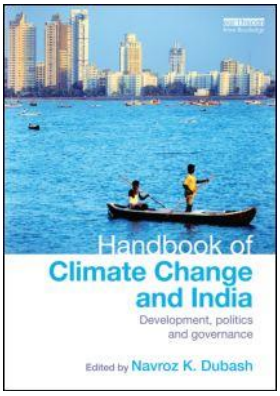

Handbook of Climate Change and India Development, Politics and Governance

Navroz K. Dubash

The impact of climate change on a shift of the apple belt in Himachal Pradesh

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3 The impact of climate change on a shift of the apple belt in Himachal Pradesh[1]

Ranbir Singh Rana, R.M. Bhagat, Vaibhav Kalia and Harbans Lal

The earth is warming up. Climate change is one of the biggest long-term challenges around the world. In Himachal Pradesh, evidence of global warming is suggested by changes like receding snowfall in the Himalayas, retreating glaciers and a shift in the temperate fruit belt upward, shifting and shortening of the *rabi* (winter) season, and disrupted rainfall pattern (Bhagat *et al.*, 2004). The impact of climate change has also been observed in production of apples and Satsuma mandarins in Japan. It has been predicted that regions favourable to the cultivation of apples and Satsuma mandarins will gradually move northward (Sugiura and Yokozawa, 2004).

Apples are a predominant fruit crop of Himachal Pradesh and in recent years they have emerged as the leading cash crop amongst fruit crops. In 2006, apples alone accounted for 46 per cent of total area under fruit crops and 76 per cent of total fruit production in the state. The area under apple cultivation has increased from 400 hectares in 1950–51 to 88,560 hectares in 2005–6 (Department of Economics and Statistics, 2006a). In 2005–06, the crop alone contributed more than Rs. 987 crore ($220 million approx.)[2] towards the state gross domestic product, which was Rs. 20,919 crore ($ 4.97 billion). The production level has gradually touched 540.3 metric tonnes with 5.6 tonne productivity in 2006 (Department of Economics and Statistics, 2006b). Impacts on apple cultivation are, therefore, of considerable importance to the economy of the state and the livelihoods of its farmers.

Over the past few years the production of apples has gradually increased but the productivity has fallen with a rate of 0.016 tons/ha annually between 1985 and 2009 (Vijayshri Sen, 2010). Of the various productivity-reducing factors, climate is the most difficult to manage. The changes in climate in the form of erratic precipitation, increase in temperature, fewer days serving as the chilling period have started affecting the mountain agricultural production systems and ultimately the food security of the people.

There is evidence in the literature that climatic changes can considerably affect apple cultivation. Apple and stone fruit trees remain dormant until they have accumulated sufficient ‘chilling units’ (CU) of cold weather. The chilling unit requirement for apple standard variety is 800–1100 (Byrne and Bacon, 1992). Daily temperatures of 70°F and higher for 4 or more hours received by the plant during a 24 to 36 hour period can actually negate chilling. As long as there have been enough CUs the flower and leaf buds develop normally. Byrne and Bacon (1992) have reported that if the buds do not receive sufficient chilling temperatures during winter to completely release dormancy, trees will develop one or more of the physiological symptoms associated with insufficient chilling: 1) delayed foliation; 2) reduced fruit set and increased buttoning;

and 3) reduced fruit quality. These physiological symptoms consequently affect the yield and quality of the fruit.

The objective of this study is to examine change in climatic parameters, especially chilling units, in Himachal Pradesh over time, and the associated changes in apple productivity. These results are further complemented by recording and analysing farmer perceptions of a changing climate and its impact on apple cultivation.

Approach and methods

Study sites

Apples are grown in all the districts of the state except Una and Hamirpur.

For the study, three sites in three apple growing districts, viz. Kullu, Theog (Shimla) and Lahaul and Spiti, representing different elevations, were selected to examine the perceptions of farmers for climate change and to relate the chill units with apple cultivation in the face of climate change. Kullu represents the lowest altitude, Theog the next highest, and Lahaul and Spiti the highest altitude among the areas studied.

