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

STATE CENTRE ON CLIMATE CHANGE

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

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EXEUTIVE SUMMARY

Agriculture sector plays a vital role in global economic, nutritional, and food security. At the same time, it is one of the most vulnerable sectors to the effects of climate change, owing to its sensitivity to extreme and sudden variations in temperature and precipitation. Particularly, in the fragile Himalayan eco-system, where over 72 million people rely on access to species-rich forests, hill agriculture, fresh water sources, and bio-diversity for their survival; the increasing pressure from burgeoning population combined with global climate change is pushing the ecological hotspot to a dangerous point, thus creating unfavourable conditions for agrarian livelihood of mountain communities. In Himachal Pradesh, around 71 per cent of 6.86 million people in the state are dependent on the agriculture sector as an income source and employment, thus exhibiting a heightened exposure and vulnerability to climate induced variations in the sector.

To this effect, a status study was conducted with a view to ascertain the impact of climate change on agricultural 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 days) were conjugated with a standardised anomaly index and a multivariate regression analysis was conducted to unearth the climate and crop yield relationship. Further, the study employed evidence from 210 household surveys conducted in five blocks (Kullu, Naggar, Anni, Banjar, and Nirmand) in District Kullu, to qualify the perceived validity of outcomes of Climate-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 assessment and perception-based Vulnerability Assessment were designed with scalable modalities that can be adapted to other districts.

There is substantial literature and research to support the expected varied impact of climate change in Himachal Pradesh that essentially focuses on assessment of historic and current climatic parameter of precipitations and temperature vis-à-vis agriculture productivity, while the discourse on its combination with farmers' perceptions on their exposure, sensitivity, and adaptive capacity to climate change remained under-theorised.

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 for the observed shifts in cropping patterns and productivity. The mean minimum temperature increased by 0.02°C during *Rabi* and *Kharif* crop seasons, the diurnal temperature decreased by 0.02°C during the *Kharif* crop season, and rainfall quantity did not register any statistically significant results. Moreover, the Standardized Anomaly Index of temperature depicted a warming trend from 1998 onwards with heightened intensity over the mean value since 2001. Further, to better understand the variations in precipitation, changes in rainy days were analysed. However, no significant variations were observed for rainy days parameter during *Kharif* crop season. While during *Rabi* crop season a decline of 0.07 in rainy days was recorded.

The statistical assessment of variations in climatic parameters of temperature and rainfall with changes in agriculture crop productivity registered maximum impact for *Rabi* crops i.e. Wheat and Barley, whereas negligible association was observed for *Kharif* crops (rice, maize, potato) i.e. variations in productivity of both Wheat and Barley were explained by statistically significant changes in climatic parameters of Maximum and Diurnal Temperature, and Rainfall. Whereas for *Kharif* crops, only Rice (with Rainfall), and Maize (with Minimum Temperature) reported statistically significant results. Rainy days did not show any statistically significant correlation with crop productivity for *Rabi* and *Kharif* crops.

For all assessed crop varieties viz. Barley, Maize, Rice, Millets, Wheat, and Potato only 26.8%, 24%, 18.4%, 11.9%, 11.3% and 9.3% of productivity variability could be explained from temperature and rainfall variations in the district. With respect to individual crops, this means that the observed increase in productivity for Maize, Rice, Wheat, and Potato from 1965-2011 is explained by variations in climatic parameters only to the extent of 24%, 18.4%, 11.3%, and 9.3% respectively. Similar interpretation stands for the decline in productivity for Barley and Millets.

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 an ongoing shift from all cereal crops to more attractive vegetable crops. 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 agriculture 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 AGRICULTURE

Agriculture is amongst the most vulnerable sectors to be affected by climate change owing to of its sensitivity to variations in temperature and rainfall, frequently occurring weather extremes, and continued exposure to atmospheric carbon dioxide (CO_2). Moreover, it is one of the few sectors that both mitigates and supports sequestration of carbon emissions while maintaining a significant global carbon footprint (approximately 13 per cent in 2010 (WRI, 2014)). Climate Change is *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*. It holds inextricable interlinks with Agriculture through concurrent crop yields, biodiversity, water use, and soil conditions that has greater global relevance as the mismatch between world population and world food production continues to grow. As per FAO forecast, if world population were to reach 9.1 billion by 2050, the world food production should increase by 70 per cent (PI, 2009).

