IMPACT OF CLIMATE CHANGE ON SHIFT OF APPLE BELT IN HIMACHAL PRADESH

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ABSTRACT:

The study examines the impact of climate change in recent years on apple shift to higher altitude in Himachal Pradesh based on climate information and farmers perceptions. It is evident that temperature in apple growing regions of Himachal Pradesh showed increasing trends whereas precipitation showed decreasing trends in the regions. The chill units calculated showed decreasing trends of chill units upto 2400 msl from Bajaura in Kullu at 1221 msl to Sarbo in Kinnaur at 2400msl. The Dhundi station situated at 2700 msl showed increasing trend of chill unit at the rate of 25.0 CUs per year. The increasing trends of chill unit at 2700 msl suggested that area is becoming suitable for apple cultivation in higher altitude. These findings have also been supported by the farmers' perceptions which clearly reflected that apple cultivation is expanding to higher altitude in Lahaul & Spitti. The average landuse per farm in Lahual and Spitti showed more than two percent shift towards apple cultivation but it showed reverse trend in other apple growing regions. The income of the farmers increased more than 10 percent in Lahual & Spitti whereas it showed a decrease of more than 27 percent in Kullu and Shimla districts from fruits in recent decade compared to 1995. The secondary data on area under apple cultivation also compounded statement that apple cultivation is expanding in Lahaul & Spitti in recent decade. The climate change has demonstrated its impact of decreasing productivity of apple crop in recent years.

1. INTRODUCTION

Apple is a predominant fruit crop of Himachal Pradesh and in recent years it has emerged as the leading cash crop amongst fruit crops. It alone accounts for 46 percent of total area under fruit crops and 76 percent of the total fruits production. The area under apple has increased from 400 hectares in 1950-51 to 88,560 hectares on 2005-06 (Anonymous, 2006). The crop alone contributes more than 987 crore towards the gross domestic product. The production level has gradually touched to 540.30mt with 5.6t productivity in 2006 (Anonymous, 2006a). The chilling hour's requirement for apple standard variety is 800-1100 (Byrne and Bacon, 1992). The amount of cold needed by a plant to resume normal spring growth following the winter period is commonly referred to as its "chilling requirement." The daily temperatures of 70°F and higher for 4 or more hours received by the plant during the previous 24 to 36 hours can actually negate chilling. Apple and stone fruit trees develop their vegetative and fruiting buds in the summer and as winter approaches; the already developed buds go dormant in response to both shorter day lengths and cooler temperatures. These buds remain dormant until they have accumulated sufficient chilling units (CU) of cold weather. When enough chilling units accumulate, the buds are ready to grow in response to warm temperatures. As long as there have been enough CUs the flower and leaf buds develop normally. 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 production of apple has gradually increased but the productivity has fallen from 10.8 to 5.8 t/ha (Awasthi *et al*., 2001). The reasons attributed to it are climate variability, soil, crop improvement etc. Among all the productivity reducing factors, climate is difficult to manage. The changes in climate in the form of erratic precipitation, increase in temperature, lesser days serving as the chilling period have started affecting the mountain agricultural production systems and ultimately the food security of the people. The objective of this study is to examine change in climatic parameters especially chilling units and farmers perceptions in Himachal Pradesh over time and its associated changes in apple productivity.

2. MATERIALS AND METHODS

2.1 Study Sites

Three study sites in three apple growing districts viz. Kullu, Shimla and Lahual and Spiti representing different elevation were selected to examine the perceptions of farmers for climate change and to relate the chill units with apple cultivations in the face of climate change. The study site of Kullu district represents 1200-2500m above mean sea level. This elevation zone represents 16.04% of the total geographical area of Himachal Pradesh. The region represents mid hill to high hills and receives snowfall in high hills during winter months. The ambient temperature ranges between 7.9°C and 25.6°C. The elevation above 2200-3250m amsl was represented by the second study site of district Shimla. This elevation zone represents 8.8 % of the total geographical area of the state. The area

is having mid hills to high hills. Mean annual temperature of the region is 15.4 °C. The study site of Lahual & Spitti, represent the northern part of the state, embody Lahaul & Spiti, part of Chamba, part of Kullu, Shimla and Kinnuar district. The annual mean temperature of this region is below 14°C.