Kullu Valley: The study site is located in Kullu district at 1,200–2,500 metres above mean sea level (msl). This elevation zone represents 16 per cent of the total geographical area of Himachal Pradesh. The geography of the region represents mid hill to high hills. The region also receives snowfall in the high hills during the winter months and serves as a great source of fresh water in Beas Basin of Himachal Pradesh. The climate of the region is by and large sub-temperate in lower hills to temperate in high hills. The ambient temperature ranges between 7.9°C and 25.6°C around the year. Temperature during the *rabi* season hovers around 12.7°C whereas during the *kharif* (monsoon) season average mean temperatures remain below 23.0°C. The mean annual temperature remains 17.0°C in the region (Bhagat *et al.,* 2007). The met station is located at 31°50′ N latitude and 77°10′ E longitude. The average mean annual rainfall is 1,095 mm. Parts of this region are known for the production of off-season vegetables, while the apple crop dominates in the higher hills (Bhagat *et al.*, 2007).

Theog Region (Shimla District): This study site is located in the district of Shimla and represents elevations of 2,200–3,250 msl. The area comprises mid- to high hills. The region is dominated by horticultural crops, viz. apple, pear and other temperate fruits. This elevation zone represents 8.8 per cent of the total geographical area of the state. It is located at the south eastern part of the state. Agricultural crops, mostly off-season vegetables, provide the majority of farmers of the region with their livelihood.

The meteorological observatory in the region is located at 31°10′ N latitude and 77°25′ E longitude. The average annual rainfall of the region varies between 1,100 mm to 1,533 mm annually from South to North. The major part of the annual rainfall is received during the south-western monsoon season. However winter rains are important for successful cultivation of apples in the region. The average mean temperature of the region is at its lowest of 7.7°C during January whereas the maximum temperature goes up to 20.7°C during June. The mean annual temperature of the region is 15.4 °C. December to February is cooler and temperatures start rising during March (Bhagat *et al.*, 2007).

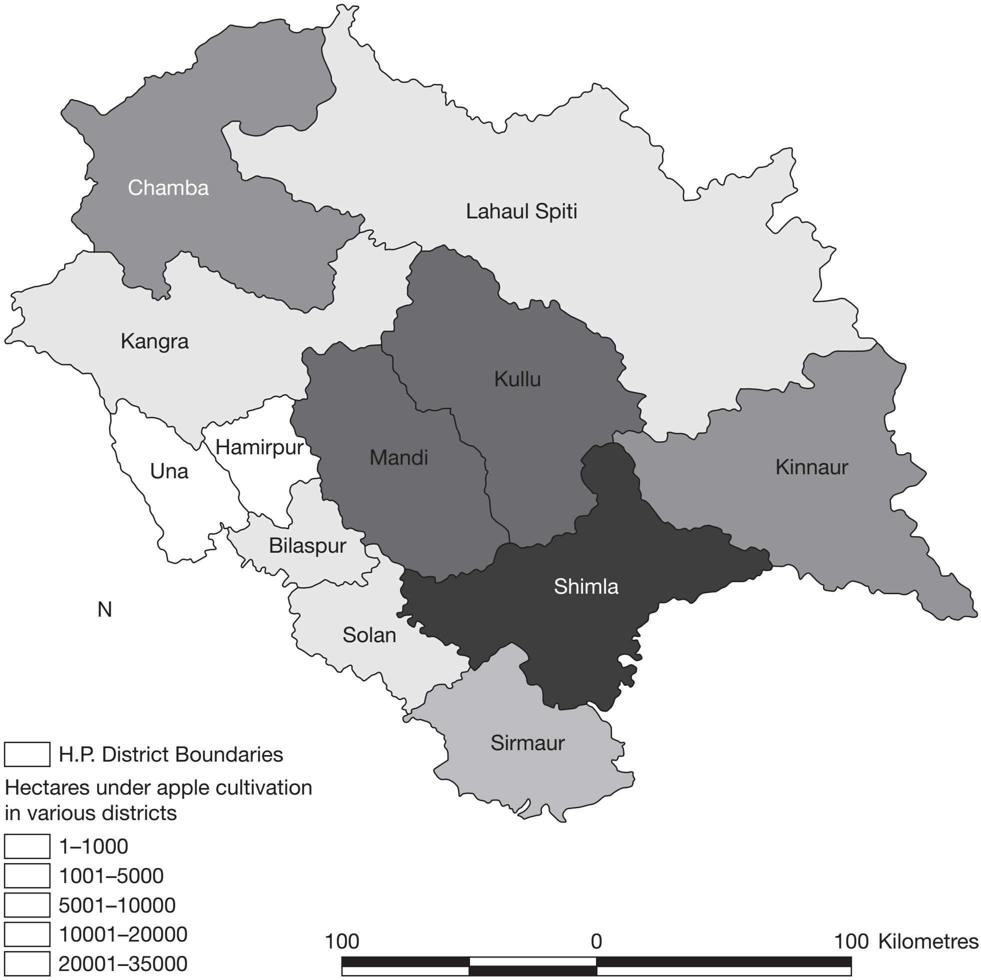

Figure 3.1 Apple growing regions of Himachal Pradesh

Lahaul and Spiti: The northern part of the state, which constitute Lahaul and Spiti, part of Chamba, part of Kullu, Shimla and Kinnuar district experience annual mean temperature below 14°C. The winter season starts from November and temperatures start decreasing until minima are obtained in January. The temperature again starts rising during the month of February, and May and June are the hottest months. Data has been gathered for farmer perceptions in Lahaul and Spiti but similar data is not available for weather trends and trends in chilling units.

