

**CLIMATE CHANGE IN APPLE GROWING AREAS OF KULLU,
DISTRICT- A CASE STUDY OF FARMER'S PERCEPTION**

THESIS

By

**ADITYA RANA
(S-2008-30-15)**

Submitted to



**CHAUDHARY SARWAN KUMAR
HIMACHAL PRADESH KRISHI VISHVAVIDYALAYA
PALAMPUR – 176 062 (H.P.) INDIA**

in

Partial fulfilment of the requirements for the degree

of

**MASTER OF SCIENCE IN BASIC SCIENCES
(DEPARTMENT OF BIOLOGY AND ENVIRONMENTAL SCIENCES)
(ENVIRONMENTAL SCIENCES)**

2010

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***Is there anything I can say,
anything I can give
or do for you.....
Because all that I am
all that I have
I owe to you.....
Affectionately dedicated to my***

BELOVED PARENTS



Dr. R.C. Chauhan
Professor (Environmental Sciences)


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(H.P) INDIA

CERTIFICATE-I

This is to certify that the thesis entitled “**Climate Change in Apple growing areas of Kullu, District- A case Study of Farmer’s Perception**”, submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science (Basic Sciences)** in the discipline of **Environmental Sciences** of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, is a bonafide research work carried out by **Ms Aditya Rana (S-2008-30-15)** daughter of **Shri Dharuv Chand Rana** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.


The assistance and help received during the course of this investigation have been duly acknowledged.

Place: Palampur
Dated: 12th July, 2010



(Dr. R.C. Chauhan) 12.7.2010
Major Advisor

CERTIFICATE-II

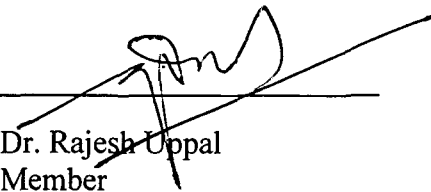
This is to certify that the thesis entitled “**Climate change in apple growing areas of Kullu, District- A case Study of farmer’s perception**” submitted by **Ms Aditya Rana (S-2008-30-15)** daughter of **Shri Dharuv Chand Rana** to the CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfilment of the requirements for the degree of **Master of Science (Basic Sciences)** in the discipline of **Environmental Sciences** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.



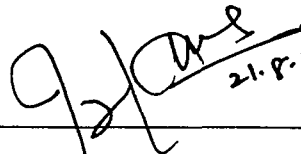
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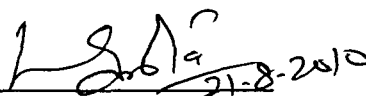
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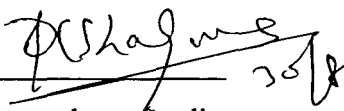
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Needless to say, all omissions and errors are mine.

Place: Palampur

Dated: 12 July, 2010


(Aditya Rana)

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ABBREVIATIONS USED

<u>Abbreviation</u>	<u>Meaning</u>
%	Per cent
°C	Degree Celsius
Anon.	Anonymous (used when author is not known)
<i>et al.</i>	et alii (and others)
etc.	et. Cetra (and others)
ha	Hectare
i.e.	id est (that is)
IPCC	International Panel on Climate Change
Km	Kilometer
m	Meter
mm	Millimeter
msl	Meters above sea level
p	Page
sq. km	square kilometer
<i>viz.</i>	videlicet (namely)
NARP	National Agriculture Research Project
NSO	National Statistical Office
UNFCC	United Nation Framework Convention on Climate Change

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ABSTRACT

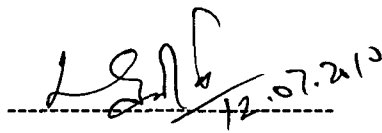
Present study entitled "Climate change in Apple Growing Areas of Kullu, District – A case Study of Farmer’s Perception" was conducted during August 2009 and January 2010. The study aimed at understanding the farmer’s awareness and perception of climate variability. A pre tested survey schedule was prepared to collect the detailed information from the apple growers regarding the climate change. The meteorological and apple area and production data of Kullu was also collected. Total 120 respondents were randomly interviewed to assess their perception of climate change. Most of the apple growers, revealed that reduction in snowfall, change in temperature, abrupt rainfall patterns and extreme weather phenomena i.e. hailstorms, droughts, torrential rains, floods, cloudbursts etc. can be ascribed to the decreased apple production. Meteorological data was used to obtain the temperature and rainfall trends. These trends showed an increase in temperature and decrease in rainfall and the similar pattern was also perceived by the farmers. Chill units showed a decreasing trend in the area when these were worked out using the UTAH model. The decrease in chill units due to an increase in temperature adversely affected the apple productivity. During the study period some of the strategic measures adopted by the farmers to combat the effects of climate change were also recorded.



Student
(Aditya Rana)



Major Advisor
(Dr. R.C. Chauhan)
12.7.2010



Head of the Department



INTRODUCTION

1. INTRODUCTION

Apples belong to the genus *Malus*, which is a member of the Rose family (Rosaceae), and have been cultivated throughout recorded history. Most table apples are of the species *M. domestica* or hybrids of it. The apple is believed to have originated in Europe or the temperate region of western Asia, although the related species known as crab-apples are indigenous in northern Asia, Europe and America. There are more than 7,500 known varieties of apples. Among the most common commercial apple cultivars are the "Red Delicious", "Golden Delicious", "Winesap", "Jonathan", "McIntosh", and "Gala". The "Granny Smith" is also popular, though tarter than the others; makes a good cooking apple (Anon. 2009).

Apple is one of the most important temperate fruit crops in India which accounts for about 10 per cent of the total fruit production of the country. Among all fruits, apple is the main crop of Himachal Pradesh occupying the place of pride in its economy with more than one hundred thousand hectares of apple trees across the state. However, decreased productivity of apple orchards in the recent years due to change in climatic conditions have become a serious concern of the growers in Himachal Pradesh. United Nation Framework Convention on Climate Change (UNFCCC) has defined climate change as a change of climate that is attributed directly or indirectly to human activity that alters the composition of global atmosphere and that is in addition to natural climate variability observed over comparable time periods. Environmental conditions play a key role in defining the function and distribution of plants, in combination with other factors. Climate change is known to have had enormous impacts on plant diversity patterns in the past and is seen as having significant current impacts. Climate change has important implications for nearly every aspect of life on earth, and effects are already being felt. Available data shows that air temperature near the earth surface rose by 0.74°C from 1906 to 2005 and scientists estimated it could be increased as much as 6.4°C on average during the 21st century (IPCC 2007).

The issue of climate change is one of the worst threats that puts serious question of the future of mankind. Changes in the atmospheric composition, mainly of greenhouse gases, threaten to bring about a substantial shift in the world's climate. The anthropogenic

and biogenic emissions of carbon dioxide and other radiatively active gases and aerosols modify the earth's atmosphere. This modification of the atmosphere has coincided with the mean surface air temperature of the earth increasing since the 1850s by about 0.05°C/decade.

If climatic factors such as temperature and precipitation change in a region beyond the tolerance of a species phenotypic plasticity, then distribution changes of the species may be inevitable (Lynch and Lande 1993). There is already strong evidence that plant species are shifting their ranges in altitude and latitude as a response to changing regional climates (Parmesan and Yohe 2003). The timing of phenological events such as flowering is often related to environmental variables such as temperature. Changing environments are therefore expected to lead to changes in life cycle events, and these have been recorded for many species of plants (Parmesan and Yohe 2003). Since, climate change will have profound and possible harmful impact on life, which can be attributed to human activities. The study of climate has become very important in recent times. The climate change impacts have been clearly deciphered by changes like dry and warm climate, change in snowfall and precipitation pattern (Bhagat *et al.* 2004). As one of the critical variables beyond our control, weather catches the interest of home gardeners, but to commercial farmers, weather fluctuations can imperil their very livelihoods.

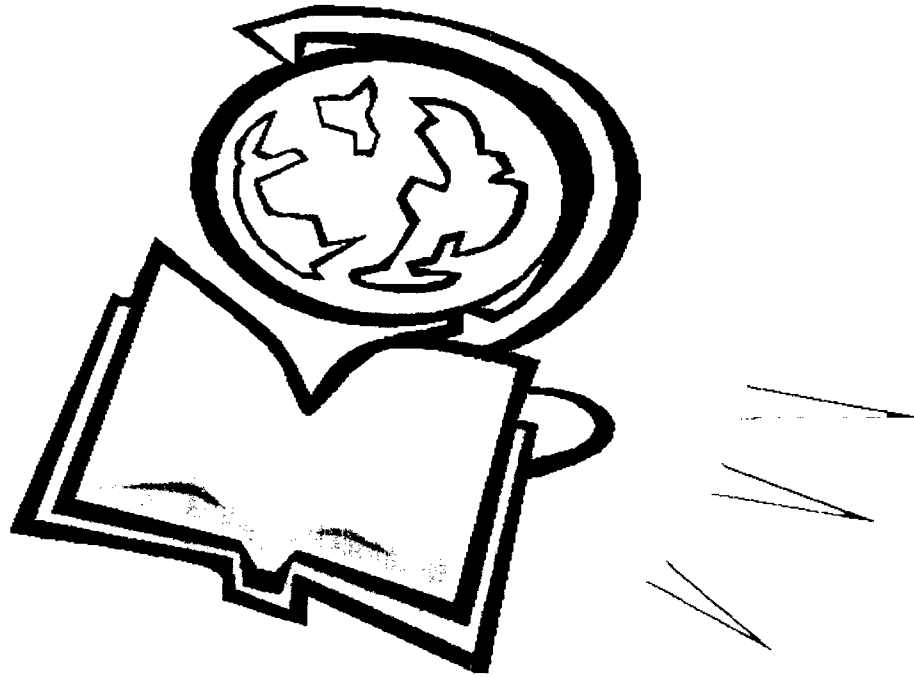
Apples require between 800 to 1,100 chilling hours of winter chill to properly set fruit. Climate change is impacting on the apple and pear industries, with increased climate variability and reduced chilling hours, which are necessary for quality fruit production. According to the National Statistical Office (NSO), accelerated climate change has decreased the production of apples, a temperate zone fruit. Cultivation, which amounted to 43,650 hectares in 1996, contracted to 29,204 ha in 2007, as many of the apple orchards in the north of the country came to halt.

Weather and climate data form a highly indispensable input to any plant growth and development. Climate data relations with plant productivity trends and projections help in the decisions and selection of enterprise planning and investments particularly in the face of climate change. Integrating the knowledge of weather and climate can optimize fruit production with maximum use of resources.

Mountainous areas of a Himalayan catchment like Kullu district in Himachal Pradesh assume importance because the impact of climatic variability on the extreme weather events and economic activities like agriculture tends to be quite pronounced in such environments. Further mountains present differential climate types within a small areal extent primarily because of its varying altitude. Hence, study of climatic variability and its effect in such areas helps in maximizing our knowledge on general subject of climate change itself. It has been seen that the Global Change is a multi-faceted issue incorporating direct and indirect effects of human activity. In this regard mountain environments are specifically important particularly the steep slopes found in these regions. Therefore, some of the sharpest environmental gradients are found in the mountains on the earth surface. In the present study Kullu district in Himachal Pradesh has been chosen as a typical high mountain environment exhibiting most of the climatic features of such mountainous areas. It is characterized by vertical zonation of eco-climatic zones controlled by decreasing temperatures with increasing elevation. It is also in transition from its pristine untouched stage to a rapidly developing economic zone.

Keeping in view the above considerations the present study entitled “Climate change in Apple Growing Areas of Kullu, District – A case Study of Farmer’s Perception” was undertaken with the following objectives:

- (i) To study the farmer’s perception of apple production and shift in Kullu District.
- (ii) To work out and correlate the effective apple chill units (UTAH model) with productivity.



REVIEW
OF
LITERATURE

2. REVIEW OF LITERATURE

Approximately 200,000 hectares of land in Himachal Pradesh is under horticulture cultivation, which yields approximately half a million tonnes of different kinds of fruit. The state earns more than Rs. 25 billion from cultivation of fruits and vegetables (Gulati 2009).

Temperate fruits occupy about 63.5 per cent of total area under fruits in H.P. Apple is the state's main fruit crop and is being grown in nine out of twelve districts. Besides apple, other fruits like pears, peaches, cherries, apricots, almonds and plums are the major commercial crops of Himachal Pradesh. Apple occupies about 41 per cent of total area under fruits and 64.1 per cent of the area under temperate fruits. Apple dominates the fruit production and contributes about 88 per cent of the total fruit production and 95 per cent of temperate fruit production in the state (Jindal *et al.* 2001).

Decreased productivity of apple orchards in the recent years has become a serious concern of the growers in Himachal Pradesh. The chilling requirement i.e. the amount of cold needed by a plant to resume normal spring growth following the winter period, is not sufficient. The dominant factor, which influences yield, is climate besides soil, cultivars, rootstocks, spacing and cultural management practices. Whereas all these factors influencing yield are manageable, the climatic factors are beyond control and as such largely determine success or failure of the crop in particular area. The research work related to the present investigation is reviewed briefly under the following sub headings:

2.1 Climate change

2.2 Impacts on productivity

2.3 Biodiversity shift

2.4 Chill units

2.1 Climate Change

Over the past few decades, the man-induced changes in the climate of earth have become the focus of scientific and social attention.

Ruggiero (1955) studied flowering in 70 apple varieties in relation to winter temperatures (April-August) in 1935, 1936 and 1937. Conclusions reached were:

(1) Flowering was delayed when the number of "cold hours" (below 7 degrees C) was below normal, and advanced when it was above normal, especially in late varieties. (2) The interval between the inception of flowering in the earliest and in the latest varieties was less in years in which the number of cold hours was above normal. (3) The duration of flowering was less in late than in early varieties, varied widely from year to year in early varieties and varied little from year to year in late varieties. (4) In years in which the number of cold hours was above normal the duration of flowering was short and showed the least variation from variety to variety. (5) There was a negative correlation between the number of cold hours before the inception of flowering and the duration of flowering.

