Impact of Climate Change Assessment on Horticulture Sector in District Kullu Himachal Pradesh

Status Report

STATE CENTRE ON CLIMATE CHANGE

Himachal Pradesh Council for Science, Technology & Environment (HIMCOSTE)

Vigyan Bhawan, Bemloe, Shimla-1 Himachal Pradesh

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ACKNOWLEDGEMENT

The State Centre on Climate Change under the aegis of the HP Council for Science Technology & Environment (HIMCOSTE) acknowledges the assistance provided by the HIMCOSTE in the preparation of this report on Kullu district. Also express deep sense of gratitude and regards to Member Secretary (EC),HIMCOSTE for his inspiring guidance, constant encouragement, valuable suggestions, indefatigable supervision. Climate Change Centre extend deep gratitude towards Dr.Manmohan Sigh Sandhu, Regional Director IMD, Shimla and Horticulture Department for providing necessary data for achieving the objectives of status report.

Special thanks to **Dr Kartar S. Verma,** Former director of research Dr YSP univ of Hort & Forestry, Solan and **Dr. Suresh Upadhyay,** Professor and Head Department of Horticulture CSK HPKV, Palampur for evaluating the report and giving their valuable comments**.**

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EXEUTIVE SUMMARY

Climate change has emerged as a real concern for the horticulture sector with visible changes in productivity, quality of crop yields, and acreage already being reported around the globe. Crop production systems in South Asia and sub-Saharan Africa are observed to be at undisputable climatic exposure, where temperature increase is already closer to or beyond the threshold, which is having a limiting impact on overall vegetative growth. A far greater impact of extreme dry and wet spells compared to changes in long-term mean precipitation is also being reported on fruit crop productivity.

Particularly, in the fragile Himalayan eco-system, where over 72 million people survive and thrive on hill-agriculture based livelihood, the increasing pressure from burgeoning population combined with global climate change is rendering the occupation challenging and un-fruitful. The Himalayan ecosystem offers an enabling environment characterised with favourable micro-climatic conditions for cultivation of a wide range of horticulture crop such as apples, plums, peaches, bananas, mangoes, pineapples, citrus fruits, walnuts and more. Fruits and vegetables cover around 16 per cent of the total crop land in Indian Himalayan Region, with the western Himalayas accounting for around 20 per cent of farmlands, and the central and eastern Himalayas with only 5 per cent. In Himachal Pradesh, which is known as the fruit bowl of India, around 71 per cent of the 6.86 million people are dependent on the agriculture / horticulture sector for employment and income sources. There is heightened exposure to climate change induced vulnerability on sector's and individual crop's sustainability.

To this effect, a status study was conducted with a view to ascertain the impact of climate change on horticulture sector in the state with a pilot study in District Kullu - one of the 12 districts nestled in the Pir Panjal range of the western Himalayas. Seasonal trends on climatic variables i.e. minimum, maximum, and diurnal temperatures, and rainfall patterns (quantity and rainy days) were conjugated with a standardised anomaly index, and a multivariate regression analysis was conducted to unearth the climate and crop yield relationship as per the phenological stages of *pre-flowering, flowering, and fruit setting and development*. Further, the study employed evidence from household surveys conducted in five blocks (Kullu, Naggar, Anni, Banjar, and Nirmand) in District Kullu, to qualify the perceived validity of outcomes of Climate-Fruit Crop yield regression analysis. The later part of the study focused on assessing the vulnerability of target population for their exposure and sensitivity to current and historic climate risks. The assessment frameworks, both statistical and perception based Vulnerability Assessment, have scalable modalities that can be adapted to other districts.

The growing share of literature is essentially focused on assessment of historic and current weather parameter such as precipitations and temperature vis-à-vis horticulture productivity with limited and under-theorised discourse on farmers' perceptions on their exposure, sensitivity, and adaptive capacity to climate change in tandem with observed changes in climatic parameters.

Based on the assessment of the statistical and perceptive impact of climate change in district Kullu, both approaches identified climate change as an instrumental component in observed shifts in cropping patterns and productivity. Higher variability in climatic variables of temperature and rainfall was observed during the ***flowering period*** as compared to ***pre-flowering*** and ***fruit setting and development*** phenological stages from 1990 to 2016. During flowering period minimum and maximum temperature increased by 0.04°C, 0.12°C per year and rainfall decreased by 6.17mm per year. Meanwhile, the maximum temperature increased by 0.04°C per year during the pre-flowering period. Higher anomalies in maximum and minimum temperature were reported during all three phenological stages indicating an overall warming trend. Meanwhile, variations in rainy days showed significant variations during fruit setting and development stage only i.e. May to August (an increase of 0.17).

The statistical assessment of variations in climatic parameters of temperature and rainfall with changes in horticulture productivity registered maximum impact during the pre-flowering phenological stage with observed statistical correlation in maximum temperature, diurnal temperature and rainfall parameters. i.e. for four fruit crops – Apple (with maximum and diurnal temperature, rainfall), Pear (with maximum and diurnal temperature, rainfall), Cherry (with minimum temperature), and Almond (with maximum temperature and rainfall) variations in productivity exhibited statistically significant correlation with changes in considered climatic parameters of temperature and rainfall during pre-flowering stage; while for flowering stage and fruit setting stage fewer cases of statistically significant correlation was witnessed between fruit crops productivity and climatic parameters. Rainy days variations did not hold statistically significant relationship with productivity for any of the fruit crops.

Apple productivity showed maximum sensitivity to climatic variations during all three stages (31%, 19%, 21%) with significant correlation observed for Pear (35%, 9%, 10%), Almond (20%, 13%, 27%), Plum (19%, 18%, 1%), Pomegranate (6%, 8%, 24%), Apricot (3%, 14%, 29%), and Cherry (13%, 16%, 8%). With respect to individual crops, this means that the observed stagnation/gradual decline in productivity for Apple crop from 1990-2016 is explained by the variations in climatic parameters only to the extent of 31 % during pre-flowering stage, 19% during the flowering stage, and 21% during the fruit setting and development stage. Similar interpretations are valid for Pear, Almond, Plum, Pomegranate, Apricot, and Cherry. Meanwhile, the productivity of Walnut was least influenced by the changes in climatic parameters across all phenological stages (2% at pre-flowering stage; 3% at flowering; and 15% at the fruit setting and development stage).

The farm-level perception-based vulnerability assessment helped in extracting other plausible intervening factors responsible for variations in cropping patterns. The in-depth interviews with 210 farming households from the five blocks in District Kullu indicated a nearly three folds increase in total fruits acreage during the last 30 year. These shifts were driven by comparable influences from changing climatic conditions, vermin menace, financial outputs, and access to better farm practices. Further, the vulnerability index, created on perceptions of farming HHs on exposure and sensitivity to climate change net of their adaptive capacities (human, natural, financial, and physical), positioned District Kullu on the lower spectrum of vulnerability and risk.

The outcomes from this status study will anchor a new resolve for outlining overreaching policy interventions to better equip the horticulture sector for climate change adaptation. Further, it will serve as a starting point to out-scale study's assessment framework and outcomes for implementation in other districts as well.

CHAPTER 1 - INTRODUCTION

CLIMATE AND HORTICULTURE

Horticulture is a vibrant sister sector of Agriculture, distinguished by scale of production and commercialisation, and assumes a pivotal role to foster food, economic, and nutritional security, globally. India is the second largest contributor to world's horticulture produce, where it accounted for a record 307.16 MT of production in 2017-18 (IBEF, 2018). Nonetheless, this high contributing sector has a wider exposure to climate change when compared to its close associate Agriculture sector, but with a relatively smaller carbon footprint. In India, 8.71 per cent of carbon emissions came from the Agriculture, Food, and Land-use in 2013 (WRI, 2018); however, the carbon sequestration quotient from a mixture of perennial horticulture crops such as tree fruits, tree nuts, vine fruits, and seasonal vegetables, herbs offering carbon storage above the ground, net offs the sector's carbon footprint.

Climate Change, *defined as climate variability induced by direct or indirect anthropogenic activities in addition to natural climate variations causing alterations in composition of global atmosphere observed over comparable time periods* has observed manifestation in the horticulture sector through two parameters – erratic precipitation (rains and snowfall), and uncertain spells of temperature rise that has unpredictable impact on fruit crop productivity. Loss in vigour, fruit bearing ability, reduction in fruit size, and increase in pest attack eventually result in low production and poor quality of temperate fruit crops such as apple, peach, plum and more. Various exploratory studies have analysed the potential impact of climate variability on horticulture productivity, especially in the context of developing countries.

Crop production systems in South Asia and sub-Saharan Africa are observed to be at the receiving end of undisputable climatic exposure. Located in lower altitudes, these developing countries are already experiencing temperatures closer to or beyond the threshold thereby any increase in mean temperatures is bound to negatively impact horticulture crop productivity (Malhotra, 2017). Samedi and Cochran (1976) highlight the role of rising temperature in limiting vegetative growth, and affecting fruit setting especially of citrus fruits which is visible through burning or scorching of blossoms in higher plains, a phenomenon generally seen in desert areas. Meanwhile, higher temperatures are also expected to alter precipitation rates leading to changes in both frequency and intensity of droughts and floods.

In South Asia, a median 11 per cent change in precipitation is expected by the end of 21st century, with decrease in dry seasons and an increase throughout the year (IPCC, 2007). In India, mean temperatures are likely to rise by 3-4 °C by the end of 21st century, as per IPCC Fourth Assessment Report on Climate Change (2007). These exacting changes in temperature and precipitation patterns, irrespective of the study area, are expected to give rise to following omnipresent issues for the horticulture industry:

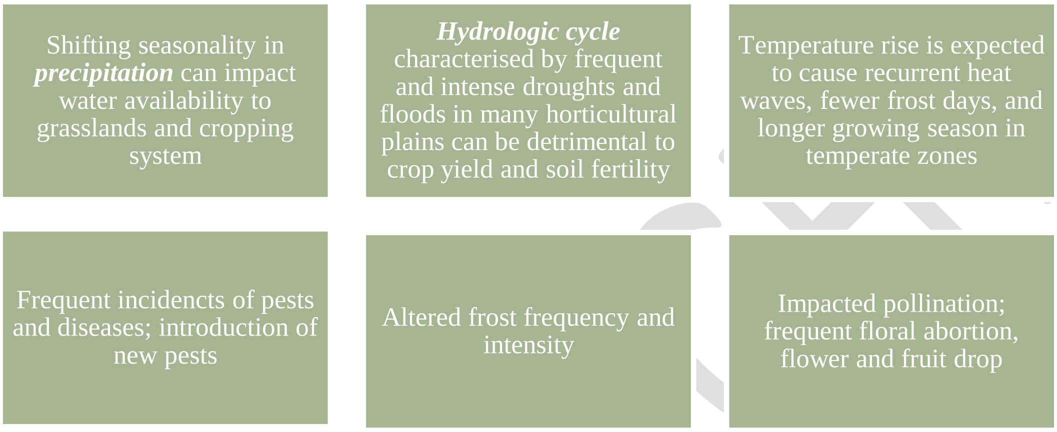


Figure 1: Horticulture and Climate Change Impact
Source: HPSCCC, 2018

Climatic variations manifest differently with respect to fruit crop varieties and phenological stages of *pre-flowering, flowering, and fruit setting and development*. Phenological stages have been identified as the preferred and appropriate indicator to quantify plants response to climate change variations (Chmielewski & Rötzer, 2001). Table 1 below discusses the impact of variations in temperature and precipitation condition with their impacts during the three phenological stages:

Table 1: Climate Change Impact and Phenological Stages

Phenological Stage	Climate Change Impact
Pre-flowering	• Flower bud initiation is extremely sensitive to temperature variations from extreme high to low-growing season temperatures • High temperatures leads to under-development of plant reproductive organs
Flowering	• Soil moisture variations driven by changing temperatures also decide the flowering time and seed germination • Temperature rise leads to early bud sprouting (2-3 weeks in Apple and Almond) and increases susceptibility to frost damage (Choudhary et al., 2015) • Moderate winds during flowering stage enables better fruit setting; however harsh winds accompanied with heavy rains at low temperatures hinders appropriate flowering • Hailstorms anytime during the flowering stage are catastrophic for fruit crops
Fruit Setting	• Orchards deep seated in valley have better fruit setting as compared to plantations in windward sides • Spring frost can either destroy flower sexual organ or completely damage blossom with impacts on fruit-set • Frequent incidents of pests and diseases under high temperature conditions
Fruit Development	• Hailstorms anytime during fruit development stage are catastrophic for fruit crops • Excessive rains and fog near maturity leads to poor fruit quality with improper colour development and fungal spots • Extreme and sudden hailstorms leads to spotting and fruit drop, especially for temperate fruits. • High temperature decreases anthocyanin accumulation in fruit trees resulting fruit discolouration • High temperatures are known to alter fruit taste and flavour, sugar content, firmness, and antioxidant activity

THE HIMALAYAS AND CLIMATE CHANGE VULNERABILITY

The Himalayan ecosystem is positioned at high vulnerability with respect to pressing perils of looming climate change. While heightened focus of recent research and discussions have been around glacial retreat and its impact on downstream water discharge, nevertheless there are growing evidences for the potential cascading impact of climate change in the Himalayas on all connected and satellite regions. The fragile Himalayan ecosystem, owing to its geological history and structural rock set-up, is fast approaching a state of disequilibrium with apparent changes in its resources and environment.

The Indian Himalayan Region (IHR) is home to over 72 million people living in over 10 states covering 95 districts expanded in an area of 5 lacs square km, representing around 16 per cent of country’s geographical area. It offers an enabling environment with favourable micro-climatic conditions for cultivation of a wide range of horticulture crops such as apples, plums, peaches, bananas, mangoes, pineapples, citrus fruits, walnuts and more. Fruits and vegetables cover around 16 per cent of the total crop land in IHR, with the western

Himalayas accounting for around 20 per cent of farmlands, and the central and eastern Himalayas with only 5 per cent (Partap & Partap, 2010). However, due to its high biological and socio-cultural diversity, the Himalayan ecosystem is susceptible to natural hazards that are prone to aggravated occurrence of floods, droughts, and landslides, caused by drastic changes in climatic conditions that stand to impact the life and livelihood of those dependent on the region for economic and social needs.

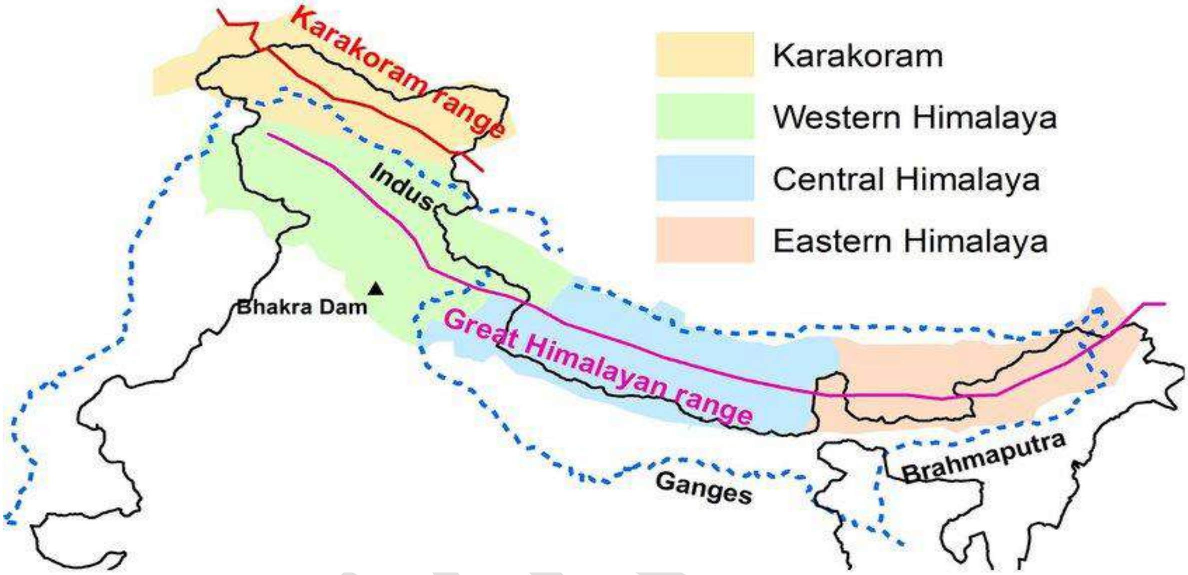


Figure 2: Geographical Representation of the Indian Himalayas
Source: Divecha Centre of Climate Change, Indian Institute of Science, Bengaluru (2018)

In the western Himalayas, in particular, striking vegetative changes are observed where in various plant species are migrating to higher altitudes owing to warming trends (Padma, 2014), while other remain in danger of extinction. Additionally, the Hindu-Kush-Himalayan region is witnessing early trends of greening while habitat loss of around 30 per cent is expected for Snow Leopards owing to continuous forest losses (Panday & Ghimire, 2012) (Forrest et al., 2012). Further, the fragile Himalayan region is also experiencing a gradual increase in temperatures higher than the world average of 0.7ºC in the last century. Increasing pressure from burgeoning population combined with global climate change is pushing the ecological hotspot to a dangerous point of no return that can be unfavourable to the agrarian livelihood of mountain communities.

SETTING THE SCENE

Himachal Pradesh is a mountainous state in the northernmost part of India, situated in the western Himalayas between latitude 30º 22' 40" N to 33 º 12' 40" N and longitude 75 º 45' 55" E to 79 º 04' 20" E. The State has a complex geological structure that dissects its topography in extreme altitudinal ranges from 350m to 6,975m above sea level. Owing to these extreme variations in elevations, it experiences varied climatic conditions, ranging from hot and sub-humid tropical in the southern tracts to cold, alpine and glacial in the northern and eastern mountain ranges with higher elevations. There are 6.86 million people in the State with almost 90 per cent residing in rural areas. There is incessant reliance on agriculture/horticulture activities as a source of income and employment for around 71 per cent of the population and mixed farming, agro-pastoral, silvi-pastoral, and agro-horticulture are the predominantly adopted farming systems. Nevertheless, of the geographic area of 55.67 lacs hectares only 10 per cent of the State's net area comes under cultivated land and 81 per cent of this cultivated area is rainfed. However, only one lac hectare of net sown area is with assured irrigation.

Himachal Pradesh is known as the fruit bowl of India with Horticulture sector contributing around 38 per cent to state's GDP from primary sector (agriculture and allied services account accounted for 10 per cent of state GDP in 2015-16); while offering a range of farm and off-farm employment opportunities. (MoSPI, 2016).

HIMACHAL PRADESH – CLIMATIC PROFILE

The State has wide-ranging exposure to climatic conditions on parameters of temperature and precipitation. Depending on the altitude, climatic conditions vary from hot and sub-humid tropical at 450m-900m in southern low tracts, warm and temperate at 900m-1,800m, cool and temperate climate at 1,900m-2,400m, and cool alpine and glacial in extreme northern and eastern mountain ranges at 2,400m-4,800m. The state's climatic profile can be better understood with respect to its division in three physiographic regions – *Outer Himalayas* (covering District Bilaspur, Hamirpur, Kangra, Una, and lower parts of Mandi, Sirmaur, Solan), *Lesser Himalayas* (covering parts of District Mandi, Sirmaur, Chamba, Kangra, Shimla), and *the Greater Himalayas or the Alpines* (covering District Kinnaur, Lahaul & Spiti, Chamba).