2.2 Socioeconomic Survey

The socioeconomic surveys were conducted in Kullu, Shimla and Lahual & Spitti regions of Himachal Pradesh to examine how apple farmers in Himachal Pradesh perceive climatic change. Weather data from 1986-2004 was used to measure the accuracy of perceptions of the farmers. Perception of climate change is structured for three valleys (Kullu, Lahual&Spitti and Shimla) with multistage stratified sampling technique by knowledge of crop climate interaction and by differential apple performance outcomes associated with the changed conditions. Local perception of the climate variables to apple production were noticed from forty farmers from each region (19 marginal, 16 small and 5 large farmers from Kullu, whereas, 4 marginal, 9 small and 27 large from Shimla and 9 small, 18 marginal and 13 large in Lahual & Spitti) to know farmers perceptions regarding climate change and its impact on apple cultivation. Perceptions were made on basis of gathering data of two periods (1995 and 2005 years) of snowfall, temperature and rainfall.

2.3 Climatic Elements Trends

The climatic elements trends for Kullu valley and Theog region were worked out using the standard procedure from the past 13 to 23 years weather database. The snow fall trends in past two decades were also calculated for 21 sites representing different elevations ranging from 1500 to 4000 msl exclusively located in Satluj basins of Himachal Pradesh.

2.4 Chill Unit Calculation Models

The Cumulative chill units' requirements of apple for Kullu (Bajaura) and Shimla (CPRI-Shimla) regions were calculated by using Ashcroft *et al* (1997) method and 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 temperature. Utah model also introduces the concept of relative chilling effectiveness and negative chilling accumulation (or chilling negation) as follows:

- 1 hour below 34^{o}F = 0.0 chill unit,
- 1 hour 35-36^{o}F = 0.5 chill units
- 1 hour 37-48^{o}F = 1.0 chill units,
- 1 hour 49-54^{o}F = 0.5 chill units
- 1 hour 55-60^{o}F = 0.0 chill units,
- 1 hour 61-65^{o}F =-0.5 chill units
- 1 hour >65^{o}F =-1.0 chill units

2.5 Recent Apple Productivity and Area Trends in Himachal Pradesh

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

3. RESULTS AND DISCUSSION

The socio-economic survey was conducted in Kullu, Shimla and Lahual and Spitti districts of Himachal Pradesh and summarized perceptions of the farmers (Table 1). Hundred percent farmers of Kullu and Shimla districts of Himachal Pradesh perceived a definite reduction in snowfall overtime during winter season. Reduction in the intensity of snowfall and changes in timing of snowfall are thought to be two important ways as to oscillate snowfall events. Farmers reported that the onset of early snow in December and January has occurred more infrequently over time and the period of snowfall now extended through the months of February and March.

(Percent Multiple Response)

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

Table 1: Farmers Perceptions Regarding Climate Change

There is a perception that the temperature distribution has undergone a significant shift in addition to an overall increase in