Socioeconomic survey

Socioeconomic surveys were conducted in Kullu, Theog (Shimla), and Lahaul and Spiti regions of Himachal Pradesh in 2006–7 to examine how apple farmers in Himachal Pradesh perceive climatic change. Weather data from 1986 to 2009 was used to measure the accuracy of the farmers' perceptions. Perception of climate change is structured for the three valleys (Kullu, Theog in Shimla, and Lahaul and Spiti) with a multistage stratified sampling technique by knowledge of crop climate interaction and by differential apple performance outcomes associated with the changed conditions. To understand farmers' perceptions regarding climate change and its impact on apple cultivation, local perceptions of the climate variables to apple production were noted from forty farmers from each region (19 marginal, 16 small and 5 large farmers from Kullu, 4 marginal, 9 small and 27 large from Theog, and 9 small, 18 marginal and 13 large in Lahaul and Spiti). Perceptions were recorded on the basis of gathering data of two periods (1995 and 2006 years) of snowfall, temperature and rainfall.

Climatic elements trends

The climatic elements trends for Kullu valley and Theog region were worked out using the standard procedure from the past two to three decades weather database. Snowfall trends in the past two to three decades were also calculated for 22 sites representing different elevations ranging from 1,500 to 4,000 metres above sea level located in Sutlej basins of Himachal Pradesh.

Chill unit calculation models used

The cumulative chill units' requirements of apple for Kullu and Theog (Shimla) regions were calculated using the method developed by Ashcroft *et al.* (1977) and the Utah model (Byrne and Bacon, 1992). The Ashcroft model uses only average temperature of coldest months, whereas the Utah model uses daily maximum and minimum temperatures. The Utah model also introduces the concept of relative chilling effectiveness and negative chilling accumulation (or chilling negation) as follows:

1 hour below 34°F = 0.0 chill unit, 1 hour 35–36°F = 0.5 chill units

1 hour 37–48°F = 1.0 chill units, 1 hour 49–54°F = 0.5 chill units

1 hour 55–60°F = 0.0 chill units, 1 hour 61–65°F = –0.5 chill units

1 hour >65°F = –1.0 chill units

Recent apple productivity and area trends in Himachal Pradesh

Apple productivity trends for the past two decades of apple growing areas and total productivity of Himachal Pradesh were also analysed. The trends of area under apple were also worked out for different region to examine the expansion of areas under apple cultivation at different elevations.

Results and discussion

Farmers' perceptions

The socio-economic survey was conducted in Kullu, Theog (Shimla) and Lahaul and Spiti regions of Himachal Pradesh. Table 3.1 summarizes farmers' perceptions

Table 3.1 Farmers' perceptions regarding climate change and its impact

Particulars	*Kullu Valley*	*Theog Region (Shimla)*	*Lahaul and Spiti*
Increasing temperature during summer	85	80	–
Prolonged summer season	66	48	–
Short summer season	10	8	–
Delayed in the onset of rainy season	85	80	–
Uneven distribution of rainfall	88	96	–
Insufficient rainfall during rainy season	77	72	–
Delay in the outset of winter season	68	48	60
Very low temp. in winter season	–	12	80
Short winter period	94	88	80
Temp. above normal during winter	92	88	15
Reducing snowfall in winter	100	100	88
High humid weather	40	36	22
Increasing foggy days in winter	16	52	–
Increasing cloudy days in winter	16	18	28
Unpredictable rainfall	76	52	–
Threat of floods	88	50	88
High velocity winds	–	–	–
Mud slides	–	–	20
High intensity of rainfall	20	–	–

recorded. One hundred per cent of farmers of Kullu and Theog regions of Himachal Pradesh perceived a definite reduction in snowfall overtime during the winter season. Farmers perceived snowfall events in two general parameters related to the intensity and the change in the timings of snowfall. Farmers reported that the onset of early snow in December and January has occurred more infrequently over time and the period of snowfall now extends through the months of February and March.