Climate change does not have even and uniform impact on any region and with these topographical and varied climate classifications in Himachal Pradesh, the vulnerability and risk quotient becomes significant and tends to vary from one region to another. There is substantial literature and research to support the expected varied impact of climate change in Himachal Pradesh. Based on the findings of short-term analysis at different altitudes, Bhutiyani et al. (2007) observed a significantly higher temperature variation in the north western Himalayan region when compared to the global average in the last century, and concluded that rate of increase in maximum temperature changes is directly linked to the changes in altitudes. Bhan and Manmohan (2011) predicted a shortening of seasons by 10-12 days per decade based on assessment of precipitation data for 20 years. Kumar et al. (2009) and Shrestha et al. (2012) reported an average increase of 1.52°C in annual minimum temperature (Kullu Valley, 1962-2004), and 1.5 °C in annual mean temperature (25 years) in the State respectively. With reference to precipitation, Himachal Pradesh is witnessing a period of uncertain and untimely rainfalls and snowfalls, which is likely to impact water availability and replenishment of snow fed gravity channels (kuhls), thus affecting irrigation support to agriculture and horticulture sector. As per the estimates from Himachal Pradesh State Action Plan on Climate Change (2012), a 40 per cent reduction in rainfall has been observed in last 25 years. In nutshell, annual temperatures are expected to rise for all seasons with significant decline in snowfall in mid-hills temperate wet agro-ecological zones. The frequency of rains is expected to increase but with diminished average intensity creating drought conditions in some pockets and accelerated summer flows in the north-western part of the State.

STATE'S AGRO-ECOLOGICAL PROFILE

Himachal Pradesh has been divided into four agro-ecological zones based on characteristics of precipitations, altitude, cultivated and irrigated area. Table 2 below highlights the details for four zones with information on district coverage. A further magnified and bifurcated agro-ecological classification is illustrated in figure 3.

Table 2: Agro-Ecological (new) Classification, Himachal Pradesh

	Zone I	Zone II	Zone III	Zone IV
Ecology	Sub Montane & Low Hill Sub-tropical	Mid Hills Sub-humid	High Hills Temperate Wet	High Hill temperate dry
Geographic Area (%)	18.43	8.37	16.54	56.61
Cropped Area (%)	40	37	21	2
Irrigated Area (%)	17	18	8	5
Altitude (m)	240-1,000	1,001-1,500	1,501-3250	Above 2501
Mean Annual Temp	15 ºC - 23ºC	14 ºC - 22ºC	9.1 ºC – 20.6ºC	9 ºC - 20ºC
Rainfall (mm)	1,100	1,500 (except Dharmshala, Palampur: 3000mm)	1,000	>1,500
Soil	Shallow, Light textured, low fertility	Loamy to Clay loam deficient in Nitrogen and Phosphorus	Shallow, acidic, silt loam to loam, deficient in Nitrogen and Phosphorus	Sandy loam, neutral to Alkaline, Low fertility
Major crops	Wheat, Maize, Paddy, Pulses, Oilseeds, Barley, Sugarcane, Potato Citrus fruits, Mango, Litchi	Wheat, Paddy, Barley, Pulses, Oilseeds Off-season vegetables Citrus Fruits	Wheat, Barley, Millets, Pseudo-Cereals (Buckwheat, Amaranthus), Maize, Potato, Oilseeds Off-season vegetables Apple and other temperate fruits and nuts	Wheat, Potato, Barley, Pseudo-Cereals (Buckwheat and Amaranthus), Peas, Minor Millets, Kuth and Temperate vegetables Apples, Grapes, Almonds, Walnuts, Apricot Zeera, Hops, Cumin, Saffron
Districts	Kangra, Una, Hamirpur, Bilaspur, Solan, and Parts of Chamba, Sirmaur	Parts of Chamba, Kangra, Mandi, Shimla, Sirmaur, Kullu, Kinnaur, Hamirpur, Bilaspur	Shimla, Chamba, Kangra, Mandi, Kullu, Solan, Sirmaur, Kinnaur, Lahaul & Spiti	Kangra, Lahaul & Spiti, Kinnaur, and Parts of Chamba, Mandi, Kullu, Sirmaur, Shimla

Source: Agro-Ecological Zonation of Himachal Pradesh – Agricultural System Information Development at micro-level, Centre of Geo-informatics, CSK Himachal Pradesh Agriculture University, Palampur **(Bhagat et al., 2006)**

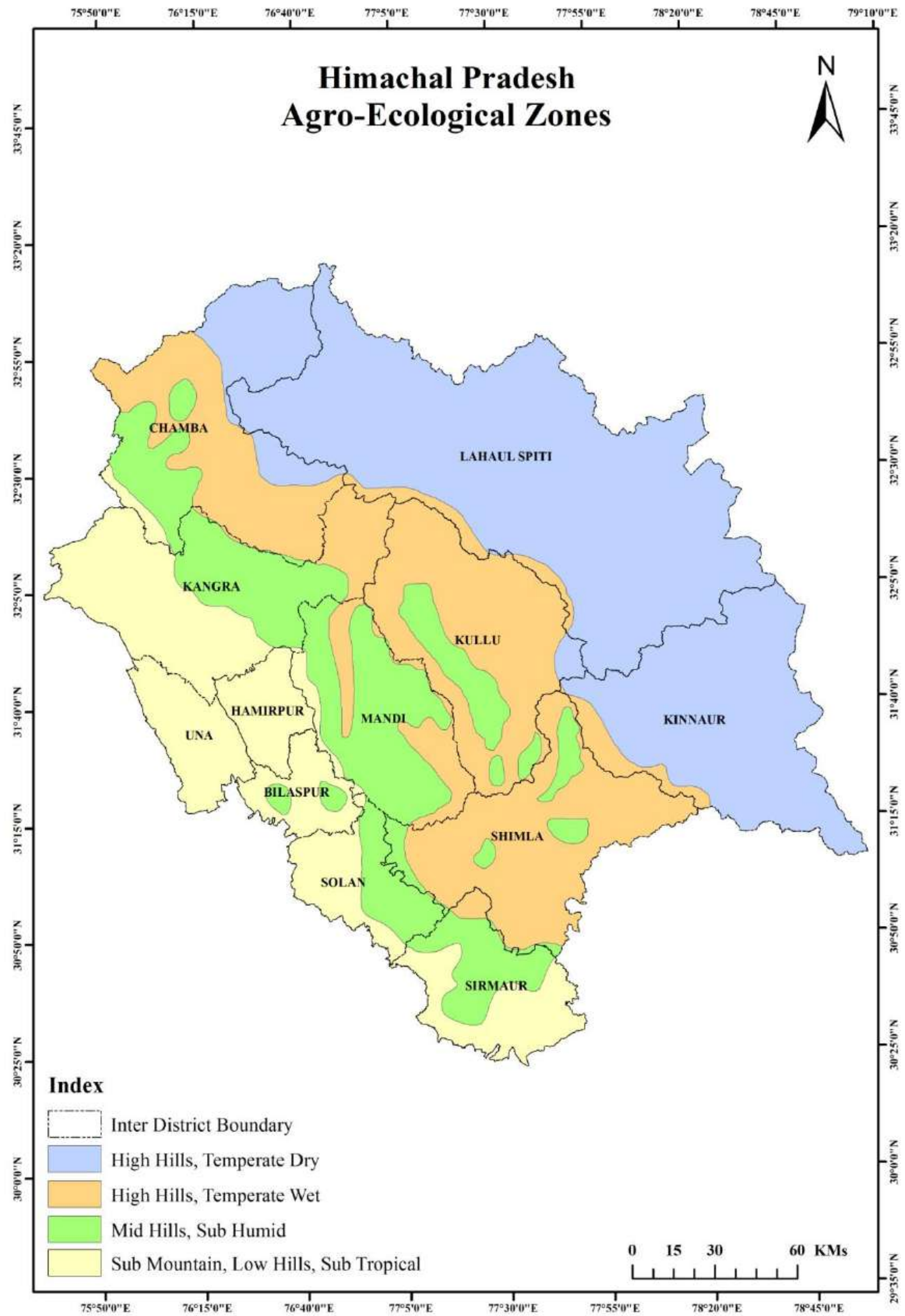


Figure 3: Himachal Pradesh Agro-Ecological Zones

Source: Adapted by HPSCCC from Agro-Ecological Zonation of Himachal Pradesh – Agricultural System Information Development at micro-level, Centre of Geo-informatics, CSK Himachal Pradesh Agriculture University, Palampur (Bhagat et al., 2006)

As noticeable from above, a majority of horticulture exposure is spread across Zone III and IV in the State which has significant share of land under apple and other temperate fruits cultivation. Nevertheless, each zone and each district is characterised with different soil, climatic, and precipitations pattern. Human managed ecosystems such as food production and livelihood sustenance are found to be highly vulnerable to climate change in Asia. Jindal et al (2001) while assessing the five-year fruit production and meteorological data highlighted the instrumental role of abnormal climatic factors during the flowering and fruit development stages causing reduction in apple productivity. The said study also underscored the presence of other factors such as monoculture of Delicious varieties, compromised standards of orchard management, amongst others being detrimental to fruit crop productivity. Meanwhile, Crepinsek and Bogataj (2004) discussed the impact of rising temperatures (per degree) on faster occurrence of leaf and fruit ripening by 2 days in apple and plum crops. Interestingly, there have been a few perception based assessments that have concluded the perceived role of climate change in altering the blossoming, bearing, and productivity of apple crop. Vedwan and Rhoades (2001) reported a remarked shift of apple belt in Kullu valley along with a significant gap in flowering periods of male and female trees. Nevertheless, the growing share of literature is essentially focused on an assessment of historic and current weather parameter such as precipitations and temperature vis-à-vis horticulture productivity with limited and under-theorised discourse on farmers' perceptions on their exposure, sensitivity, and adaptive capacity to climate change in tandem with observed changes in climatic parameters.

To bridge this gap, a status study was conducted with a view to ascertain the impact of climate change on horticultural sector in the state with a pilot study in District Kullu - one of the 12 districts nestled in the Pir Panjal range of the western Himalayas. Seasonal trends on climatic variables of minimum, maximum, and diurnal temperatures, and rainfall patterns were conjugated with a standardised anomaly index and a multivariate regression analysis was conducted to establish the climate and crop yield relationship during the phenological stages of *pre-flowering, flowering, and fruit setting and development*. Further, the study employed evidence from the household surveys conducted in five blocks (Kullu, Naggar, Anni, Banjar, and Nirmand) in District Kullu to qualify the perceived validity of outcomes of multivariate linear regression analysis. Essentially, the later part of the study focused on assessing the vulnerability of target population owing to their exposure and sensitivity to current and historic climate risks.

ORGANISATION OF STATUS REPORT

The status report designed to provide a snapshot view of statistical and perceived impact of climate change on horticulture in the state with an astute focus on District Kullu, and is organised as:

1. Discussion on the Assessment Framework employed for Statistical Assessment and perception-based Vulnerability Assessment
2. Case study outline with details on adopted methodology
3. Presentation of Key Findings on Climate-Crop Juxtaposition based on statistical measurements
4. Evaluation of the outcomes of perception-based Vulnerability Assessment
5. Conclusion with a reflection on report results for future adaptation planning, and government interventions

CHAPTER 2 – ASSESSMENT FRAMEWORK

Since the study aims to assess two different discourses on climate change vulnerability of the horticulture sector, it is imperative to elucidate assessment frameworks adopted for each objective.

CLIMATE TREND ASSESSMENT

To better understand the impact of climate change variable of temperature and precipitation (rainfall) vis-à-vis parameters of horticulture productivity, the following statistical measures were employed.

TREND ANALYSIS

Seasonal trends on climatic variables such as minimum, maximum, and diurnal temperatures, and rainfall (quantity and days) were conducted using the Mann Kendall Test – a widely accepted statistical test for analysis of trend in climatologic and hydrologic time series (Pohlert, 2018). This statistical test comes with two-fold advantages – first, being a non-parametric test it does not require the master data to be normally distributed. Second, the test shows low sensitivity to abrupt data breaks and inhomogeneous time series. Therefore, data gaps are plugged by assigning a common value smaller than the smallest measure value in the master data set. The Mann Kendall Test works on the basic null hypothesis H_o of no trend i.e. data is independent with a random order that is tested against the alternative hypothesis H_1.

The test follows a time series of *n* data points with *Ti* and *Tj* as two subsets of data where *i = 1,2,3,…, n-1 and j = i+1, i+2, i+3, …, n.*

In the ordered time series, each data point is compared with the subsequent data point, and in case the subsequent data point is of higher value, the statistic *S* is incremented by 1, for a lower value of subsequent data point, S gets decremented by 1. The net results of all iterations give the final value of *S i.e. Mann Kendall S statistic*

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign\ (T_j - T_i)$$

$$Sign\ (T_j - T_i) = \begin{cases} 1\ if\ T_j - T_i > 0 \\ 0\ if\ T_j - T_i = 0 \\ -1\ if\ T_j - T_i < 0 \end{cases}$$

Where *Tj and Ti* are the annual values in years j and i, j > i, respectively

A positive (negative) value of *S* indicates an upward (downward) trend.

Magnitude of the trend is determined by *Sen's Slope,* which essentially computes the linear rate of change and intercept. First, a set of linear slopes is ascertained, and then the Sen's Slope is calculated as the median from all linear slopes that gives the magnitude of the observed seasonal trend. Another statistics linked to the Mann Kendall test is the *p-value.* Smaller the p-value (smaller than 0.05), greater is the weight of evidence against the null hypothesis of no trend.

For this study, the statistical Mann Kendall test is carried on software XLSTAT2017. The null hypothesis is tested at 95% confidence level for minimum, maximum, and diurnal temperate, and rainfall (quantity and days) for the time period 1990-2016. Further, annual trends were conducted for productivity of apple, pear, plum, peach, apricot, cherry, pomegranate, walnut, and almond crops

STANDARDIZED ANOMALY INDEX (SAI)

SAI is a commonly used index used for regional climate change studies that can be premeditated by subtracting the long term mean value of temperature and rainfall data set from individual value and dividing by their standard deviation (Koudahe et al., 2017). In this manner standardized temperature indices for mean minimum, maximum and diurnal temperature of horticulture (for three phonological stages) were computed for the study area. Similarly, the standardized precipitation indices were also calculated for the pre-flowering (November-February), flowering (March-April), and fruit-setting and development stages (May- August).

MULTIVARIATE LINEAR REGRESSION MODEL

To ascertain the climate-crop yield relationship, linear multivariate regression statistical measure is selected. In multivariate linear regression model, a dependent variable is guided by multiple independent variables and hence, multiple coefficients are determined. Key to a successful outcome is associated with a careful selection of independent variables for which a correlation matrix is created. In this study, Pearson's correlation coefficient was used to measure the strength of association between climatic variables and crop productivity. For interpretation purposes, a correlation coefficient of -1 indicates perfectly negative linear relation; a correlation of 0 indicates no linear relationship between the two variables (but possibly a non-linear relationship); and, a correlation coefficient of 1 shows a perfectly positive linear relation. The value of correlation coefficient can never be less than -1 or more than 1.

Here, the regression analysis helped to confirm the contribution of anomalies in studied climatic parameters on crop productivity, which can be explained by following linear model:

$$\Delta P = constant + (\alpha \, x \, \Delta T_{min}) + (\beta \, x \, \Delta T_{max}) + (\gamma \, x \, \Delta T_{dt}) + (\delta \, x \, \Delta R) + (\varepsilon \, x \, \Delta Rd)$$

Where, ΔP is the observed change in the productivity due to minimum, maximum, diurnal temperature, and rainfall in the respective phenological stages of the fruit crops. Coefficients α, β, γ, and δ are the coefficients of minimum, maximum, diurnal temperature and rainfall, respectively. ΔT_{min}, ΔT_{max}, T_{dt}, ΔR, and Δ*Rd* are the observed changes in minimum, maximum, diurnal temperature, rainfall and rainy days respectively for the cropping seasons during the study period.

PERCEPTION-BASED VULNERABILITY ASSESSMENT

WHAT IS VULNERABILITY?

Vulnerability as a concept is a non-observable and non-measurable extent to which a system is likely to be affected on exposure to a hazard or risk. IPCC identifies vulnerability as a predisposition of an ecosystem or a socio-economic system to be adversely affected in face of a stressor. While there are numerous definitions and views on defining vulnerability (Hinkel, 2011), it is conceptualized as an intrinsic property with manifestation in existence of adaptive capacity and sensitivity of a system vis-à-vis its exposure to a hazard or a stressor. Nevertheless, four consistent themes are observed across a range of literature aimed at defining vulnerability, which are:

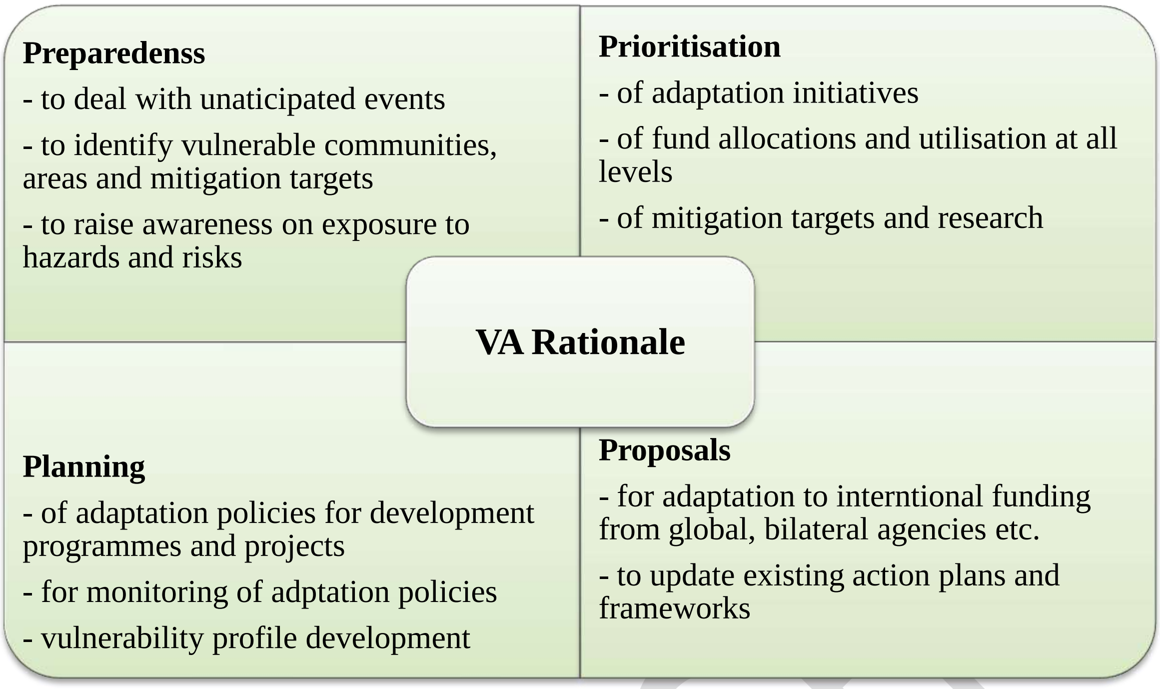
- It is a spatial concept and contextual to inherent characteristic of the effected community and/or region
- Being a theoretical construct, vulnerability is deductively assessed and its quantification through a single metric remains a challenge.
- Vulnerability is dynamic and changes in accordance with developments in socio-economic factors of the affected and changes in climatic and physical conditions.
- Finally, and exposure to external stressor doesn't always lead to vulnerability

IPCC identifies vulnerability as a function of presence/absence of (adaptive) capacity to respond positively or negatively (sensitivity) in face of an exposure to external stress or hazard. Over the years the discourse on vulnerability has undergone significant changes. IPCC Fourth Assessment Report (2007) synthesised vulnerability as a resultant of exposure, sensitivity, and adaptive capacity. Meanwhile, IPCC Fifth Assessment Report (2014) prescribed 'vulnerability independent of physical events' concept where vulnerability is taken as a system property with sensitivity and adaptive capacity as the only cofactors, and exposure is considered as an external agent.

WHY ASSESS VULNERABILITY?

Vulnerability Assessment has been central to IPCC endorsed approach to effective climate change adaptation planning. Over the years the discourse on vulnerability definition and assessment has undergone significant changes with shifting views on its intrinsic and extrinsic determinants, as discussed above.