temperature. 85 percent farmers of Kullu and 80 percent farmers of Shimla noticed an increase in temperatures. The hottest period of the year is no longer, but has shifted ahead. 88 percent farmers of Kullu and 96 percent farmers of Shimla valley reported uneven and insufficient distribution of rainfall during 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 the rain, resulting in lower temperatures and thereby a late onset of spring. The farmers also opinioned that winter period has shortened and there is delay in onset of winter season. Number of chilling hours and thereby the time of bud break depends upon the amount of snow. For normal pollination and fruit bearing conditions for an apple crop a snow level of 2.5 to 3 ft seems to represent. 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 conducted in three regions concludes that land use pattern in all farmers including small, marginal and large farmers has shifted to orchard cultivation to nearly 2.4 percent in Lahual and Spitti in recent decade compared to 1995 whereas the land use per farmer under orchard decreased in Kullu and Shimla (Table 2). In Kullu and Shimla (1500-2200m) there is remarkable increase in the area under off-season vegetable cultivation. The survey also revealed that average areas per farmers under apple increased by 0.60 hectare in Lahual and Spitti whereas Kullu and Shimla showed decrease in areas under apple cultivation. The table 2 reflects that income of the farmers from fruits increased by more than 10 percent in Lahual & Spitti in recent decade compared to 1995 whereas for the same period in other apple growing regions it showed sizeable decrease of 27 to 30 percent in recent decade. The off season vegetables have shared more than 84 per cent of the area under field crops in Theog Region (Above 2000m).

(Socio-economic survey of the regions)

District	**All farmers (Small, Marginal, and large)**	
	1995	2005
Land use pattern (Orchard)		
Lahual & Spitti	1.93	4.34
Kullu	27.0	21.0
Shimla	22.8	21.7
Apple area(ha)		
Lahual & Spitti	0.48	1.09
Kullu	0.55	0.45
Shimla	0.62	0.60
Income from fruits (Percent)		
Lahual & Spitti	17.2	29.1
Kullu	69.9	39.6
Shimla	59.3	32.8

Table: 2 Change in Land use Pattern, Apple Area and Income from Fruits per Farmer in Apple Growing Regions of H.P.

3.1 Climatic Elements Trends in Apple Growing Region

3.1.1 Kullu Valley: The study site is located in Kullu district representing 1200-2500 m above mean sea level. This elevation zone represents 16.04% of the total geographical area of Himachal Pradesh. The geography of the region represents mid hill to high hills in the region. The regions also receive snowfall in high hills during winter months and serve 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 to 25.6°C around the years. Temperature during rabi season hovers around 12.7°C whereas during kharif season average mean temperature remain below 23.0°C. Mean annual temperature remains 17.0°C in the region. The met station is located at 31°50' N latitude and 77°10' E longitude. The average mean annual rainfall is 1095 mm. Parts of this region are known as the bowls of off season vegetable of Himachal Pradesh; apple crop dominates in the higher hills.The 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°Cin last two decdes. During *rabi* season temperature showed increase nearly 5.5°C whereas *kharif* season showed decrease in temperature to the tune of 1.7°C. Among months, June to September, temperature showed decreasing trends. Rainfall in the region showed exceptional decrease of 270mm. *Rabi/winter* season showed decreasing trend of rainfall @ 18mm whereas *kharif* season showed increasing trends. Evaporation showed decreasing trends @ 14.5mm annually during *rabi and 8.6mm kharif*. However, the decrease was more during *kharif* season. Rainfall at Katrain at higher elevation showed increasing trend @ 2.5mm per year in past four decades. Socio-economic transformations have also taken place in this region in a big way, as the area is fast developing as a tourist hub of Himachal Pradesh.

The mean annual temperature showed an increase by 1.1°C in the region based on past two decade weather data. During *rabi* seasons temperature increased by 2.4°C whereas *kharif* season showed decrease in temperature to the tune of 0.9°C. Precipitation in the region also showed unprecedented decrease of 14.5mm annually. *Rabi/winter* season showed decreasing trend of precipitation @ 18mm whereas *kharif* season showed increasing trends. Evaporation also observed to be decreased @ 14.5mm annually during *rabi and kharif*. Decrease was more during *kharif* season.

3.1.2 Theog region: This study site is located in the district Shimla and represents elevation above 2200-3250m amsl. The area is having mid hills to high hills. The region is dominated by horticultural crops viz. Apple, Pear and other temperate fruits. This elevation zone represents 8.8 % of the total geographical area of the state. It is located at southeastern part of the state. Agricultural crops, mostly off-season vegetables provide livelihood to majority of the farmers of the region.