Awasthi *et al.* (1986) have indicated that irregular bearing behaviour of Starking Delicious is largely influenced by climatic conditions. The rains and hails during flowering adversely affect the fruit set whereas moderate temperature of 20 degree C with relatively low rains during flowering results in good fruit set.

Atkins and Morgan (1990) calculated full-bloom date of pip and stone fruit trees in Hawkes Bay, New Zealand, based on the accumulation of chill units necessary to break dormancy, and the number of post-dormancy heat units. Twenty years of full-bloom dates for 7 varieties were correlated with hourly temperatures, derived by fitting a sine-curve with shifted phase to daily maximum and minimum temperature data, and the model was used to predict the effect on full-bloom dates of 3 temperature change scenarios:- Daily min. and max. both increased by 1.5 degrees C (S1), max. increased by 3 degrees C, min. unchanged (S2), and summer min. and max. increased by 1 degrees C, winter min. and max. increased by 2 degrees C (S3). All 3 scenarios delayed full bloom of apples and pears, with S2 giving the greatest delay, and the most years with insufficient chilling. However, the full-bloom of Golden Queen peach, with a lower chilling requirement, was advanced by 7, 4 and 9 days by S1, S2 and S3, respectively. It was suggested that the warmer temperatures may give inferior flower quality, but they improved growing conditions, resulting in greater variability.

According to study done by Jindal *et al.* (2001) several factors can be attributed to declining trends in productivity like expansion of apple cultivation to marginal areas, monoculture of Delicious varieties, declining standards of orchard management and

fluctuating abnormal climatic conditions. According to the study made the fruit production and meteorological data during past 5 years indicated great role of the abnormal climatic factors during flowering and fruit development in lowering apple productivity.

Jonaitis (2001) carried out a study to analyse the dynamics of the day's absolute maximum and minimum temperatures in Vilnius, Lithuania, in different years of the 20th century and its effect on the emergence rate of adult apple ermine moths (*Y. malinellus*) in the last three decades. During the 20th century, the range of the absolute minimum and maximum temperatures of the day varied from -35 to +35 degrees C. A large number of absolute maximum temperatures (up to 56%) and minimum temperatures (58%) were registered in the second half of the 20th century. The intervals of temperature fluctuations were also higher at the end of the 20th century. The changes in the course of emergence of adult apple ermine moths and the trends of the long-term dynamics of the day's temperatures were thoroughly investigated during 28 vegetative seasons of 1973 to 2000. The period of the emergence of adult apple ermine moths lasted from 15 to 35 days. The time of emergence varied from 0 to 25 days. The emergence of adult apple ermine moths occurred from the end of the first ten-day period of June till the middle of the first ten-day period of August. Earlier emergence of adult apple ermine moths was recorded in 1984. Since 1998, the emergence of adult individuals has occurred even earlier.

Vedwan and Rhoades (2001) studied the perception of climate change by farmers in the Western Himalayas of India. It was concluded that climatic changes have altered the blossoming, bearing and hence the apple fruit yield. Climate changes have also affected the fruit quality and the degradation in distinct patterns. It was also remarked that apple belt is moving up in the Kullu valley. Due to climate change there was a gap noticed between the flowering periods of male and female trees. The pine plantations have caused a marked change in weather. It flowers at the same time as apple and produces a lot of pollen which interferes with the pollination process in apple. It was also remarked that Bajaura was once the starting point for apple but now there is no apple.

Bukovcanova and Mezey (2004) determined the phenology of the summer apple cultivar James Grieve Red, spring cultivar Prima and winter cultivar Golden Delicious as affected by daily average temperature, global radiation, average air temperature and

rainfall. The phenological phases of all the cultivars tested were dependent on the average daily temperature and global radiation, and were less dependent on rainfall. Cultivar James Grieve Red was picked 23 days earlier in 2003 compared to 1993-97, whereas cultivars Prima and Golden Delicious were picked 15 days earlier in 2003 compared to 1993-97.

Crepinsek and Kajfez (2004) reported that a 1 degrees C rise would shorten the period from leaf appearance to the start of ripening in apple trees by 2 days, or by 4-5 days with a 3 degrees C rise. Similar results were obtained for plum trees. However, for grape vines, a 1 degrees C rise would shorten the period by 1-2 weeks in cultivars with a growth period of 150-200 days and an active temperature sum requirement of 2300-3000 degrees C.

Kajfez (2004) using data from 1955 to 2000, the effect of climate on phenological phases (peak flowering and appearance of first ripe fruits) was determined for plum, apple and hazel. Meteorological data were obtained from weather stations throughout Slovenia (Celje, Ilirska Bistrica, Lesce, Ljubljana, Maribor, Murska Sobota, Novo Mesto and Ratece). Due to the effects of global warming, development occurred earlier over time, with flowering and ripening advanced by 2-7 days every 10 years. Based on a scenario of continuing warming of the Slovenian climate, a model for predicting flowering time in fruit trees growing in the Ljubljana area was developed based on expected rises of 1, 2, 3 or 4 degrees C in the early months (February-April) of the year. The model predicted that plum trees would show the greatest response to temperature rises, with a 1 degrees C rise advancing flowering date by 1 week in comparison with 1965-90, while for pear the advance would be 4 days.

Wolfe (2005) evaluated spring phenology changes from 1965 to 2001 in northeastern USA utilizing a unique data set from 72 locations with genetically identical lilac plants (*Syringa chinensis*, clone "Red Rothomagensis"). A previously validated lilac-honeysuckle "spring index" model to reconstruct a more complete record of first leaf date (FLD) and first flower date (FFD) was also utilized for the region from historical weather data. In addition, mid-bloom dates for apple (*Malus domestica*) and grape (*Vitis vinifera*) collected at several sites in the region during approximately the same time period were also examined. Almost all lilac sites with significant linear trends for FLD or FFD versus year had negative slopes (advanced development). Regression analysis of

86per cent of the observed variability in flowering. All three models simulated similar time-course changes in the duration of the chilling effect at all three locations [i.e., a mean increase in the duration of this effect (by 3-5 d) since the end of the 1980s]. Consequently, it suggested that the duration of the heat effect had decreased (10-13 d) to explain the advance in flowering time. Hence, global warming has, simultaneously, exerted two opposing effects in France from 1976 to 2002: (i) a slower mean rate of completion for the chilling requirement, and (ii) a higher mean rate of completion for the heat requirement.

Bhusal (2009) carried out research in Lumle and Ghandruk VDC of Kaski district (Nepal). The study examines how farmers' perceptions regarding climate change correspond with temperature and rainfall data recorded at meteorological station in Lumle and documents local adaptation responses to the impacts of climate change, and its variability. Impacts were observed contributing to loss of species and local landraces, declining productivity and yield, outbreak of diseases and pests, rapid encroachment by invasive species, and emergence of human diseases. Hence, local knowledge, practices and innovations are important elements for community-based coping and adaptation mechanisms.

Blanke and Kunz (2009) examined the effects of climate change on pome fruit phenology at Klein Altendorf in the Rhineland fruit-growing region in the West of Germany, using 50 years of weather data and phenology records, including beginning of flowering (F1), full bloom (F2), harvest date and leaf drop of apple and pear, with the following results: 1. Fifty years of weather records and pome phenology data showed a distinct separation between a first phase (1958-1987), which was 0.42 degrees C cooler, and a second phase (1988-2007), which was 0.66 degrees C warmer than the long-term, 50 year temperature average of 9.4 degrees C, indicating the start of the climate change in 1988. 2. Annual average temperatures rose from 8.8 degrees C to 10.2 degrees C, i.e. by 1.4 degrees C over 50 years at Klein Altendorf, which affected the apple phenology. A comparison of the second phase (average temp. 10.1 degrees C) with the first phase (9.0 degrees C) resulted in a temperature rise of 1.1 degrees C; the temperature rise in the winter (1.2 degrees C) was greater (by 0.2 degrees C) than in the summer (1.0 degrees C). This temperature rise in the last 20 years (second phase, 1988-2007) was more

pronounced in the winter months January (+1.7 degrees C) and February (+1.8 degrees C) than in the spring months March and May both with +1.4 degrees C leading to enhanced early post-bloom fruit drop, and July (+1.3 degrees C) and August (+1.6 degrees C). 3. Annual precipitation remained constant at ca. 600 mm with an increase in February, March and April and an equivalent decrease in May (-10 mm) and July (-7.0 mm) during fruit development. 4. Soil temperatures increased by 2.6 degrees C and hence greater than the air temperature (+1.45 degrees C) over the last 50 years; this increase was most pronounced between January and March. 5. Minimum air temperatures increased also by 2.6 degrees C from -6.1 degrees C in March 1958 to -3.5 degrees C in March 2007. The more advanced flowering, brought about by warmer January to March temperatures, now coincides with late spring frosts, thereby maintaining the risk of yield loss due to spring frost in April, a month when the minimum temperature still continues to drop. 6. On average, apple and pear flowering was 10 days earlier without extension of the flowering period after warm winters and appeared more severely affected than the harvest period (3-9 days) and leaf drop (2-3 days earlier) with distinct varietal differences. The apple flowering period was 4 days shorter in the last 10 years and reduced from 12-15 days to 8-10 days. Early maturing cultivars ripened 3-4 days earlier, while late maturing cultivars ripened 8-12 days earlier.

Eccel *et al.* (2009) the general trend towards earlier flowering dates of many temperate tree species is likely to result in an increased risk of damage from exposure to frost. A phenological model of apple flowering was applied to a temperature series from two locations in an important area for apple production in Europe (Trentino, Italy). Two simulated 50-year climatic from the HadCM3 general circulation model were statistically downscaled to the two sites. In the phenological model, the heat requirement (degree hours) for flowering was parameterized using two approaches; static (constant over time) and dynamic (climate dependent). Parameterization took into account the trees adaptation to changing temperatures based on either past instrumental records or the downscaled outputs from the climatic simulations. Flowering dates for the past 40 years and simulated flowering dates for the next 50 years were used in the model. A significant trend towards earlier flowering was clearly detected in the past. This negative trend was also apparent in the simulated data.

2.2 Impacts on Productivity

Climate change has a significant impact on the productivity of various crops throughout the world. Few studies done in this aspect have been listed here.

Climatic change may have an impact on the productivity of conifers by influencing the morphology (size and surface characteristics) and function (capacity for gas exchange) of conifer needles. Apple *et al.* (2000) tested the responses of needles to climatic variables, Douglas fir (*Pseudotsuga menziesii*) saplings were grown in sunlit controlled environment chambers at ambient or elevated (+200 parts per million above ambient) CO₂ and at ambient or elevated temperature (+4 degrees C above ambient). Needle characteristics, including length, width, area, stomatal density (stomata per mm²), per centage of stomatal occlusion, and the morphology of epicuticular wax, were evaluated. Needle function was evaluated as stomatal conductance to water vapour and transpiration. Needle length increased significantly with elevated temperature but not with elevated CO₂. Neither elevated CO₂ nor elevated temperature affected stomatal density or stomatal number in these hypostomatous needles. Epicuticular wax was less finely granular at elevated than at ambient temperature and was similar in appearance at elevated and ambient CO₂. Stomatal conductance and transpiration increased with elevated temperature and associated increased vapour pressure deficit; however, neither conductance nor transpiration was affected by elevated CO₂. These results indicated that simulated climate change influences Douglas fir needle structure and function.

Partap and Partap (2002) studied the various problems concerning apple productivity in apple valleys in Hindu-Kush Himalayas. One such problems being the climate change. It was concluded in the study that temperate fruit belt is moving upward and productivity of apple, which is the major fruit crop in Himachal Pradesh, has been adversely affected.

Singh (2003) discussed the changing weather pattern to be the most important single factor responsible for declining apple productivity in Himachal Pradesh. Reduction in annual snowfall and fluctuating temperatures during flowering period adversely affects the apple productivity. The occurrence of hails in many areas also contributes to low productivity.

Gautam *et al.* (2004) studied the decreasing trend in productivity of apple orchards, and found that in the last decade changing climate scenario has caused a serious concern to the fruit growers and planners of the country. Several factors like inadequate pollinizer proportion, reduction in natural population of pollinating agents, inadequate winter chilling, occurrence of spring frosts, hails and gales, nutrient deficiencies, droughts etc. are the main factors leading to poor fruit setting in Delicious. More than 70 per cent of orchards have less than 20 per cent pollinizer proportion, whereas a minimum of 25 per cent is required in our agro climatic conditions for good fruit set. Moreover, there is a lack of diversity in pollinizing cultivars as mainly Golden Delicious and Red Gold are being predominantly used which have attained biennial bearing tendency and their bloom seldom coincides with the flowering period of Delicious cultivars. The population of natural pollinators has gone down due to indiscriminate use of pesticides and deterioration in ecosystem. Managed bee pollination is very limited and available bee hives during bloom hardly meet 2-3 per cent of the demand. All these factors have lead to poor fruit setting of Delicious.

Sharma *et al.* (2004) conducted studies at two locations (Seobagh and Larankelo) in Kullu District, Himachal Pradesh, India to evaluate the effect of bee pollination and pollinizer proportion on apple productivity. *Apis cerana* colonies were kept in apple orchards in two different orchards at both locations, i.e. one with insufficient pollinizer proportion and another with sufficient pollinizer proportion. Observations pertaining to increase in bee visits, fruit set and fruit yield in comparison with apple orchards with natural crop pollination were recorded. Results revealed an increase in bee visits in experimental orchards along with significant increases in fruit set and fruit yield. However, the increases in fruit set and fruit yield were significantly higher in orchards with sufficient pollinizers compared with those with insufficient pollinizer proportion. There was significant increase in fruit yield in the orchards where bees were kept. At Larankelo, increases of 10.83 and 53.8 per cent in apple yield were recorded in 2000 in orchards with sufficient and insufficient pollinizer proportion due to placement of *Apis cerana* colonies. The respective increases in apple yield in 2001 were 39.50 and 24.40 per cent.