While vulnerability is defined by the predisposition of a system to external stresses, it is the preparedness of the system that actually determines the aftermath situation in case of an interaction with a hazard or risk. This need for awareness and preparedness is what sets the premise for vulnerability assessment. The rationale for the need to conduct a vulnerability assessment is discussed below:



Quantification of vulnerability through a single metric is neither straightforward nor recommended as it may diminish the inherent complexity and multi-dimensionality associated with each cofactor and vulnerability assessment (Alwang et al., 2001). Hence, Vulnerability Index is considered as a proxy indicator to streamline discussion on vulnerability assessment in terms of a single meter.

This study employed the vulnerability framework prescribed in IPCC 2007 Working Group II Assessment Report as opposed to the IPCC 2014 framework, for the following reasons:

- IPCC 2014 framework provides an assessment of the overall exposure-independent vulnerability of a system (intrinsic to a system) i.e. with or without climate change in the future, whereas the older framework considers both current vulnerability and vulnerability under climate change scenario. Since, this study's key objective to juxtapose vulnerability assessment with the statistically observed changes in the climatic parameters of temperature and precipitation, the IPCC 2007 framework was selected.

- Secondly, IPCC 2007 framework is considered to be a quick method to identify current drivers of vulnerability without extensive data requirements on socio-economic, bio-physical, and institutional indicators as prescribed under IPCC 2014 VA framework. Since, our study's inherent limitation is availability of latest data across all variables, the said method was deemed appropriate by authors.

- Finally, IPCC 2014 framework poses a risk of mal-adaptation i.e. adaptation measures taken solely on basis of risk assessment, which are avoided in the IPCC 2007 framework as proposed interventions will be specific and directed to strengthen vulnerable aspects and areas.

Therefore, to corroborate and substantiate the outcomes of climate trend assessment on historic and current data, a Perception-based Vulnerability Assessment was conducted in District Kullu of Himachal Pradesh.

The study developed a vulnerability assessment framework where in Climate Change Vulnerability is measured as a composite function of *adaptive capacity* and climate *sensitivity* under *exposure* to climate variability. Vulnerability Assessment (VA) helped in gaining a better insight on the *why's and the how's* associated with a perception on climate change impact (direct or indirect) vis-à-vis household adaptation capacity in each development blocks. The similar logics were employed in the analytical climate change vulnerability conducted a part of the HP State Strategy & Action Plan on Climate Change (2012). The said methodology mapped district-level vulnerability as a measure of adaptive capacity and trade sensitivity of selected import-sensitive crops.

The functional relationships between the indicators of exposure, sensitivity, and adaptive capacity with vulnerability quotient were identified and drawn by the study team, and are hypothesized in table 3.

Vulnerability is defined as a function of character, magnitude, and rate of variation in a system, climatic exposure, its sensitivity, and adaptive capacity

Exposure: These are extrinsic factors that stimulate a direct or indirect impact and are represented by character, magnitude, and rate of change in the system

Sensitivity: Refers to the degree to which a system is affected by internal or external disturbances. These are the innate characteristics of a system that can be represented by changes in temperature, rainfall, floods, fires and more. For this study, sensitivity was indicated by impacts of climate change and extreme events on agriculture land, irrigation sources, diseases and pest incidences for different agricultural crops.

Adaptive Capacity: Reflects the system's ability to modify its characteristics or behaviour to better manage its response to existing and/or anticipated external stresses (Brooks, 2003). Appropriate adaptive capacity is essential to ensure effective design and implementation of adaptation strategies for reduction in the likelihood and magnitude of environmental impact. For the study, adaptive capacity of farming household is considered on four livelihoods related assets- physical, human, natural, and financial.

Source: HPSCCC, 2018

Table 3: Measurement Matrix for Exposure, Sensitivity, and Adaptive Capacity Indicators

	Hypothesized Variable Relationshipw
Exposure	
Temperature	+
Snowfall	-
Drought	+
Strong winds	+
Flash floods	+
Hail events	+
Sensitivity	
Loss of arable land due to flooding/siltation/sinking/drought	+
Land size affected	+
Availability of irrigation water	-
Conflicts for irrigation water	+
Diseases	+
Insects	+
Adaptive capacity	
Human assets	
Education	+
Employment	+
Knowledge on adaptation measures	+
Extension services	+
Natural assets	
Land holding	+
Production	+
Livestock	+
Irrigation coverage	+
Crop diversification	+
Physical assets	
Access to technology	+
Access to improved farming material	+
Water harvesting structure	+
Fertilizer usage	+
Financial assets	
Income diversification	+
Insurance penetration	+
Access to credit facility	+
Access to farm subsidies	+

Source: HPSCCC, 2018

To assess the outcome of primary data survey, a Principal Component Analysis (PCA) was conducted using the SPSS statistical tool. PCA is one of the basic approaches to factor analysis employed to ascertain the total variance in data and transform original variable to smaller set of linear combinations. It is essentially utilised in situations where the research objective is to determine minimum number of factors to explain maximum data variance. In case of social surveys, PCA helps in establishing a factor loading range from -1.0 to 1.0, and pulls out principal components pertaining to thematic inference desired. In this study, information from structured survey was subjected to PCA on indicators of Exposure, Sensitivity, and Adaptive Capacity to measure Vulnerability of the sector to changes in climatic parameters.

CHAPTER 3 - PILOT CASE AND METHODS

DISTRICT KULLU – A BACKGROUND

Nestled in the Pir Panjal range of the western Himalayas, District Kullu borders Lahaul & Spiti on north-east, Kinnaur on the east, Shimla on south-east, Mandi on south-west, and Kangra on the west. Spread across an area of 5503 sq. km, Kullu is the fifth largest district in the State, divided into five development blocks (Kullu, Naggar, Banjar, Anni, and Nirmand) fed by rivers the Beas and the Satluj.

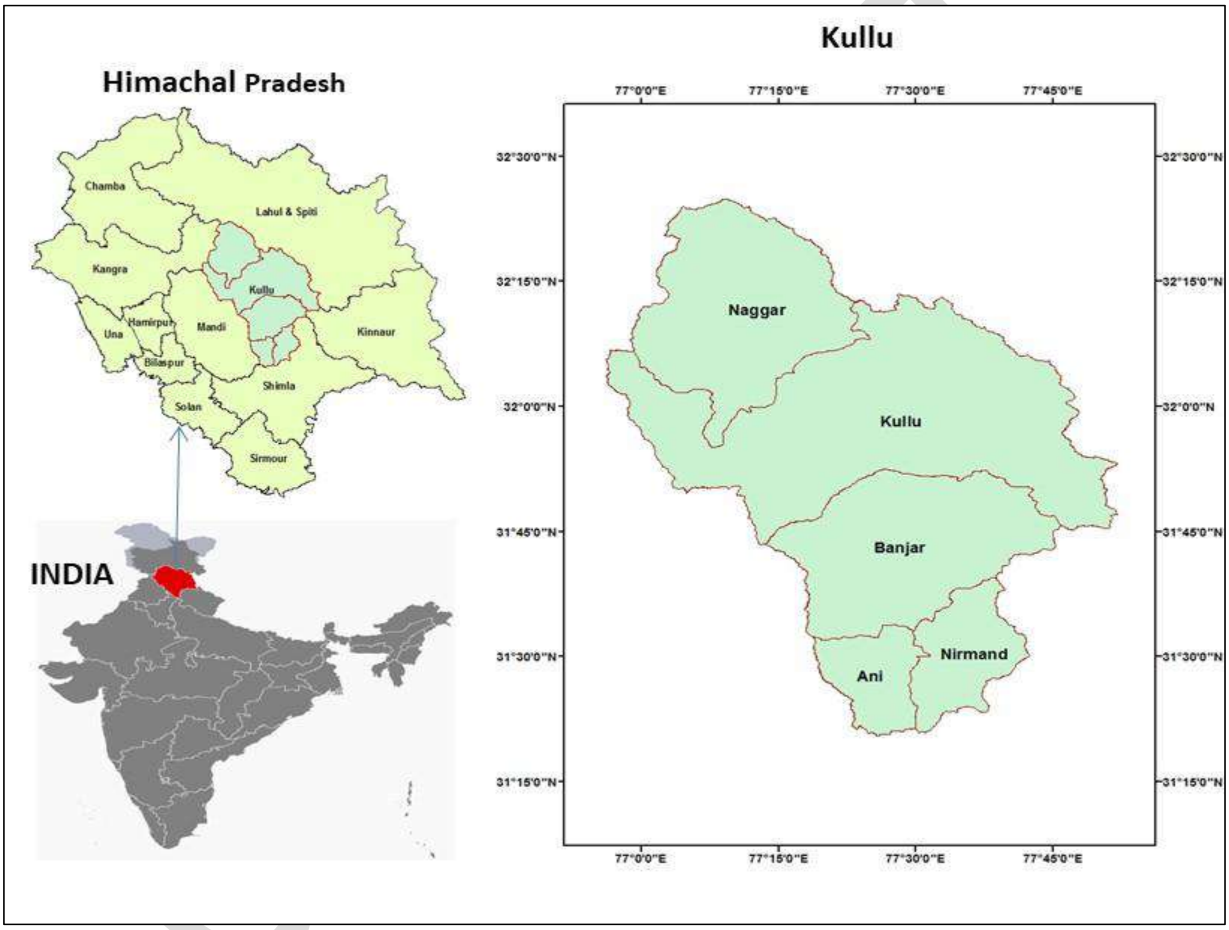


Figure 4: Map of District Kullu, Himachal Pradesh
Source: HPSCCC, 2018

With a population of 437,903 individuals, the district has a population density of 80 persons per sq. km. and around 95 per cent concentration in rural areas. Agriculture is the main source of livelihood providing employment to almost 78 per cent of the population supplemented by a flourishing tourism industry (Census, 2011). Table 5 illustrates horticulture profile of the Himachal Pradesh and District Kullu (wherever available) with details on ecological zones, land use, irrigation, and major crops.

Table 4: Himachal Pradesh: Horticulture Profile

Horticulture Profile – Himachal Pradesh			
Horticulture Land Use	**Total Geographical Area ('000 ha):** 229.202	**% of Total Cultivable Area:** 37.58 %	**% Area under Temperate Fruit:** 63.5 %
Agro-Ecological Zone – *District Kullu*	Western Himalayas, Zone II (sub-temperate and sub-humid hills), Zone III (wet-temperate high hills)		
Agro Climatic Zone (NARP)*	1. Low Hills/Valley Areas (35.50%) 2. Mid Hill Mild Temperate Areas (44.23%) 3. High Hill Temperate Areas (16.50%) 4. High Hill Wet Temperate Areas (4.41%)		
Economic Profile	**Gross Value of fruit Produce:** INR 3117.35 Cr.	**Per Capita Income from Fruits:** INR 4547	**Employment:** 900 lacs Man-days
Infrastructure	**Progeny-cum-Demonstration orchards & Nurseries:** 97 *(5 in Kullu)*	**Private Registered Nurseries:** 568 *(130 in Kullu)*	**Packing and Grading Houses:** 11
Major Fruit Crops	*Fruit Crops:* Apple, Plum, Peach, Apricot, Pear, Cherry, Pomegranate, Strawberry, Kiwi, Olive, Orange, Malta, Lime, Galgal, Other citrus fruits, Mango, Litchi, Guava, Papaya, Jackfruit, Loquat. *Nuts:* Almond, Walnut, Picanut, Hazelnut		
Apple Cultivation	***Altitude:*** 1,500-2,700m with 1,000-1,500 hours of cold weather with 7 °C or below winter temperature. *Growing Season*: Ideal Temperature of 21to 24 °C , 100-125 cm annual rainfall (evenly distributed) ***Soil:*** Loamy, rich in organic matter, pH 5.5-6.5 ***Varieties in Himachal Pradesh:*** *Clonal Rootstock:* M9, M26, M7, MM106, MM11 *Scab Resistant:* Prima, Priscilla, Sir Prize, Jonafree, Florina, Macfree, Nova Easy Grow, Nova Mac, Liberty, Freedom, Firdous *Hybrids:* Lal Ambri, Sunehari, Chaubatti Princess, Chaubatti Anupam, Ambred, Ambrich, Ambroyal *Low Chilling:* Michal, Schlomit, Anna, Tamma, Vered, Neomi, Tropical Beauty, Parlin's Beauty *Pollinizing:* Red Gold, Golden Delicious, Mc Intosh, Lord Lambourne, Winter Banana, Granny Smith, Golden Spur, Tydeman's Early		

Source: ENVIS Centre, Himachal Pradesh (2016), *HPAGRISNET* (2017)

KULLU AND THE CLIMATE

The district has cold-dry weather with maximum temperature variations from 15.1°C in January to 37.2°C in July, and minimum temperature ranging from 19.4°C in July to -1.5°C in January. Kullu experiences mild summers and harsh winters where upper regions receive snow and sleet falls. Rainfall is well distributed from January to September (confined to lower heights), with maximum downpour in the month of July. Agro-climatic conditions in District Kullu are conducive for cultivation of temperate and subtropical fruits such as apple, peach, plum pear, almonds, and walnuts.

However, exposure to natural events such as flash floods, cloudburst, and droughts are common and frequent compared to the other districts in the state. As per the findings from climate change hazards and risks assessment conducted by the Indian Himalayas Climate Adaptation Programme, over the time period of 1950-2014, Kullu accounted for over 40 per cent of the recorded flood events, and had maximum exposure of agricultural land to glacial lake outburst floods in the State (IHCAP, 2015). This increased exposure and sensitivity to extreme variations in climatic parameters and inherently diverse climatic profile, renders District Kullu an interesting and appropriate character to pilot an assessment of climate change impact on horticulture productivity in Himachal Pradesh.

METHODS

Within the context of collocation of climate variability and agriculture productivity in District Kullu, Himachal Pradesh, a pilot study was designed 1) *to determine the statistical impact of variations in climatic parameters (temperature and rainfall) vis-à-vis horticulture crop productivity*; 2) *to conduct a perception–based climate change vulnerability assessment of farmers' community on key parameters of risk exposure, sensitivity, and adaptive capacity*.

To that effect, the study methodology was divided for primary and secondary data assessments in accordance with the above mentioned study objectives.

SECONDARY DATA SOURCES AND TECHNIQUE

The study employs three different statistical measures viz. trend analysis based on Mann Kendall Test, Standardized Anomaly Index, and Multivariate Linear Regression Analysis to ascertain the impact of variation in climatic parameters on horticulture sector pertaining to phonological stages of *pre-flowering, flowering* and *fruit-setting and development*.

CLIMATE DATASETS

The mean minimum, maximum, diurnal temperatures, and rainfall data for Kullu District was collected from India Meteorological Department (IMD), Shimla covering a time period of 1990-2016. Datasets were further categorised for different phenological stages i.e. *pre flowering, flowering, and fruit setting and development stages* from November to February, March to April and May to August respectively.

HORTICULTURAL DATASETS

Apple, Pear, Plum, Peach, Apricot, Cherry, Pomegranate, Walnut and Almonds horticulture crops acreage and production data was collected from the Directorate of Horticulture, Himachal Pradesh, covering the time period 1980 to 2016.

PRIMARY DATA PROCESS

Primary observations were collected between September 2017 and February 2018 by a team of 6 experienced surveyors in District Kullu district. Structured interviews were administered in five development block viz. *Kullu, Naggar, Banjar, Anni, and Nirmand* to elicit responses qualifying the attributes of the proposed vulnerability assessment framework viz. exposure, sensitivity, and adaptive capacity to climate change. A total of 210 farmer households were selected following a random selection process of taking 10 HHs from 10% of panchayats from each of the five blocks *(Kullu 70 HH, Naggar 40 HH, Banjar 40 HH, Anni 30 HH, Nirmand 30 HH)*. Nevertheless, due relevance was given to selection of villages that represent extreme altitude gradient of the district (1,089-6,632m), thus ensuring representation of different crop cultivations. The map below lists the 31 villages surveyed in the five development block. Detailed information on village and block profile with demographic and agricultural profile and the questionnaire are attached in Appendix A and B, respectively.

METHODOLOGY CONSTRAINTS

Nevertheless, the study should be viewed with its intrinsic shortcomings. The data on acreage and production of horticulture crops had several gaps and outlier values that were correct using estimates of historic data trend and mean values. Similar data gaps were observed in temperature and rainfall figures that were addressed using the above mentioned approximations. Finally, the study should be taken as a case study assessment, *prima facie*, and not as estimation for the entire state. For the primary study, interview outcomes are subject to response bias[1], where respondents could have given socially desirable and obvious answers.

[1] Response bias are systematic tendencies of respondents to give socially and/or politically desirable answers that lead to halo effects or severity/leniency bias

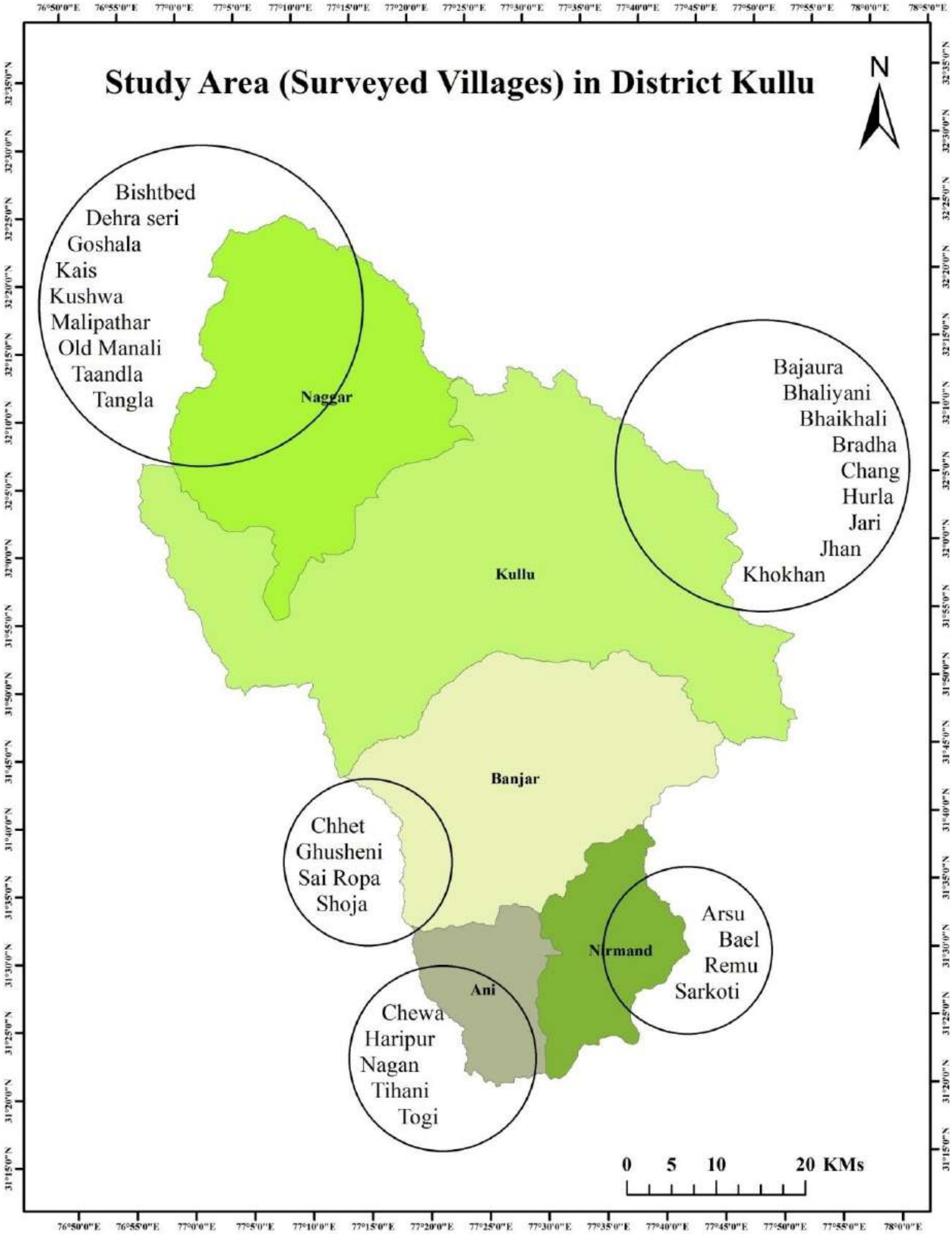


Figure 5: Study Area with Villages surveyed in Five Development Blocks, District Kullu, HP
Source: HPSCCC, 2018

CHAPTER 4 – CLIMATE TREND AND HORTICULTURE: DISTRICT KULLU

CURRENT CLIMATE TRENDS –DISTRICT KULLU

To capture the nerve of climatic changes in the district, temperature (min, max, diurnal), and rainfall (quantity and days) are considered as explanatory indicators. Based on the statistical analysis, Mann Kendall trend test, a highly significant change in climatic variables was observed in ***flowering season*** from March to April in comparison to ***pre-flowering and fruit setting season***. Table 5 exhibits the results of Mann Kendall test at 95% confidence level for minimum, maximum, and diurnal temperate, and rainfall for the time period 1990-2016.