Agriculture in itself exists as a complex milieu of interactions between a range of plants and animal commodities, linkages between exacting components governed by risk perceptions, personal experiences and preferences, knowledge and skill, and external influences from market demand, government policies, and the climate (Walthall et al., 2012). In this regard, a large number of exploratory studies have analysed the potential impact of climate variability on agricultural productivity and livestock alike, especially in the context of developing countries. Rural landscapes and the equilibrium between the forest and the agrarian ecosystems is expected to be significantly impacted (Walker & Steffen, 1997) (Bruijnzeel, 2004) as would be the pressing concerns around food security due to unstable crop production, induced market changes, and supply chain infrastructures (Sanchez, 2000) (Siwar et al., 2013). Many studies also highlight agriculture’s supplementary role as a provider of renewable natural resources, landscape protection, biodiversity conservation, and an avenue to maintain socio-economic activities in rural areas (Klein et al., 2014).

There are certain succinct factors linking climate change to agriculture that need to be understood to get a better grasp of their dependencies.

- *Precipitation*: Water cycle is critical to agricultural system and shifting seasonality in precipitation can impact the water availability for grasslands and cropping system.
- *Hydrologic*: Hydrologic cycle characterised by frequent and intense droughts and floods in many agricultural plains can be detrimental to crop yield and soil fertility.
- *Heat*: Anticipated temperature rise is expected to result in recurrent heat waves, fewer frost days, and longer growing season in temperate zones.
- *CO_2* : Concentration of CO_2 is predicted to increase within the range 463-1099 parts per million by 2100[1] and the response of higher CO2 concentration is expected to be on C3 species i.e. *wheat, rice, and soybeans (accounting for more than 95% world's species)* more than on C4 species (*Corn and Sorghum).*
- *Crop Biodiversity*: Adverse impact on distribution of wild crop relatives, an important genetic resource for crop breeding. Climatic changes directly govern physiological constraints on growth and reproduction of wild species, and indirectly drive the ecological factors of resource competition.
- *Economic Consequences*: Fluctuations in crop yield can lead to price rise for most important agricultural crops such as rice, wheat, maize, and soybeans that will have a spill-over surge in feed and meat prices.

The figure 1 below gives a pictorial representation of direct and indirect interactions of climate change with agriculture production and anthropogenic induced vulnerability.

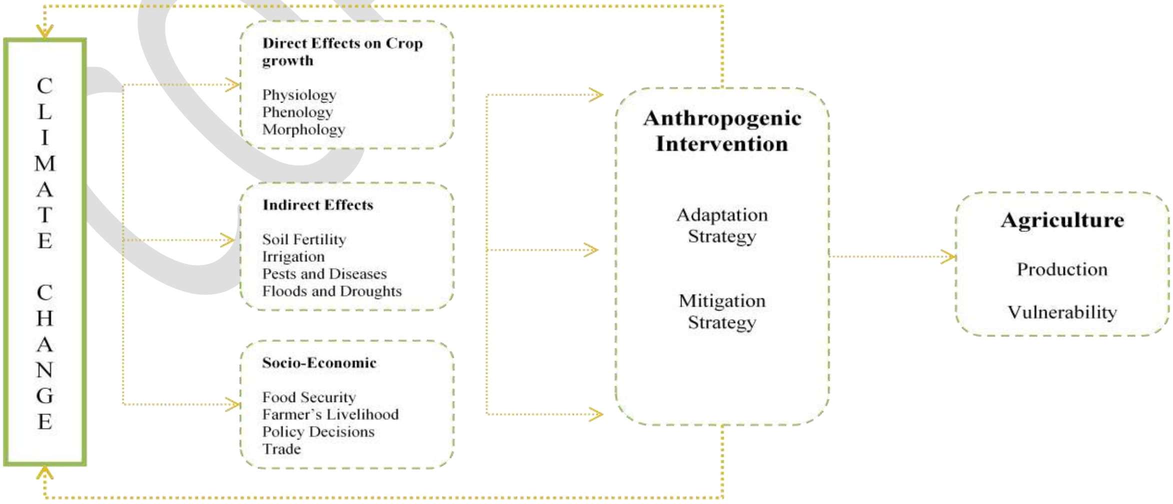


Figure 1: Agriculture and Climate Change Impact
Source: Indian Agriculture Research Institute, New Delhi