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 1100 mm to 1533 mm annual from South to North. Major part of the annual rainfall is received during South-western monsoon season. However winter rains are important for successful bearing of apple in the region. The average mean temperature of the region touches minimum of 7.7°C during

January whereas maximum temperature goes up to 20.7°C during June month. Mean annual temperature of the region is 15.4 °C. December to February month is cooler and temperature starts rising during March.In the Theog valley showed more increase in rainfall in *rabi* season than *kharif* season. Mean temperature showed increase of 1.8°C annually. The increase of the order of 2.4°C was observed during *rabi* season whereas it was 1.2°C in *kharif* season. June month alone showed decrease in temperature. Rainfall showed decreasing trend during *rabi* season and increasing trends by 5.1mm during *kharif* season. Rainfall during September to February decreased unprecedented.

3.1.3 Lahual & spitti: The northern part of the state, which constitute Lahaul & Spiti, part of Chamba, part of Kullu, Shimla and Kinnuar district experience annual mean temperature below 14°C. Winter season starts from November and temperature starts decreasing until minima are obtained in January. Temperature again starts rising during the month of February and May and June are the hottest months.

3.2 Cumulative Chilling units

The data on cumulative chill units of coldest months showed decline of more than 9.1 units per year in last 23 years of period. The reduction was more during November and February months. Average 11.9 chill units per year were decreased at Bajaura during November to February months (Table 3).

Month	Kullu		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+932.74	-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

Table 3: Cumulative Chill Units' Trends (Mean Monthly Model) Equations for Different Winter Months at Kullu and Shimla

The Utah model showed decrease of more than 6.4 chill units (Fig.1) every year due to increase in surface air temperature at Kullu. The decrease of chill units during November to February ranged between -3.5 to -17.9 per year in Shimla. The magnitude was more during December to February due to late onset of snow in the region. Vedwan and Robert (2001) also reported that the lack of early cold in December and January adversely affect the chilling requirements, which range from 700 to 1200 hours per year. The late cold during April can delay the blossoming and reduce the pollination activity of bees. The snowfall recorded at 21 sites (Fig. 2) showed that snowfall is decreasing every year for last two decades. The decrease was more in recent decades. The snowfall trends in two recent decades over different sites representing elevations ranging from 2000 to 4000 msl showed a decrease of 36.8mm annually last 22 years averaged 21 sites. The decline in snowfall is one of the major regions in reduction of chill units in apple growing region.

Monthly snowfall analysis indicated a sharp decrease of snowfall over past 22 years from 21 observation sites during September to December, which are important for temperate crops. The snowfall showed increasing trends during January (27mm per year) and February (23mm), which revealed delay of snowfall (Fig 3). During winter months i.e. March to May showed decreasing trends of snowfall in H.P. The analysis clearly indicated that snowfall in past two decades decreased due to increase in temperature/change in climate as evident from the temperature analysis of apple growing regions.