There is a perception that the temperature distribution has undergone a significant shift in addition to an overall increase in temperature. Eighty-five per cent farmers of Kullu and 80 per cent farmers of Theog (Shimla) noticed an increase in temperatures. 88 per cent farmers of Kullu and 96 per cent of farmers of Theog (Shimla) reported uneven and insufficient distribution of rainfall during the rainy season.

The other signs of climate change which were reported by the farmers were: short summer season, humid weather, increasing foggy days in the winter and unpredictable rainfall. The perception of a reduced intensity of snowfall leads to the perception of a changed climatic pattern on the whole. According to farmers, late snowfall in February and March occurs mostly as a mixture of sleet and rain, resulting in lower temperatures and thereby a late onset of spring. Farmers also claimed that the winter period has shortened and there is a delay in the onset of the winter season, number of chilling hours and thereby the time of bud break. For normal pollination and fruit-bearing conditions for an apple crop a snow level of 2.5 to 3 ft is required in higher hills. Early snow is regarded as durable, long lasting and full of nitrogen. Late snow on the other hand, is described as watery, transitory and understood to adversely impact pollination and apple fruit bearing.

The socioeconomic survey concludes that between 1995 and 2005 land-use pattern in all farmer classes, small, marginal and large, has shifted toward orchard cultivation in Lahaul and Spiti, while the area under orchard per farmer decreased in Kullu and

Theog (Table 3.2). In Kullu and Theog, there is a remarkable increase in the area under off-season vegetable cultivation. The survey also revealed that average areas per farmer under apple cultivation increased by 0.60 hectare in Lahaul and Spiti whereas Kullu and Theog showed a decrease in areas under apple cultivation. The data (Table 3.2) reflects that the income of farmers from fruits increased by more than 10 per cent in Lahaul and Spiti between 1995 and 2005. However, for the same period, the other two apple growing regions showed a sizeable decrease of 27 to 30 per cent. Off-season vegetables have shared more than 84 per cent of the area under field crops in Theog region.

Climatic elements trends in the apple growing region

Kullu Valley Climate change is apparent in this region due to a perceptible shift of apple cultivation to higher hills. Mean annual temperature in Kullu Valley showed an increase of 4.1°C over the last two decades from 1986 to 2005. During the *rabi* season the temperature showed an increase of nearly 5.5°C whereas the *kharif* season showed a decrease in temperature of 1.7°C. Moreover, the temperature from June to September showed a decreasing trend. Rainfall in the region showed an exceptional decrease of 270 mm. *Rabi* season showed a decreasing trend of rainfall of 18 mm per year whereas *kharif* season showed increasing trends. Evaporation showed decreasing trends of 14.5 mm annually during *rabi* and 8.6 mm during *kharif*. However, the decrease was more during *kharif* season.

Theog Region (Shimla) The Theog valley in the Shimla district showed more increase in rainfall in *rabi* season than *kharif* season. During the period 1990 to 2009, the mean temperature recorded at CPRI Shimla showed an increase of 1.54°C annually. An increase of the order of 2.4°C was observed during *rabi* season whereas it was 1.2°C during the *kharif* season. June alone showed a decrease in temperature. Rainfall showed a decreasing trend during *rabi* season and increasing trends by 5.1 mm during

Table 3.2 Change in land-use pattern, apple area and income from fruits per farmer in apple-growing regions of Himachal Pradesh

District	*All farmers (small, marginal and large)*	
	1995	*2005*
Land-use pattern (Orchard)		
Kullu	27.0	21.0
Theog	22.8	21.7
Lahaul & Spiti	1.93	4.34
Apple area (ha)		
Kullu	0.55	0.45
Theog	0.62	0.60
Lahaul & Spiti	0.48	1.09
Income from fruits (per cent)		
Kullu	69.9	39.6
Theog	59.3	32.8
Lahaul & Spiti	17.2	29.1

kharif season. Annual rainfall showed decreasing trends by 27 mm annually. Rainfall decrease during September to February was unprecedented.