[1] Estimates of CO_2 concentration range from 478 ppm to 1099 ppm by 2100, given the range of emissions and uncertainties about the carbon cycle

According to the Intergovernmental Panel on Climate Change (IPCC), temperatures in India are likely to rise by 3-4°C by the end of 21st century (2007). Without any adaptation measure, this temperature increase is expected keep the agriculture sector reeling with lower farm incomes by 15 per cent and 18 per cent for irrigated and un-irrigated areas respectively. According to the Economic Survey 2018, the impact of climate change exhibited through temperature and rainfall variations is highly non-linear and is observed in extreme cases of increased temperatures and rainfall shortfalls. Furthermore, divergent observations are made for irrigated and un-irrigated and thus, respective crop varieties (rainfed crops such as pulses vis-à-vis cereals), with almost twice more for un-irrigated areas. Commodity wise impact of climate change as modelled by International Central Research Institute for Dryland Agriculture (CRIDA) is illustrated in figure 2 and table 1 below.

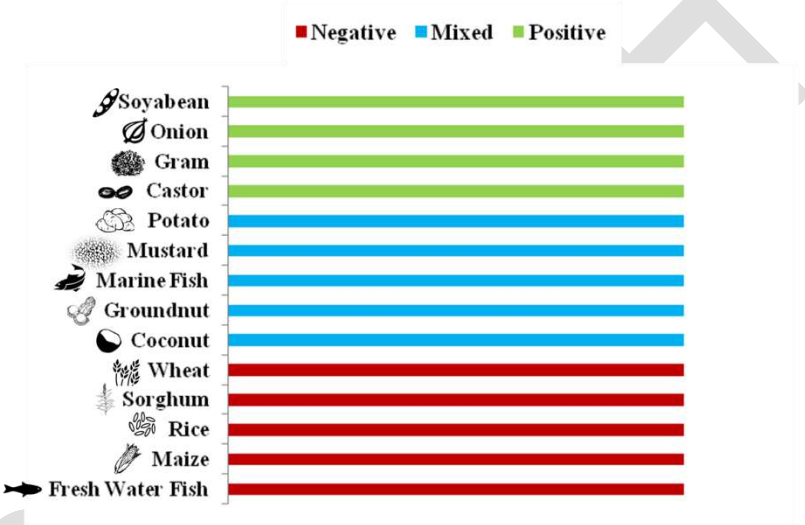


Figure 2: Commodity-wise Climate Change Impact, India
Source: Adapted by HPSCCC from Down to Earth, 2018 (Goswami, 2017)

Table 1: Impact of Weather Shocks on Agricultural Yields, India
(% decline in response to temperature increase and rainfall decrease)

	Extreme Temperature Shocks	Extreme Rainfall Shocks
Average Kharif	4.0%	12.8%
Kharif, Irrigated	2.7%	6.2%
Kharif, Un-irrigated	7.0%	14.7%
Average Rabi	4.7%	6.7%
Rabi, Irrigated	3.0%	4.1%
Rabi, Un-irrigated	7.6%	8.6%

Source: Economic Survey, 2018, Ministry of Finance, Government of India (Economic Survey, 2018)

THE HIMALAYAS AND CLIMATE CHANGE VULNERABILITY

The Himalayan ecosystem in particular 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 is home to over 72 million people living in over 10 states covering 95 districts spread in an area of 5 lacs square km, representing around 16 per cent of country's geographical area. Due to its high biological and socio-cultural diversity, the Himalayan ecosystem is inherently susceptible to natural hazards that are prone to aggravated occurrence of floods, droughts, and landslides, caused by drastic changes in climatic conditions.