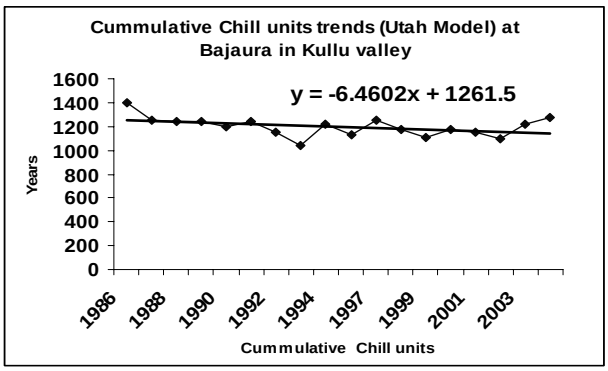


Figure 1. Cumulative Chill Units Trends (Utah Model) in Kullu Valley

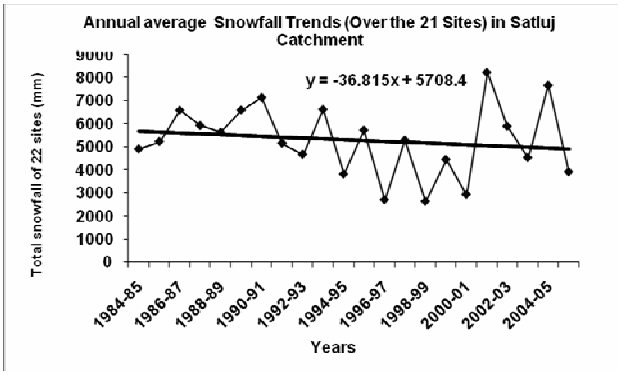
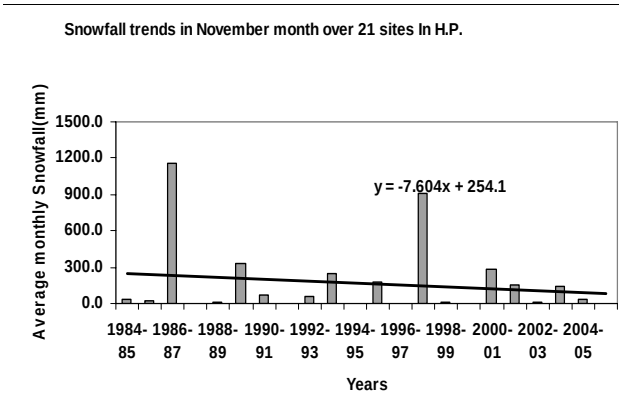


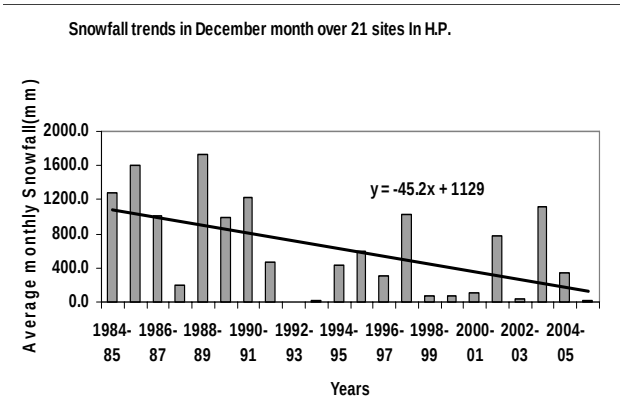
Figure 2. Snowfall trends in Himachal Pradesh

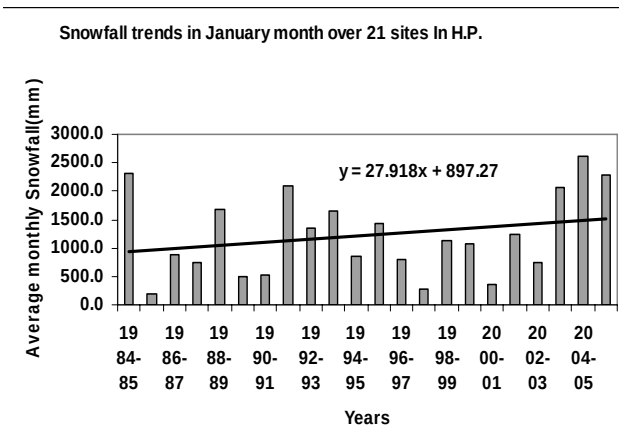
The delay of snowfall occurrence and early withdraw of snowfall occurrence reflected in decrease in apple tiled over past two decades. Such trends in snowfall occurrence in high altitude areas increased the opportunity of growing more crops during March to October. The decrease in snowfall during early winter season and early withdrawal of seasonal snowfall contributes towards the less cumulative chill units for apple