Cumulative chilling units

As discussed earlier, changes in chilling units can have a substantial impact on apple cultivation. Vedwan and Robert (2001) report that the lack of early cold in December and January adversely affects the chilling requirements, which ranges from 700 to 1200 chill unit hours per year. Late cold during April can delay blossoming and reduce the pollination activity of bees. Jindal *et al.* (2001) report that winter temperatures and precipitation, especially in the form of snow, are very crucial for induction of dormancy, bud break and ensuring flowering in apples. They further report that the apple crop requires 1,200–1,500 hours of chill depending upon its variety. Fewer than 1,000 chilling hours results in a poor fruit set which consequently leads to poor yield of the crop. The period of November to February is important for chilling hours. However, November to January is more beneficial than February. Jindal and Mankotia (2004) report that at least 1,200 chilling hours are required for proper bud and flowering in Mashobra conditions of Himachal Pradesh. Apple size and quality are mainly dependent upon climatic conditions in summer as they influence fruit development during April to June.

The results for the areas under study here are reported in Figures 3.2–3.5 and in Table 3.3. The Utah model showed a decrease of more than 6.4 chill units' hours every year due to increase in surface air temperature at Bajaura in Kullu (Figure 3.2). Similar trends are reported for Shimla (Figure 3.3) Central Potato Research Institute (CPRI, Shimla) at –19.0 CU per year and Bhang in Kullu (Figure 3.4) at –3 per year. For the highest altitude site, Dhundi in Kullu, the data report an increasing trend of 26 over the period (Figure 3.5).

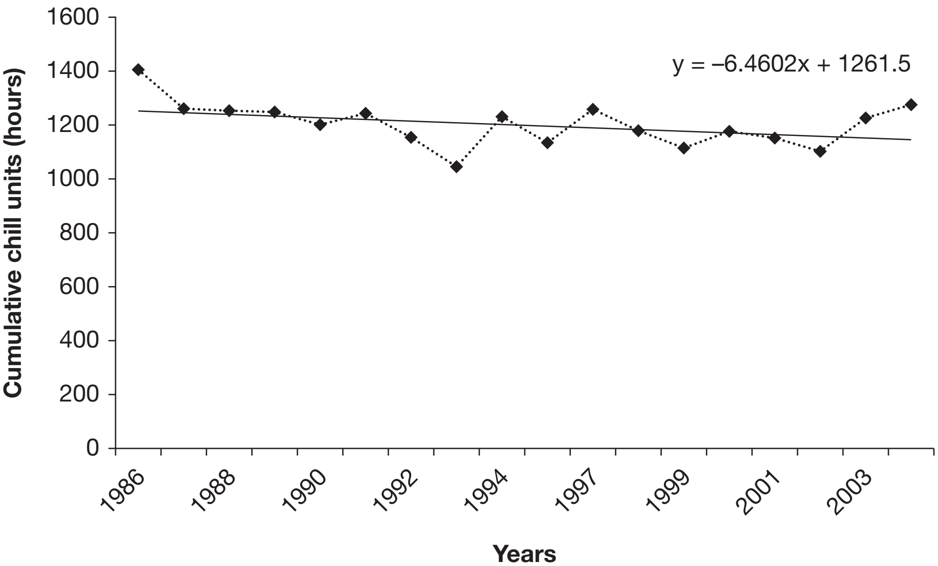

Figure 3.2 Cumulative chill unit trends (Utah model) at Bajaura in the Kullu Valley, 1986–2003

Turning to data for particular months (Table 3.3) the data for Bajaura in Kullu on cumulative chill units of coldest months (November–February) showed a decline of more than 9.1 units per year in the last 23 years of period (Table 3.3). The reduction was greatest during November and February months from 1986 to 2006.

In Shimla (CPRI, Shimla) the decrease of chill units during November to February ranged between –3.5 and –17.9 per year, with particularly steep declines from December to February due to the late onset of snow in the region (Table 3.3).

