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Impact of climate change on apple crop 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. The temperature trends in apple growing regions of Kullu and Shimla indicated 1.8 to 4.1 ^{0}C rise in past two decades which reflected in decrease of chill units (CU) hours accumulations. The annual snow fall decreasing rate of 36.8 mm with decreasing trends of snowfall during early winters (October & December) and late winters (March and April) clearly indicated the shrinking winter period in high hills. The CU hours showed decreasing trends upto 2400 meter above mean sea level (amsl) from Bajaura in district, Kullu at 1221 m amsl to Sarbo in district Kinnaur at 2400 m amsl. The Dhundi station situated at 2700 m amsl showed increasing trend of chill unit at the rate of 25.0 CUs per year. The increasing trends of chill units at 2700 m amsl 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 and Spitti and Kinnaur. 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 of Himachal Pradesh. The income of the farmers increased more than 10 percent in district Lahual and 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 data on area under apple cultivation also compounded statement that apple cultivation is expanding in Lahaul and Spitti in recent decade. The climate change has demonstrated its impact of decreasing productivity of apple crop in recent years.

Key words: Climate change, apple, chill units hours and productivity

The climate change is one of the biggest long term challenges around the world. In Himachal Pradesh, evidences of global warming could be clearly deciphered by changes like receding snowfall in the Himalayas, retreating glaciers and shifting of temperate fruit belt upward, adversely affecting productivity of apples, shifting and shortening of rabi season, forward and disrupted rainfall pattern. (Bhagat *et al*., 2004). The impact of global climate change has also been observed in production of apple and Satsuma mandarin in Japan. It was predicted that favourable regions to cultivate apples and Satsuma mandarins will gradually move northward (Sugiura and Yokozawa, 2004).

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, 2006a). The crop alone contributes more than 987 crore towards the gross domestic product. The production level has gradually touched to 540.3 metric tonne with 5.6 tonne productivity in 2006 (Anonymous, 2006b). The chilling hour's requirement for apple standard variety is 800-1100 (Byrne and Bacon, 1992).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 remain dormant until they have accumulated sufficient chilling units (CU) of cold weather. As long as there have been enough CUs the flower and leaf buds develop normally. Byrne and Bacon, 1992 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 production of apple has gradually increased but the productivity has fallen with a rate of 0.016 tons/ hac annually (Vijayshri Sen, 2010). 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 high hill 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.

MATERIALS AND METHODS

Study sites

Three study sites in three apple growing districts viz. Kullu, Shimla and Lahual and Spitti representing different elevations 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.

Kullu valley

The study site is located in Kullu district representing 1200-2500 m amsl level. This elevation zone represents 16.0% of the total geographical area of Himachal Pradesh. The geography of the region represents mid hill to high hills in the region (Bhagat *et al* ;2007). 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 temperature range found 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. The annual mean temperature, however remains 17.0°C in the region (Bhagat *et al* ; 2007). The meteorological observation is located at 31°502 N latitude and 77°102 E longitude. The average mean annual rainfall is 1095 mm.

Theog region (District Shimla)

This study site is located in the district Shimla and represents elevation above 2200-3250 m 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. 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 through South-West 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.

Lahual and Spitti

The northern part of the state, which constitute Lahaul & Spiti, part of Chamba, part of Kullu, Shimla and Kinnaur district, experiences annual mean temperature below 14°C. As winter season starts from November and the temperature starts decreasing till minimum reached in January. Temperature again starts rising during the month of February and May and June are the hottest months.

Socioeconomic survey

The socioeconomic surveys were conducted in Kullu, Shimla and Lahual and Spitti regions of Himachal Pradesh to examine how apple farmers in Himachal Pradesh perceive climatic change. Weather data from 1986 to 2009 was analysed to examine the accuracy of perceptions of the farmers. Perception of climate change is structured for three valleys (Kullu, Lahual and 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 and Spitti) to know farmers perceptions regarding climate change and its impact on apple cultivation. Perceptions were made on basis of gathering data from farmers for two periods before 1995 and 1995 to 2006 of snowfall, temperature and rainfall changes.

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. The snow fall trends in past two to three decades were also calculated for 21 sites representing different elevations ranging from 1500 to 4000 m amsl located in Sutlej basins of Himachal Pradesh.