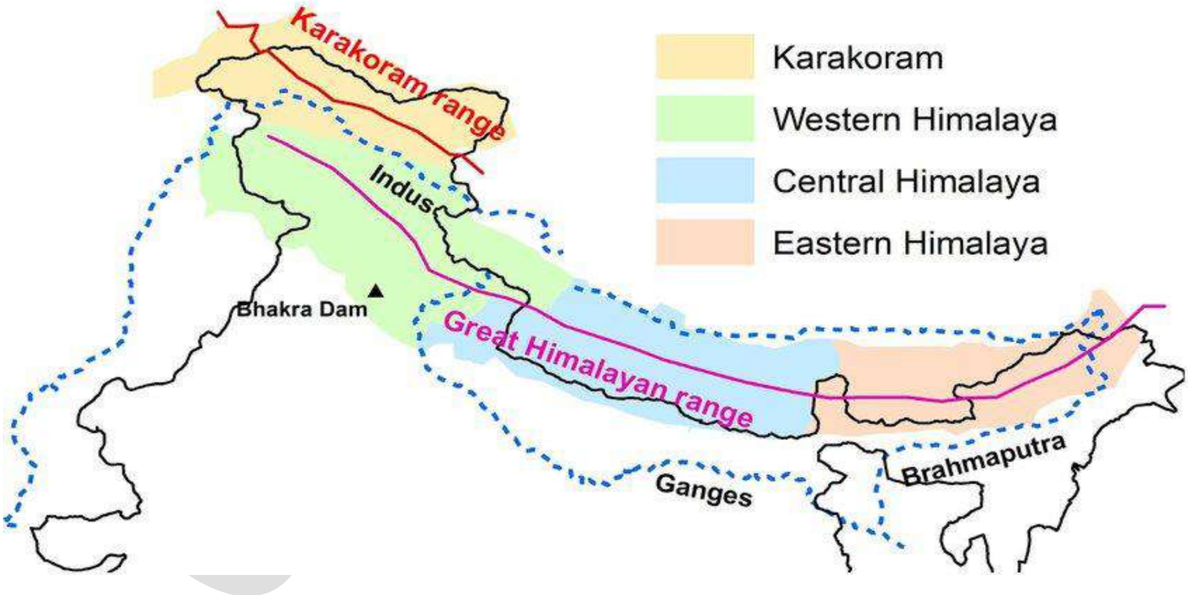


Figure 3: Geographical Representation of the Indian Himalayas
Source: Divecha Centre of Climate Change, Indian Institute of Science, Bengaluru (2018)

Further, human reliance on mountain ecosystems is well established for its verve to provide ecological and social security. Mountains are regions of heightened economic importance and social relevance offering invaluable access to species-rich forests, hill agriculture, fresh water sources, bio-diversity and the traditional gen. Nevertheless, this fragile ecosystem is undergoing dramatic changes that stand to impact the life and livelihood of those dependent on its products and services. In the western Himalayas, particularly, striking vegetative changes are observed where various plant species are migrating to higher altitudes due to warming trends (Padma, 2014), and other are in grave 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 0.7º C 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 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. Major food crops in the state are rice, maize, barley, jowar, pulses, millet, potato and many other off-season vegetables and a comprehensive profile of horticulture crops.

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 with regional variance. 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 averages in the last century, and concluded that rate of increase in maximum temperature changes is directly linked to the changes in altitudes. Bhan and Singha (2011) predicted a shortening of seasons by 10-12 days earlier 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. 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. 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 is divided into four agro-ecological zones based on characterised 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 4.