Belliveau *et al.* (2007) compared the findings of two studies on farmers' vulnerability to climate and other risks, completed in British Columbia's Okanagan Valley between the fall of 2002 and the summer of 2004. Reflecting the agricultural

character of the Okanagan region, the studies presented target apple and (wine) grape producers, respectively. Findings point out the various climate and non-climate risks that producers identify as characterizing "bad years" and the farm-level adaptations employed to manage the associated risks. The chapter concludes by discussing the meaning of these results in terms of producers' capacities to adapt to multiple risks and the nature of grape and apple growers' vulnerabilities.

2.3 Biodiversity Shift

Biological diversity is under serious threat due to global warming induced climate change. Species not able to cope with this change may develop spatial and temporal changes.

Sugiura and Yokozawa (2004) studied the impact of global warming on the production of apple (*Malus domestica*) and satsuma mandarin (*Citrus unshiu*) in Japan. The annual mean temperature was used to simulate possible changes in favourable regions for the cultivation of apple and satsuma mandarin. The temperature ranges assumed to be appropriate for fruit production were 6 to 14 and 7 to 13 degrees C for apples and 15-18 degrees C for satsuma mandarins. The database of Climate Change Mesh Data (Japan) was used to calculate annual mean temperatures under the climate change scenario, derived from four Atmosphere-Ocean General Circulation Models (AOGCM) at all 10x10 km mesh. It was predicted that the favourable regions to cultivate apples and satsuma mandarins will gradually move northward. In 2060s, the plains of central Tohoku will be unfavourable for apple cultivation, while most of Hokkaido will be suitable. The plains of northern Tohoku are predicted to attain the annual mean temperatures higher than those of the current main producing districts. By 2060s, the favourable areas for satsuma mandarin production will possibly move from the southern coastal sites to inland areas of western and southern Japan, the plains of Kanto and the littoral zones of the Japan Sea in the central and western Japan and in southern Tohoku. Therefore, global warming will greatly affect the cultivation environment of apples and satsuma mandarins in Japan by the middle of the 21st century.

Hanewinkel *et al.* (2009) evaluated the economic effects of a predicted shift from Norway spruce (*Picea abies* (Karst)) to European beech (*Fagus sylvatica* (L)) for a forest area of 1.3 million ha in southwest Germany. The shift was modelled with a generalised

linear model (GLM) by using presence/absence data from the National Forest Inventory in Baden-Württemberg, a digital elevation model, and regionalised climate parameters from the period 1970 to 2000. Two scenarios from the International Panel on Climate Change (IPCC) (B1, A2) for three different time scales (2030, 2065, and 2100) were investigated. The GLM predicted a decrease of the suitable area for growing Norway spruce between 21 per cent (B1, 2030) and 93 per cent (A2, 2100) in comparison to 2000. This corresponded to a reduction in the potential area of Norway spruce from between 190,000 and 860,000 ha. The financial effect of this reduction in area was then evaluated by using a classical Faustmann approach, namely the land expectation value (LEV) as an economic parameter for forests of Norway spruce versus European beech. Underlying cash flows were derived from a distance dependent, single-tree growth simulator (SILVA) based on data for prices and costs of the year 2004. The sensitivity of these results to changing interest rates, risk levels, and rotation lengths was estimated. Results suggested that managing forestland for profitability will be increasingly difficult under both climate scenarios.

2.4 Chill units

Deciduous fruit trees need a certain amount of cold (chill) during winter in order to break dormancy and start flowering and growing in spring. If trees get insufficient winter chill they may experience delayed and uneven flower and leaf bud development.

Jindal and Mankotia (2004) investigated the influence of winter temperatures on effective chill units, physiological changes associated with bud dormancy of apple. The effective chill units were calculated using the UTAH model. It was observed that with the increase in chilling exposure the days required for bud break were reduced.

Wrege *et al.* (2006) studied the impact of increasing air temperatures on the number of chilling hours of State of Rio Grande do Sul, Brazil. It was indicated that with the increment of few degrees rise in temperature there would be substantial decrease in the number of chilling hours, leading to a condition of practically not enough chilling hours for growing temperate fruits in Rio Grande do Sul.

The deep insight into past literature clearly signifies the alarming rates of climate change not only in terms of horticulture but in forestry as well. Global warming is adversely affecting the crops productivity in the various regions in India and other countries as well. Kullu district is facing the adverse impacts of climate change with most of the impacts on the apple growers. Therefore, this study based on local people's perception is an endeavour which may provide methods of assessing climate change impacts and adaptation on livelihood of the local people.



MATERIALS
AND
METHODS

3. MATERIALS AND METHODS

An apposite selection and application of scientific methodology is a pre-requisite for conducting any investigation as it adds to meticulousness, consistency and authenticity of the findings/ facts relating to the research problem and the present study is no exception. Therefore, this chapter is devoted to explain the methodology used in the present study. This includes the selection of the study area, data collection technique and analytical framework employed to draw inferences.

Materials and methods have been discussed under following subheadings:

- 3.1 Study area
- 3.2 Physiographic features of the study area
 - 3.2.1 Area
 - 3.2.2 Agro-climatic conditions
 - 3.2.3 Agro-ecological situation
- 3.3 Study Site
- 3.4 Data collection
 - 3.4.1 Survey schedule
 - 3.4.2 Primary data collection
 - i. Demographic parameters
 - ii. Climatic trends
 - 3.4.3 Secondary data collection
- 3.5 Chill Unit Calculation Model Used
- 3.6 Analytical framework
- 3.1 Study area**

The present study has been undertaken in the Kullu District of Himachal Pradesh which comprises the apple belt in the state and is famous throughout India for its apples. The name kullu traces its origin from the word “kullut” also known as “the valley of

village Gods". The geographical extent of the district is between 30°51'00" North latitude and 77°06'04" East longitudes. Beas and Satluj are the principal rivers of the district and entire drainage of the District is received by the two rivers. The economy of the people in the Kullu district is basically agrarian with 80 per cent of the people are engaged in agrarian activities. Agro-climatic conditions prevailing over the area provide ideal conditions for the production of temperate and sub tropical fruits like apple, peach, plum pear, almonds, walnuts etc. are being made to set up orchards in the district (Chauhan and Srivastava 1998).

3.2 Physiographic features of the study area

3.2.1 Area

The total geographical area of the District is 5503 sq.km. The altitude of the District ranges from 500-5000 m above the mean sea level, but the habitation is only up to 3500 m. The District comprises of physiographic areas viz., Ujhi, Lug, Rupi, Kharahal and Seraj areas. There are five developmental blocks in the District, namely, Kullu, Naggar, Banjar, Ani and Nirmand (District Agricultural Plan 2009).

3.2.2 Agro-climatic conditions

The District is characterized with cold dry weather. The maximum temperature varies from 15.8°C in January to 32.8°C in June, whereas the minimum temperature ranges from 21.1°C in July to as low as 0.7°C. The upper regions experience snow and sleet fall while rains are confined to lower heights. The natural calamities such as, flashfloods, cloudbursts and droughts are common and frequent and have caused heavy losses to the farmers during the past years (District Agricultural Plan 2009).

3.2.3 Agro-ecological situation

Kullu District falls under two agro-climatic zones i.e., mid hill sub humid zone (Zone II) and high hill wet temperate zone (Zone III) as identified under NARP.

In the 1960s and 1970s, the economy in the valley underwent a transformation from subsistence agriculture, based on the cultivation of cereal crops, to commercial horticulture particularly apple production. The rapid changes occurring in the valley included, in addition to the expansion of horticulture, increase in tourism, literacy rates, income levels, electrification, and other indicators of development (Verma and Pratap 1992).

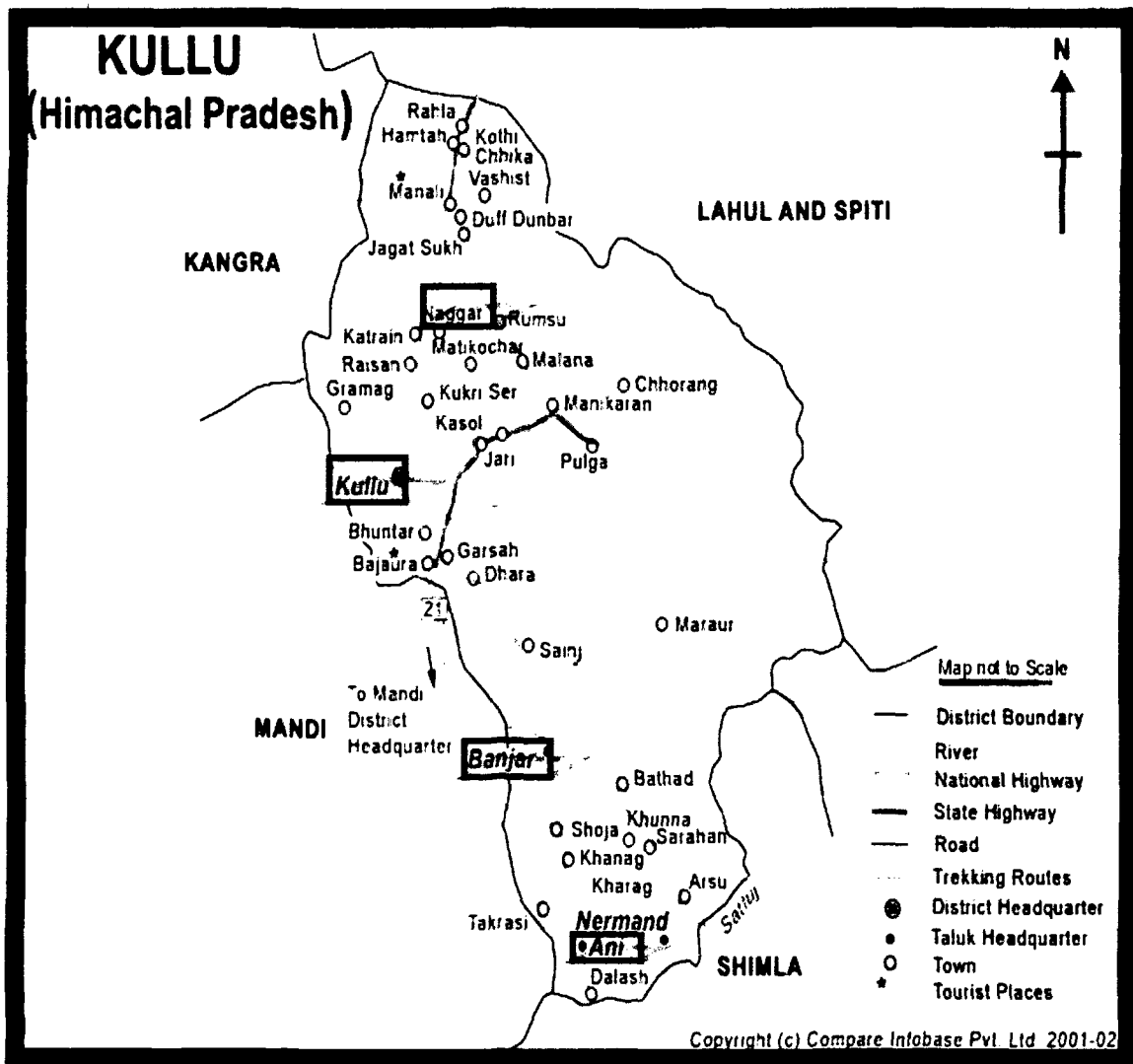


Fig 3.1: Map of the Kullu District

3.3 Study Site

Four blocks Kullu, Banjar, Naggar, and Ani of the District representing different elevation and are dominant by the apple cultivation 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.

3.4 Data collection

Both primary and secondary data were used in this study. The primary data was generated through a specially prepared schedule by questionnaire method from the sampled apple growers in four blocks to study the farmer's perception of apple production and shift of temperate fruit belt. Thirty farmers from each region comprising small, marginal and large farmers were selected to know farmer's perception regarding climate change and apple productivity.

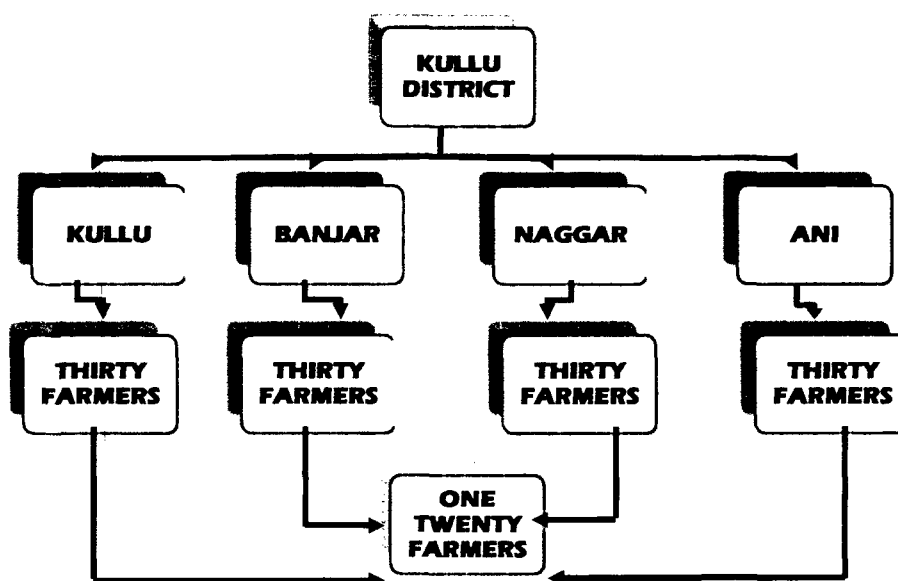


Fig 3.2 Data collection

3.4.1 Survey schedule

A survey schedule was prepared for collection of detailed information from the apple growers. The questionnaire includes the structured questions on different aspects to extract the detailed information on climate change, its impacts on apple productivity, apple quality, shifting trends, extreme weather phenomena and strategic measures to combat the change (Appendix- I).