Table 5: Mann Kendall Test Results – Climatic Trends for pre-flowering, flowering and fruit setting seasons (1990-2016)

	Mean	Sen's slope	p-value
Pre Flowering (November- February)			
Av. Max Temperature	18.77	**0.04**	**0.04**
Av. Min. Temperature	3.08	0.01	0.52
Diurnal Temperature	15.69	15.69	0.19
Total Rainfall	216.39	-2.58	0.20
Rainy Days	4.28	-0.07	0.28
Flowering (March – April)			
Av. Max. Temperature	24.74	**0.12**	**0.01**
Av. Min. Temperature	8.27	**0.04**	**0.00**
Diurnal Temperature	16.47	0.07	0.06
Total Rainfall	176.65	**-6.17**	**0.00**
Rainy Days	9.73	-0.04	0.51
Fruit- Setting (May- August)			
Av. Max. Temperature	31.49	0.03	0.23
Av. Min. Temperature	17.66	0.02	0.29
Diurnal Temperature	13.82	0.01	0.76
Total Rainfall	360.35	0.98	0.76
Rainy Days	12.97	**0.17**	**0.00**

Source: HPSCCC, 2018

As per the analysis, both the ***average maximum and minimum temperatures*** registered an inclining trend progressing at a rate of 0.12°C and 0.04°C per year between 1990 and 2016 (as exhibited by Sen's slope), while the ***rainfall*** quantity exhibited a significant decline of 6.17 mm per year, during the ***flowering-season*** i.e. between March and April. During the ***pre-flowering season*** i.e. November to February, the ***mean maximum temperature*** increased by 0.04°C per year. Further, to better understand the variations in precipitation, changes in ***rainy days*** were analysed, which exhibited statistically significant variations in the ***fruit-setting stage only*** i.e. between May and August (an increase by a factor of 0.17 days). The remaining climatic variables did not exhibit any significant variations during *pre-flowering, and fruit setting* and *development stages.*

Figure 6 illustrates the trend variation in climatic parameter during the three phenological stages

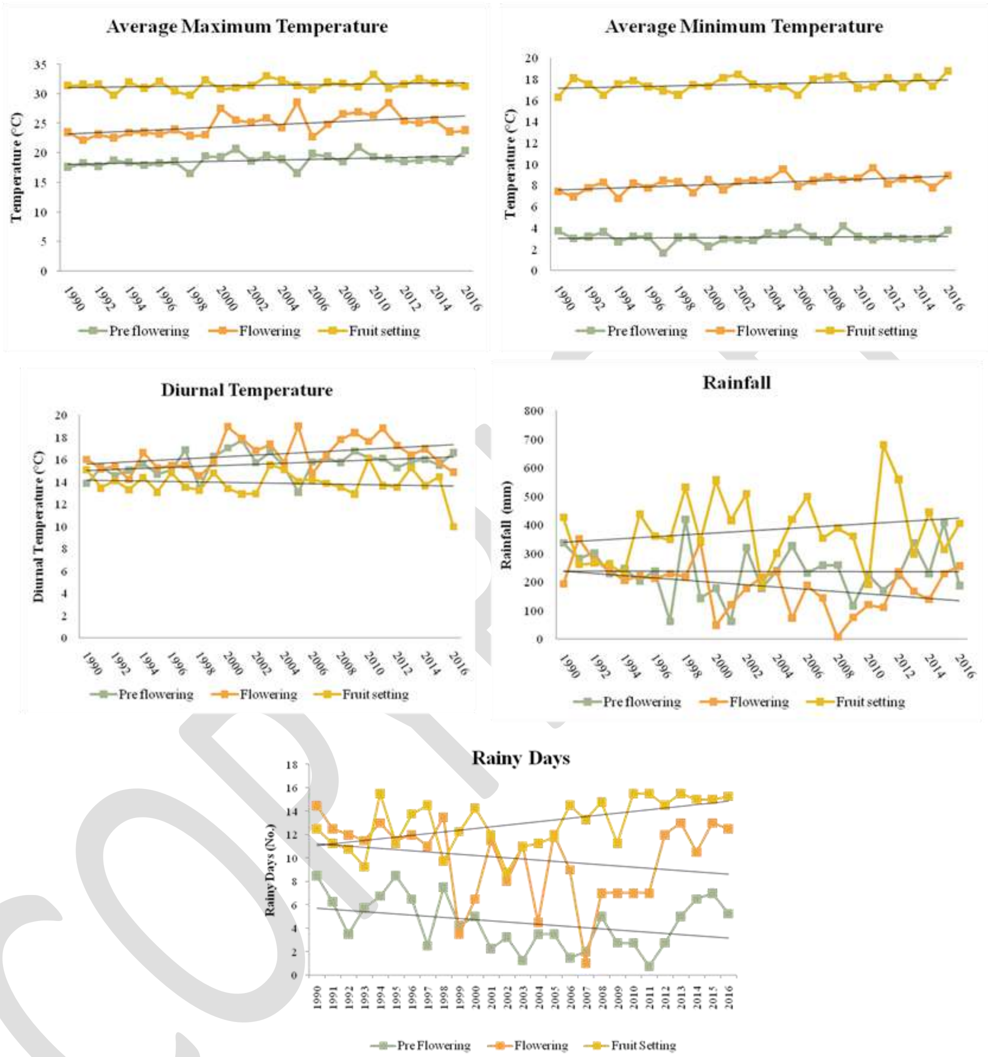


Figure 6: Variations in Climatic Parameters- Minimum T, Maximum T, Diurnal T, Rainfall, and Rainy Days during *pre-flowering, flowering, and fruit setting stages* (1990-2016), District Kullu, HP
Source: HPSCCC, 2018

A cooling period in mean maximum temperature during ***pre-flowering and flowering stages*** was observed up to 1999 (figure 7) followed by a continuous warming trend with temperatures rising above the long term averages from 2000 till 2016. Trend analysis of anomalies from 1990 to 2016 depicted a significant deviation in minimum and maximum temperature from their respective long term average values (Table 6). For instance, during the

flowering and pre-flowering season the mean maximum temperature was higher than the flowering and pre-flowering season the mean maximum temperature was higher than the long term averages, post 2000. For ***fruit setting and development stages***, 9 out of 14 warming years were recorded after 2000 (figure 7).

Table 6: SAI for Mean Annual Maximum, Minimum, Diurnal Temperature, Rainfall, and Rainy days from (1990 -2016), District Kullu, HP

	Mean	Sen's slope	p-value
Pre Flowering (November- Feb)			
Av. Max Temp	18.77	**0.04**	**0.04**
Av. Min. Temp	3.08	0.01	0.54
Diurnal Temp	15.69	0.03	0.19
Total Rainfall	216.39	-3.00	0.96
Rainy Days	4.28	-0.04	0.19
Flowering (March – April)			
Av. Max. Temp	24.74	**0.07**	**0.00**
Av. Min. Temp	8.27	**0.06**	**0.00**
Diurnal Temp	16.47	0.01	0.76
Total Rainfall	176.65	-0.006	0.07
Rainy Days	9.73	-0.02	0.19
Fruit- Setting (May- August)			
Av. Max. Temp	31.49	0.04	0.24
Av. Min. Temp	17.66	0.03	0.30
Diurnal Temp	13.82	0.01	0.76
Total Rainfall	360.35	0.03	0.20
Rainy Days	12.97	**0.07**	**0.01**

Source: HPSCCC, 2018

The anomalies in the ***annual mean minimum temperature*** exhibited the similar pattern expect for the pre-flowering stage (figure 8), where from 1990 to 2002, minimum temperature remained below the long term averages with intermittent respites in pre flowering, flowering and fruit setting and development stages. Across all phenological stages, minimum temperature rose steadily from 2002 to 2016, with 6, 3, and 7 breaks from warming for the three stages chronologically. Nevertheless, the most significant incline in mean minimum temperature for was observed during the ***flowering period*** (Table 6). Variations in diurnal temperature from the long term averages were not found to be of any statistical significant for all phenological stages.

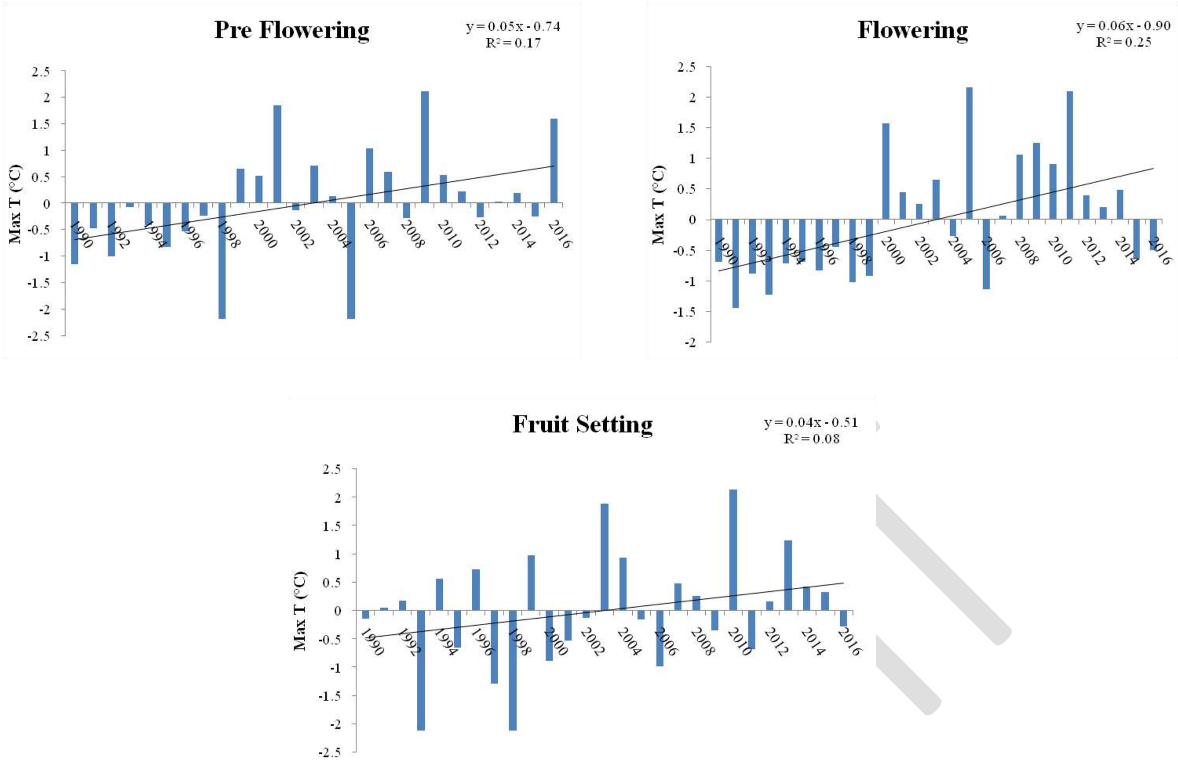


Figure 7: SAI for Mean Maximum Temperature during *pre-flowering, flowering, and fruit setting stages* (1990-2016), District Kullu, HP

Source: HPSCCC, 2018

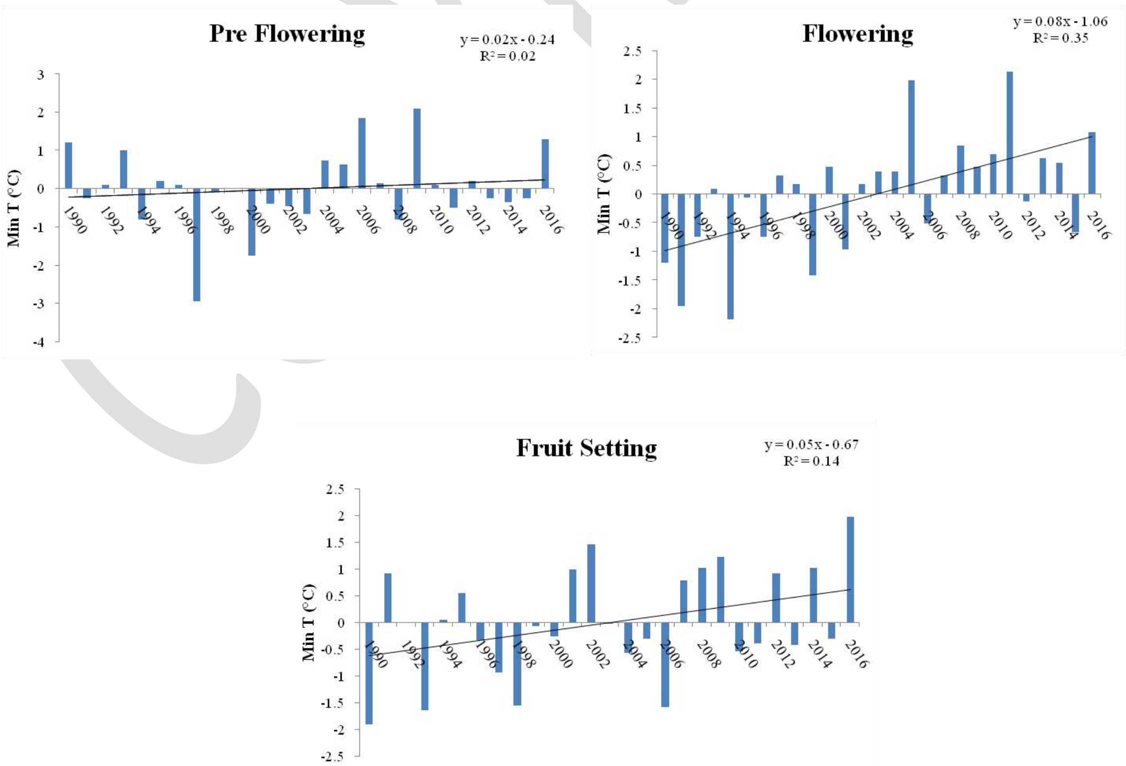


Figure 8: SAI for Mean Minimum Temperature during *pre-flowering, flowering, and fruit setting stages* (1990-2016), District Kullu, HP

Source: HPSCCC, 2018

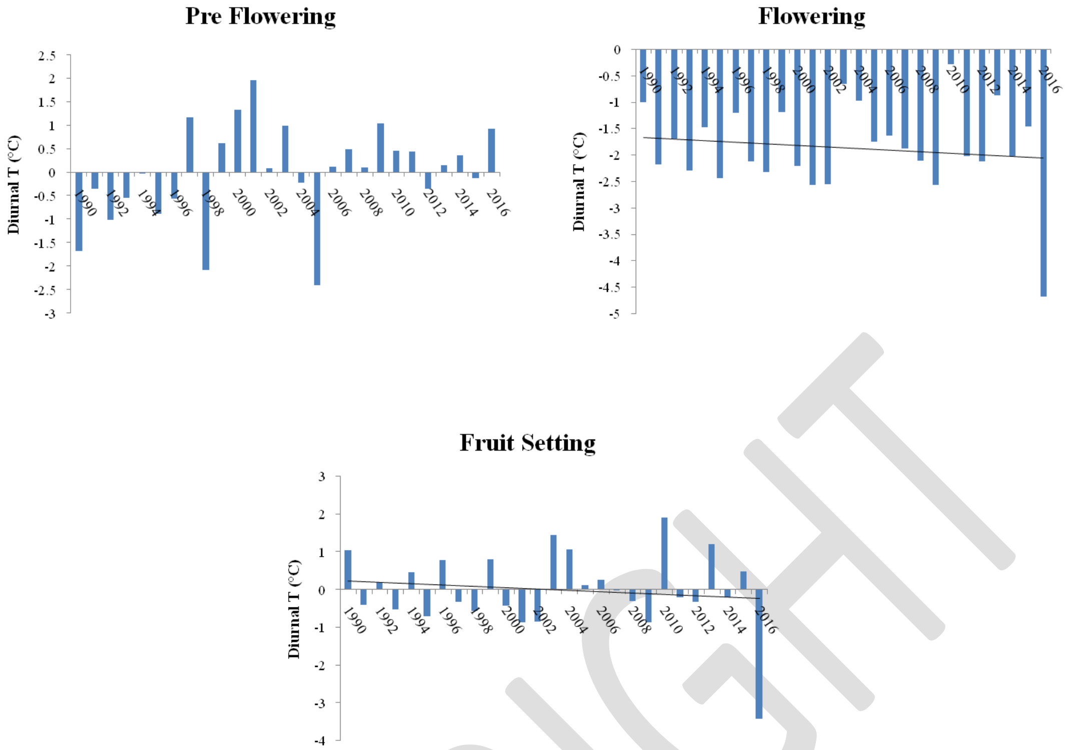


Figure 9: SAI for Mean Diurnal Temperature during *pre-flowering, flowering, and fruit setting stages* (1990-2016), District Kullu, HP
Source: HPSCCC, 2018

Rainfall pattern during the phenological stages of pre-flowering, and fruit setting and development stages did not show any variation over the long term averages, except during the flowering stage where rainfall registered a decreasing trend post 2002, with small spikes in 2003, 2004, 2012, 2015, 2016 (figure 10). Meanwhile for ***rainy days*** patterns during pre-flowering season, there was a consistent decline from 2002 to 2012, there after small peaks in 2014 and 2015 (figure 11). Similarly, during the flowering season, 2001 onward consistent decline in rainy days was witnessed till 2012, post which rainy days increased till 2015. Statistically significant variations are observed during the ***fruit setting stage*** only (table 6), where 2005 onwards there was increase in rainy days with a small dip in 2009.