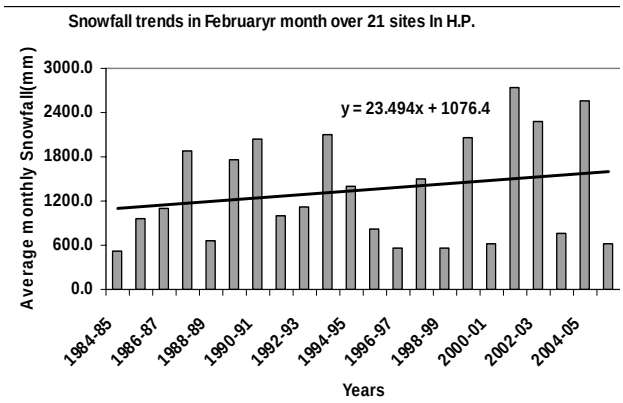
Jindal *et al*. (2001) reported that winter temperatures and precipitation especially in the form of snow are very crucial for induction of dormancy, bud break and ensuring flowering in apples. They further reported that apple requires 1200-1500 hours of chill depending upon the variety. The chilling below 1000

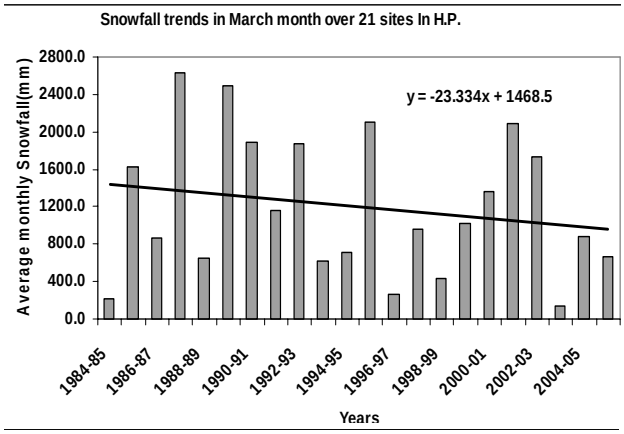
results in the poor fruit set which consequently lead to poor yield of the crop. The period of November to February is important for chilling hours. However, November to January is more beneficial than February. Jindal and Mankotia (2004) reported that at least 1200 chilling hours are required for sparking delicious apple for proper bud and flowering in Mashobra conditions of Himachal Pradesh. The apple size and quality mainly dependent upon the summer climatic conditions as it influences the fruit development during April to June. The decrease in snowfall during March to May period have caused increase in temperature in apple growing regions and reflected in low yield of apple in below 1500 m asl apple growing regions.

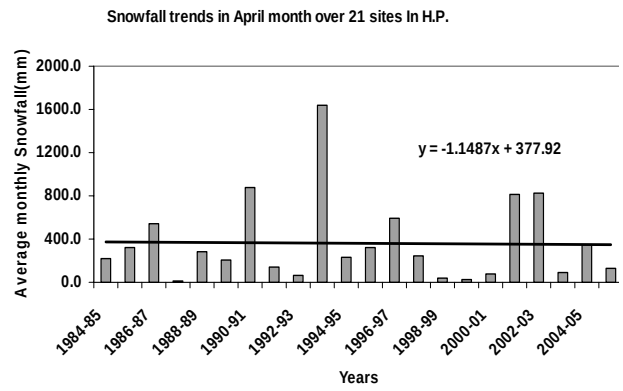












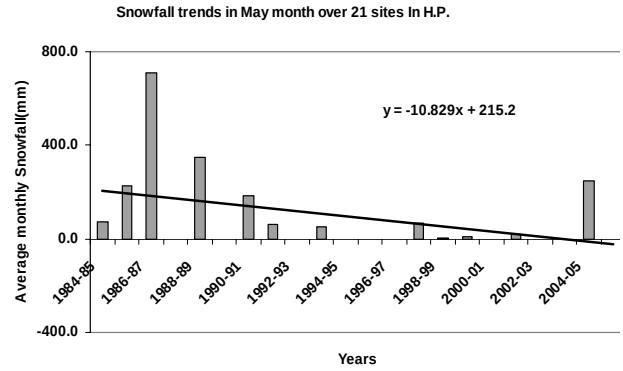


Figure 2. Monthly Snowfall Trends in Himachal Pradesh

Similar, studies were also carried out for Shimla district (Fig 4). The data also exhibited the same trends of decrease of chill units. The decrease was 19.0 chill units per year. The significant decrease in chill units was observed during December to February in Shimla. The temperature trends in corresponding period showed increase in minimum and maximum temperature by 1.6 and 1.3^{0}C.