3.4.2 Primary data collection

The data for present study was collected through pre tested schedule by personal interview method. The study aimed at understanding the impact of climate change and variability and the resulting socio-economic responses which take into account farmer's awareness of weather fluctuations.

Growers were asked about apple production during the last several years. Subsequently, they were asked about what, in their view, explained the variability in yields. If they mentioned climate as one of the variables, they were then questioned about the ways in which they perceive climate to have changed, any reasons underlying the change, as well as their response to the change. Focus was laid on the relatively clear and shared perceptions of climate and then traced the linkages to a body of local knowledge, including cultural notions of risk and vulnerability and the subsequent response of the apple growers. The information was gathered on following aspects:

i. Demographic parameters: The information was drawn from the apple growers which includes data on age, family size/structure, education and farming experience.

ii. Climatic trends: Various climatic parameters were taken into consideration for the study. Temperature trends, rainfall patterns, snowfall trends, extreme weather phenomenon were main parameters studied. Changes in housing and clothing pattern, changes in the planting; flowering and fruiting time of apple fruit, source of water, pest infestation, introduction of new varieties, changes in appearance and taste and quality of apples, effect on pollinators, decrease in apple production, change in choice of crops, shift of orchards were used to draw useful inferences.

3.4.3 Secondary data collection

The daily maximum and minimum temperature and rainfall data was collected from the records of Hill Agricultural Research and Extension Centre at Bajaura that were maintained for the period of twenty five years i.e. 1985 to 2009. The temperature data was also used to calculate chill units.

Apple area and production data from 1985 to 2009 was collected from the Deputy Director, Horticulture, Kullu to be correlated with the chill units.

3.5 Chill Unit Calculation Model Used

Apple fruit trees need a certain amount of cold (chill) during winter in order to break dormancy and start flowering and growing in spring. If trees get insufficient winter chill they may experience delayed and uneven flower and leaf bud development. This in turn can cause a reduced crop, smaller fruit size, uneven size distribution, a long harvest period, poor fruit quality and the development of vigorous shoots.

The effective apple chill units were worked out and correlated with productivity using UTAH model (Byrne and Bacon 1992) because it introduces the concept of relative chilling effectiveness and negative chilling accumulation (or chilling negation).

UTAH Model

1 hour below 32 degrees F = 0.0 chill unit

1 hour 35-36 degrees F = 0.5 chill units

1 hour 37-48 degrees F = 1.0 chill units

1 hour 49-54 degrees F = 0.5 chill units

1 hour 55-60 degrees F = 0.0 chill units

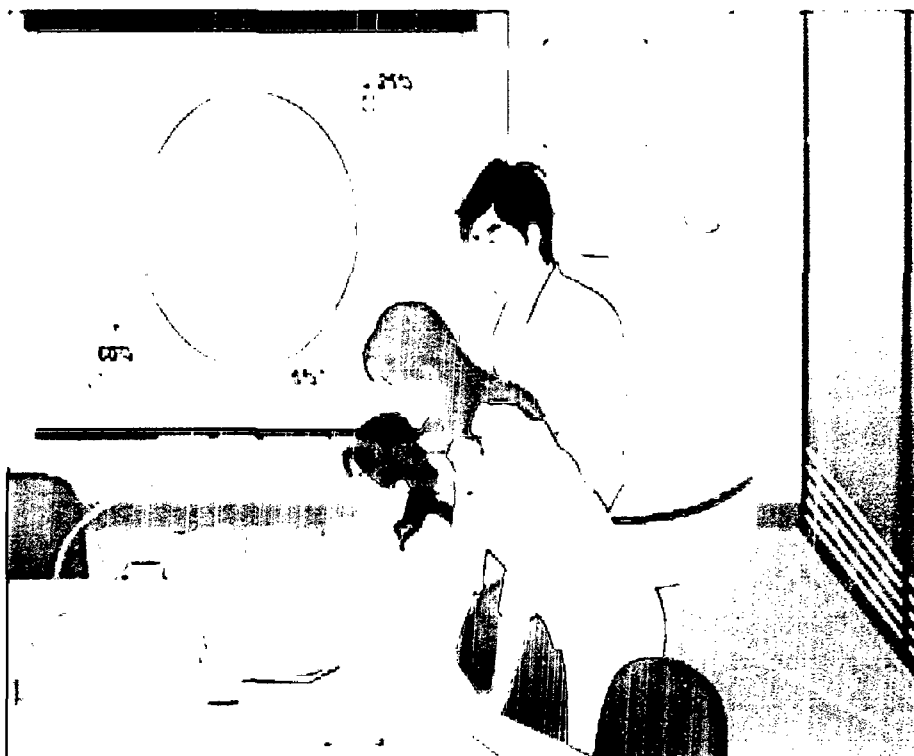
1 hour 61-65 degrees F = -0.5 chill units

1 hour >68 degrees F = -1.0 chill units

3.6 Analytical framework

Analytical techniques adopted in any scientific investigation form the foundation of scientific enquiry. This is because the fidelity and validity of the scientific findings of an investigation depend on the appropriateness of the technique employed. To meet out the objectives of the present study, both tabular and statistical tools were employed for analysis and interpretation of data.

Climatic data recorded at meteorological station (trends and variability) was used as a tool to assess local people's perceptions of climate change and variability. Tests were undertaken for linear trend in annual means and seasonal means of temperature and rainfall at the Bajaura station. Descriptive statistics for simplistic presentation based on summary counts of the questionnaire structure were used to provide insights into farmer's perceptions of climate change and variability. Farmer's perceptions of climate change were assessed by comparing local rainfall and temperature data trend with the responses given by the farmers.



RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

The results obtained from the present study entitled "Climate change in Apple Growing Areas of Kullu, District – A case Study of Farmer's Perception" have been presented in this chapter. The farmer's perception and various climatic parameters to relate their perception of climate change have been discussed in detail. Efforts have been made to present the findings in orderly and logical manner and the results are discussed in this chapter under following subheadings:

4.1 Farmer's perception on climate change

4.1.1 Temperature

4.1.2 Rainfall

4.1.3 Snowfall

4.1.4 Extreme weather phenomena

4.1.5 Adaptation measures

4.2 Productivity trends

4.3 Chill units trends

4.4 Correlation studies

4.1 Farmer's perception on climate change

Perception is the process by which information or stimuli from our environment is received and transformed into psychological awareness (Ban and Hawkins 2000). This varies with the individual's past experiences and present sets or attitudes. During the present study all the respondent farmers in the four blocks selected were exclusively questioned regarding the change in climate which they have come across in the last few years. The survey was conducted from August 2009 to January 2010.

4.1.1 Temperature

There was a perception that the temperature distribution had undergone a significant shift in addition to an overall increase in temperature. The results revealed that 95 per cent of local people interviewed perceived long-term changes in temperature. While, 100 per cent perceived that temperature had been increased. 100 per cent of the

farmers in all the four blocks i.e. Kullu, Naggar, Banjar, Ani perceived that summer season was prolonged and temperature has also gone up in this season in recent years (Table 4.2).

Majority of the respondents (100%) in Kullu block, 83 per cent in Banjar, 97 per cent in Naggar and 80 per cent in Ani block perceived that the duration and the intensity of cold in winters have decreased. Earlier situation like low temperature favourable for effective chill accumulation, good flowering and hence, good production now restricted only to higher altitudes. Orchardists were of the opinion that apple orchards are neither productive nor economically viable in lower Kullu Valley area due to rise in temperature (Table 4.2).

Majority of the farmers to the tune of 90 per cent in Kullu and Ani block reported temperature above normal during winters. Whereas, such effects were less felt by the respondents in other blocks. Only 67 per cent people in Banjar and 30 per cent in Naggar block professed higher temperature than usual in winter. However, some respondents to the tune of 33 per cent belonging to higher altitude (1300-2700 msl) of Banjar and about 40 per cent belonging to Naggar at higher elevation (1500-2800 msl) were still experiencing the spell of very low temperature in the winter months (Table 4.2).

The respondents reported that the lack of chilling, late snowfall and quick rise in temperature in February have become common these days leading to reduction in the period of pollination and uncondusive weather during fruit setting. Similar findings of rising temperatures and changes in weather conditions affecting apple crop have been ascertained by Meena and Kumar (2008). Apple trees will fail to enter bud development resulting in no flowers and potentially tree death due to substantial lack of winter chilling.

Change in the flowering, fruiting time of apples was also reported by almost 60 per cent respondents. Apple flowering was reported to take place in the month of March-April previously, but now has been observed to shifted a month earlier i.e. February-March. The fruit setting also used to happen in the months of June-July but now was reported to occur in May-June. Change in the planting time of apple was reported by almost 10 per cent of the people. Earlier people used to transplant apple saplings in the month of December-January but now these are being transplanted in the month of January-February and they ascribed it to the change in climatic conditions. The view of

the respondents can be strengthened by the findings of Ruggiero (1955) who studied flowering in 70 apple varieties in relation to winter temperature and concluded that flowering was delayed below 7 degrees C and advanced when it was above the normal temperature, especially in late varieties. Farmers also believed the periodicity of temperature to be influenced by the timing of snowfall. The short winter period, reducing snowfall in winter and increasing temperature during the summer season were among the most visible signs of changing climate as opined by 90 per cent of the farmers in the Kullu district. Similar increasing trends in temperature have been observed by Vedwan and Rhoades (2001).

The temperature data from the Hill Agricultural Research and Extension Centre, Bajaura for the past twenty five years i.e. 1985-2009 was analyzed and trends were obtained for the maximum temperature and minimum temperature.

The maximum temperature showed an increasing trend whereas, minimum temperature revealed a decreasing trend (Fig 4.1 and 4.2) which clearly indicated a warming trend in the study area. During the last 25 years, an increase of about 1.18°C in maximum temperature and 0.53°C decrease in minimum temperature was recorded which further strengthened the views of 90 per cent of the respondents regarding the change of climatic conditions.

The average temperature in the last 25 years for the period of five years was plotted graphically and an increasing trend was observed in it. The average maximum temperature (25.68°C) was recorded for the period 2005-2009 and it was 0.68°C more than (24.90°C) for the period 1985-1989 (Fig 4.3) which validates people's saying about increasing temperature in the recent decade. Results concur to the same results by Jonaitis (2001) who concluded that the intervals of temperature fluctuations were higher at the end of twentieth century.

People reported increase in temperature and specifically more increase in it during the winter months. The winter and summer month's temperature analysis showed an increasing trend in both the cases with winter months showing more increase in temperature which supported the farmer's perception (Fig 4.4). Blanke and Kunz (2009) examined the effects of climate change on pome fruit in Germany and concluded similar results that temperature rise in winter (1.2°C) was greater (by 0.2°C) than in the summer (1.0°C).

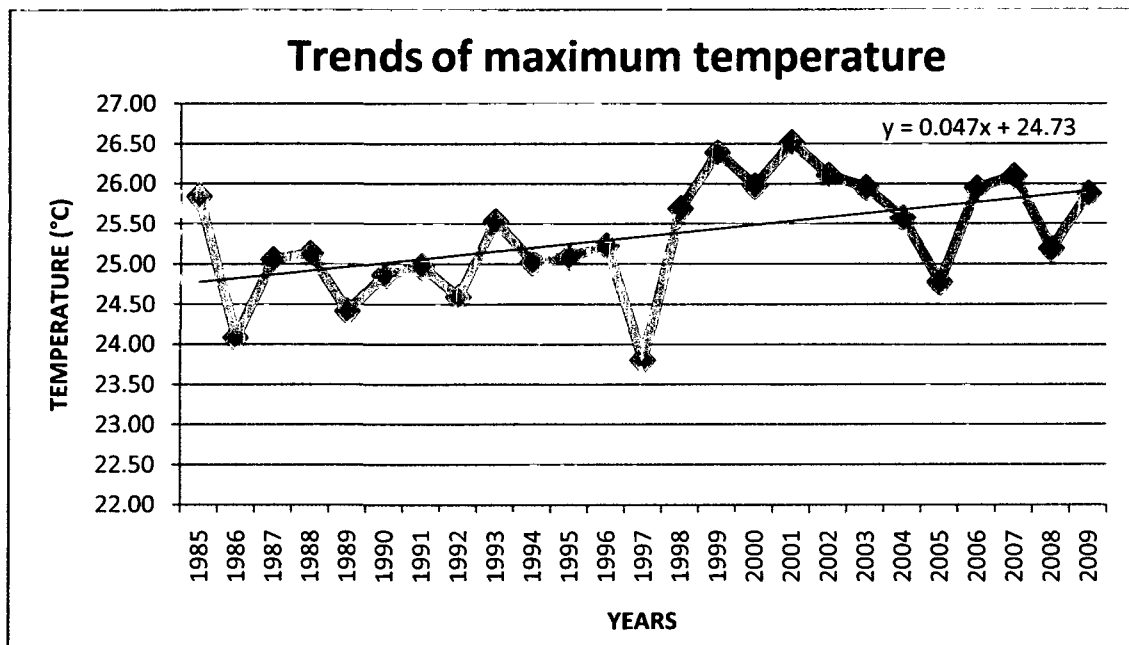


Fig 4.1: Trends of maximum temperature.