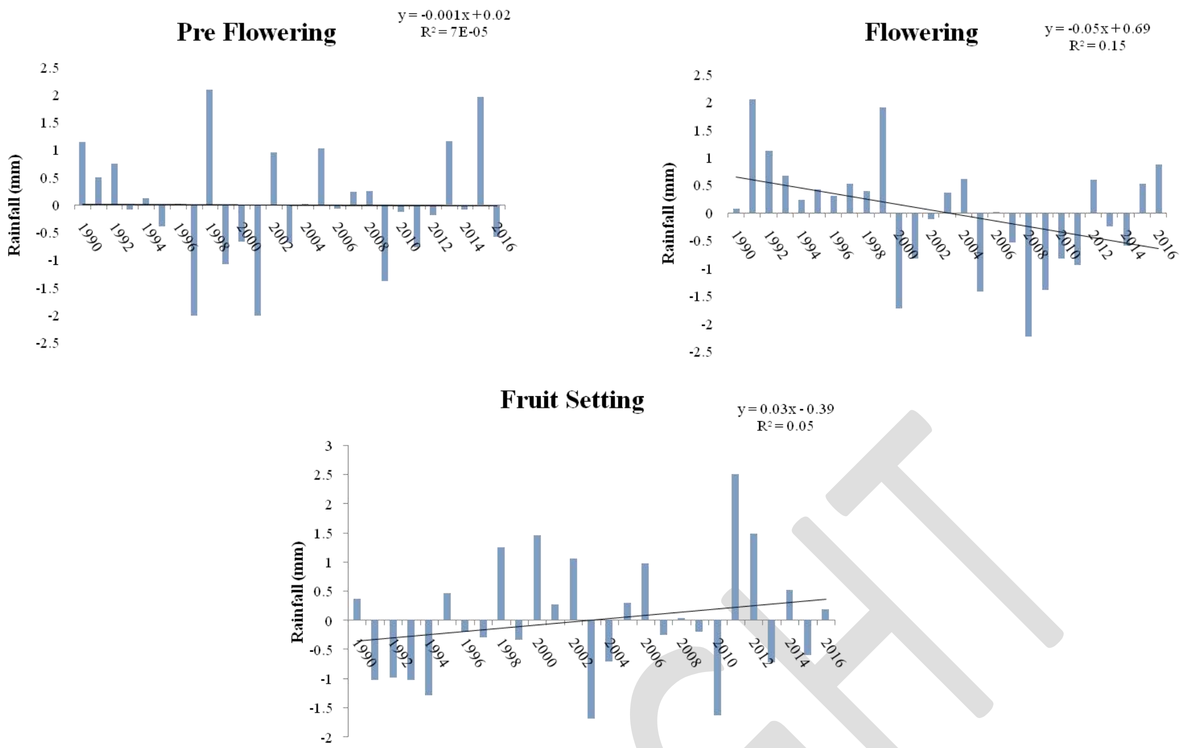


Figure 10: SAI for Mean Annual Rainfall during *pre-flowering, flowering, and fruit setting stages* (1990-2016), District Kullu, HP

Source: HPSCCC, 2018

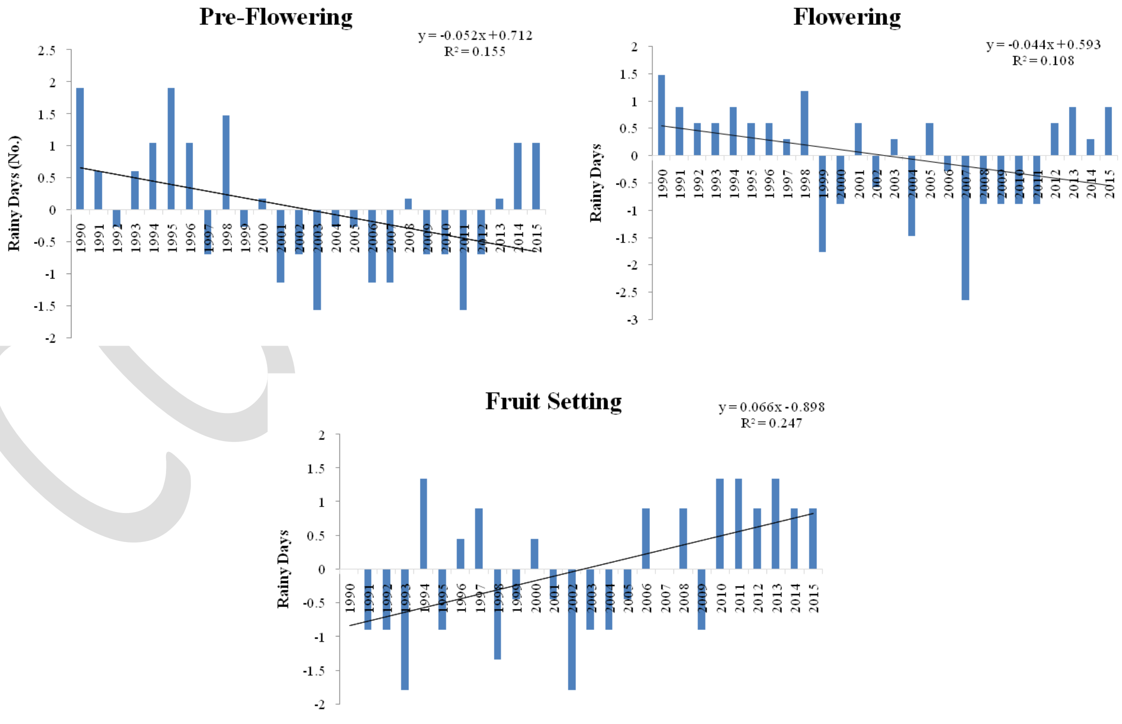


Figure 11: SAI for Mean Annual Rainy Days during *pre-flowering, flowering, and fruit setting stages* (1990-2016), District Kullu, HP

Source: HPSCCC, 2018

The discussed variations in temperature and rainfall patterns are not confined to District Kullu but are corroborated by observations from other studies in the Himalayan region. Poudel and Shaw (2016) observed an increase of 0.07°C in minimum temperature and 0.02°C in maximum temperature from 1980 to 2010 in Nepal bound Himalayan region, while comparing minimum annual temperatures with maximum temperatures. Shekhar et al. (2010), in their assessment of climatic variations in the mountain ranges of the western Himalaya viz. Pir Panjal, Shamshawari, Greater Himalaya, and Karakoram, recorded increase in seasonal mean, maximum, and minimum temperatures by 2.0°C, 2.8°C, and 1°C, respectively. Meanwhile, Bhutiyani et al. (2007) reported a significant increase in temperature in the north-west Himalayas by about 1.6°C with faster pace of winter warming. Specifically in Himachal Pradesh, the rate of increase in maximum temperature was observed to vary with altitudinal zones (higher altitudes registered higher rate of increase). Erratic precipitation patterns have been reported during different phenological stages by other studies as well. In district Kullu, Vishvakarma et al. (2003) reported 7 cm decrease in rainfall, 12 cm decrease in snowfall, and an increase of 0.25-1°C increase in mean maximum and minimum temperatures.

FRUIT CROP PRODUCTIVITY – DISTRICT KULLU

ACREAGE, PRODUCTION, PRODUCTIVITY ASSESSMENT OF MAJOR HORTICULTURE CROPS

In District Kullu, the acreage under orchards has increased sharply from 675 ha in 1965 to 9,477 ha in 2010, registering a growth of 1,304 per cent. To get a better overview in this growth trajectory, temporal trend of changes in acreage, production, and productivity for Apple, and other fruit crops viz. Plum, Peach, Apricot and Pear in Kullu district were studied.

Acreage under apple cultivation increased from 10,264 ha in 1980 to 26,029 ha in 2015 (an increase of 153.59 per cent) and the production surged from 29,058 MT to 143,474 MT (1980-2015), as illustrated in Figure 12. Nonetheless, productivity of Apple did not register any statistically significant variations, with minimum productivity of 1.21 t ha-1 in 1994 and maximum of 7.97 t ha-1 in 2010 there after declining to 5.51 t ha-1 by 2016.

For other temperate fruits, the composite acreage increased by 52.34 per cent (2,178 ha in 1980 to 3,318 ha in 2015), the total production surged by 1108.42 per cent (2,956 MT in 1980 to 35,724 MT in 2015), and productivity increased from 1.36 to 10.77 t ha^{-1} in past 35 years (Figure 13). Composite area under dry fruits i.e. Almond, Walnut, and Picanut increased by 108 per cent from 530 ha to 1106 ha till 2001, thereafter declined to 322 ha by the end of 2015. While, production of dry fruits registered a similar trend, productivity showed consistent decline, moving from 0.58 t ha^{-1} in 1980 to 0.21t ha^{-1} in 2015 (Figure 14).

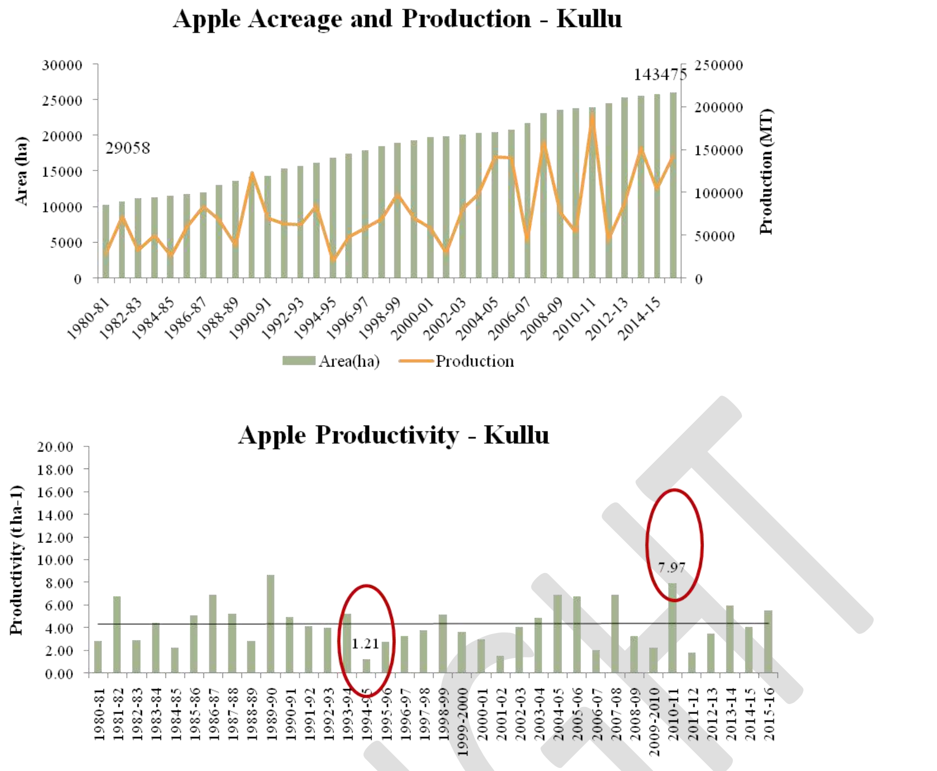


Figure 12: Variations in Annual Acreage, Production, and Productivity – Apple (1980-2016), District Kullu, HP
Source: HPSCCC, 2018

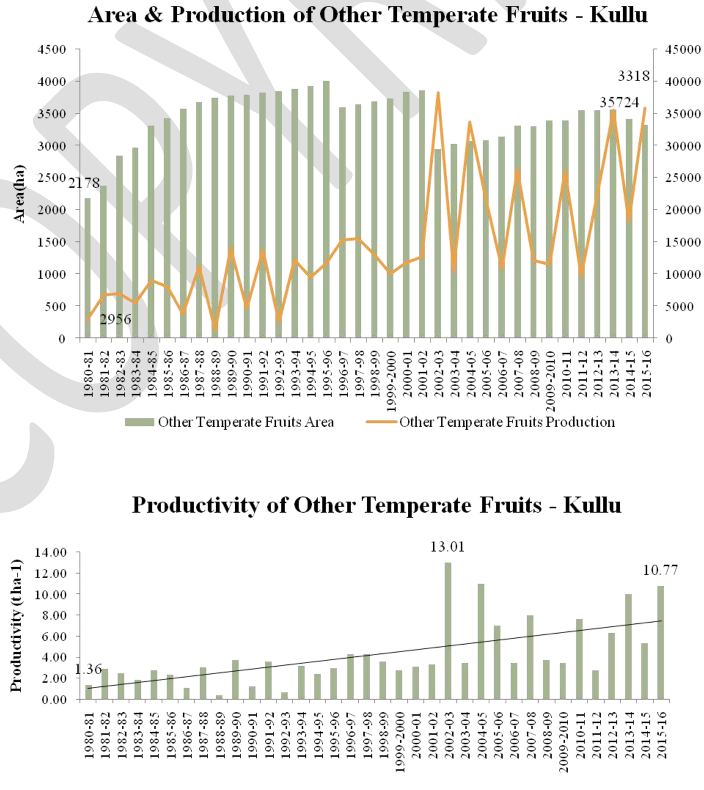


Figure 13: Variations in Annual Acreage, Production, and Productivity – Other Temperate Fruits: Plum, Peach, Apricot, Pear (1980-2016), District Kullu, HP
Source: HPSCCC, 2018

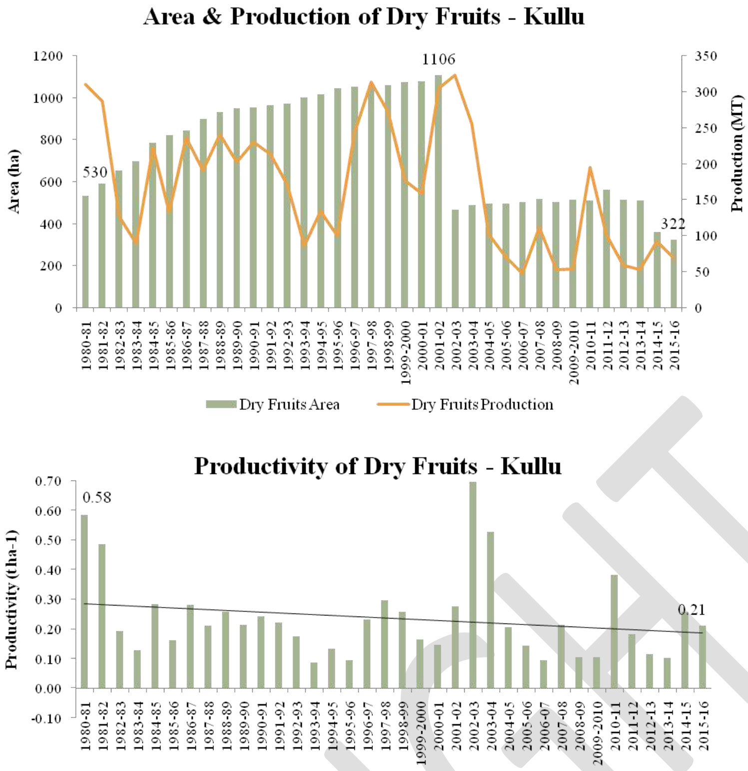


Figure 14: Variations in Annual Acreage, Production, and Productivity – Dry Fruits: Almond, Walnut, Picanut (1980-2016), District Kullu, HP

Source: HPSCCC, 2018

Dwelling deeper into the productivity trends for the horticulture crop, an overall increasing productivity trend is recorded for Pear, Peach, and Apricot, with statistically significant p-values at 95 per cent confidence interval, while for productivity of apple, plum, cherry, pomegranate and walnut statistically significant observations weren't registered. Highest increase was observed in case of Pear (1.09 t $ha^{-1}yr^{-1}$) followed by Peach (0.04 t $ha^{-1}yr^{-1}$) and Apricot (0.01 t $ha^{-1}yr^{-1}$); while Almond crop recorded a net decrease in productivity by 0.005 t $ha^{-1}yr^{-1}$ (Table 7)

Table 7: Mann Kendall Test Results – Crop Yields for Fruit Crops (1990-2016)

Fruits Productivity	Mean	Sen's slope	p-value	Confidence interval
Apple	4.03	0.06	0.38	0.036,0.077
Pear	16.78	**1.09**	**0.00**	0.911,1.273
Plum	3.69	0.04	0.28	0.022,0.050
Peach	**1.05**	**0.04**	**0.00**	0.024,0.049
Apricot	**0.30**	**0.01**	**0.00**	0.009,0.011
Cherry	0.51	-0.006	0.18	-0.008,-0.004
Pomegranate	1.06	.0005	0.95	-0.005,0.013
Walnut	0.60	0.00	0.65	-0.001,0.00
Almond	**0.12**	**-0.005**	**0.00**	-0.006,-0.004

Source: HPSCCC, 2018

Trend data in tandem with the outcomes of Mann Kendall Test results hint toward a shift in focus from Apple crop to other stone crop and a consistent decline in dry fruit, solely in terms of productivity. Consistent trends have been reported by different research studies upholding the role of climate change in impacting the productivity of apple and other temperate fruits in Himachal Pradesh. While, Singh (2003) discussed the role of changing weather patterns such as reduced annual snowfall and fluctuating temperatures during flowering period in determining the success of apple crop in Himachal Pradesh; Gautam et al. (2004) unearthed the factors of reduction in natural pollinating agents, inadequate winter chilling, frequent spring frosts and hails, droughts as reasons for poor fruit setting in Delicious variety. Therefore, at this stage it becomes imperative to get a better insight into factors leading to this supposed transition with specific role of climate change led variations in individual crop productivity. The next section explores the juxtaposition of horticulture crop productivity with respect to climate change variations, through a multivariate regression analysis.

CLIMATE- FRUIT CROP JUXTAPOSITION

To determine the relationship between climatic variables during phenological periods and productivity of temperate fruit crops, a correlation analysis was performed. Highly significant correlation between climate variability and productivity was observed during the ***pre-flowering stages***, with a predominant impact on the productivity of Apple, Pear, and Almond crops (table 8). Apple productivity exhibited strong negative correlation with maximum and diurnal temperatures during the pre-flowering period with coefficient values of -0.47 and -0.40 respectively. That means with an increase in ***mean maximum and diurnal temperatures***, during the ***pre-flowering stages***, apple productivity declines. These results are in accordance with the works of Sharma et al., (2013) who observed a negative but significant correlation between maximum temperature and productivity during different stages of fruit growth and development of apple in Shimla. Productivity of Pear and Almonds, too had a negative correlation of -0.40, -0.34 respectively with variations in maximum temperature during the study period.

With reference to variations in ***mean minimum temperature***, only Cherry crop showed significant positive correlation of 0.33 during the ***pre-flowering season***. That is with slight increase in minimum temperature, cherry crops shows increased productivity. This is in consonance with the expected ideal conditions for cherry crop that is observed to be highly susceptible to frost damage and during bud development requires temperatures no lower than - 6°C (Lang, 2001).

For ***rainfall variations*** during the ***pre-flowering season***, statistically significant positive correlation was observed for the productivity of apple, pear and almond (0.51, 0.56 and 0.32, respectively) i.e. with increased in rainfall during the pre-flowering period, these crops stand a chance to benefit through better productivity. During the pre-flowering seasons soil is expected to be moist and soft to facilitate the development of early root system, hence evenly spread rainfall is considered a beneficial factor for these crops. Yet, a weather extreme during the pre-flowering stage could wipe-out the entire plantation. With reference to variations in rainfall days, none of the fruit crops showed significant correlation in productivity, during the pre-flowering stage.

During ***the flowering*** period, apple productivity assumed a positive correlation with variations ***in mean minimum temperature*** (0.35). The results are supported by Caprio and

Quamme (2005) who linked warmer weather during spring as a beneficial factor for pollination and fruit set, thus favouring overall productivity of crop.

Meanwhile, Plum crop yield showed maximum sensitivity to variations in climatic parameters of ***mean maximum and diurnal temperatures***, and ***rainfall*** during the ***flowering stages*** with a negative correlation of -0.38 and -0.40 with maximum and diurnal temperatures respectively; and a positive correlation of 0.34 with rainfall. This means, with an increase in mean maximum temperature during the flowering stages, the plum crop yield declines, while an increase in rainfall supports the fruit productivity. Higher temperatures during the flowering stages of plum fruit are observed to fasten the flowering process that impacts the overall productivity (Cosmulescu et al., 2010). With reference to variations in rainy days, none of the fruit crops showed significant correlation in productivity, during the flowering stage.

For the ***fruit setting and development stages***, productivity of pomegranate and almond crops were positively correlated with the ***diurnal temperature*** (0.34 and 0.45); and almond productivity was positively correlated with ***mean maximum temperature*** (0.33). Rest of the crops did not show any statistically significant productivity changes in response to variations in temperatures at 95 per cent confidence interval. With changes in quantity of ***rainfall***, apple, apricot and pomegranate productivity exhibited an indirect relationship with the correlation coefficient values of -0.31, -0.35 and -0.33 respectively.

Pomegranate fruit flourishes in hot and dry climate during the fruit setting and development stages. Pomegranate and Almonds are observed to be tolerant to fluctuations in diurnal temperatures, which support the outcomes of our study. Meanwhile, the prescribed negative correlation with rainfall variations for apple, apricot, and pomegranate during the fruit development stages is supported by the findings of Kwon et al., (2008), who reported compromised fruit quality due to heavy precipitation during the later stages of fruit development. Wetter weather during the stage of fruit setting and development stages are found to result in increased losses from rain-induced fruit drop and cracking in temperate fruits. For instance, in case of pomegranate, rainfall during the fruit maturation stage leads to rapid fruit cracking and significantly lower productivity. With reference to variations in rainy days, none of the fruit crops showed significant correlation in productivity, during the fruit setting stage.