The chill unit trends calculated for different sites representing different elevations (Table 4 and Fig. 3 to 6) showed decreasing trends upto elevation of 2400 msl Sarbo (Kinnaur) whereas the chill units calculated for site Dhundi in Kullu (Fig. 6) which is situated above 2700 msl revealed increasing trend of chill unit at the rate of 25 CU per year in recent decade. This reflected that areas above 2500 msl are becoming suitable for apple cultivation in recent decade. These findings were also supported by the socio-economic survey conducted in Kullu and Lahual and Spitti. The majority of farmers in Kullu and Lahual & spitti are of the opinion that apple crop is shifting upward to higher elevation. The secondary data (Anonymous, 2006a) also reported an increase in area under apple crop in Lahual and Spitti in recent decade. The majority of croplands are above 2500 m asl in Lahual and Spitti. The upward shift in apple was also reported by the Partap and Partap (2002) in a case study conducted on apple crops in Kullu districts.

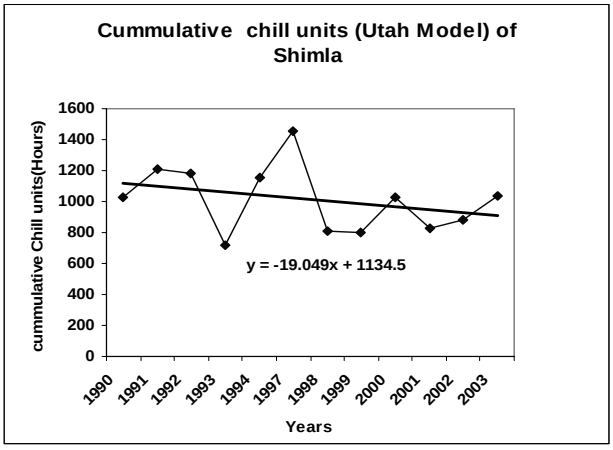


Figure 4. Cumulative Chill Units Trends (Utah Model) in Shimla

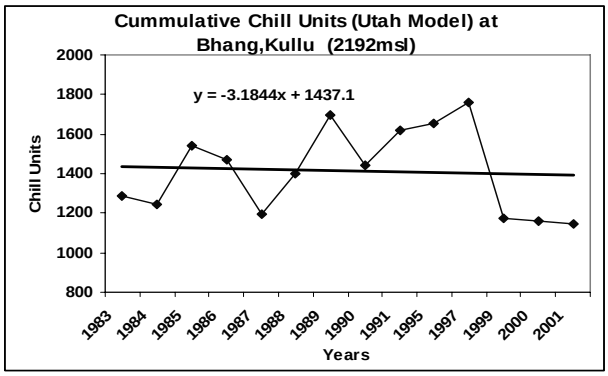


Figure 5. Cumulative Chill Units Trends (Utah Model) at Bhang

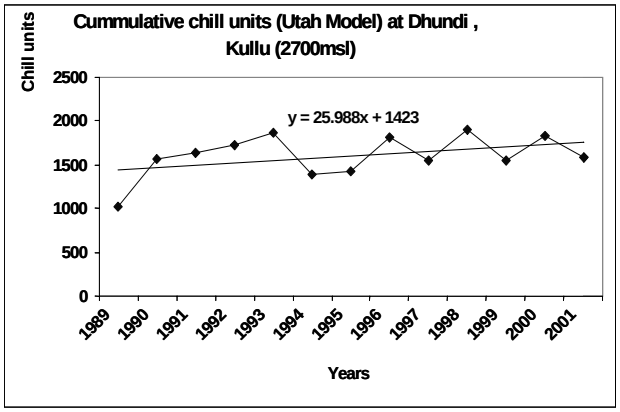


Figure 6. Cumulative Chill Units Trends (Utah Model) at Dhundi

The area under apple cultivation in recent years have fallen (92,820ha) in 2001-02 and 86,202 ha in 2004-05 in the entire state whereas, area in Lahaul & Spitti and Kinnaur district which lie above 2500 msl showed increase every year in recent decade which is 533 hectare in 2004-05 from 334.0 ha in 1995-96 and 7700 ha in 2004-05 from 5516 ha in 1995-96, respectively. The farmers perception were also summarized for these apple growing region using farmers survey revealed that per farmer area under apple showed decrease in Kullu and Shimla by 18.2 and 3.3 percent respectively. The area in higher elevation (above 2500 msl) namely Lahual and Spitti valley showed substantial increase by more than 127 percent over the recent decade.

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=-3.2+1437.1	-3.2	
4	Dhundi (Kullu)	2700	Y=25.99=1423	+25.99	