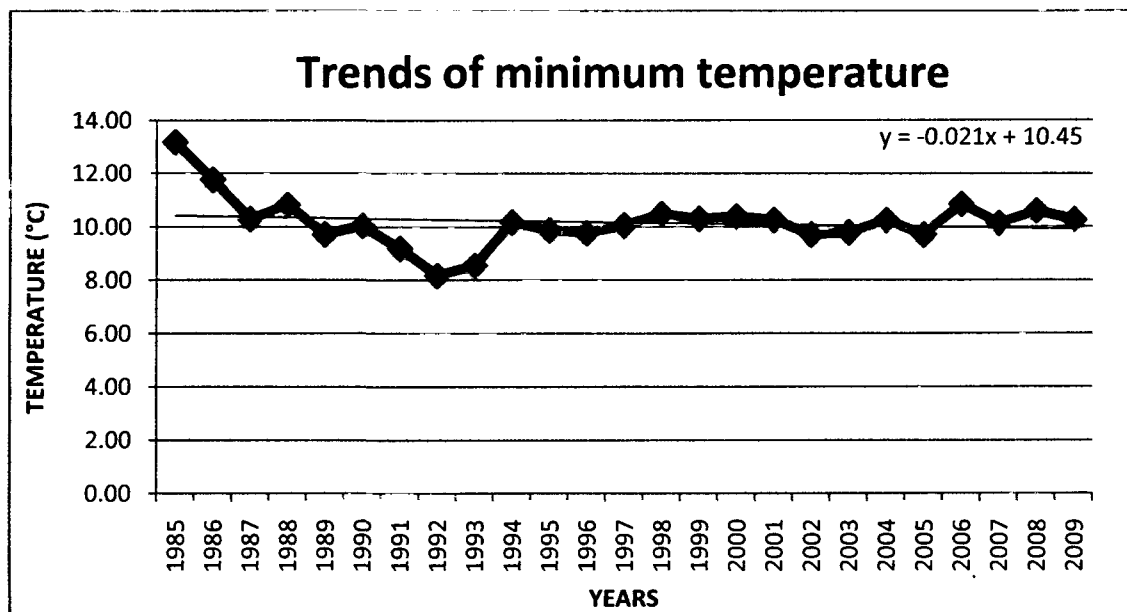


Fig 4.2: Trends of minimum temperature

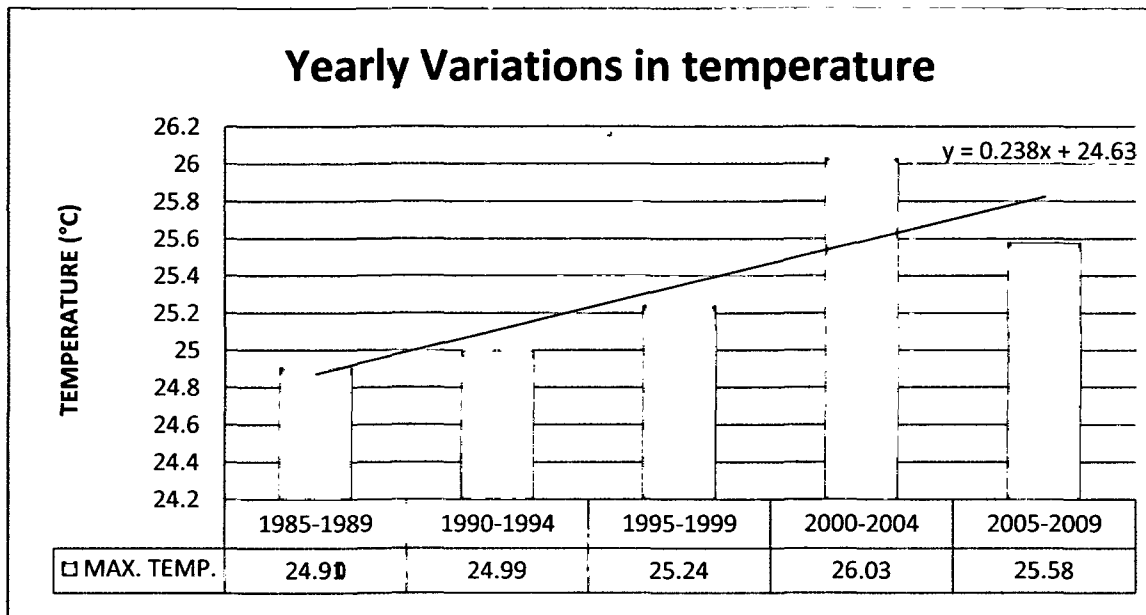


Fig 4.3: Yearly variations in temperature

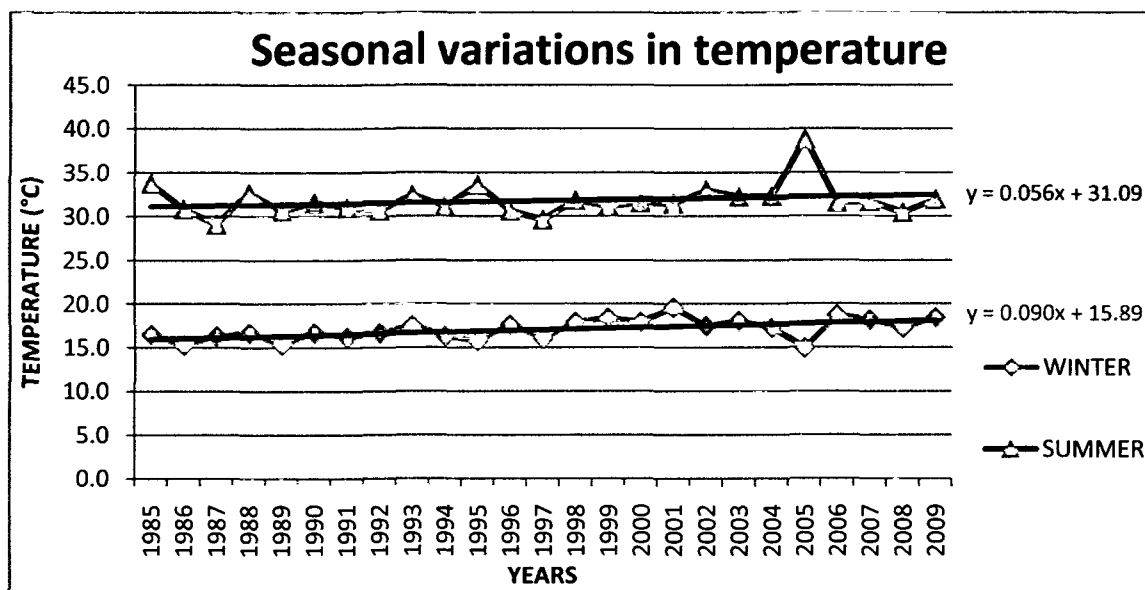


Fig 4.4: Seasonal variations in temperature

Table 4.1: Analysis of temperature data from 1985 to 2009

Temperature (°C)	Yearly	Summer	Winter
Mean	25.4	27.9	20.3
Standard Deviation	0.7	1.35	1.08
Maximum Average Temperature	26.5	33.5	22.7
Minimum Average Temperature	23.8	27.8	18.5
Trend	0.047	0.0636	0.0701
Total change calculated from the trend	0.04	0.20	0.70

Temperature data for 25 years was analyzed on yearly, winter (November to February) and summer (May and June) months (Table 4.1). Change in temperature was observed most in the winter season followed by summer. The monthly variations in temperature were observed more prominent in comparison to yearly variations. The analysis showed that local people's perceptions appear to be in accordance with the meteorological data of the region. Bhusal (2009) also reported the same findings.

4.1.2 Rainfall

Rainfall is another major climatic factor influencing the apple productivity as it controls the soil moisture and relative humidity. Every respondent in all the four blocks of the district reported an increase in the unpredictable pattern of rainfall with incidences of occurrence of rain at any time of the year. They also experienced that the rainfall was unevenly distributed. Monsoon showers arrived later than the usual. Dry summers with extended drought spells because of decreased rainfall impaired the fruit quality especially the fruit size and colour (Table 4.2). Jindal *et al.* (2001) also reported that the adverse climatic conditions like humidity, rainfall and temperature during summers influence the size and quality of fruits which also strengthened the farmers' perception.

All the respondents in the Kullu block at an elevation of 1200 to 1550 msl of the district reported huge reduction in the amount of the rainfall. They were no more dependent on the rainfall as the source of water to the orchard. Unpredictive and low

rainfall has forced the people to go for the adoption of various irrigation methods like lift irrigation, tank irrigation, usage of own wells (but the water table has also lowered down as per people's perception). They have also switched over to the techniques of rain water harvesting (Table 4.2).

Yet, at higher altitudes, it was found that 97 per cent people are dependent on the rainfall only. However, a decrease in natural spring water was attributed by the respondents to the low snowfall in the catchment area. Almost 90 per cent people perceived an increase in the incidents of drought in lower Kullu valley in the recent years. Also, 100 per cent farmers said that the rainfall now followed an erratic pattern contributing to soil fertility loss and crop damage. Thus, it had an adverse impact on livelihoods of the most of the people. Less rain was received than the usual. The delay in the onset of the rainy season was also reported by the 90 per cent respondents in the Naggar block and 100 per cent in the rest of the blocks (Table 4.2).

To relate the farmer's perception regarding the changing rainfall pattern in the district, the trends for rainfall data from the meteorological station were computed.

The data on rainfall from 1975 to 2009 when plotted graphically showed an erratic pattern with an overall decreasing trend over the years. The annual rainfall was found to be decreasing at the rate of 2.752 mm per year with an overall decrease of 93.57 mm in the last 34 years. The decrease was in accordance with the people's observation and such an erratic pattern indicated that farmer's in such scenario couldn't predict the usual rainfall pattern. The farmers also felt that these situations put some pockets of the district under drought conditions (Fig 4.5). Similarly, it was concluded by Yubi *et al.* (2005) that the precipitation over the Longdong Loess Plateau decreased from 1961 to 2000.

During the present investigation local perceptions indicated that incidence of rainfall in December and January had decreased. Accuracy of farmer's perception was measured using the trends of rainfall in December and January.