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	14ºC - 22ºC	9.1ºC – 20.6ºC	9ºC - 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)

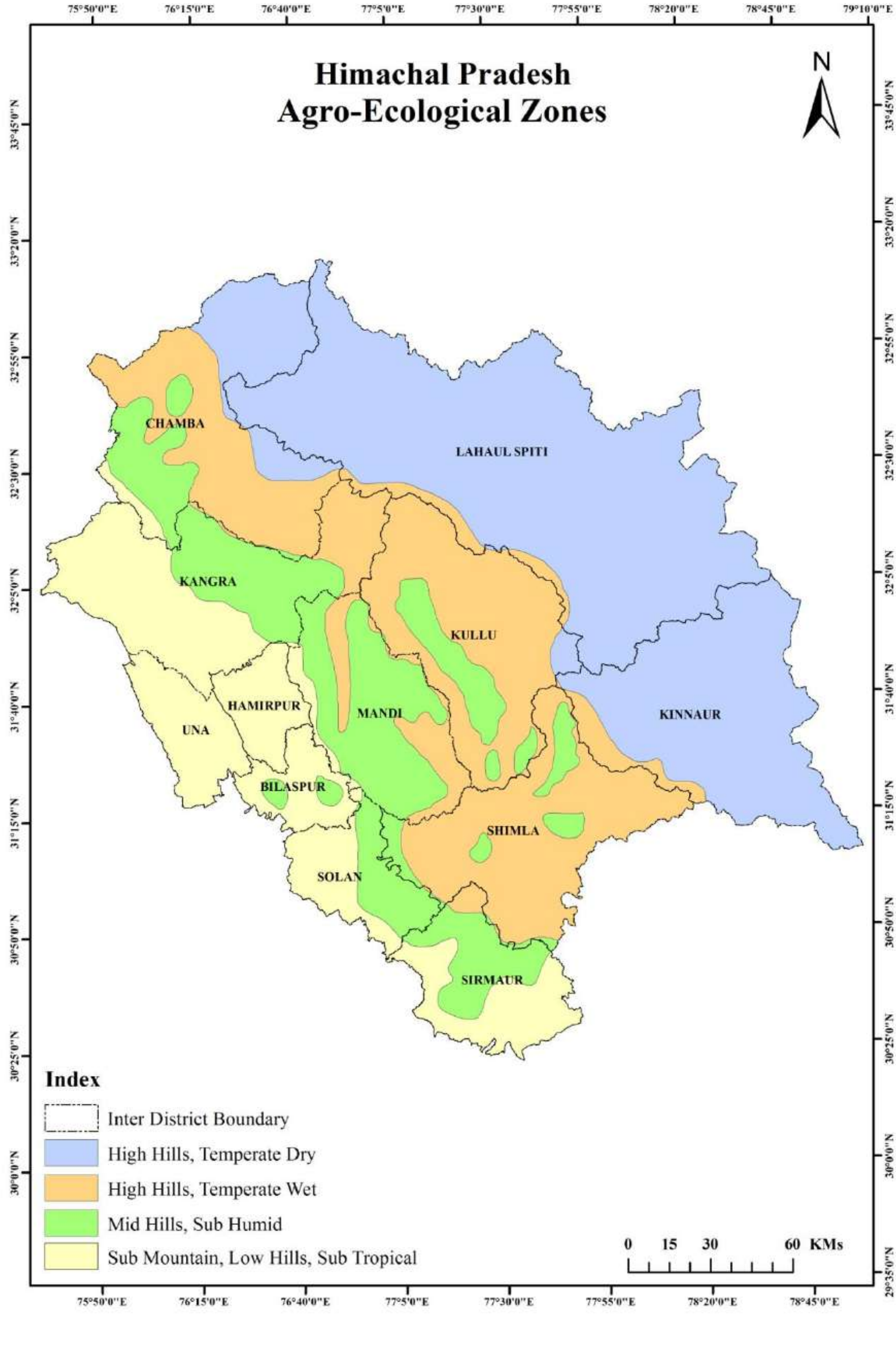


Figure 4: Himachal Pradesh Agro-Ecological Zones

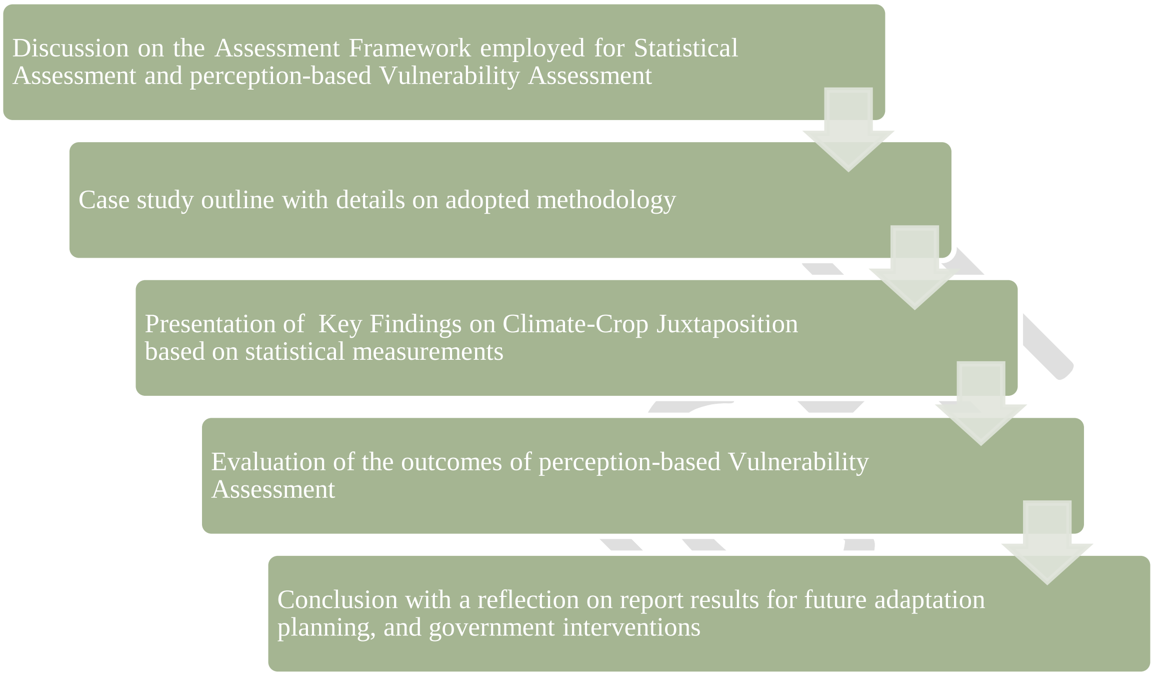
Source: Adapted by HPSCCC from Agro-Ecological Zonation of Himachal Pradesh – Agricultural System Information Development at micro-level, Centre of Geo-informatics, CSK Himachal Pradesh Agriculture University, Palampur (Bhagat et al., 2006)

As noticeable from above, a majority of agriculture exposure is spread across Zone II and III in the State. Nevertheless, each zone and each district is characterised with different soil, climatic, and precipitations pattern. As per IPCC estimates, high confidence negative impacts of climate change on crop yields are observed across crop categories than positive impacts. Human managed ecosystems such as food production and livelihood sustenance are found to be highly vulnerable to climate change in Asia. Saseendran et al. (2000) observed a reduction in crop duration due to increased temperature and predicted a possible increase in crop (rice) yields under rainfed conditions in Kerala. Kaur et al (2011) identified direct and indirect effects of change in climatic patterns of temperature, precipitation, and humidity on yields of *rabi* and *kharif* crops. Nevertheless, this growing share of literature is essentially focused on an assessment of historic and current weather parameter such as precipitations and temperature vis-à-vis agriculture productivity, while the discourse on its combination with farmers' perceptions on their exposure, sensitivity, and adaptive capacity to climate change remains under-theorised.

To bridge this gap, a status study was conducted to ascertain the impact of climate change on agricultural activities 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 (quantity and days) were conjugated with a standardised anomaly index and a multivariate regression analysis was conducted to establish the climate and crop yield relationship during *Rabi and Kharif seasons.* 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 agriculture in the state with an astute focus on District Kullu, and is organised as:



CHAPTER 2 – ASSESSMENT FRAMEWORK

Since the study aims to assess two different discourses on climate change vulnerability of the agriculture 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 agriculture productivity the following statistical measures were employed.

TREND ANALYSIS

Seasonal trends on climatic variables of 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, 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, rainfall and rainy days for the time period 1971-2016. Further, annual trends were conducted for productivity of wheat, barley, rice, maize, and millets.