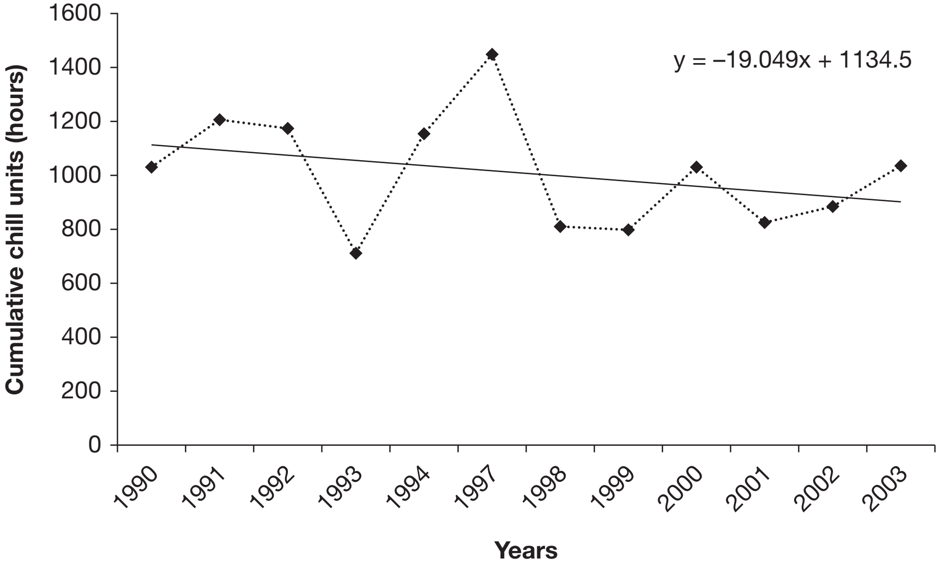

Figure 3.3 Cumulative chill units (Utah model) of Shimla, 1990–2003

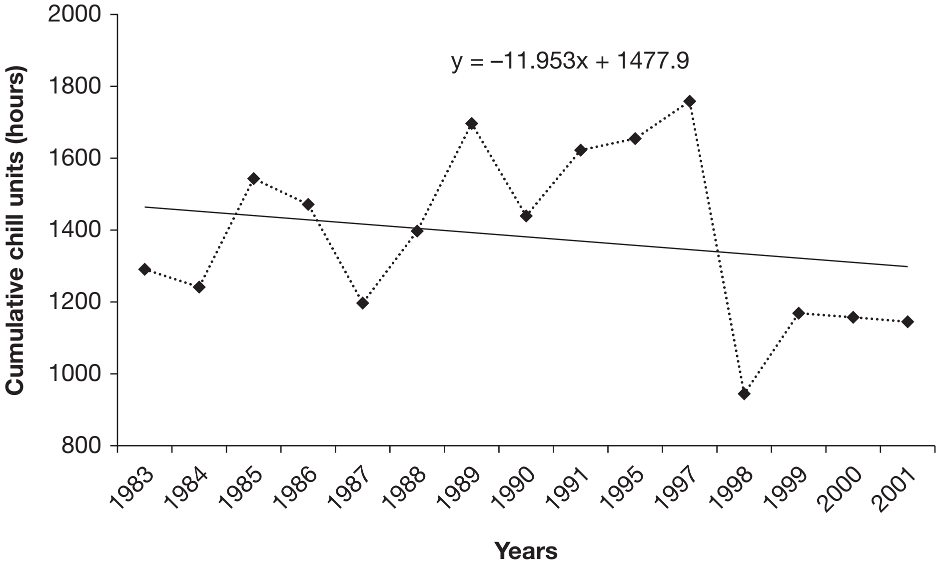

Figure 3.4 Cumulative chill units (Utah model) at Bhang, Kullu, 1983–2001

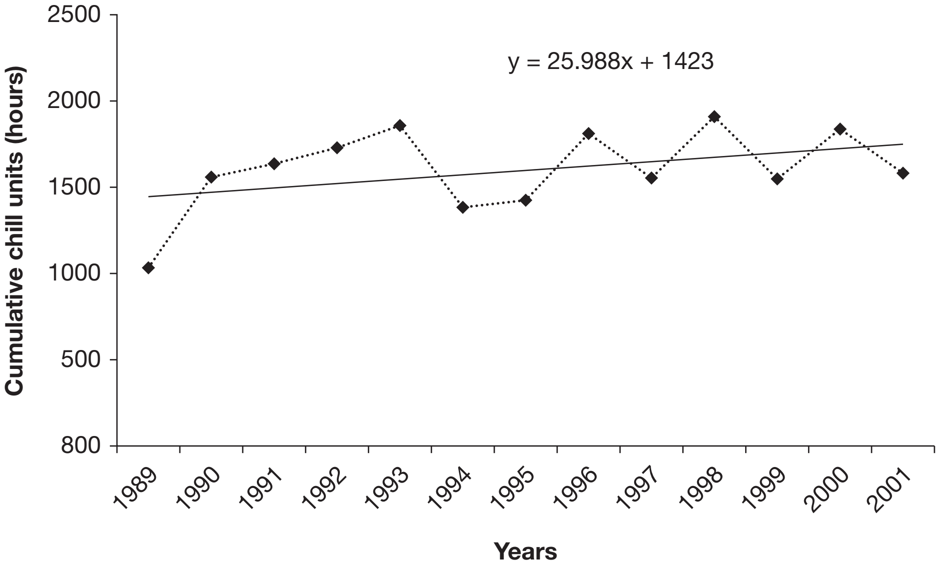

Figure 3.5 Cumulative chill units (Utah model) at Dhundi, Kullu (2700 msl), 1989–2001