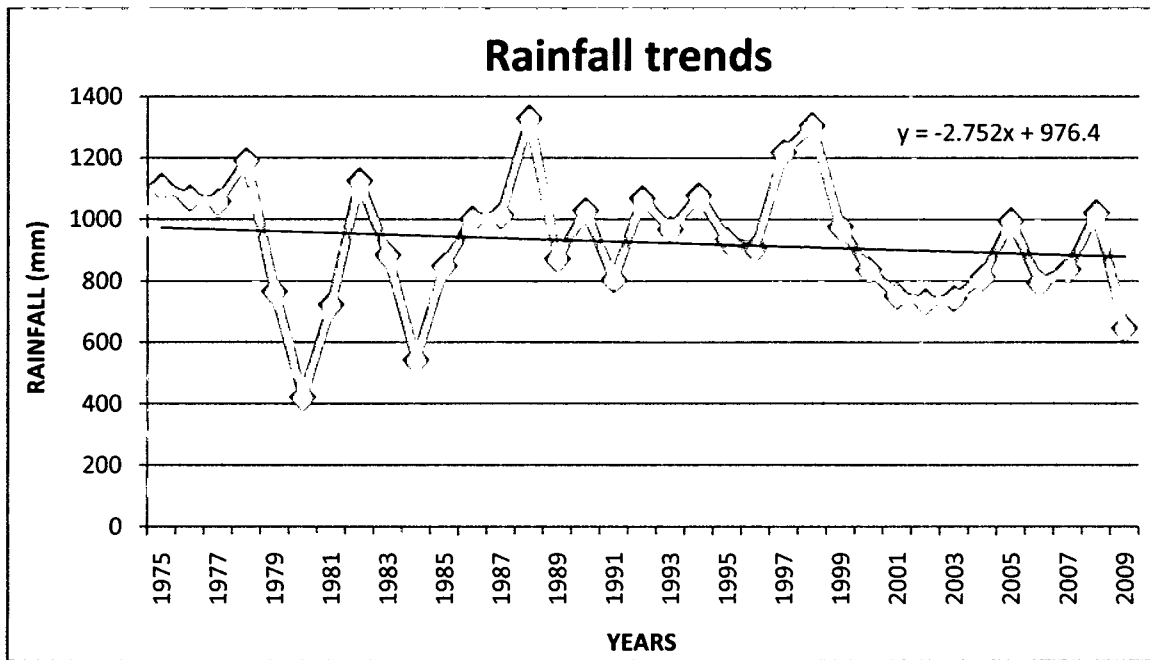


Fig 4.5: Rainfall trends

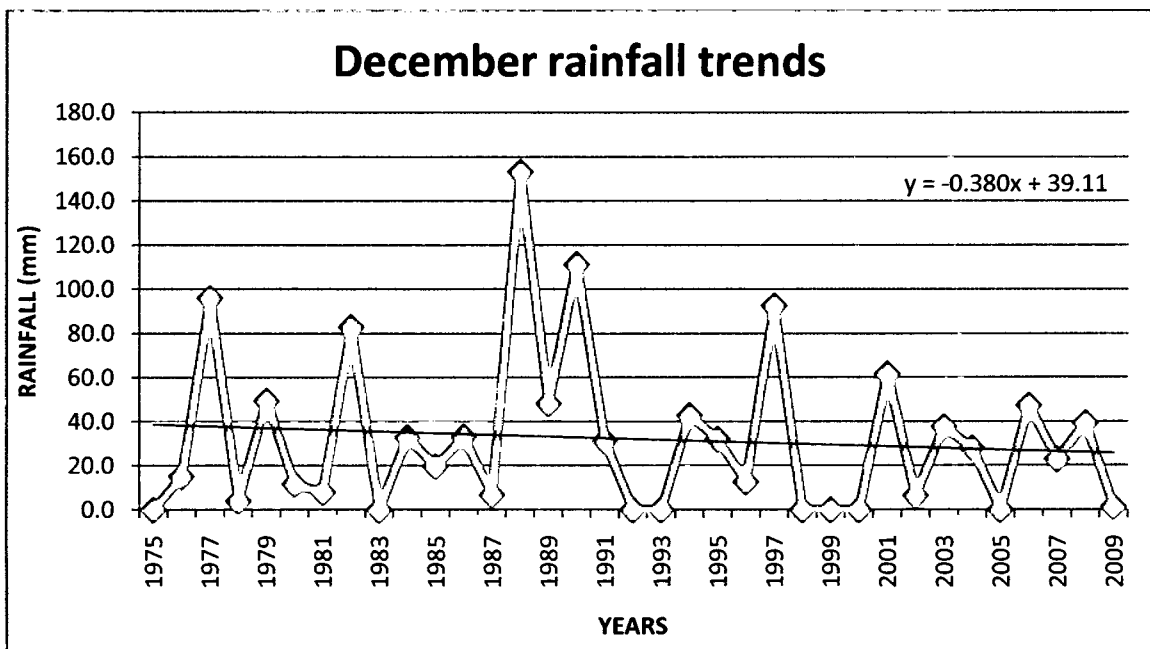


Fig 4.6: December rainfall trends

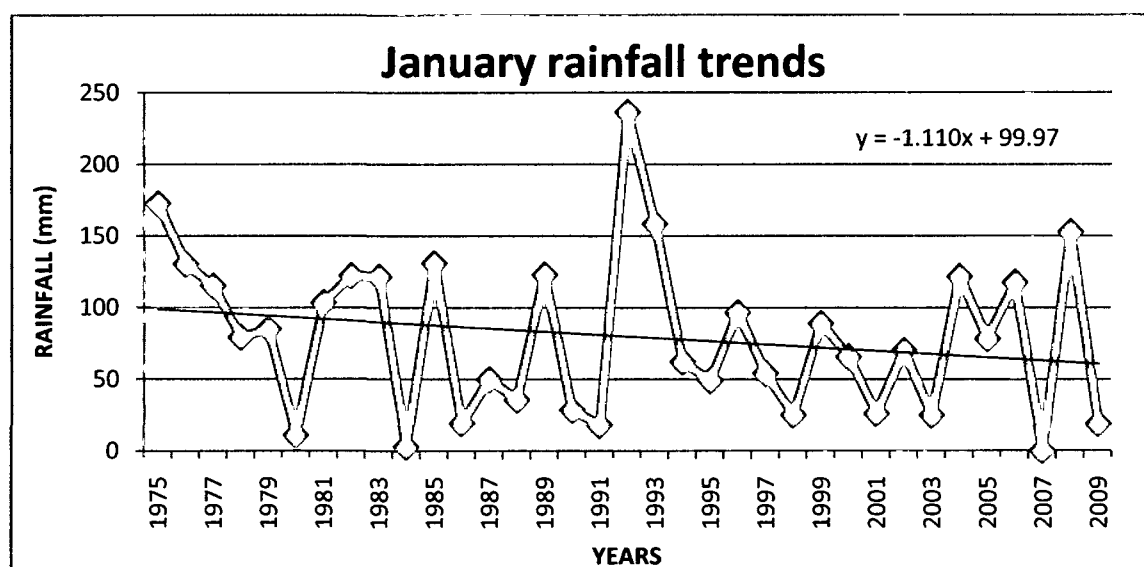


Fig 4.7: January rainfall trends

Both the months showed a decrease in overall rainfall. However, decrease was more pronounced in the month of January (1.11 mm per year) which is detrimental month for good chill accumulation (Fig 4.6). Bhusal (2009) reported similar findings in Nepal with less or no rainfall in the recent years in the monsoon months.

4.1.3 Snowfall

Precipitation especially in the form of snow is very crucial for induction of dormancy, bud break and ensuring flowering in the apple. The results of the study revealed that 100 per cent of the people perceived a definite reduction of snowfall over time. They felt that the decrease was more in the recent decade. In some areas of the district such as Kullu block complete absence or negligible snowfall was reported by the people. Lower Kullu valley, which used to be the initial point of apple belt, now received no snowfall at all. Almost 90 per cent people in the Kullu block and 40 per cent in Anni block reported no snowfall since past few years (Table 4.2). The findings of Meena and Kumar (2008) also revealed that twenty years ago snowfall was a regular phenomenon at Kullu town but in the last 20 years, only 2 – 3 instances of snowfall have been recorded. Local perceptions taken by Vedwan and Rhoades (2001) also concluded the similar results of comparatively less snowfall in the recent years.

In other blocks of the district which received optimum snowfall some aberrations in the snowfall events were perceived. Snowfall events were thought to oscillate in two important ways as opined by farmers:

1. Reduction in the frequency and intensity of snowfall
2. Change in the timing of snowfall

For normal pollination and fruit bearing conditions for an apple crop a snow level of four to five feet was considered optimum by the people. But the reduced intensity of snowfall resulted in poor fruit quality and hence poor yield. Exceptional decrease in snowfall was reported by the farmers during recent years in comparison to the previous years of late 80s and early 90s. Respondents at Naggar block pointed out that, 'the snowfall used to be four to five feet previously, which has now decreased to two to three feet'. Next to the chilling hour requirement of apple and its dependence on snowfall, the most commonly mentioned aspect of the biophysical environment was soil moisture. The farmers also told that snowfall is of significant importance for maintaining soil moisture in the orchards. Both the intensity and the distribution of snowfall were utilized as benchmarks for assessing the effect of snowfall (Table 4.2). Vedwan and Rhoades (2001) also considered snowfall very critical for the maintenance of proper levels of soil moisture.

Majority of the people to the tune of 98 per cent felt that the timing of the snowfall has undergone a change, more specifically early snowfall in the months of December and January was no longer a common phenomenon. 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 (Table 4.2). Similar findings of reduction in the intensity and changed pattern of snowfall were deduced by Vedwan (2006). Farmers considered early snow as durable, long lasting and full of nitrogen, late snow on the other hand, was described as watery, transitory and understood to adversely affect pollination and apple fruit bearing. 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.

4.1.4 Extreme weather phenomena

People perceived that the development of infrastructure such as roads, trails and buildings and an intensification of agricultural/ horticultural, timber extraction (for fuel and building material), and grazing activity have increased the risks associated with landslides, floods, and other erosion processes. Extreme weather calamities such as occurrence of floods and cloudbursts were common phenomena now. About 17 per cent, 20 per cent and 10 per cent farmers in Naggar, Ani and Kullu block respectively felt that the threat of floods has increased. Farmers to the tune of 17 per cent felt that the chances of cloudbursts in the Naggar block were more. Whereas, 7 per cent people felt that the chances of cloudbursts are more in the Kullu and Ani blocks. Landslides were recorded most in the Naggar block of the district as indicated by 80 per cent of the farmers (Table 4.2).

Earlier situations like very low temperature in the winter season (useful for the induction of dormancy, bud break and ensuring flowering in apples) were no longer experienced by the farmers. In fact, the temperature at times remained above normal during the winter season. According to farmers, late snowfall in February and March resulted in lower temperatures and thereby a late onset of spring.

Other signs of climate change reported by the people were high humid weather, increasing foggy days. Almost 20 per cent people in the Naggar block reported that the threat of forest fires has also increased. Forest fire incidences were reported by 23 per cent respondents in Ani block. Abnormal occurrence of hailstorms and the warmer wind patterns were also perceived. Farmers reported increase in the hailstorms in all the blocks. 27 per cent in Banjar and 97 per cent farmers in Naggar block held increase in hailstorms responsible for harming the apple crop. Majority of the people (90%) in Kullu block felt increased spells of dry period leading to the drought conditions. However, 10 per cent respondents at Naggar and 37 per cent at Ani block also felt the same (Table 4.2).

Almost 100 per cent people reported decrease in number of the pollinators (honey bees) (Table 4.2). Some people also said that some species of butterflies have vanished from the area and were not seen now. They attributed changed climatic conditions and

excessive use of pesticides for the depletion of pollinators and butterflies. Gautam *et al.* (2004) also held indiscriminate use of pesticides responsible for the decrease in the population of natural pollinators. 100 per cent respondents of all the four blocks felt an increase in pest infestation due to the increasing temperature. Yubi *et al.* (2005) also concluded that warming winters increased the incidences of diseases and insect pests of fruit trees.

Farmers to the tune of 23 per cent felt that the orchards in lower Kullu valley were no more commercially productive. Hence, preferred shifting their orchards to the higher elevations which they thought were becoming suitable for apple cultivation because of the decreasing cold at higher altitudes favouring the apple crop. The similar views have been expressed by 10 per cent people at Ani block (Table 4.2). Verma *et al.* (2007) reported increase in apple productivity in Kinnaur despite decrease in the cold. Thus, indicating that higher altitudes, earlier unsuitable due to extreme cold conditions were now becoming suitable for apple cultivation. Partap and Partap (2002) also concluded in their study that temperate fruit belt is moving upward and productivity of apple, which is the major fruit crop in Himachal Pradesh, has been adversely affected.

Moreover, the construction of roads, execution of hydroelectric projects, denudation of forests, illegal and non-scientific mining, increased tourist load, haphazardly settled migratory labour and increased population pressure etc. have also led to more of the pollution leading to changes in the climate. 10 per cent people considered the construction of Pandoh and Larji dam to have adversely affected the local climate of the nearby areas. They felt that after the construction of the dams there was more of the pollution, less rainfall (in the Sainjh area), increased intensity of fog affecting the colour of apple (appearance of black patches). It was also perceived by the people that the construction of tunnel blocked the pathway of high velocity winds necessary for wind pollination. Almost half of the respondents (47%) in Banjar and Naggar block felt increase in high velocity winds which adversely affected the flowering stage of the crop. Some people also reported that shift of fruit belt took place due to the construction of Larji dam. However, people at Nagar and Ani block did not considered any adverse effect from the dams' construction (Table 4.2)

Table 4.2: Farmer's perception regarding climate change

PARTICULARS	KULLU (30) (%)		BANJAR (30) (%)		NAGAR (30) (%)		ANI (30) (%)	
	YES	NO	YES	NO	YES	NO	YES	NO
Pest infestation increased	100	0	100	0	100	0	100	0
Change in planting time of apple crop	27	73	33	67	3	97	17	83
Introduction of new varieties	70	30	23	77	20	80	33	67
Advancement in flowering time	90	10	67	33	83	17	67	33
Change in appearance of apple	90	10	67	33	73	27	83	17
Change in taste and quality	87	13	30	70	27	73	67	33
Decrease in pollinators	93	7	100	0	100	0	100	0
Advancement in fruit setting	93	7	77	23	87	13	67	33
Decrease in apple production	100	0	100	0	100	0	100	0
Change in choice of crops	77	23	30	70	10	90	37	63
Fertilizer requirement increased	77	23	100	0	100	0	93	7
Change in snowfall pattern	100	0	100	0	100	0	30	70
Non-occurrence of snow	90	10	0	100	0	100	40	60
Increasing temp. during summer	100	0	100	0	100	0	100	0
Prolonged summer season	100	0	100	0	100	0	100	0
Short summer season	0	100	0	100	3	97	0	100
Delay in the onset of rainy season	100	0	100	0	90	10	100	0

Uneven distribution of rainfall	100	0	100	0	100	0	100	0
Insufficient rainfall during rainy season	100	0	43	57	90	10	83	17
Delay in the outset of winter season	100	0	100	0	100	0	100	0
Very low temp. in winter season	0	100	33	67	40	60	7	93
Short winter period	100	0	83	17	97	3	80	20
Temp. above normal during winter	90	10	67	33	70	30	90	10
Reducing snowfall in winter	100	0	100	0	100	0	100	0
High humid weather	10	90	37	63	13	87	13	87
Increasing foggy days in winter	0	100	53	47	3	97	30	70
Increasing cloudy days in winter	100	0	77	23	90	10	87	13
Unpredictable rainfall	100	0	100	0	100	0	100	0
Threat of floods	10	90	0	100	17	83	20	80
High velocity winds	3	97	47	53	47	53	23	77
Forest fires	3	97	3	97	20	80	23	77
Mud slides	10	90	0	100	80	20	10	90
Hails	7	93	27	73	97	3	7	93
High intensity of rainfall	17	83	80	20	17	83	33	67
Drought	90	10	0	100	10	90	37	63
Soil erosion	10	90	3	97	10	90	10	90
Increase in glacial melting	100	0	100	0	100	0	100	0
Impact of Pandoh/ Larji dam on climate	20	80	3	97	0	100	0	100
Strategic measures adopted	97	3	20	80	20	80	23	77
Shifting of orchard to higher altitude	23	77	0	100	0	100	10	90

4.1.5 Adaptation measures

During the study period the farmers told about some local coping and adaptation strategies adopted by them in response to observed risks and hazards related to climate and non-climatic factors. Majority of the farmers in Kullu block (97%) resorted to strategic measures so as to combat the adverse effects of climate change as compared to 20 per cent in Banjar and Naggar and 23 per cent in Ani block (Table 4.2). Some of the strategic measures adopted by them are listed below:-

- Shift towards new varieties: - orchardists found traditional varieties (Royal, Red Delicious, Commercial, Laldevi, Kalidevi, Jonathan, Rich a red etc.) not suitable for cultivation in lower altitudes and hence, shifted their choice to low chill varieties (Gala, Vance, Vance delicious, Spur red, Oregon spur etc.). These varieties required fewer chills and were early maturing.
- Change of choice of crops (fruits and vegetables): - to compensate the loss from the low productivity of apples, farmers have also introduced alternate crops like pears, kiwis, pomegranates and persimmon and vegetables crop along with apples.
- Irrigation methods: - people at lower altitudes (Bajaura) were no more dependent on the rainfall as the source of water to the orchard. They have adopted various irrigation methods like lift irrigation, tank irrigation, usage of own wells. Local people have also switched over to the techniques of rain water harvesting.
- Shift of orchards to higher altitudes: - orchardists felt higher altitudes were getting more suitable for apple cultivation and hence shifted their orchards toward upper valley. People at Bajaura and nearby areas felt significant decrease in apples with almost no orchard left productive upto commercial level.
- Bee keeping: - many farmers felt decrease in number of pollinators. To combat this change, many farmers had their own source of pollinators. Some farmers at the time of pollination hired bee colonies for successful pollination.
- More spray of chemicals: - many farmers felt an increase in pest infestation. To eradicate them chemicals were sprayed in the orchard. However, the no. of sprays had increased from 3-4 sprays to 10-12 sprays per year.