To summarise the above discussion on the regression outcomes of detrended [2] climatic variables of minimum, maximum, diurnal temperature, rainfall, and rainy days with the productivity of selected crops of apple, pear, plum peach, apricot, cherry, pomegranate, walnut, and almond. Of the three phenological stages, maximum impact of climatic parameters was observed during the ***pre-flowering stage*** i.e. the contribution of climatic variables in impacting the productivity of Apple, Pear, Cherry, Pomegranate, and Almond crops. R-squared statistics is used to ascertain the percentage of variation in productivity (positive or negative) that is explained by variations in minimum, maximum, diurnal temperature and rainfall. Therefore, during the ***pre-flowering stage***, climatic factors accounted for 35 per cent of the increase in Pear productivity, 31 per cent variation in Apple productivity, 13 per cent of productivity decline in Cherry, and 20 per cent decline in the Almond crop productivity. For the phenological stages of ***flowering stage***, variations in climatic parameters of temperature and rainfall accounted for 19 per cent of the variability in Apple productivity, 18 per cent (increase) in Plum, and 16 per cent (decline) in productivity of Cherry; and during ***the fruit setting and development*** stages 29 per cent variations (increase) in Apricot productivity, 24 per cent in Pomegranate, 21 per cent variations in Apple, and 27 per cent of decline in Almond productivity are explained by the considered climatic parameters. Factors of quality planting material and better orchard management practices are touted to be the explanatory reasons for remainder variations in fruit crop yield (Jindal & Chauhan, 2001).

In nutshell, amongst all the studied crops, Apple productivity showed maximum sensitivity to climatic variations during all three stages (31%, 19%, 21%) with significant correlation observed for Pear (35%, 9%, 10%), Almond (20%, 13%, 27%), Plum (19%, 18%, 1%), Pomegranate (6%, 8%, 24%), Apricot (3%, 14%, 29%), and Cherry (13%, 16%, 8%). With respect to individual crops, this means that the observed variations in productivity for Apple crop from 1990-2016 is explained by the variations in climatic parameters only to the extent of 31 % during pre-flowering stage, 19% during the flowering stage, and 21% during the fruit setting and development stage. Similar interpretations are valid for Pear, Almond, Plum, Pomegranate, Apricot, and Cherry. Meanwhile, the productivity of Walnut was least influenced by the changes in climatic parameters across all phenological stages (2% at pre-flowering stage; 3% at flowering; and 15% at the fruit setting and development stage).

[2] Climate and productivity data was detrended by computing the difference in values from one year to the next.

Table 8: Multivariate Linear Regression Analysis – Crop Yields and Climatic Parameters, (1999- 2016)

S No.	Crops	Variable / Statistics	Pre flowering						Flowering						Fruit Setting and Development					
			Min T	Max T	DT	RF	RD	R^2	Min T	Max T	DT	RF	RD	R^2	Min T	Max T	DT	RF	RD	R^2
1.	Apple	Coefficient p-value	-0.12 0.29	**-0.47 0.01**	**-0.40 0.02**	**0.51 0.00**	-0.27 0.09	**0.31**	**0.35 0.04**	0.06 0.38	-0.10 0.31	-0.14 0.25	-0.03 0.44	**0.19**	-0.25 0.11	0.13 0.27	0.27 0.10	**-0.31 0.05**	0.05 0.39	**0.21**
2.	Pear	Coefficient p-value	-0.05 0.41	**-0.40 0.02**	**-0.37 0.04**	**0.56 0.00**	-0.20 0.17	**0.35**	0.06 0.39	-0.16 0.22	-0.24 0.12	0.12 0.29	0.18 0.19	**0.09**	-0.01 0.49	0.16 0.21	0.16 0.23	-0.22 0.41	0.13 0.27	**0.10**
3.	Plum	Coefficient p-value	0.03 0.44	0.02 0.47	0.00 0.50	0.24 0.12	0.03 0.43	**0.19**	-0.16 0.23	**-0.38 0.03**	**-0.40 0.02**	**0.34 0.05**	0.08 0.08	**0.18**	0.09 0.34	0.01 0.48	-0.00 0.42	-0.02 0.45	0.86 0.34	**0.01**
4.	Peach	Coefficient p-value	0.10 0.33	0.02 0.46	-0.03 0.45	-0.10 0.32	0.04 0.42	**0.05**	-0.14 0.26	-0.04 0.42	0.02 0.47	0.05 0.41	0.07 0.35	**0.03**	0.15 0.24	0.12 0.29	0.02 0.46	-0.15 0.23	0.17 0.21	**0.08**
5.	Apricot	Coefficient p-value	0.07 0.36	-0.04 0.43	-0.07 0.37	0.12 0.28	0.03 0.44	**0.03**	-0.14 0.25	-0.17 0.21	-0.14 0.25	-0.05 0.40	-0.14 0.25	**0.14**	-0.17 0.21	0.09 0.33	0.19 0.19	**-0.35 0.04**	0.21 0.15	**0.29**
6.	Cherry	Coefficient p-value	**0.33 0.05**	0.06 0.38	-0.10 0.31	0.06 0.40	0.09 0.33	**0.13**	-0.27 0.10	-0.17 0.21	-0.08 0.36	-0.01 0.49	-0.14 0.25	**0.16**	0.03 0.45	0.14 0.25	0.11 0.29	-0.20 0.16	0.14 0.26	**0.08**
7.	Pomegranate	Coefficient p-value	0.09 0.33	-0.00 0.49	-0.05 0.41	0.14 0.25	-0.15 0.24	**0.06**	-0.15 0.23	-0.14 0.24	-0.11 0.31	0.08 0.35	0.16 0.21	**0.08**	-0.14 0.25	0.28 0.09	**0.34 0.05**	**-0.33 0.05**	0.11 0.29	**0.24**
8.	Walnut	Coefficient p-value	-0.07 0.38	0.06 0.39	0.09 0.33	-0.12 0.28	0.05 0.41	**0.02**	-0.12 0.28	-0.10 0.32	-0.07 0.38	0.08 0.35	0.13 0.26	**0.03**	0.22 0.14	0.26 0.10	0.11 0.30	-0.30 0.08	0.06 0.39	**0.15**
9.	Almond	Coefficient p-value	-0.25 0.11	**-0.34 0.05**	-0.21 0.16	**0.32 0.05**	-0.19 0.18	**0.20**	0.12 0.29	-0.06 0.39	-0.14 0.26	0.13 0.27	-0.08 0.33	**0.13**	-0.24 0.12	**0.33 0.05**	**0.45 0.01**	-0.14 0.25	-0.19 0.17	**0.27**

Source: HPSCCC, 2018

CONCLUDING POINTERS

Crop Variations:

Pear, Peach and Apricot crops should statistically significant increase in productivity as per Mann Kendal test results

Productivity of Apple, Plum, Cherry, Pomegranate and Walnut did not show any statistically *significant changes from 1990-2016 as per results of Mann Kendall Test*

Apple Crop - minimum productivity of 1.21 t ha-1 in 1994 and maximum of 7.97 t ha-1 in 2010, there after declining to 5.51 t ha-1 in 2016.

Climatic Variations:

*Higher variability in temperature and rainfall parameters observed during **flowering period** as compared to **pre-flowering and fruit setting period** from 1990 to 2016*

Flowering period - minimum and maximum temperature increased by 0.04°C, 0.12°C per year respectively, and rainfall decreased by 6.17 mm per year

Pre-Flowering period - Maximum temperature increased by 0.04°C per year from 1990 to 2016

Fruit-setting period – Rainy days increased by 0.17 from 1990-2016

Higher anomalies in maximum and minimum temperature reported during all three phenological stages indicating a warming trend

Climate Crop Juxtaposition:

Strong relationship between climate variability and productivity of fruit crops during pre-flowering period in comparison to rest of two phenological stages i.e. for four fruit crops – Apple (with maximum and diurnal temperature, rainfall), Pear (with maximum and diurnal temperature, rainfall), Cherry (with minimum temperature), and Almond (with maximum temperature and rainfall) variations in productivity exhibited statistically significant correlation with changes in considered climatic parameters of temperature and rainfall during pre-flowering stage; while for flowering stage and fruit setting stage fewer statistically significant correlation was witnessed between fruit crops productivity and climatic parameters.

Amongst all temperate fruit crops, Apple found to be most vulnerable to impact of climatic variability at all three phenological stages while Walnut was least vulnerable

CHAPTER 5 – CLIMATE CHANGE VULNERABILITY: CASE STUDY, DISTRICT KULLU

The outcomes from the statistical analysis only give a plausible variation in horticultural productivity vis-à-vis changes in climatic parameters of temperature and rainfall, owing to statistical and data limitations of time period, gaps, and statistical relevance of sample space and absence of scientific validation. Therefore, individual farm data from five blocks of Kullu district was collected and analysed to conduct a perception-based Vulnerability Assessment.

Literally transcribed information from all the interviews was tabularized to feed in the PCA, as highlighted in earlier section. Table 9 below gives details on socio-economic status of farmers in District Kullu.

Table 9: Socio-Economic Profile Interviewed Farmer Community, District Kullu, HP

No. of Farming HH Interviewed	**210**
Female : Male	29:71
Percentage of traditional cultivators	89%

Farm Experience	**Blocks**					**District Average**
	Kullu	**Naggar**	**Banjar**	**Anni**	**Nirmand**	
<10 years	2.9	0	4.8	0	4.0	2.34
10-20 years	5.7	7.3	7.1	10.3	12.0	8.48
>30 years	91.4	92.7	88.1	89.7	84.0	89.18

Land Holding	**Blocks**					**District Average**
	Kullu	**Naggar**	**Banjar**	**Anni**	**Nirmand**	
Marginal (<6 bigha)	40.0	56.1	69.0	37.9	36.0	47.8
Small(6-12 bigha)	32.9	34.1	16.7	20.7	36.0	28.1
Semi-Medium(12-24 bigha)	25.7	7.3	9.5	37.9	20.0	18.7
Medium(24-60 bigha)	1.4	2.4	4.8	3.4	8.0	4.0
Large(>60 bigha)	0	0	0	0	0	0

Source: Field Survey, HPSCCC, 2018

From above data it is evident that of the surveyed farmers, less than 3 per cent had less than 10 years of farming experience, thus almost all can be categorized as experienced farmers. Additionally, in terms of land holding, agriculture is dominated by marginal farmers (47.8%) followed by small (28.1%), semi-medium (18.7%) and large (4%). Population of farmers with marginal holding was highest in block Banjar (69%) followed by Naggar (56.1%), Kullu (40%), Anni (37.9 %) and Nirmand (36%). None of the interviewed farmers had land holdings greater than 60 bighas.

TEMPORAL VARIATIONS

The study captured individual farm data from the 210 surveyed farmers on temporal changes in acreage (1988-2018) for cultivation different fruit crops viz. – Apple, Pomegranate, and other stone fruits.

Farmers' preferences for different fruit crops and their respective acreage between 1988 and 2018 are plotted in figure 14. Total fruit acreage for the interviewed farming households increased nearly three folds from 1.96 bigha to 6.12 bigha per household during last 30 years, with significant increase for apple cultivation (1.76 to 5.48 bigha / HH) followed by pomegranate (0.10 to 0.39 bigha /HH), and stone fruits (0.10 to 0.25 bigha / HH). While acreage under apple crop increased in all five development blocks, Nirmand Block in particular showed maximum increase (nearly 8 folds).

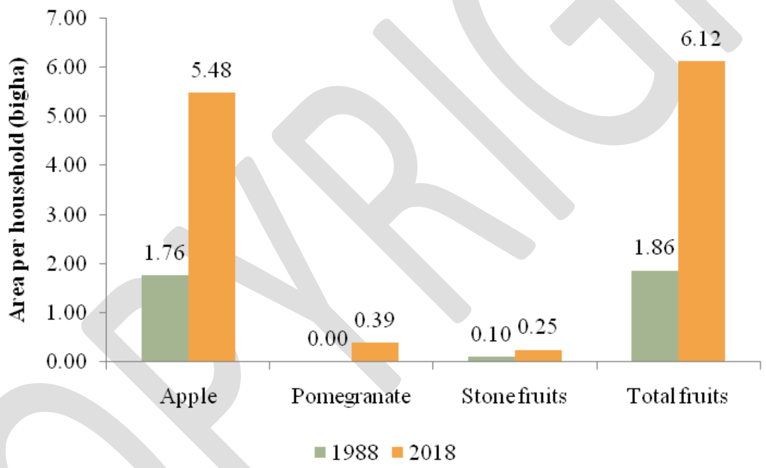


Figure 15: Acreage under different Fruit Crops, Field Survey, District Kullu, HP
Source: Field Survey, HPSCCC, 2018

Pomegranate was introduced in Himachal Pradesh as a new commercial crop in last 25-30 years and no commercial cultivation was practiced in 1988, as evident from Figure 15. Nevertheless, in 2018, all development block except for Nirmand, had adopted the new crop as part of their horticulture profile. Farmers from the Kullu block reported highest acreage under pomegranate i.e. 1.38 bighas, followed by Banjar (0.22 bigha), Naggar (0.20 bigha) and Anni (0.16 bigha per household).

Meanwhile, the acreage for stone fruits i.e. plum, apricot, and peaches registered an increasing trend in Anni and Banjar Block, whereas it remained on the decline in Kullu and Naggar Block. The heightened shift in focus to Pomegranate is attributed to its attractive and competitive market price, less chilling requirements, better shelf life, and ongoing shifting of apple line to higher altitudes (2200-3000 msl) due to warming trends at 1,500 to 1,800 meters above mean sea level (Parmesan & Yohe, 2003) (Partap & Partap, 2002).

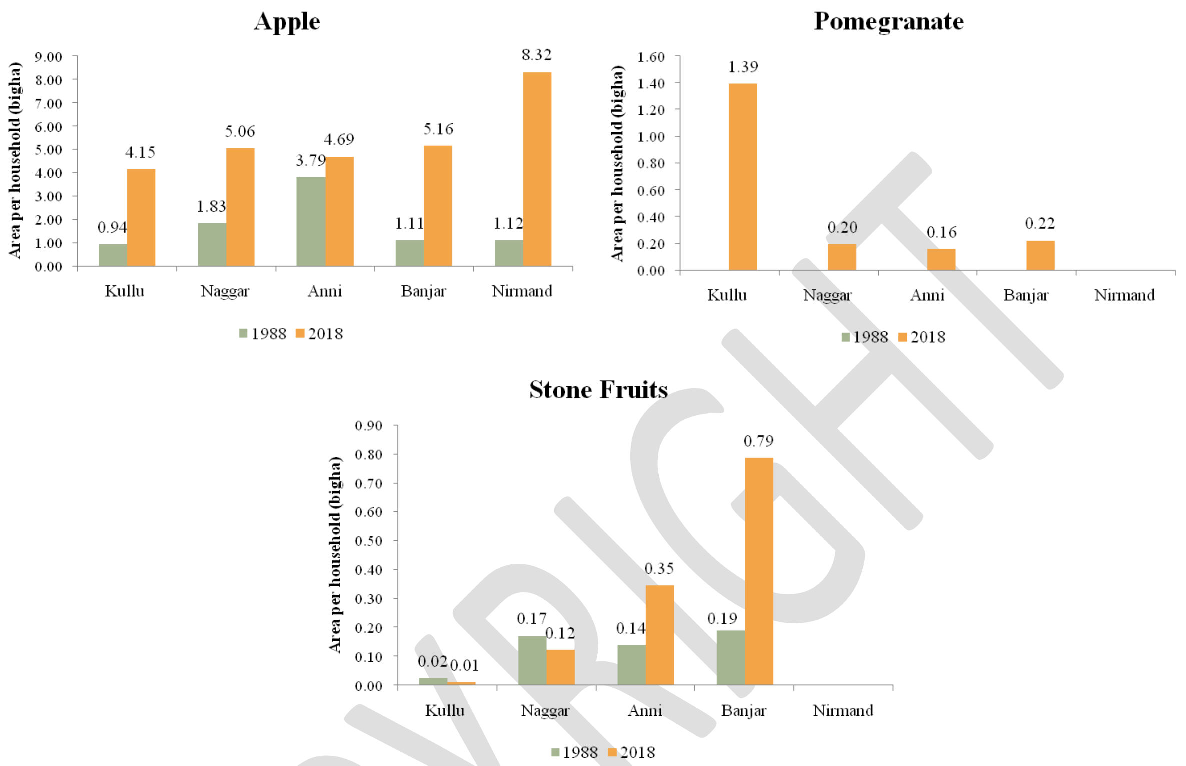


Figure 16: Block-wise Acreage under different Fruit Crops, Field Survey, District Kullu, HP
Source: Field Survey, HPSCCC, 2018

Similar to the case of transition from grain crops to high-value cash crops such as carrots, spinach, and garlic, initial adoption amongst the farmers was due to the demonstration effect[3] rather than result based outcomes. However, with the rising challenges of apple cultivation at existing altitudes and under current climatic situations, stark acceptance of pomegranate is being witnessed. Statistically, between 1990 and 2016, acreage under pomegranate increased from 2 ha to 358 ha in Kullu District, as per data from the Department of Horticulture, Himachal Pradesh. Therefore, at this stage it is fare to say that both the economic and climatic parameters are influencing the farmers to alter their crop choices and patterns. The next section explores this perceived shift in detail.

[3] Demonstration or Duesenberry effect is the effect on individual behaviour driven by observation of actions of the community and the consequences faced by them. The term is often used in political science and sociology to describe the role of development/adoption by one place/individual as a catalyst for another place/individual.

SHIFTING CROPPING PATTERNS – REASONS AND RESPONSE

For a better understanding on observed shifts in cropping practices, succinct questions were administered on ten contributing factors under four major categories - *climatic variables, farm management practices, financial and vermin menace.* Illustration below gives details on farmers' response on each of the variables and the respective 10 factors along with their graphical representation (figure 19).

