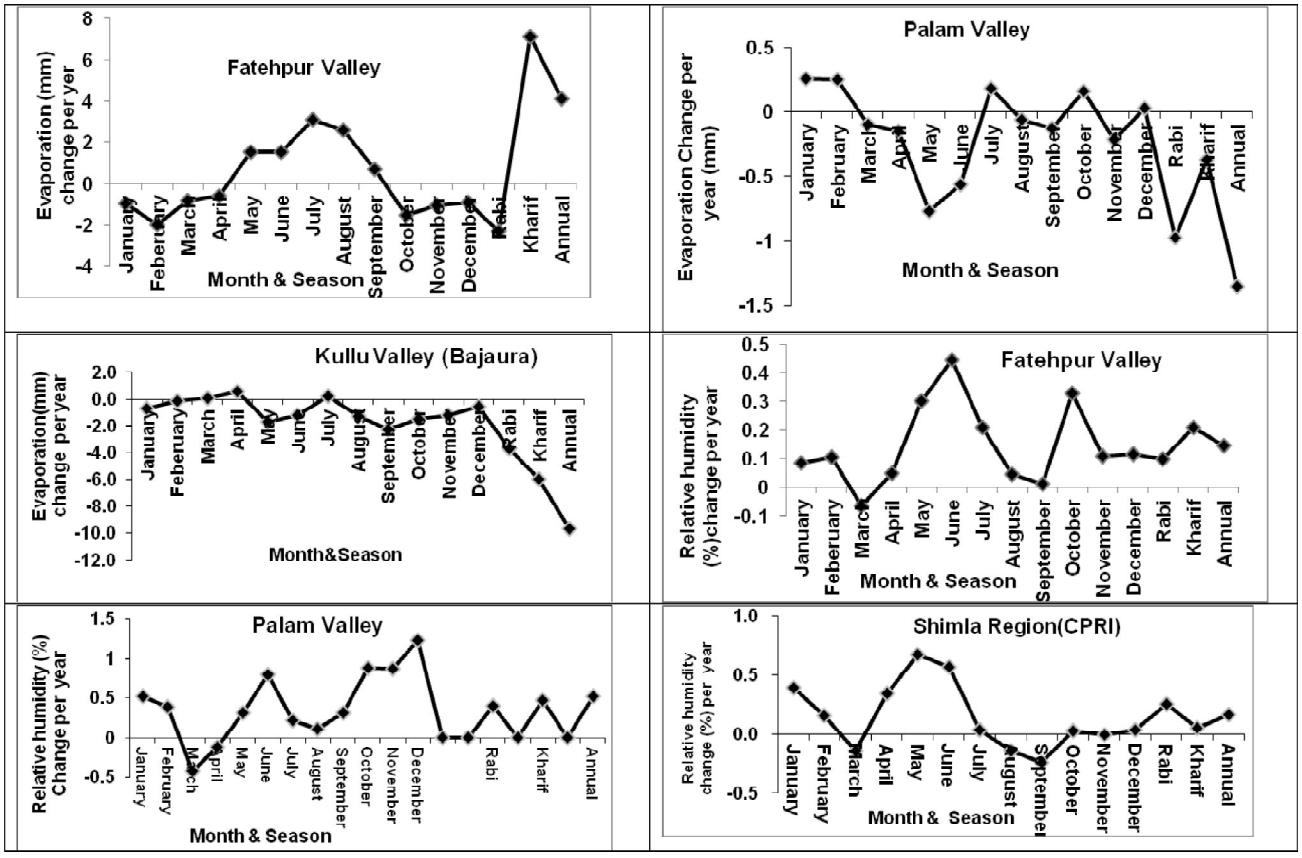


**Fig. 4 :** Evaporation and Relative humidity change per year (mm) at different locations

rainfall was more in kharif (-20.2 mm $y^{-1}$) compared to *rabi* (-8.4 mm $y^{-1}$). Kullu valley (Fig.3) at Bajaura also showed decrease in rainfall except in the month of June and September. The rate of decrease of rainfall during *rabi* season was -1.96 mm $y^{-1}$ compared to slight increase of kharif season rainfall. On the contrary to this monthly mean precipitation at Bhuntar (Fig.3) in Kullu valley indicated increasing trends. In Shimla during 1969 to 87 (Fig.3) a decreasing trend of rainfall was observed during June to September and January to February. The decrease was significant in kharif season whereas, *rabi* season exhibited increasing trend of 7.44 mm $y^{-1}$. Rainfall recorded at CPRI Shimla (Fig.3) indicated decreasing trends in kharif (2.20 mm $y^{-1}$) and rabi season (-8.50 mm $y^{-1}$).