- Usage of composts: - some people were also using organic composts (vermin composts) in place of chemical ones.
- Polyhouses and floriculture: - as people were facing threats of low productivity, they also switched over to alternate sources of income, such as setting up of poly houses and floriculture (carnations).

4.2 Productivity trends

Although India ranks 10th in world production of apple, yet the decreasing trend in productivity of its orchards, in the last decade due to changing climate scenario has caused a serious concern to the fruit growers and planners of the country. Apple is the major fruit crop of district occupying about 85 per cent of the total area under fruits and contributing more than 87 per cent to total fruit production. Area under apple as well as that under total fruits has continuously increased over time (District Agricultural Plan 2009).

Data related to area under apple orchards and apple production collected from Deputy Director, Horticulture, Kullu was used to calculate productivity. The apple production in the district showed an uneven trend whereas the area under cultivation was constantly increasing.

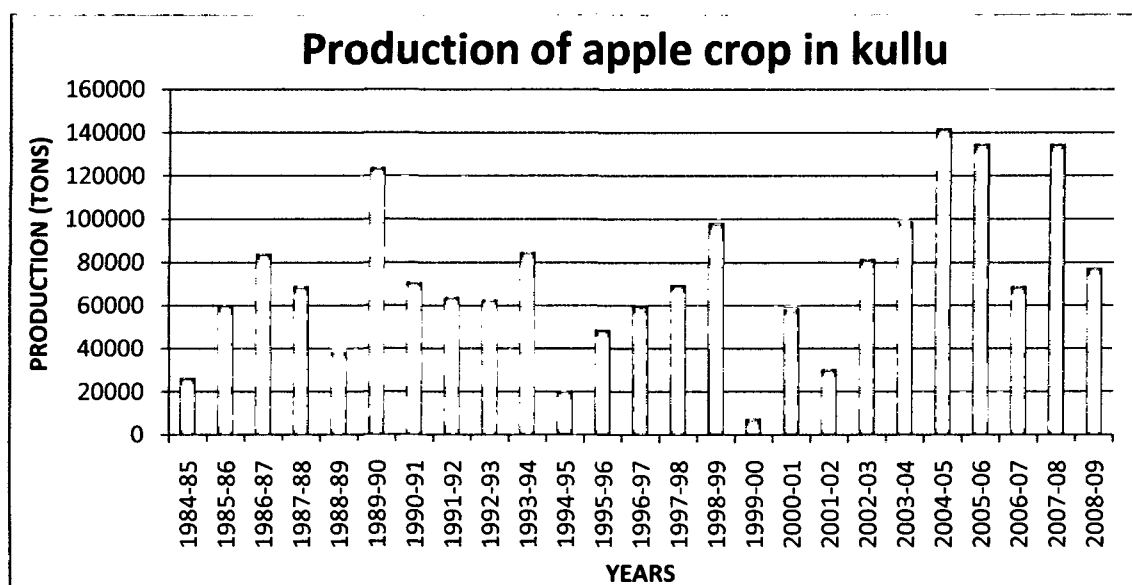


Fig4.8: Production of apple crop in Kullu.

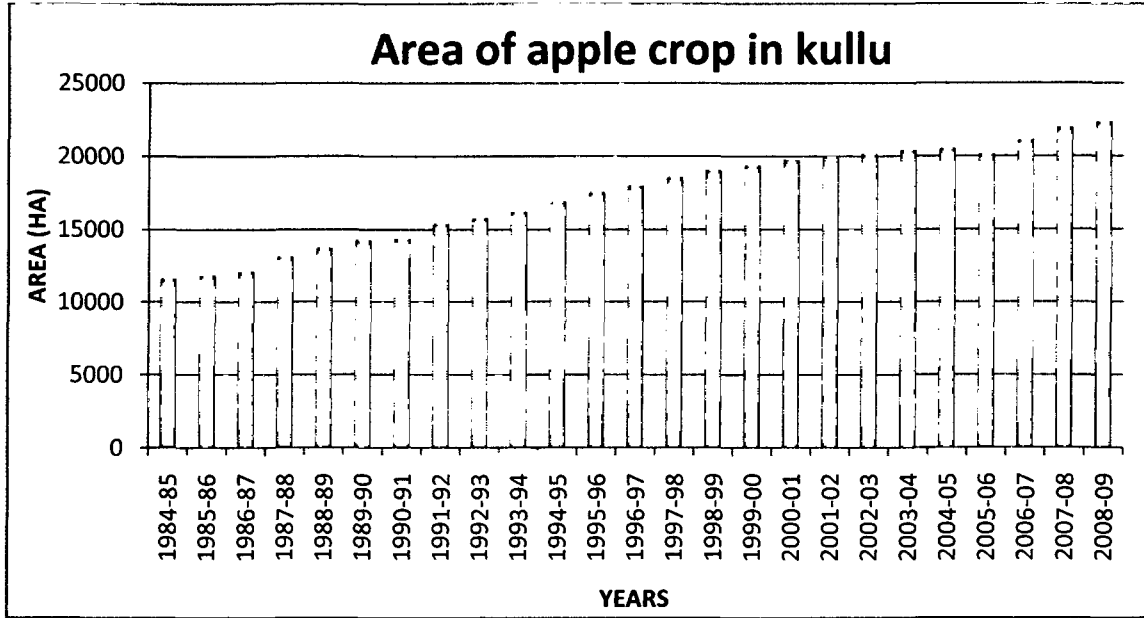


Fig4.9: Area of apple crop in Kullu.

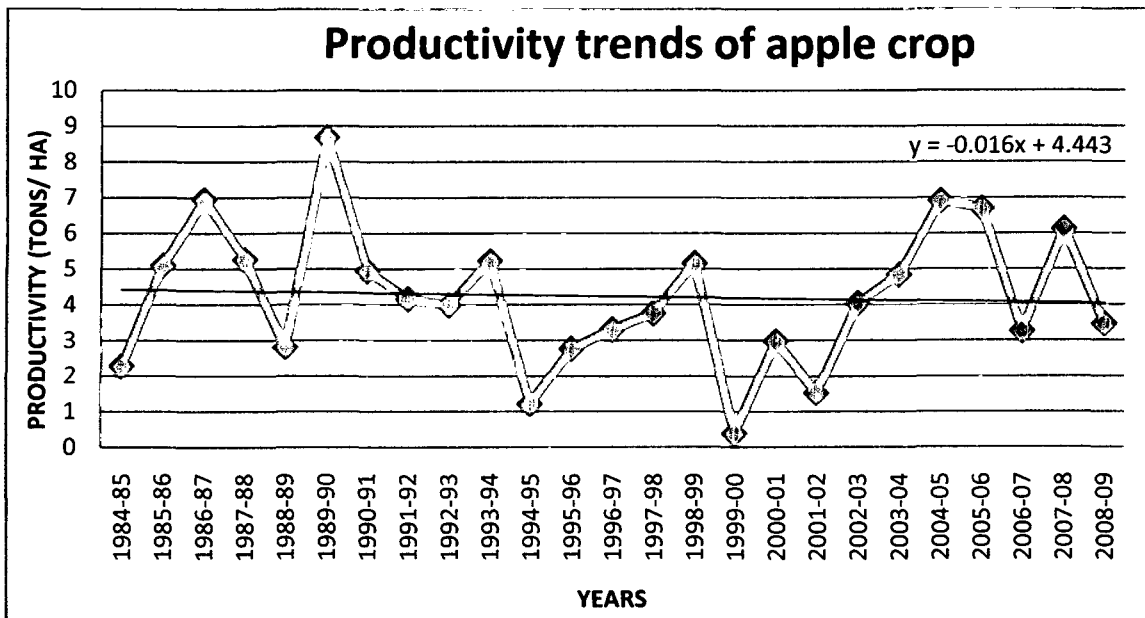


Fig4.10: Productivity trends of apple crop.

The apple productivity over the years showed a fluctuating pattern with an overall decreasing trend with a rate of 0.016 tons/ ha annually and 0.4 tons/ ha decrease in the last 25 years. Year 1990 recorded the highest productivity (8.68 tons/ha) in the 25 years (Fig 4.10). The maximum temperature remained around 16.7°C, minimum temperature was 2.03°C and rainfall was 102.73 mm in winters. These climatic conditions during the year were quite suitable for it being a good crop year. In the year 2000 maximum temperature increased to 17.9°C, minimum temperature and rainfall decreased to 0.9°C and 89 mm respectively. These contributed negatively to the apple crop resulting in the lowest productivity (0.38 tons/ha) (Fig 4.10). Singh (2003) too discussed the changing weather pattern to be the most important single factor responsible for declining apple productivity in Himachal Pradesh. Reduction in annual snowfall and fluctuating temperatures during flowering period adversely affected the apple productivity. The occurrence of hails in many areas was also reported to be responsible for low productivity.

4.3 Chill units trends

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". A chill unit is a measurement allocated when temperatures are in between certain parameters. The Chilling hours requirement according to American standards for standard apple variety is 800-1100 chill units (Byrne and Bacon 1992).

The Cumulative chill units' requirement of apple for Kullu (Bajaura) region was calculated by using UTAH model. The period of November to February was found important for chilling hours. So, cumulative chill units were calculated every year for the period of four months. The model showed a decrease of 8.20 chill units every year and 205.25 chill units for the 25 years due to an increase in temperature (Fig 4.11). This study also concur to the similar studies conducted on chill units calculated by UTAH and ASHCROFT models for Kullu and Shimla by Bhagat *et al.* (2007). They reported decrease in chill units at Bajaura at the rate of 11.9 chill units per year and the decrease of chill units ranged from 3.5 to 17.9 per year in Shimla. Verma *et al.* (2007) also calculated chill units for Mashobra, Kinnaur and Kullu and found decreasing trend in chill units at all the three places. Productivity decreased in Mashobra and Kullu with this decrease in chill units. However, they reported increase in productivity in Kinnaur indicating that very cold areas are now becoming suitable for apple cultivation due to an increase in temperature.

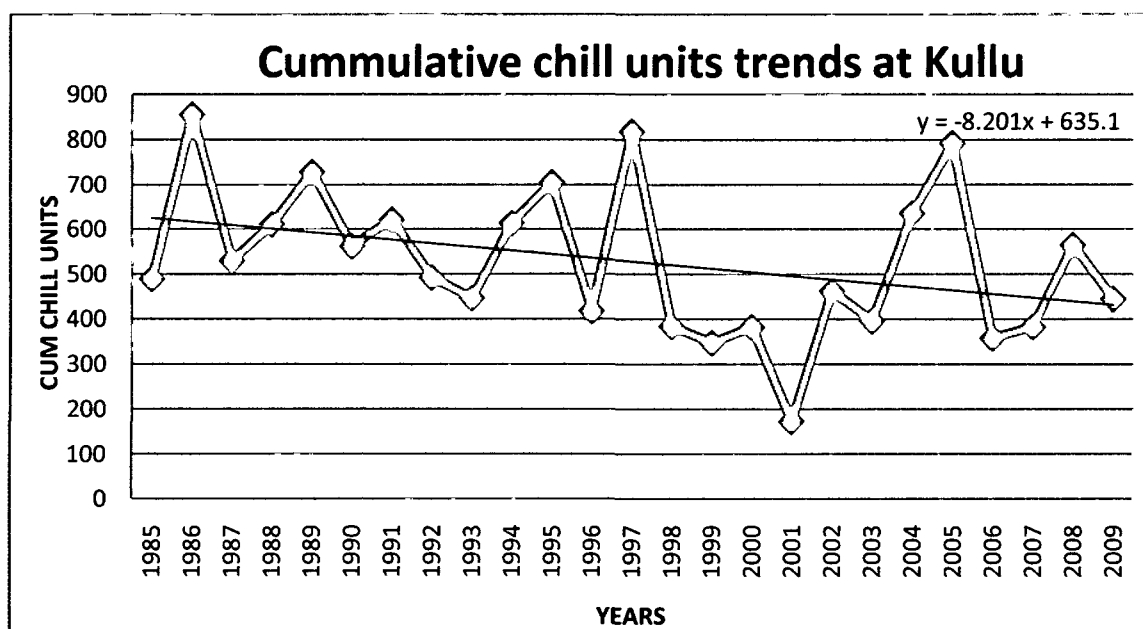


Fig 4.11: Cumulative Chill units trends at Kullu.

4.4 Correlation studies

Correlations were worked out between various weather parameters (maximum and minimum temperature and rainfall), cumulative chill units and productivity.

Amongst all these only the maximum and minimum temperature showed a negative correlation with the productivity signifying an inverse relationship between the temperature and the productivity. If maximum and minimum temperature further increases it will result in lowering down of productivity. Whereas, rainfall showed a positive correlation, thereby, implying that with an increase in this parameter, the productivity will also increase. When chill units were correlated with the productivity, a positive correlation was obtained which clearly signifies a direct relation between them (Table 4.3). Chill units in last twenty five years have decreased upto 205.25 chill units. This amount of decrease in chill units resulted in 0.4 tons/ ha decreases in productivity in past twenty five years. Decrease in chill units was recorded due to an increase in temperature. Thus, future increase in temperature will decrease chill units which further will decrease the productivity.