Table 3.3 Cumulative chill unit trends (mean monthly model) equations for different winter months at Kullu (Bajaura) and Shimla (CPRI, Shimla)

Month	*Kullu (Bajaura)*		*Shimla (CPRI, Shimla)*	
	Equations	*Slope*	*Equations*	*Slope*
November	Y = –14.35+788.7	–14.35	Y = –3.55+585.0	–3.55
December	Y = –9.10+1034.1	–9.10	Y = –15.03+932.7	–15.03
January	Y = –10.85+1159.3	–10.85	Y = –17.94+1164.3	–17.94
February	Y = –13.28+1043.5	–13.85	Y = –14.96+1085.6	–14.96

The broad picture above is further reinforced by snowfall data. The snowfall trend in the two recent decades from 1984/85 to 2005/06 over different sites representing elevations ranging from 2,000 to 4,000 msl showed a decrease of 36.8 mm annually in the last 22 years averaged over 22 sites (Figure 3.6). The decrease was greater in recent decades. The decline in snowfall is one of the major regions in reduction of chill units in apple growing regions.

Monthly snowfall analysis indicated a sharp decrease of snowfall over the past 22 years from 22 observation sites during the period September to December, which is important for temperate crops. The snowfall showed increasing trends during January (27 mm per year) and February (23 mm) which revealed delay of snowfall.

The analysis clearly indicates that snowfall in the past two decades decreased due to an increase in temperature/change in climate as evident from the temperature analysis of apple growing regions. The delay of snowfall occurrence and early withdrawal of snowfall occurrence is reflected in a decrease in apple yield. Such trends in snowfall occurrence in high altitude areas increased the opportunity of growing more

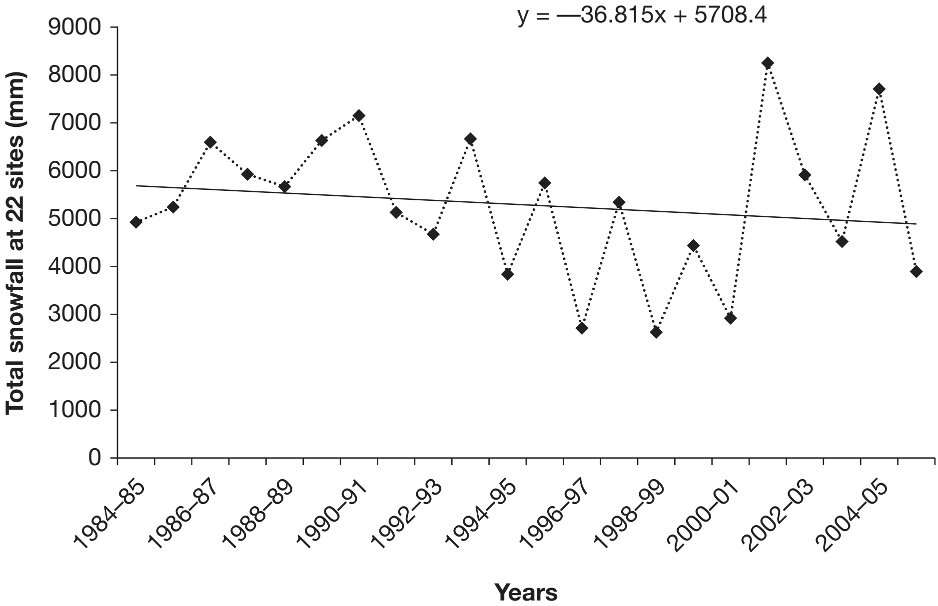

Figure 3.6 Annual average snowfall trends in Satluj catchment, 1984–2005

crops during March to October. The decrease in snow fall during early winter season and early withdrawal of seasonal snowfall contributes towards the decreased cumulative chill units for apple cultivation.