Chill unit (CU)

The Cumulative chill units' requirements of apple for Kullu and 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

Table 1: Farmers perceptions regarding climate change

(Percent multiple response)

Particulars	Theog region	Kullu valley	Lahaul and 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 2: Change in land use pattern, apple area and income from fruits per farmers in apple growing regions of H.P.

District	Land use pattern (Percent Orchard in total land holding)		Apple area(ha)		Income from fruits (Percent)	
	1995	2005	1995	2005	1995	2005
Lahaul & Spitti	1.93	4.34	0.48	1.09	17.2	29.1
Kullu	27.0	21.0	0.55	0.45	69.9	39.6
Shimla	22.8	21.7	0.62	0.60	59.3	32.8

accumulation (or chilling negation) as follows:

Temperature (°F) for 1 hour	Chill unit
< 34	0.0
35–36	0.5
37–48	1.0
49–54	0.5
55–60	0.0
61–65	-0.5
>65	-1.0

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.

RESULTS AND DISCUSSION

Farmers' perceptions

The socio-economic survey was conducted in Kullu, Shimla and Lahaul 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. 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 shortened and 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

Table 3: Cumulative chill units' trends (Mean monthly model) equations for different winter months at Kullu and Shimla

Month	Kullu	Shimla
November	Y=-14.35 X+788.7	Y=3.55 X+585.0
December	Y=-9.10 X+1034.1	Y=15.03 X+932.74
January	Y=-10.85 X+1159.3	Y=17.94 X+1164.3
February	Y=-13.28 X +1043.5	Y=14.96X+1085.6

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 during February and March is received mostly as a mixture of sleet and rain resulting in lower temperatures and late onset of spring season. The farmers also believed that winter period has shortened and there is delay in onset of winter season, number of chilling hours which ultimately affect the bud breaking. For normal pollination and fruit bearing conditions for an apple crop a snow level of 2.5 to 3 ft is required 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 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 (1500-2200 m amsl) 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 data (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 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 (2000 m amsl).

Climatic trends

Kullu valley

The climate change is apparent in this region due to a perceptible shift of apple cultivation to higher hills. The annual mean temperature in Kullu Valley showed an increase of 4.1°C in last two decades. During *rabi* season temperature showed an 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 270 mm. *Rabi/winter* season showed decreasing trend of rainfall @ 18 mm per year whereas *kharif* season showed increasing trends. Evaporation showed decreasing trends @ 14.5 mm annually during *rabi and 8.6mm kharif*. However, the decrease was more during *kharif* season.

Theog region

In the Theog valley (Shimla), the rainfall increase was more in in *rabi* season than *kharif* . Mean temperature showed increasing trend at the rate 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, however on the whole, the rainfall decrease was found at a rate of 27 mm/ year. Rainfall during September to February decreased unprecedented.

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 CU per year were decreased at Bajaura during November to February months (Table 3). The Utah model showed decrease of more than 6.4 chill units' hours (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. 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. Jindal and Mankotia (2004) reported that at least 1200 chilling hours are required for