Table 4.3: Correlation matrix

CORRELATION	Productivity	Max. Temp.	Min Temp.	Rainfall	Chill units
Productivity	1	-0.265740727	-0.023339683	0.299126391	0.202175737
Max. Temp.		1	0.136096018	-0.515136703*	-0.86656212**
Min. Temp.			1	0.011478892	0.045555846
Rainfall				1	0.361480699
Chill units					1

* $p < 0.05$; ** $p < 0.01$



SUMMARY
AND
CONCLUSIONS

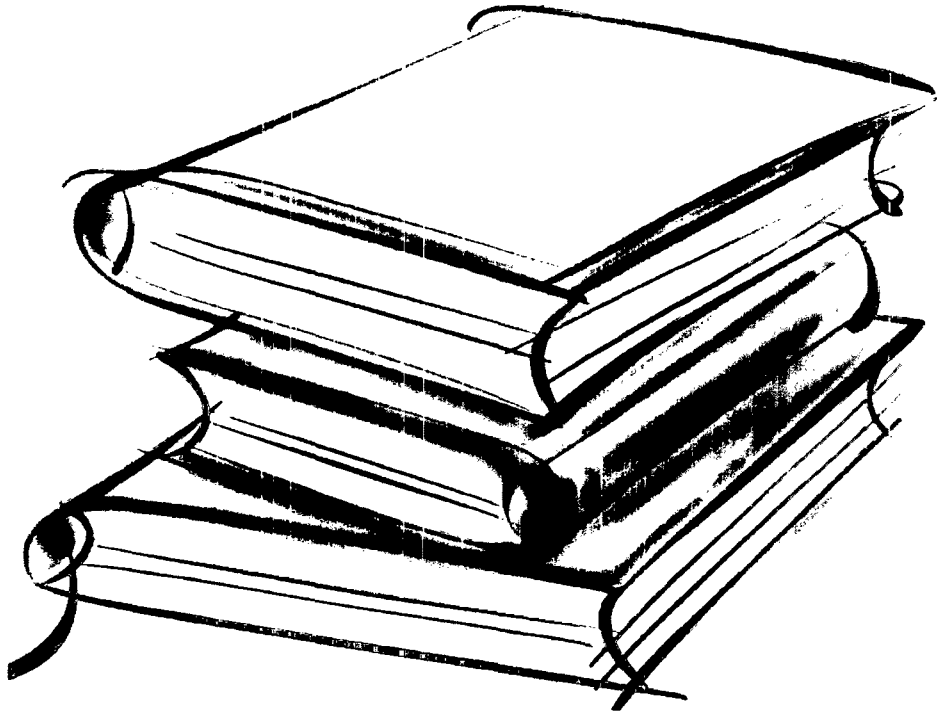
5. SUMMARY AND CONCLUSIONS

Ecosystems contribute inconspicuously to human beings by supplying vital goods and services including genetic resources, habitat, maintenance and climate etc. The combined effects of climate variability and other global change drivers may impose dramatic impacts on the species and ecosystems worldwide, with potential detrimental consequences on human society. India has varied climate and home for many temperate, sub temperate and tropical fruits. Environmental conditions play a key role in defining the function and distribution of plant diversity. It has important implications for nearly every aspect of life on earth and effects are already being felt.

The present study has been undertaken in the Kullu district of Himachal Pradesh which comprises an apple belt of significance in the state and is famous throughout India for its apples. The study clearly revealed the impact of changing climatic conditions in the district which are adversely affecting the apple productivity and hence, livelihoods of the people. Almost all the people felt an increase in temperature over the years (Table 4.2). The increase was felt with increasing warming days in summers, increased duration of summer season, short winter periods and comparatively warmer winter than usual. This increase in temperature led to an advancement in flowering period and consequently advancement in fruit setting as well. The perceived increase in temperature was related to the data from Hill Agricultural Research and Extension centre, Bajaura and similar increasing trend was obtained when the data was analyzed (Fig 4.1 and 4.2). Similarly, 100 per cent people felt a decrease in the intensity and frequency of rainfall in the last few years. At some places, like lower Kullu valley abrupt patterns of rainfall led to the drought like situations. The trends worked out for the rainfall data (Fig 4.6) also revealed the similar pattern of abrupt rain distribution over the years as perceived by the farmers. Whereas, at places like Naggar block, unpredicted rainfall was reported to harm apple crop and was also a causal factor of landslides. Snowfall was no longer a common phenomenon in Kullu block as per perception of 90 per cent people (Table 4.2). However, at higher altitudes people felt there was a change in timing as well as the intensity of the snowfall. Snowfall being a crucial factor in apple productivity, its

decrease led to decreased chill accumulation. A remarkable increase in the extreme weather phenomena like increased threats of flood, cloudbursts, drought, hailstorms etc. was felt in all the four blocks which was attributed by the farmers to the changing climatic conditions (Table 4.2). Even the construction and developmental works were held responsible by the respondents for changing local climate because of pollution and increased population. It was remarked by many people that (Seo goya ujhi valley) the suitable ecological niche of apple cultivation has shifted ahead to Raisan from lower valley which earlier used to be the starting point for apple cultivation. The orchardists were facing the problems of degraded appearance, flavour, texture and storage ability, more insect pest incidences and overall depletion in productivity. In order to sustain the productivity of apple in low lying areas the farmers have opted for the plantation of low chill cultivars (Gala, Spur, Vance etc.) in orchards which are less sensitive to climatic changes. Majority in the lower belts have also shifted their choice of crops to other fruits like pears, pomegranate, kiwis etc. and commercial vegetables which fetched higher prices. The calculation of chill units revealed a decreasing trend (Fig 4.10). As the chilling requirement was not met in lower areas, the apple crop, the mainstay of the economy of the district was reported to suffer a big loss. Many farmers felt that higher altitudes have become more suitable for apple cultivation and some of them shifted their orchards to higher altitudes (Table 4.2). The farmers revealed that beside these, beekeeping, floriculture, polyhouses, sprinkler irrigation methods, inter cropping, introduction of pollinizer plants etc. were the other strategic measures adopted to compensate the loss.

During the course of present investigation the farmer's perception showed increase in temperature, decrease in chill accumulation, decreasing and erratic rainfall and snowfall patterns, shifting of ecological niche of apple to the higher altitudes, decrease in apple production and adoption of alternate crops to compensate the loss from decreasing apple productivity. Most of the apple growers, attributed reduction in snowfall, change in temperature, abrupt rainfall patterns and extreme weather phenomena i.e. hailstorms, droughts, torrential rains, floods, cloudbursts etc. for the poor apple production.



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APPENDICES

APPENDIX - I

QUESTIONNAIRE TO STUDY THE FARMER'S PERCEPTION:-

1. Farmer's introduction :

- 1.1 Name of the farmer Sh/Smt. -----
- 1.2 Father / Husband name Sh. -----
- 1.3 Age (years) -----
- 1.4 Education -----
- 1.5 Farming experience -----
- 1.6 Village -----
- 1.7 Block -----
- 1.8 Tehsil -----
- 1.9 District -----
- 1.10 Date of interview -----
- 1.11 Signature -----
- 1.12 Checked by -----

2. Information about household economy and agriculture :

2.1 Family size

Sr.no.	Particulars	Male	Female	Total
1	Family members			
2	Literate			
3	Illiterate			
4	Workers			
5	Non-workers (>60 yrs) (<16 yrs)			

2.2 Changes in housing pattern

(Yes/ No)

- a) Earlier choice of house - thatched/ slate house/ cemented
- b) Present choice of house - thatched/ slate house/ cemented

2.3 Changes in clothing pattern (Yes/ No)

a) Usage of blankets in clothes

2.4 How much land do you have?

2.5 Which crops are you growing?

a) Food crops -----

b) Cash crops -----

2.6 How much area have you given to each crop?

CROP	AREA

3. About apple :

3.1 How much area have you given to the apple orchard? -----

3.2 How important is apple for you –

a) Economy

b) Consumption purpose

3.3 Which variety of apple have you planted?

3.4 (i) What is the source of water to the apple orchard?

a) Rainfall

b) Glaciers

c) Irrigation

(ii) If irrigation is needed what are the reasons for less water availability?

- a) Less rainfall
- b) Increased temperature

3.5 (i) Do you spray pesticides in the orchard? (Yes/ No)

(ii) Which are the major insects/ pests in the orchard?

(iii) Has the infestation of pests /insects increased/ decreased in recent years? (Yes/ No)

If yes

Increase/decrease in no. of pests is due to

- a) Climate change
- b) Resistance to pesticides

3.6 Is there any change in the planting time of apple crop? (Yes/ No)

If yes

- (i) What was the earlier planting time? _____
- (ii) What is the new planting time? _____
- (iii) Reasons for changing planting time?
 - a) Change in temperature (increase / decrease)
 - b) Change in snowfall pattern
 - c) Change in rainfall pattern

3.7 Have you introduced new varieties of apple? (Yes/ No)

If yes

- (i) Name of varieties
-

- (ii) Reasons for introducing new variety
 - a) Better yield
 - b) Better colour
 - c) Better taste
 - d) Less sensitive to climatic changes
 - e) Low chill cultivar

3.8 Is there any change in the flowering time of apple tree (i.e. advancement or delay in flowering by a week or 10 days or more)?
(Yes/ No)

If yes

- (i) What was earlier flowering time? _____
- (ii) What is the new flowering time? _____
- (iii) Reasons for changes in flowering time
 - a) Change in temperature (increase / decrease)
 - b) Change in snowfall pattern
 - c) Change in rainfall pattern

3.9 Has this advancement or delay led to the:-

Loss in fruit production

Increase in fruit production

3.10 Is there any change in the appearance of apples? (Yes/ No)

If yes

- (i) Change in colour _____
Reasons - a) Cloudy weather
b) Temperature changes
- (ii) Change in size _____
Reasons - a) High temperature
b) Poor rains

3.11 Is there any change in the taste and quality of apples? (Yes/ No)

If yes

What kind of change in taste and quality of apple?

3.12 Is there any effect of climate change on pollinators (i.e. increase / decrease in no. of pollinators)? (Yes/ No)

3.13 Is there any significant change in the fruit setting in apple trees?

(Yes/ No)

If yes –

Advancement in fruit setting by a week time

Delay in fruit setting period by a week time

3.14 What is the yield of the apple? _____

3.15 How much apples do you market? _____

(i) Where do you sell your apples?

PLACE	QUANTITY SOLD	PRICE PER KG
LOCAL MARKET		
CITY MARKET		
EXPORT		

3.16 Do you think apple production is decreasing these days? (Yes/ No)

If yes, possible reasons for decrease in production

- a) Change in snowfall pattern
- b) Increase in temperature
- c) Change in rainfall pattern
- d) Pollination problems
- e) Insects/pests attack
- f) Shift of fruit belt to higher altitudes

3.17 Have you changed your choice of crops (shifting to vegetable crops)?

(Yes/ No)

If yes,

- (i) What are the reasons for change?
 - a) Low production leading to loss.
 - b) Degradation of quality and size of the apple.
 - c) Any other, please specify?

(ii) What are the new crops?

3.18 Has the requirement of inputs such as fertilizers, FYM, irrigation,
pesticides increased / decreased? (Yes/ No)

4. Information on climate :

4.1 What is the altitude of the area (meters amsl)?

4.2 Agro climatic conditions of the area (farmer's perceptions)

a) Temperature

In winter – low/ moderate/ high

In spring – low/ moderate/ high

In summer – low/ moderate/ high

In rainy season – low/ moderate/ high

b) Rainfall

In winter – low/ moderate/ high

In spring – low/ moderate/ high

In summer – low/ moderate / high

In rainy season – low/ moderate/ high

c) Humidity

In winter – low/ moderate/ high

In spring – low/ moderate/ high

In summer – low/ moderate / high

In rainy season – low/ moderate/ high

4.3 When do you have snowfall in winter?

- a) ----- (month) before apple flowering.
- b) ----- (month) during apple flowering.
- c) ----- (month) after fruit set.

4.4 Is there any change in the snowfall pattern? (Yes/ No)

a) If yes then increase /decrease in which months

MONTH	INCREASE	DECREASE
NOVEMBER		
DECEMBER		
JANUARY		
FEBRUARY		

4.5 What kind of change do you feel in climate (i.e. temperature, rainfall, snowfall, humidity, other weather phenomena) in your area?

- a) Increasing temperature during summer (Yes/ No)
If yes specify months -----
- b) Prolonged summer season (Yes/ No)
- c) Short winter season (Yes/No/)
- d) Reductions in the intensity of snowfall from average 5-6 feet to 3-4 feet in recent days (Yes/ No)
- e) Changes in the timing of snowfall (Yes/ No)
If yes, then
Early snowfall (months) -----
Late snowfall (months) -----
- f) Delay in the onset of rainy season (Yes/ No)
- g) Uneven distribution of rainfall (Yes/ No)
- h) Insufficient rainfall during rainy season (Yes/ No)
- i) Delay in the onset of winter season (Yes/ No)
- j) Very low temperature in winter season (Yes/ No)
- k) Temperature above normal during winter (Yes/ No)
- l) High humid weather (Yes/ No)
- m) Increasing foggy days in winter (Yes/ No)
- n) Unpredictable rainfall (Yes/ No)
- o) Increasing cloudy days in winter/summer (Yes/ No)

- | | |
|---|-----------|
| p) Threat of floods | (Yes/ No) |
| q) Threat of cloudbursts | (Yes/ No) |
| r) High velocity wind | (Yes/ No) |
| s) Threat of forest fires increased | (Yes/ No) |
| t) Hails | (Yes/ No) |
| u) Mudslides | (Yes/ No) |
| v) High intensity of rainfall during winter | (Yes/ No) |
| w) Drought | (Yes/ No) |
| x) Soil erosion (wind / water) | (Yes/ No) |
| y) Increase in glacial melting | (Yes/ No) |

4.6 Is there any impact on climate after the construction of pandoh dam?
(Yes/ No)

4.7 To compensate for the loss by climate change what strategic measures
have you taken?

Brief Biodata of the Student

Name: Ms. Aditya Rana
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Academic Qualifications

Qualification	Month	Year	School/ Board/ University	Marks (%)	Division
High School (Matriculation)	March	2003	St. Pauls' School, Palampur. ICSE Board	70.16	First
10+2	March	2005	St. Pauls' School, Palampur. H.P. Board of School Education	72.6	First
B.sc	July	2008	CSK HPKV	76.8	First
M.sc	July	2010	CSK HPKV	77.8	First