5	CPRI Khalini (Shimla)	2159	Y= -19.0+1134.5	-19.0	
6	Mashobra (Shimla)	2250	Y= -37.8+1930.5	-37.9	Reported by Verma et al.(2007)
7	Sarbo (Kinnaur)	2400	Y=-32.0+1399.3	-32.0	Reported by Verma et al.(2007)

Table 4: Cumulative Chill units Trends (Utah model) Equations for Different Sites and at Different Elevation

REFERENCES

Anonymous, (2006). Economic Survey of Himachal Pradesh, Department of Economics & Statistics, Himachal Pradesh, Page (30-39)

Anonymous, (2006a) Statistical outline of Himachal Pradesh, Department of Economics & Statistics, Himachal Pradesh, Page (86-89).

Awasthi, R.P., Verma, H.S, Sharma, R.D., Bhardwaj, S.P. and Bhardwaj, S.V. (2001).Causes of low productivity in apple orchards and suggested remedial measures. In "Productivity of temperate fruits". Edited By K.K. Jindal and D.R. Gautam. Page 1-8.

Byrne, D. H., and T. A. Bacon. (1992). Chilling estimation: its importance and estimation. The Texas Horticulturist 18 (8): 5, 8-9.

Ashcroft, G.L., E.A. Richardson and S.D. Seeley (1977) A statistical method of determining chill unit and growing degree hour requirements for deciduous fruit trees. *Hort Science 12(4): 347-348.*

Jindal, K.K. and Mankotia, M.S. (2004). Impact of changing climatic conditions on chilling units, physiological attributes and productivity of apple in western Himalayas. Acta Horticulture 662:111-117.

Jindal, K.K., Chauhan, P.S. and Mankotia, M.S. (2001) Apple productivity in relations to environmental components. In: Productivity of temperate fruits. Edited By K.K.Jindal and D.R.Gautam pp 12-20.

Partap, U and Partap, T. (2002) Warning Signals from the Apple Valleys of the Hindu Kush-Himalayas- Productivity Concerns and Pollination Problems. Shreshtha, A.B.M. (Ed) Centre for Integrated Mountain Development (ICIMOD), PO Box 3226, Kathmandu, Nepal.

Vedwan, N. and Robert, E.R. (2001) Climate Change in the Western Himalayas of India: A Study of Local Perception and Response. Climate Research 19:109-117.

Verma, K. S., Mankotia, M. S.., Bhardwaj, S. K., Thakur, C.C and Thakur, M (2007). Project Progress Report (2004-07) of project entitled "Impact Vulnerability and Adaptation to Climate Change" submitted to network project on climate change, ICAR, New Delhi.