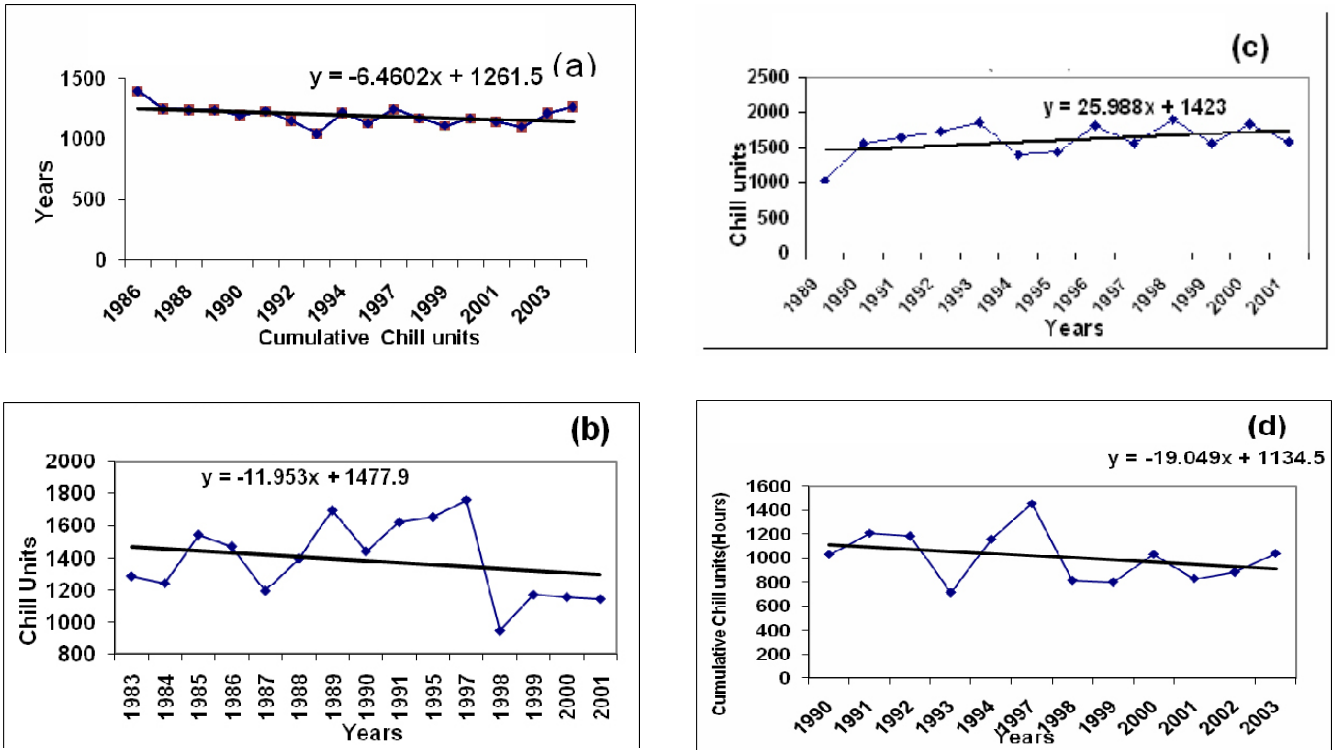

Fig. 1: Cumulative chill units (CU) trends at (a) Bajaura (b) Bhang (c) Dhundi and (d) Shimla

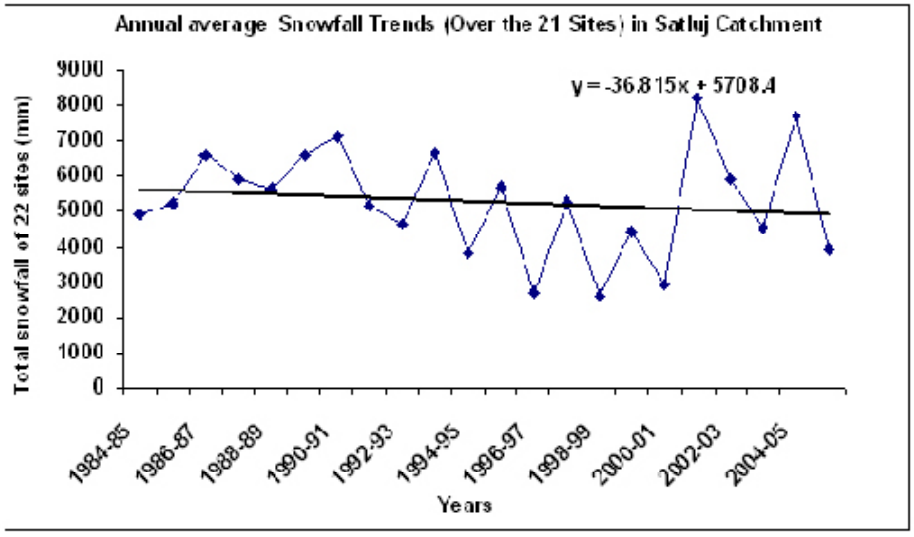

Fig. 2: Snowfall trends in Himachal Pradesh

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 amsl apple growing regions. Similar, analysis carried out for Shimla district (Fig.1) which also showed similar trend with regard to chill units. The data also exhibited the same trends of decrease of chill units. The decrease was 19.0 m units per year. The significant decrease in chill units was observed