***Evaporation***

The Fatehpur valley (Fig.4) showed increasing trend during May to September. The rise of evaporation was higher during summer and South West monsoon season. The evaporation trends showed increase during kharif season (7.1mm $y^{-1}$) and decrease during rabi season. Palam valley (Fig.4) marked a significant decrease in evaporation during April to June. The decrease was observed more during rabi (-0.97 mm $y^{-1}$) than kharif season (-0.37 mm $y^{-1}$). Bajaura during 1986 to 2009 (Fig.4) indicated decreasing trends in all months except April.

***Relative humidity***

The relative humidity (RH) showed increasing trends at all the study sites. The Fatehpur valley (Fig. 4) showed an increasing trend in all the months except March, August and September. The average relative humidity for kharif and rabi season indicated increasing trends to the tune of 0.099 and 0.208% $y^{-1}$ respectively. Palam valley (Fig.4) showed an increase in relative humidity in all the months except March and April. The increase was higher during kharif season than rabi. The relative humidity in Shimla region (Fig.4) also showed an increasing trend except in the month of March, August, September and November. The significant rise was observed during rabi (0.68 % $y^{-1}$) compared to kharif (0.05 % $y^{-1}$).

***Future climate Scenarios (IPCC-2004) for Himachal Pradesh***

Future projections of minimum temperature are showing increasing trends but magnitude of increase is higher than maximum temperature. For the years 2020, 2050 and 2080, it ranges between 1.35 to 1.72, 2.54 to 3.19 and 3.74 to 5.18 respectively, in all the scenarios. A2 scenario showed the higher range of increase than B2 (Table 1). Maximum temperature showed increasing trends in all the scenarios for the years 2020, 2050 and 2080 and its projections on per day basis are 0.72 to 1.3 Kelvin per day for 2020 in all the scenarios but A2C scenarios projected the maximum rise of $1.3^0$C for 2020. The projections for the years 2050 and 2080 are 1.13 to 2.12 Kelvin and 1.90 to 3.98 Kelvin respectively. Amongst the scenario A2 showed maximum increase for 2050 and 2080 (Table 1). The rainfall future scenarios showed increase in daily rainfall (0.12 to 19 mm for 2020) in rainfall for Himachal Pradesh. The projections for the years 2050 and 2080 showed increasing trends of annual average daily rainfall (0.13 to 0.41mm) for 2050 and 0.28 to 0.68 mm for 2080 (Table 1). The lowest increase was shown in the A2c Scenarios for 2020, 2050 and 2080.

## CONCLUSION

Maximum temperature trends at different elevations showed increase in all the locations with exception at Shimla during 1969 to 1987. The increase was more during rabi season than kharif season. The mean annual rainfall trends showed decrease in all locations in different elevations except during *rabi* season in higher elevations. The decrease of rainfall was more in mid hill agro climatic zone of Palam valley compared to other regions under study. The rainfall during *kharif* season showed increasing trends at Fatehpur in Dhaulakuan and Palampur whereas in higher elevations at Shimla, it showed decreasing trends. The increasing trends of evaporation were observed at lower plains regions at Fatehpur, Sirmour whereas at higher elevations viz. Palam and Kullu valley registered decreasing trends. Relative humidity in general showed increasing trends at Palam and Fatehpur valley. The climate future scenarios showed increase in minimum and maximum temperature for Himachal Pradesh. All scenarios showed increase in daily rainfall deviation of 0.08 to 0.68 mm per day for 2020 to 2080. Keeping in view the climatic trends elaborated in the study, agriculture strategies are required to make mountain agriculture more resilient to climate change.

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