The trend reported here is further reinforced by data from other studies by other researchers. The chill unit trends calculated for different sites representing different elevations (Table 3.4) combining our work and other studies showed decreasing trends up to elevation of 2,400 msl in Sarbo (Kinnaur) whereas the chill units calculated for site Dhundi in Kullu (Figure 3.5) which is situated 2,700 metres msl revealed an increasing trend of chill unit at the rate of 25 CU per year in the recent decade. This reflected that areas above 2,500 msl are becoming suitable for apple cultivation in the most recent decade. These findings were also supported by the socio-economic survey conducted in Kullu and Lahaul and Spiti. The majority of farmers in Kullu and Lahaul and Spiti are of the opinion that the apple crop is shifting upward to higher elevation. The secondary data (Department of Economics and Statistics, 2006b) also reported an increase in area under apple crop in Lahaul and Spiti and Kinnaur in the most recent decade. The majority of croplands are above 2,500 msl in Lahaul and Spiti and Kinnaur. The upward shift in apples was also reported by Partap and Partap (2002) in a case study conducted on apple crops in Kullu districts.

The climate data and data on chill units in Table 3.4 shows that lower altitudes have become less suitable for apple cultivation, while higher altitudes have become more suitable. Cultivation data indicates corresponding changes on the ground.

The area under apple cultivation in recent years has fallen from 92,820 ha in 2001–2 to 88,560 ha in 2005–6 in the entire state. However, the area under apple cultivation in Lahaul and Spiti and Kinnaur district, which lies above 2,500 msl, showed an increase in cultivation under apple every year between 1995–96 and 2006–07. It went

Table 3.4 Cumulative chill unit trend equations for different sites and at different elevations (Utah model)

Sr No.	*Stations*	*Elevation (msl)*	*Chill unit trend equations*	*Slope of trend equation*	*Remarks*
1	Bajaura (Kullu)	1221	Y = –6.4+1261.5	–6.4	
2	Katrain (Kullu)	1420	Y = –25.93+2299	–25.93	Reported by Verma *et al.* (2007)
3	Bhang (Kullu)	2192	Y = –11.953+1477.9	–3.2	
4	CPRI Khalini (Shimla)	2159	Y = –19.0+1134.5	–19.0	
5	Mashobra (Shimla)	2250	Y = –37.8+1930.5	–37.9	Reported by Verma *et al.* (2007)
6	Sarbo (Kinnaur)	2400	Y = –32.0+1399.3	–32.0	Reported by Verma *et al.* (2007)
7	Dhundi (Kullu)	2700	Y = 25.99+1423	+25.99	

up to 621 hectares in 2006–7 from 334.0 ha in 1995–96 and 8151 ha in 2006–07 from 5,516 ha in 1995–96, respectively. Farmer perceptions reinforce the findings reported here. Surveys of farmers revealed that per farmer area under apple showed a decrease in Kullu and Shimla of 18.2 and 3.3 per cent respectively. The area at higher elevation (above 2,500 msl) namely Lahaul and Spiti valley showed substantial increase by more than 127 per cent over the recent decade.

Conclusion

The temperature in apple growing regions of the mountain state of Himachal Pradesh showed increasing trends whereas precipitation showed decreasing trends. The chill units requirements for apple cultivation showed decreasing trends up to 2,400 msl from Bajaura in Kullu at 1,221 msl to Sarbo in Kinnaur at 2,400 msl. The Dhundi observation station situated at 2,700 msl showed increase of chill units of the order of 25.0 CUs per year. The increasing trends of chill unit at 2,700 msl suggested that the area is becoming suitable for apple cultivation at a higher altitude. These findings have also been supported by farmers' perceptions which clearly reflect that apple cultivation is expanding to a higher altitude in Lahaul and Spiti. The average land use per farm in Lahaul and Spiti showed more than a 2 per cent shift towards apple cultivation but it showed a reverse trend in other apple growing regions situated at low elevations. The income of the farmers increased more than 10 per cent in Lahaul and Spiti whereas it showed a decrease of more than 27 per cent in Kullu and Shimla districts from fruits in recent decade compared to 1995. Climate change has demonstrated its impact with the decreasing productivity of apple crops in recent years at lower elevations, providing opportunity for more apple cultivation at higher elevation regions of Himachal Pradesh.

Notes

1 This chapter was first published in the ISPRS Archives XXXVIII–8/W3 *Workshop Proceedings: Impact of Climate Change on Agriculture*. The research could not have been completed without the assistance of Dr. P.K. Aggarwal, National Professor, and Project Coordinator, Division of Environment Sciences, IARI New Delhi and Dr G.G.S.N. Rao National coordinator, CRIDA Hyderabad for sanctioning the project and providing the financial sanctions. The data on snowfall from 22 sites provided by the Bhakra Beas Management Board Chandigarh is highly acknowledged. The authors are also thankful to CSK Himachal Pradesh Agriculture University for providing the necessary facilities to carry out the research.

2 The figure is a round approximation. For all such conversions in this chapter: $1 = INR 45.

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