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, and rainfall patterns during *Rabi* and *Kharif* seasons were computed for the study area. Similarly, the standardized precipitation indices were also calculated for the cropping seasons.

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 variable (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 cropping season of the crop. Coefficients α, β, γ and δ are the coefficients of minimum, maximum, diurnal temperature and rainfall, respectively. ΔT_{min}, ΔT_{max}, T_{dt}, ΔR, ΔRd 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

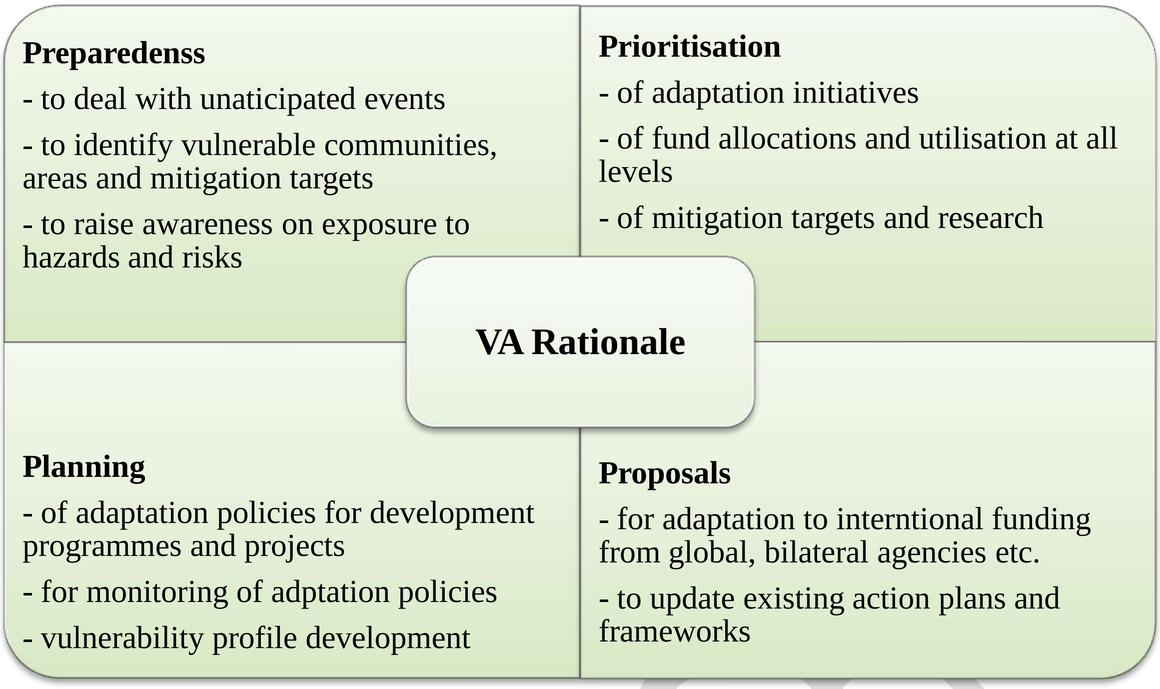
- Being a theoretical construct, vulnerability is deductively assessed and its quantification through a single metric remains a challenge.
- Vulnerability is dynamic and changes in accordance with developments in socio-economic factors of the affected and changes in climatic and physical conditions.
- 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 stands to 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 IPCC Fourth 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 is to contrast 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 assessment conducted as a part of the HP State Strategy & Action Plan on Climate Change, (2012).

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 (Gallopin, 2003). 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 Relationship
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 determine the total variance in data and transform original variable to smaller set of linear combinations. It is 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.