Climate: *Increasing Temperature, Abnormal Rainfall, Droughts, Hails*
Farm Management Practices: *Availability of High-yield Varieties, Irrigation Facility*
Finance: *Ability of Cash Crops, Market Availability*
Vermin Menace: *Monkey menace, Stray Animals*

Table 10: Shifting Cropping Patterns – Reasons and Response, Field Survey, District Kullu, HP

Variables	Factors	Kullu	Naggar	Banjar	Anni	Nirmand	Total
Climate	Increasing temperature	84.0	15.0	72.0	65.0	87.5	64.7
	Abnormal rainfall	85.7	12.5	100	60	55	62.6
	Drought	84.5	12.5	96.7	100	87.7	76.3
	Hail	35.7	5	76.5	90	70.6	55.6
	Average	**72.48**	**11.25**	**86.30**	**78.75**	**75.20**	**64.80**
Farm management	High-yield varieties	82.6	12.5	100	76.7	90	72.4
	Irrigation facility	100	7.5	100	90	82.5	76.0
	Average	**91.30**	**10.00**	**100.00**	**83.35**	**86.25**	**74.18**
Financial	Cash Crops Availability	95.7	82.5	96.7	80	71.9	85.4
	Market Availability	94.3	17.5	100	90	87.5	77.9
	Average	**95.00**	**50.00**	**98.35**	**85.00**	**79.70**	**81.61**
Vermin Menace	Monkey menace	80	40	100	93.3	90	80.7
	Stray animals	77.1	35	96.7	96.7	92.5	79.6
	Average	**78.55**	**37.5**	**98.35**	**95**	**91.25**	**80.13**

Source: Field Survey, HPSCCC, 2018

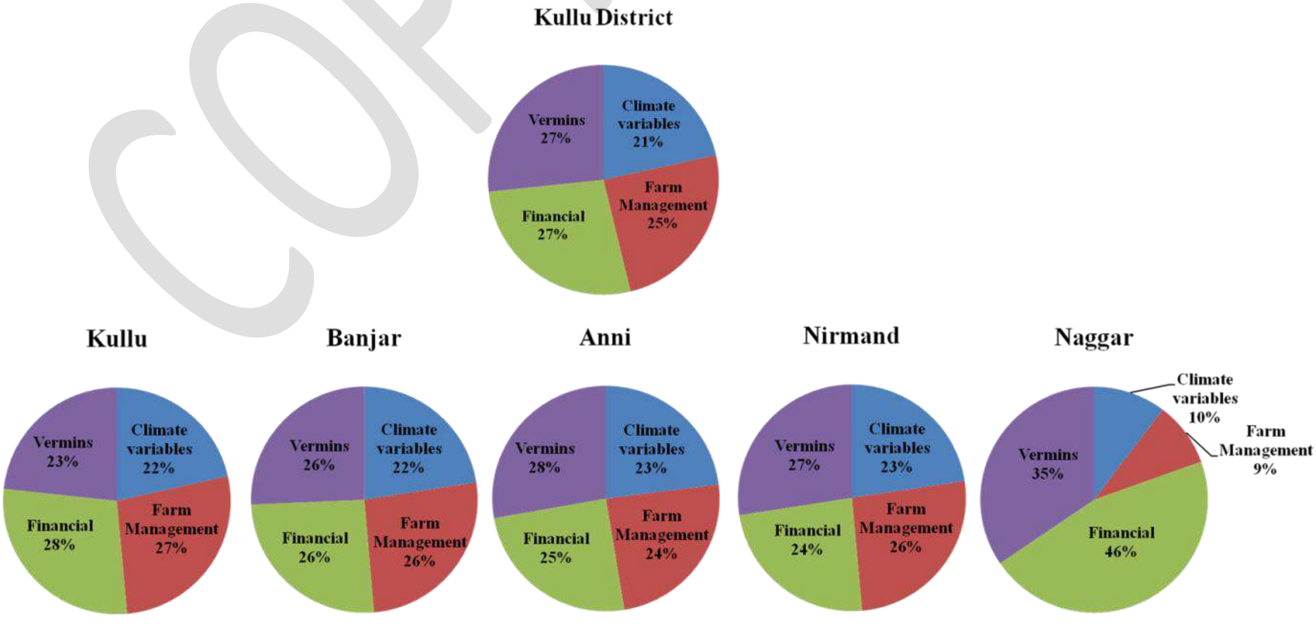


Figure 17: Intervening factors for shifting cropping patterns for individual blocks and district Kullu, HP
Source: Field Survey, HPSCCC, 2018

The field survey for both horticulture and agriculture crops was conducted with same 210 farming households on same parameters, as almost all farmers were found to engage in agro-horti mixed farming approach. Therefore, the outputs for this study shares similarity with the field survey conducted for the agriculture sector in District Kullu.

Within climatic patterns, droughts were cited as the major reason for a shift in cropping patterns for farmers across the five blocks in District Kullu, followed by increasing temperatures, abnormal rainfalls, and hailstorms. However, for the farmers in the Naggar block the predominant factor for changing cropping patterns was availability of cash crops i.e. increased uptake of (cash) fruit crop – Apple. With the gradual and consistent shift of apple line in district Kullu (as discussed in the earlier sections), respondents from Naggar block acknowledged the greater acceptance of Apple as a preference over other traditional crops that reaps better economic return through easy market access (tourist and commercial) and a better price.

Collectively, there was comparable distribution of factors leading to shift in cropping patterns at the district level in the order - Vermin menace (27%), Financial (27%), Farm Management Practices (25%), and Climate variable (21%) (Figure 16). As also observed from the outcomes of statistical assessment – multivariate linear regression analysis, climatic variations had limited explanatory power for variations in crop productivity, additionally, in social studies, interview outcomes are subject to response bias where the respondents tend to give desirable and/or most obvious response.

Nevertheless, the study was extended to assess the perceived vulnerability of sampled farmer community in conjugation with their exposure, sensitivity, and adaptive capacity against climate variability.

PERCEPTION-BASED VULNERABILITY ASSESSMENT

The synthesized case study findings from District Kullu were appraised against the measurement matrix on Exposure, Sensitivity, and Adaptive Capacity outlined in the development of perception-based vulnerability assessment framework[21] and discussed below.

EXPOSURE:

Exposure is the measure of spatial and temporal magnitude and extent of exposure of a community to climate change. To measure the exposure of farming community to climate change, their perception on climate variables *viz*. temperature, rainfall, snowfall, drought, strong winds, flash floods and hail frequency was measured in all five block of District Kullu. Farmers were found to assume an acute observation on changes in climatic patterns with capabilities to engage in an informed discussion. Table 11 summarises the output of PCA for block-wise variations in Exposure indicator.

Table 11: Block-wise scores and variations in Exposure Indicator, District Kullu, HP

Exposure Indicator	Scores	Kullu	Naggar	Banjar	Anni	Nirmand	p-value
Temperature	***0.20***	0.03	0.02	-0.005	-0.06	-0.02	0.37
Rainfall	***0.50***	0.07	-0.19	-0.17	0.17	0.08	**0.004**
Snowfall	***0.47***	0.13	-0.23	-0.16	0.18	-0.05	**0.00**
Drought	***0.45***	0.12	0.08	-0.23	-0.17	-0.10	**0.002**
Strong Winds	***0.56***	0.004	0.17	-0.14	-0.19	0.07	**0.04**
Flash flood frequency	***0.64***	0.45	0.05	-0.48	-0.28	-0.27	**0.00**
Hail frequency	***0.53***	0.05	0.06	-0.07	0.04	-0.12	0.40

Source: Field Survey, HPSCCC, 2018

The weights obtained from PCA analysis for the indicators of exposure ranged from 0.20 (temperature) to 0.64 (flash flood frequency) and followed the order Temperature (0.20) < Drought (0.45) < Snowfall (0.47) < Rainfall (0.50) < Hail frequency (0.53) < Strong Winds (0.56) < Flash flood frequency (0.64). All the weights of climate variables were positive thereby indicating a direct relationship with the overall exposure index and showing a perceived exposure of surveyed population to increased frequency of climatic events – floods, hail, rainfall, snowfall, and droughts. A further investigation revealed statistically significant variation in exposure indicators across the district, except for temperature rise and hail events (based on interpretation of p-values).

Highest exposure to temperature rise was observed in block Kullu (0.03) followed by Naggar (0.02) explaining the positive perception to temperature rise in two blocks, whereas, for development block Anni, Banjar, and Nirmand a negative mean exposure was recorded at -0.06, -0.005, and -0.02 respectively, indicating no perceived impact of temperature increase on their crops. Meanwhile for rainfall variability, highest exposure was reported by development block Anni (0.17), Nirmand (0.08), and Kullu (0.07). Farmers interviewed from the Nirmand Block had reported maximum increase in acreage of Apple crop (nearly 8 folds), which is being reflected here as heightened perceived exposure of rainfall extremes or shortfall to their crop yield. Similar analogy can be drawn for the farmers from Anni Block with respect to increase area under stone fruits.

Highest exposure to drought in Kullu block was accounted to limited support of irrigation water and higher dependence on rain-fed practices, whereas its proximity to river, streams, and rivulets in valley regions led to heightened exposure to flash floods. The exposure to hail events varies from -0.12 in Nirmand to 0.06 in Naggar with prominent impact in fruit growing pockets owing to direct loss exposure (physical appearance of cash crops such as apple is directly associated with its market value and demand).

SENSITIVITY:

Farmers' sensitivity to climate change is the response of the components of farming system to climate induced disturbances. It is essentially an indicator of a system's likely response to a possible externally induced stress. In this study, farmers' perception on *loss of land due to climate hazard, size of land affected, impact of climate change on availability of irrigation water, conflicts for irrigation water, insect and pest incidences due to change in weather pattern* were taken as sensitivity indicators. Table 12 summarises the output of PCA for block-wise variations in Sensitivity indicator.

Table 12: Block-wise scores and variations in Sensitivity Indicator, District Kullu, HP

Sensitivity Indicator	Scores	Kullu	Naggar	Banjar	Anni	Nirmand	p value
Loss of arable land due to flooding / siltation / sinking / drought	***0.31***	-0.05	-0.07	0.05	0.08	0.06	0.10
Land size affected	***0.39***	-0.05	-0.26	0.14	0.14	0.14	**0.00**
Availability of irrigation water	***0.73***	-0.07	-0.12	-0.15	0.26	0.15	**0.04**
Conflicts for irrigation water	***0.68***	0.30	-0.03	-0.10	-0.32	-0.19	**0.00**
Diseases	***0.03***	0.02	0.03	-0.03	-0.03	-0.03	**0.00**
Insects	***0.05***	0.04	0.06	-0.04	-0.04	-0.05	**0.00**

Source: Field Survey, HPSCCC, 2018

All the indicators had a positive relationship with the sensitivity index. According to respective weights gathered from PCA, availability of irrigation water (0.73) emerged as the most influential parameter succeeded by water related conflicts (0.68), affected land size (0.39), loss of agricultural land to natural hazard (0.31), insect (0.05), and pest infestations (0.03). In details, highest loss of arable land was observed in Anni (0.08) then Nirmand (0.06), Banjar (0.05), Kullu (-0.05) and Naggar (-0.07). Changes in land size due to changes in climatic conditions reported same trend across the five development blocks. Index value for conflicts for irrigation water was highest in Naggar (0.30) where in other blocks no influence was perceived for the same. Diseases and insect incidences highly influenced the sensitivity index of the farmers of Naggar (0.03, 0.06) and Kullu blocks (0.02, 0.04), these are the blocks with significant acreage under apple and pomegranate which are susceptible to pest incidences and infestations such as fruit root rots, woolly aphid, etc. Climate change (temperature and precipitation) induced sensitivities on parameters of heightened crop diseases and insects have been found in other studies as well (Mboup et al., 2012) (Coakley et al., 1999).

ADAPTIVE CAPACITY:

To ascertain the adaptive capacity of interviewed farming community in district Kullu, data on four livelihood assets *viz.* human, natural, physical and financial assets was collected (Table 13).

Table 13 : Block-wise scores and variations in Adaptive Capacity Indicator, District Kullu, HP

Adaptive Capacity Indicators	**Scores**	**Kullu**	**Naggar**	**Banjar**	**Anni**	**Nirmand**	**p value**	**Kullu District**
Human assets								
Education	0.09	0.002	-0.002	-0.007	0.00	0.002	0.75	**-0.0003**
Employment	0.17	-0.06	0.19	0.004	-0.13	-0.04	**0.02**	**-0.008**
Knowledge on adaptation measures	0.77	0.89	2.43	0.63	-2.07	-2.63	0.19	**0.05**
Extension services	0.74	0.02	0.00	0.26	0.02	-0.21	0.17	**0.01**
Natural assets								
Land holding	0.64	-0.07	0.18	0.18	-0.18	-0.06	0.15	**0.00**
Production	0.45	-0.07	-0.05	0.01	0.01	0.13	0.73	**-0.01**
Livestock	0.60	0.02	0.003	-0.04	0.62	-0.03	**0.00**	**-0.0005**
Irrigation coverage	0.41	-0.04	0.13	0.00	0.02	-0.07	**0.03**	**0.00**
Crop diversification	0.53	-0.05	0.04	0.01	0.008	0.02	**0.00**	**0.0004**
Physical assets								
Access to technology	0.66	0.001	0.24	0.02	-0.04	-0.23	**0.04**	**0.0008**
Access to improved farming material	0.60	0.07	0.05	-0.01	0.02	-0.16	0.43	**0.003**
Water harvesting structure	0.47	0.23	-0.13	-0.18	-0.11	-0.07	**0.00**	**-0.004**
Fertilizer usage	0.43	0.33	-0.13	-0.28	-0.32	-0.04	**0.00**	**0.01**
Financial assets								
Income diversification	0.66	0.002	-0.002	-0.01	0.00	0.002	0.75	**-0.0003**
Insurance penetration	0.55	-0.06	0.19	0.004	-0.13	-0.004	**0.02**	**-0.008**
Access to credit facility	0.66	0.89	2.43	0.63	-2.07	-2.63	0.19	**0.05**
Access to farm subsidies	0.69	002	0.00	0.26	0.02	-0.21	0.17	**0.01**

Source: Field Survey, HPSCCC, 2018

As apparent from the table above, access to technology made the highest contribution to *physical adaptive capacity* with a weight of 0.66 followed by farmer's access to improved farming material (0.60), construction of water harvesting structures (0.47), and fertilizer usage (0.43). Under *financial assets*, access to subsidies for agriculture input was rated the most relevant asset to boost adaptive capacity (0.69), followed by diversified income sources as well as farmers access to credit facility (0.66) and crop insurance coverage (0.4). Under *human asset* induced adaptive capacity, relevance of extension services was vehemently voiced, tailgating the possession of knowledge on available adaptation strategies. Extension services cover ongoing interactions with government officials from different departments, distribution of resilient seeds, crop insurance, and more extended support. This observation magnifies the active role of relevant departments to strengthen farmers' capacity in addressing extreme and unpredictable perils of changing climatic parameters.

In second step PCA, highest weight was perceived for physical assets (0.82) followed by financial assets (0.76), human assets (0.75) and natural assets (-0.01). Data in Table 14 shows that physical assets are the most important perceived determinants of overall adaptive capacity followed by financial and human assets. Physical assets *viz.* access to advance technology and improved farming material, and fertiliser usage supplements natural assets and enhances the farm output. Construction of water harvesting structures in the farms maximizes the usage potential of rainwater resources and increases the adaptive capacity of farmers particularly in the rainfed agriculture areas. Moreover, higher on-farm water storage will lessen the dependence on rainfed agriculture that is more susceptible to weather shocks and results of anthropogenic climate change. Nevertheless, the interviewed farming community fared the lowest on natural capacity indicating that the absence of inherent adaptation potential linked to land size, irrigation support, option for crop diversification and in case of an extreme climatic event, farmers perceive a low capacity without outside intervention.

Table 14: Block-wise Composite Scores and Variations in Adaptive Capacity Indicator, District Kullu

	Scores	Kullu	Naggar	Banjar	Anni	Nirmand	p value
Human adaptive capacity	***0.75***	0.11	0.11	-0.06	-0.09	-0.16	**0.01**
Natural adaptive capacity	***-0.01***	0.002	0.003	-0.002	0.001	0.0001	**0.0001**
Physical adaptive capacity	***0.82***	0.51	0.03	-0.37	-0.37	-0.41	**-0.006**
Financial adaptive capacity	***0.76***	0.65	1.99	0.67	-1.66	-2.19	**0.04**

Source: Field Survey, HPSCCC, 2018

VULNERABILITY INDEX:

Vulnerability Index was developed following the logic of ***Adaptive Capacity net of Exposure and Sensitivity*** to Climate Change, which varied significantly across the blocks (Table 15). On the collective perception for vulnerability, farmers' community in Nirmand block exhibited highest value on vulnerability index (2.44). Farmers appeared least equipped on all asset classes of human, natural, physical, and financial capacity. They had high perception on exposure to rainfall and hailstorms owing to the growing share of apple orchards in the block. Further, the interviewed farmers had limited access to knowledge on adaptation measures, any extension services, and showed least awareness and access to credit facility to supplement farm losses, if any. Meanwhile, Naggar block came out to be least vulnerable block of the district with minimum exposure and sensitivity and higher adaptive capacity followed by Banjar and Kullu, whereas, Nirmand and Anni blocks were observed with high perceived vulnerability due to low adaptive capacity (figure 18)

To conclude, District Kullu had low exposure (-0.002), sensitivity (-0.01) and marginal adaptive capacity (0.04) to climate change induced variations with respect to horticulture activity (similar to agriculture), thus fared toward the lower spectrum of vulnerability index. The output is supported by the results of district-level mapping in the State's Action Plan on Climate Change, (2012), which reported low to medium level exposure and sensitivity on observed climate data with low adaptation capacity for the district. The report rates District Kullu on medium level of vulnerability based on1960-1990 database at global level.

Table 15: Block-wise Vulnerability Index – Exposure and Sensitivity net of Adaptive Capacity, District Kullu, HP

	Kullu	Naggar	Banjar	Anni	Nirmand	District
Exposure	0.86	-0.05	-1.26	-0.16	-0.41	**-0.002**
Sensitivity	0.19	-0.52	-0.18	0.01	0.10	**-0.01**
Adaptive capacity	1.27	2.13	0.25	-2.13	-2.75	**0.04**
Vulnerability Index	**-0.22**	**-2.70**	**-1.69**	**1.98**	**2.44**	**-0.052**

Source: Field Survey, HPSCCC, 2018

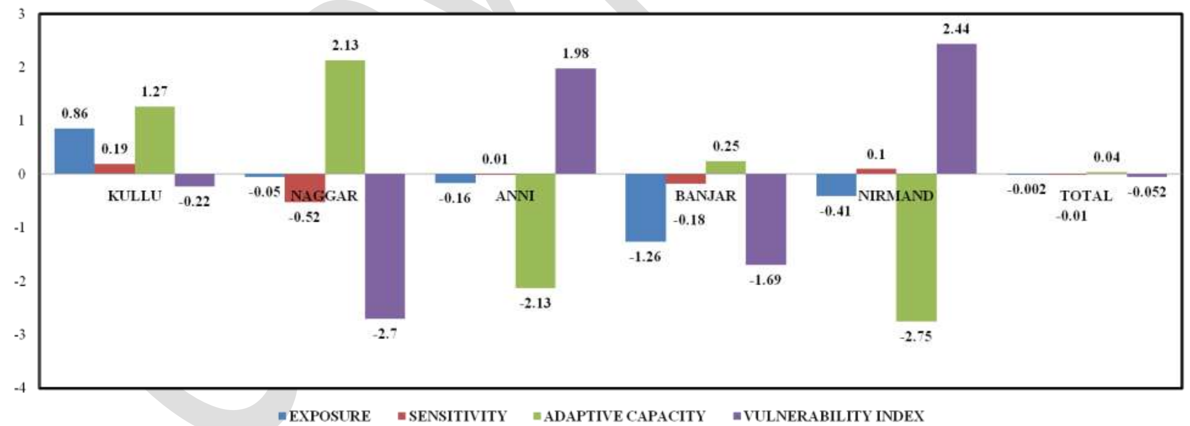


Figure 18: Block-wise Vulnerability Index – Exposure and Sensitivity net of Adaptive Capacity, District Kullu, HP
Source: Field Survey, HPSCCC, 2018

CONCLUDING POINTERS:

Crop Acreage

- *Total fruits acreage increased nearly three folds during last 30 years, for interviewed HHs*
- *Apple acreage increased in all five blocks, with maximum increase in Nirmand block (nearly 8 folds)*
- *Increased acceptance of new cash crop: Pomegranate; Maximum uptake in Kullu Block*
- *Acreage under stone fruits viz. Plum, Apricot, Peaches witnessed an increasing trend in Anni and Banjar blocks; while a decreasing trend in Kullu and Naggar blocks*

Shift in Cropping:

Comparable distribution of factors for Kullu district

- *Vermin Menace – 27%*
- *Financial – 27%*
- *Farm Management Practices – 25%*
- *Climate – 25%*

Except for Naggar Block

- *Vermin Menace – 35%*
- *Financial – 46%*
- *Farm Management Practices – 9%*
- *Climate – 10%*

Perception-based Vulnerability Assessment:

Vulnerability Index *(Adaptive Capacity net of Exposure and Sensitivity to Climate Change), varied significantly across the blocks*

Key Observations on individual parameters:

Exposure: *Statistically significant exposure to climatic variations in rainfall, snowfall, hailstorms drought, and floods; more predominant in fruit pockets of Nirmand and Anni Blocks*

Sensitivity: *Climate Change induced sensitivity affects land size and availability to agriculture, irrigation support, pest population and crop diseases (Naggar and Kullu blocks for their apple and pomegranate crops)*

Adaptive Capacity:

Lowest perceived adaptive capacity associated with natural assets covering land holding, irrigation coverage, crop diversification, production, and livestock capital

Greater relevance of Physical, Financial, Human capital to support adaptation against climate change exposure and sensitivity

Naggar block least vulnerable with minimum exposure and sensitivity and higher adaptive capacity followed by Banjar and Kullu, whereas, Nirmand and Anni blocks had high perceived vulnerability due to low adaptive capacity

District Kullu had low exposure and sensitivity and marginal adaptive capacity climate change induced variations with respect to horticulture activity; sits on lower spectrum of vulnerability index

APPROACHES TO CLIMATE CHANGE ADAPTATION – AT FARM LEVEL

Field survey exercise was utilised to get a preliminary insight into measures adopted by the interviewed farmers' community in District Kullu to better address climate change induced changes in their cultivation practices for horticulture crops. The Table 16 below summarises the adopted adaptation strategies, where in major approaches are highlighted.