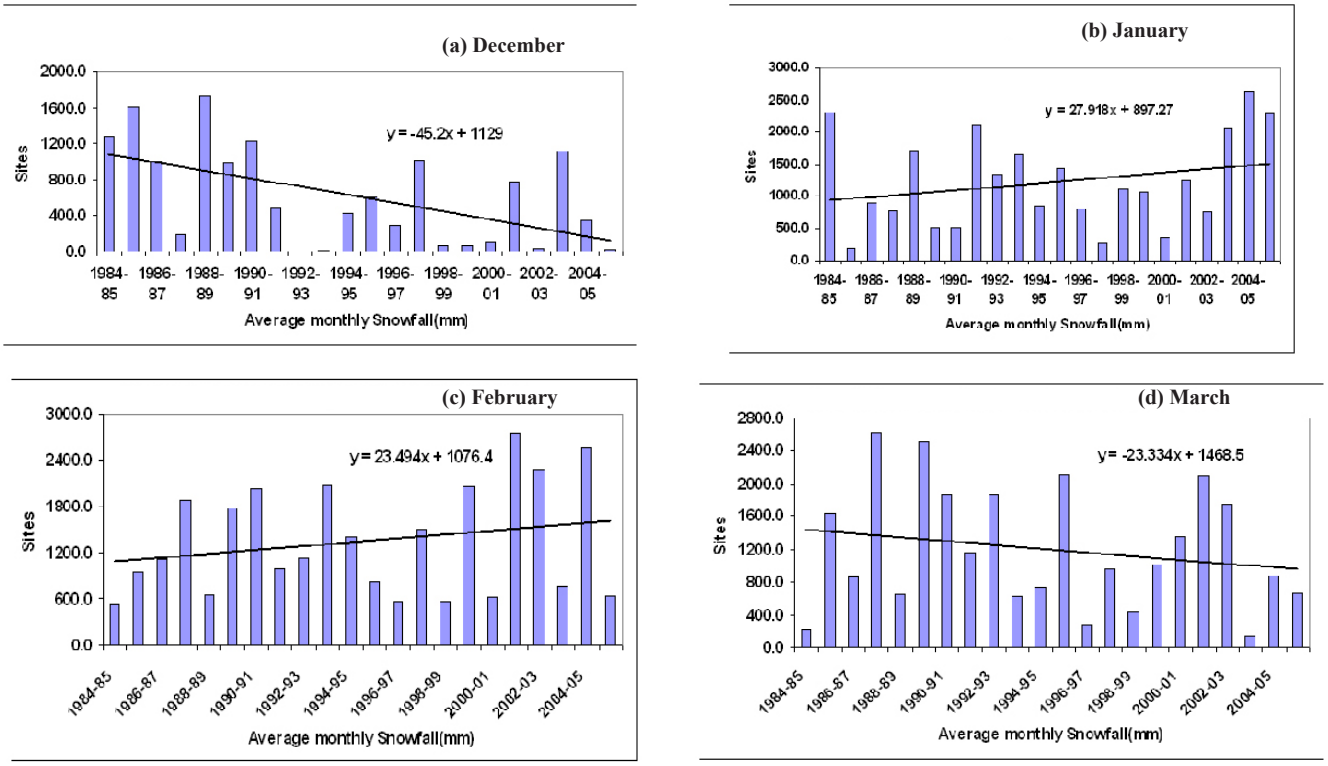

Fig. 3: Average snowfall trend for the months of (a) December, (b) January, (c) February, (d) March

during December to February in Shimla.

The snowfall trends in two recent decades over different sites representing elevations ranging from 2000 to 4000 m amsl showed a decrease of 36.8mm annually last 22 years averaged 21 sites (Fig.2). The decrease was more 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 past 22 years from 21 observation sites during September to December which is important for temperate crops. The snowfall showed increasing trends during January (27mm per year) and February (23mm) which revealed delay of snowfall (Fig. 3).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. The delay and early withdrawal of snowfall events might reflect in decrease in apple yield. The reason being such trends in snowfall occurrence in high altitude areas increased the opportunity of growing more crops during March to October. The decrease in snow fall during early winter season and early withdrawal of seasonal snowfall contributes towards the less cumulative chill units for apple.

CONCLUSIONS

The temperature in apple growing regions of the mountain state of Himachal Pradesh,India showed increasing trends whereas precipitation showed decreasing trends. The chill unit requirements of apple cultivation showed decreasing trends upto 2400 m amsl from Bajaura in Kullu at 1221 m amsl to Sarbo in Kinnaur at 2400 m amsl. The Dhundi observation station situated at 2700 m amsl showed increase of chill units of the order of 25.0 CUs per year. The increasing trends of chill unit at 2700 m amsl 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 and 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 situated in lower elevations. The income of the farmers increased more than 10 percent in Lahual and Spitti whereas it showed a decrease of more than 27 percent in Kullu and Shimla districts from

fruits in recent decade compared to 1995.

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