Change in crop choices in tandem with changing climatic conditions characterised with droughts, floods, rising temperatures, rainfalls, frequent hails was the widely adopted adaptation choice by around 72 per cent of the respondents. Among the different blocks, 90 per cent farmers of Kullu have adopted mixed crop livestock system and 74.3 per cent increased number of fruit/ nut trees in comparison to rest four blocks of the district. Extensive use of fertilisers to maintain and perhaps, increase crop productivity was the second most favoured strategy, as expected from logical deductions. Use of high-yield varieties, short duration crops, crop diversification, and mixed cropping were other popular adaptation strategies. Yet, around 30 per cent of the responding famers decided to move to off-farm economic options of private/government jobs, and small businesses, while other 19 per cent moved to "greener" urban areas. 45 of 210 farming HHs adopted no adaptation measure to tackle changing farming conditions induced by changing climate.

Table 16: Climate Change Adaptation Strategies, Field Survey, District Kullu, HP

Adaptation Strategies	Blocks					Kullu District
	Kullu	Naggar	Banjar	Anni	Nirmand	
Change in Crop	95.7	65.9	31.0	72.4	92.0	**71.4**
Use of HYV	82.9	48.8	28.6	65.5	72.0	**59.6**
Alteration inn Planting Dates	74.3	17.1	33.3	41.4	36.0	**40.4**
Crop Diversification	62.3	22.0	35.7	37.9	48.0	**41.2**
Use of Drought Resistant Crops	20.0	7.3	23.8	31.0	40.0	**24.4**
Planting Short Duration Crops	35.7	12.2	50.0	31.0	36.0	**33.0**
Use of Resilient Varieties	21.4	17.1	19.0	34.5	32.0	**24. 8**
More Fruit/ Nut Trees	74.3	36.6	33.3	34.5	44.0	**44.5**
Mixed Crop Livestock System	90.0	51.2	52.4	37.9	56.0	**57.5**
Water Harvesting Structure	48.6	14.6	7.1	17.2	32.0	**23.9**
Practice Reuse of Water	15.7	2.4	11.9	24.1	40.0	**18.8**
Soil Conservation Techniques	32.9	17.1	14.3	17.2	40.0	**24.3**
Buy Insurance	8.6	26.8	9.5	3.4	16.0	**12.9**
Migration Urban Areas	22.4	12.2	4.8	24.1	32.0	**19.1**
Find Off-Farm Jobs	32.9	26.8	14.3	31.0	48.0	**30.6**
Lease your Land	11.4	9.8	11.9	24.1	40.0	**19.4**
Use of Chemical Fertilizer	80.3	80.5	47.6	79.7	64.0	**70.4**
No Adaptation	1.4	14.6	47.6	13.8	32.0	**21.9**

Source: Field Survey, HPSCCC, 2018

ADAPTATION STRATEGIES CONSTRAINTS– FARM LEVEL PERCEPTIONS

With an idea to capture ground reality in policy recommendations to be furnished from this status report, farmers were asked to elucidate on challenges faced in their adaptation to climate change. Interestingly, it was the role of government as an enabler that emerged as a unanimous category of concern reflected in – *absence (no-awareness) of government policy on climate change, insufficient reach of extension services to enable knowledge on adaptation measures, credit facilities, and government subsidies.* Additionally, lack of access to appropriate technology and its misfit with indigenous methods of cultivation, and perceived high cost of adaptation measures compared to farmer's marginalised socio-economic profile, difficult operational terrain and inability to access climate resilient and pocket friendly crop varieties were some of the other cited concerns.

CHAPTER 6 – CONCLUSION & RECOMMENDATIONS

The status report was designed to elucidate statistical and perceptive impact of climate change in Himachal Pradesh with a study focused in District Kullu. Both approaches identified climate change as an instrumental component in observed shift in cropping patterns and productivity, nevertheless its absolute impact could perhaps be ascertained through field experiments and in-situ simulation studies, which was not within the scope of the study.

Higher variability in climatic parameters of temperature and rainfall was observed during the ***flowering period*** as compared to ***pre-flowering*** and ***fruit setting and development*** phenological stages from 1990 to 2016. During flowering period mean minimum and maximum temperature increased by 0.04°C, 0.12°C per year respectively and rainfall decreased by 6.17 mm per year. Meanwhile, the mean maximum temperature increased by 0.04°C per year during the pre-flowering period. Higher anomalies in maximum and minimum temperature were reported during all three phenological stages indicating an overall warming trend. Meanwhile, variations in rainy days showed significant increase of 0.17 during fruit setting and development stage only i.e. May to August.

The statistical assessment of variations in climatic parameters of temperature and rainfall with changes in horticulture productivity registered maximum impact during the ***pre-flowering*** phenological stage i.e. for four fruit crops – Apple (with maximum and diurnal temperature, rainfall), Pear (with maximum and diurnal temperature, rainfall), Cherry (with minimum temperature), and Almond (with maximum temperature and rainfall) variations in productivity exhibited statistically significant correlation with changes in considered climatic parameters of temperature and rainfall during *pre-flowering stage*; while for flowering stage and fruit setting stage fewer statistically significant correlation was witnessed between fruit crops productivity and climatic parameters. Rainy days variations did not hold statistically significant relationship with productivity of any of the fruit crops during any of the phenological stages.

Amongst all studied crops, Apple productivity showed maximum sensitivity to climatic variations during all three stages (31%, 19%, 21%) with significant correlation observed for Pear (35%, 9%, 10%), Almond (20%, 13%, 27%), Plum (19%, 18%, 1%), Pomegranate (6%, 8%, 24%), Apricot (3%, 14%, 29%), and Cherry (13%, 16%, 8%). With respect to individual crops, this means that the observed variations in productivity for Apple crop from 1990-2016 is explained by the changes in climatic parameters only to the extent of 31 % during pre-flowering stage, 19% during the flowering stage, and 21% during the fruit setting and development stage. Similar interpretations are valid for Pear, Almond, Plum, Pomegranate, Apricot, and Cherry. Meanwhile, the productivity of Walnut was least influenced by the changes in climatic parameters across all phenological stages (2% at pre-flowering stage; 3% at flowering; and 15% at the fruit setting and development stage). Remaining variability can be attributed to other factors of farming techniques, orchard management, vermin menace, etc.

The farm-level perception-based vulnerability assessment helped in extracting other plausible intervening factors responsible for variations in cropping patterns. These in-depth interviews with the farming community from the five blocks in District Kullu indicated an increase in total fruits acreage nearly three folds (1.96 bigha to 6.12 bigha per household) during last 30 years. For the interviewed farming HHs, apple acreage increased in all five blocks, with maximum increase in Nirmand block (nearly 8 folds); while, an increased acceptance of pomegranate was also registered with maximum uptake in Kullu Block. Acreage under stone fruits viz. plum, apricot, peaches also increased but only in Anni and Banjar Blocks of District Kullu. These shifts in crop cultivation were driven by comparable influences from changing climatic conditions, vermin menace, financial outputs, and access to better farm practices. This outcome is in sync with the findings from the statistical analysis that gave limited explanatory quotient to varying climatic patterns. The vulnerability index, created on perceptions of interviewed 210 farming HHs on exposure and sensitivity to climate change net of their adaptive capacities (human, natural, financial, and physical), positioned District Kullu on the lower spectrum of vulnerability and risk.

The study qualified the results of statistical trend of climatic variables during the three phenological stages vis-à-vis horticulture crop productivity juxtaposed with a perception-based assessment, however, it demands field based experimental validation and simulation exercises to plug-in data gaps, inaccuracies, inconsistencies, and a large scale assessment of population capturing varying altitude gradient in the state.

POLICY RECOMMENDATIONS:

RESEARCH:

Coordinated efforts are suggested to government agencies operating at interplay of horticulture, science & technology, and environmental concerns to fund and support field level experiments and simulation studies for a better understanding on direct and indirect impact of changing climatic parameters on cropping patterns. Strategic research is advised on development of resilient crop varieties, appropriate soil conservation and water management measures with specific focus on elevation extremes in the State.

GOVERNMENT SUPPORT:

Continuous access to extension services is critical for ensuring robust and resilient farm level adaption to climate change. While farmers improvise indigenous techniques in response to changing climatic conditions (often misunderstood as weather patterns), they unequivocally and vehemently voice the need for sustained government support for clarity on policies and schemes, latest technology and crop varieties, subsidies and credit facilities. Departments are urged to apply accountable checks and balances in assessing the reach (impact) of their interventions and if required adopt a hand-holding approach to help farmers integrate resilient techniques in their farming practice.

CAPACITY BUILDING:

In addition to the farming community, sensitisation and skill development is imperative for the field level and local extension officers by engaging them in a wider range of initiation topics of cultivation practices, seeds selection, soil and water management, and more importantly skills to capture and internalise farmers' sentiments and perceptions into climate change policy and interventions.

ANIMAL MENACE:

Crop damage by vermin especially monkeys is one of the biggest crop damage exposure for farmers in the State. As per estimates of the Department of Agriculture, and Horticulture, around 1.56 lacs ha of cultivated area is affected by this detrimental menace, representing up to 89 per cent of yield loss in extreme cases. Unfortunately, prevalent practice of manual guarding does not provide complete protection and other devised strategies of simians sterilisation also remain ineffective. Thus, it was cited as the top reason for shifting crop varieties in District Kullu. Coordinated state government intervention is desired for effective implementation and adoption of different schemes such as Mukhya Mantri Khet Sanrakhan Yojana designed to subsidise installation of solar and regular electric fencing.

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APPENDIX A

H. P. Sate Centre on Climate Change
State Council for Science Technology and Environment, Bemloe, Shimla-171001
Questionnaire for Field Survey

Questionnaire No.	
Date	
District	
Block	
Panchayat	
Village	
Name of the respondent	

1. Gender: [ ] Male [ ] Female
2. Status in the household (HH): [ ] HH head [ ] House wife [ ] others (specify) ______
3. Age ________________Years
4. Marital status: [ ] Single [ ] Married [ ] Widowed [ ] Separated/Divorced
5. Farming experience: a) <10 yrs ( ) b) 10- 30 yrs ( ) c) >30 yrs ( )

6. Status of Land holding

Land holding status	
Marginal (<6 bigha)	
Small (6-12 bigha)	
Semi medium (12-24 bigha)	
Medium (24-60 bigha)	
Large (>60 bigha)	

7.1. Perception on climatic variability in last 30 years

Parameters	**Increasing**	**Decreasing**	**No change**
Temperature			
Precipitation			
Snowfall			
Prolonged dry season/ drought			
Early rainfall			
Late rainfall			
Strong wind			
Extreme cold			
Unpredictable rainfall			
Temperature above normal during winter			
Frost			
Natural hazards			
Drought			
Flash floods			
Landslides			
Hail frequency			
Frost			

7.2. Have the extreme weather events (drought, floods, landslides, snow/ hail, cloudbursts) affected any of the following?

a) Life of the family member [ ] Yes [ ] No. If yes, how many? _____________
b) Family physical property, e.g. damage of house, car, business etc [ ] Yes [ ] No.
c) Agricultural land (Siltation, flooding, sinking of land etc) [ ] Yes [ ] No. If yes, indicate the size affected in acres____________________

7.3. Effects of climate change on water resources

	Increased	No change	Decreased	Reason
Availability of portable water in the last 10 years				
Availability of irrigation water in the last few years				
Water level in streams				
Water level in river				
Water level in well				

7.4. How often are there conflicts over the use of water in your community for agriculture, irrigation, etc?

Never	Rarely	Sometimes	Often	Always

8. Change in cropping pattern

	Rabi /Winter cropping (Area in bigha)		Remarks
	Presently	30 years ago	
Wheat			
Barley (Jau)			
Potato			
Mustard			
Blackgram			
Peas			
Masoor			
Cauliflower			
Cabbage			
Knol- Khol (Ganth gobhi)			
Carrot			
Radish			
Spinach			
Others			

	Kharif /Monsoon cropping (Area in bigha)		Remarks
	Presently	30 years ago	
Paddy			
Maize			
Bajra			
Jwar			
Finger millet/ Koda/ Ragi/ Mandua/ Kodra			
Amaranth/ Saliara/ Seul/ Bathu			
Fagopyrum/ Ogla/ Kathu/ Kuttu			
Rajmah			
Moong			
Masoor			

Kulthi			
Ginger			
Turmeric			
Chillies			
Tomato			
Capsicum			
Brinjal			
Beans			
Soybean			
Others			

9a. Reason for change in cropping pattern

Reason	√
Climate change	
Increased Temperature	
Excessive Rainfall	
Monsoon failure	
Drought	
Hailing	
Technical reasons	
Small land holding	
Lack of irrigation facilities	
Market availability	
Preferences for cash crops If Yes, Specify the crops	
Others	
Availability of food grains in PDS	
Monkey menace	
Wild pig/ stray animal menace	
Availability of high yielding varieties	

9b. Reasons for low acreage under traditional crops (millets, kodo, bathu, ragi, chulai etc.)

	√	**Remarks**
Changing food preferences		
Non availability of market		
Difficulty in processing		
Non availability of seed		
Non diversification of traditional recipes		
Others		

10. Effect of climate related variables on:

	Increased	**Decreased**	**Same**	**Don't know**
Production				
Quality of produce				
Insect pest attack				
Disease incidences				
Pollinator population				

11. Disease/ pest incidences

11.1 Occurrence of crop disease increased (↑), decreased (↓) or no change (-) in past 30 years

Diseases		**Increased**	**Decreased**	**No change**	**Remarks**
Wheat rust (Ratua)					
Maize leaf blight (jhulsa rog)					
Paddy blast (Jhulsa rog)					
Potato blight (Ageta/ picheta jhulsa)					
Tomato blight (Ageta/ picheta jhulsa)					
Pea	Rust (Ratua)				
	Powdery mildew (Safed churni)				
Crucifers (Cabbage, cauliflower)	Leaf spot				
	Leaf blight				
Capsicum	Collar blight/ rot				
	Root rot				
Beans	Leaf spot				
	Collar rot				
	Rust				
Bacterial wilt in vegetables					
Fusarium wilt					
Apple scab					
Apple / pear/ stone fruits premature leaf fall					
Apple/ pear/ stone fruits root rot					
Apple/ pear/ stone fruits crown gall					
Apple canker					
Pomegranate fruit rot					

11.1 Occurrence of crop pest infestation increased (↑), decreased (↓) or no change (-) in past 30 years

Pests		**Increased**	**Decreased**	**No change**	**Remarks**
Maize	Stem borer				
	Cob borer				
Paddy	Stem borer				
	Shoot borer				
	Gandi bug				
Potato Aphids					
Tomato Aphids					
White fly in vegetables					
Black diamond moth					
Fruit borer Brinjal / tomato					
Cut worm of vegetable/pulses					
Apple	Woolly aphid				
	Sanjosescale				
	Stem borer				
Pear	Woolly aphid				
	Sanjosescale				
	Stem borer				
Pomegranate butterfly					

12. ADAPTATION STRATEGIES

a) Have you changed the types of crops grown in your farm in the last 10 years?
[ ] Yes [ ] No

b) If yes, which of the following reasons could be the cause?
[ ] lack of sufficient moisture in the soil [ ] declining soil fertility [ ] Need to increase revenue [ ] availability of cheap alternative crop varieties [ ] Other (specify) ____________

13.1 Which of the following adaptation strategies have you adopted in your HH?

S No	Adaptation options	Adopted? Yes or No	Reasons for not adopting 1: lack of money, 2: lack of information, 3: shortage of labour, 4. Lack of access to farm inputs. 5. Lack of access to water. 6. Shortage of land. 7.Other
1.	Change in crop		
2.	Change in crop variety		
3.	Change of planting dates		
4.	Crop diversification		
5.	Use of drought resistant crops		
6.	Planting short season crops		
7.	Use of resilient crop varieties		
8.	Planting fruit/ nut trees		
9.	Mixed crop livestock system		
10.	Build a water-harvesting scheme		
11.	Practice reuse of water		
12.	Implement soil conservation Techniques		
13.	Buy insurance		
14.	Put trees for shading		
15.	Irrigate more		
16.	Migrate to urban area		
17.	Find off-farm job		
18.	Lease your land		
19.	Use of chemical fertilizer		
20.	Seeking support from veterinary officers		
21.	No adaptation		

13.2 Which of the following factors are the most important hindrances to your adaptation to climate change?

S No.	Factor	Ranks		
		1	2	3
1.	Lack of access to early warning information			
2.	Unreliability of seasonal forecast			
4.	High cost of adaptation			
5.	Lack of credit facilities			
6.	Inability to access improved crops varieties/ seeds			
7.	Ineffectiveness of indigenous methods			
8.	Lack of government subsidy on farm inputs			
9.	Limited knowledge on adaptation measures			
10.	Absence of government policy on climate change			
11.	Lack of extension services			

12.	Lack of labour			
13.	Lack of access to water			
14.	Shortage of land			
15.	Insecure property rights			
16.	Lack of access to irrigation facilities			
17.	Lack of access to technology			
18.	No barriers			

APPENDIX B

Block	Panchayat	Village	Altitude (m)	Population	Households	Major Horticulture Crops
Nirmand	Nirmand	Sarkoti	1550	6593	1513	Apple
	Gadej	Bael	950	877	214	Apple, Mango
	Twar	Remu	1500	1498	358	Apple, Mango
	Arsu	Arsu	1950	1657	346	Apple
	Kot	Dhar	NA	4400	900	Apple
Anni	Dalash	Chewa	1850	2850	650	Apple
	Behna	Tihani	1300	1977	529	Apple, Pear, Pomegranate
	Dhingidhar	Togi	NA	2250	601	Apple, Peach, Plum
	Taluna	Nagan and Haripur	1000	805	194	Apple, Mango, Guava, Pomegranate
Banjar	Sharchi	Gushaini	1600	NA	NA	Apple, Peach, Pear
	Kandi Dhaar	Sai Ropa	1450	NA	NA	Apple, Peach, Pomegranate
	Chaini	Chhet	1620	NA	NA	Apple, Pear, peach
	Khadagaad	Shoja	2550	2720	650	Apple

Kullu	Bhaliyani	Bhaliyani	6360	2600	526	Apple, Pomegranate
	NA	Madgaon	NA	NA	NA	Apple, Pomegranate
	Koti Sari	Bhaikhali	NA	2100	550	Apple, Pomegranate
	Khokhan	Khokhan	7923	3193	692	Apple
	Hurla	Hurla	7601	1805	400	Apple, Pomegranate
	Jari	Jari	4991	2725	584	Apple
	NA	Jhan	NA	NA	NA	Apple
	Jha	Bradha	8168	2619	527	Apple
	Haat	Bajaura	3625	5852	1255	Apple
	NA	Phatnaal	NA	NA	NA	Apple
	Chang	Chang	NA	1900	441	Apple, Pomegranate
	Ratocha	Ratocha	6525	1468	265	Apple
	Karzan	Sajla	6039	622	144	Apple
Naggar	Kais	Bishtbed	NA	NA	NA	Apple
	Kais	Taandla	NA	NA	NA	Apple
	Shanag	Goshala	5493	850	181	Apple, Pomegranate
	NA	Kushwa	6719	NA	NA	Apple
	Manali	Old Manali	6530	831	178	Apple, Pomegranate
	Benchi	Malipathar	NA	2102	559	Apple
	Raison	Dehra Seri	NA	1061	NA	Apple, Plum (senta rosa)
	Malipathar	Malipathar	NA	NA	NA	Apple
	NA	Tangla	NA	NA	NA	Apple