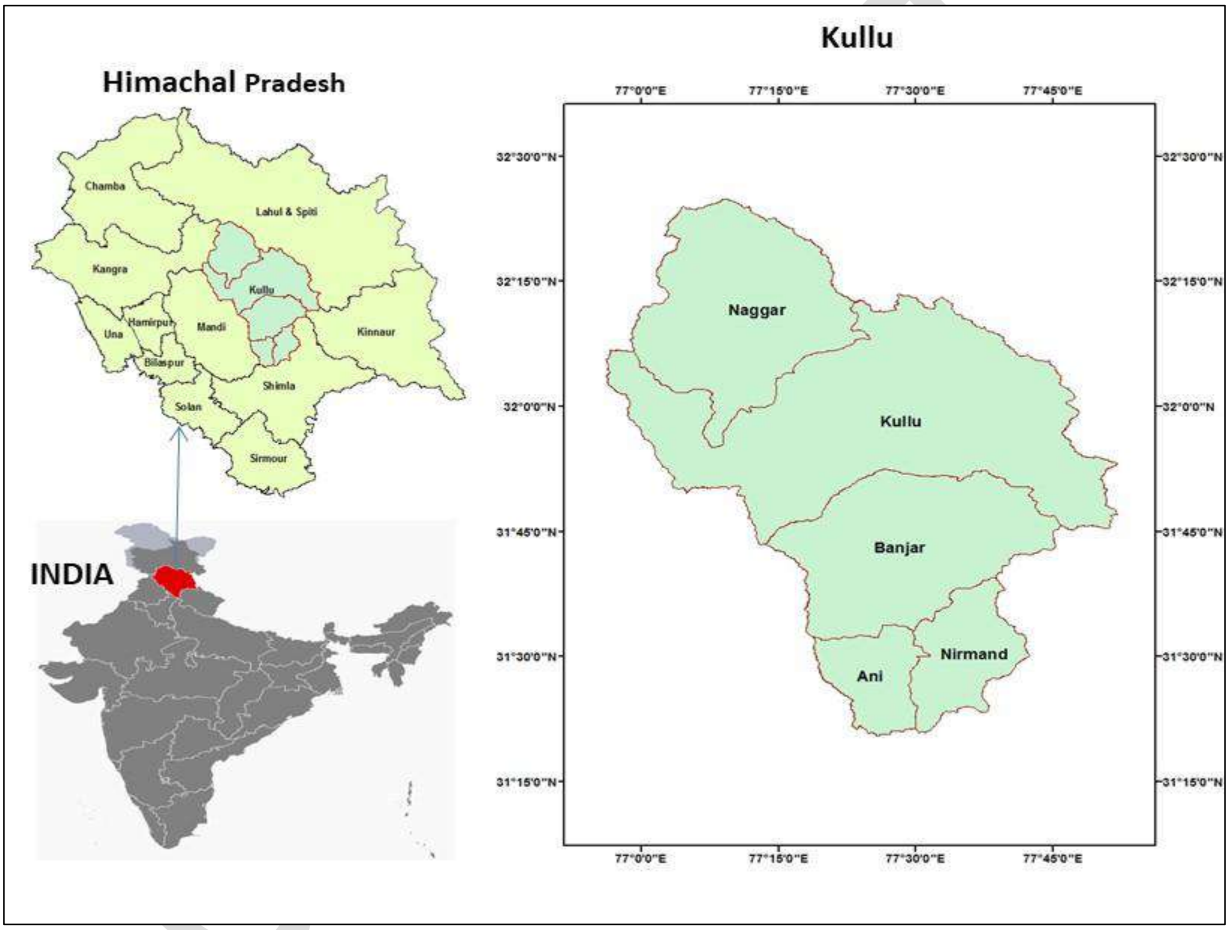


Figure 5: Map of District Kullu, Himachal Pradesh
Source: HPSCCC, 2018

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 4 illustrates agricultural profile of the district with details on ecological zones, land use, irrigation, and major crops and their sowing windows.

Table 4: District Kullu: Agriculture Profile

<table>
<tr><td colspan="6">Agriculture Profile – District Kullu</td></tr>
<tr><td>Agricultural Land Use</td><td>Total Geographical Area ('000 ha) : 550.3</td><td colspan="2">Net Sown Area ('000 ha): 36.3</td><td colspan="2">Cropping Intensity: 179%</td></tr>
<tr><td>Agro-Ecological Zone</td><td colspan="5">Western Himalayas, Zone II (sub-temperate and sub-humid hills), Zone III (wet-temperate high hills)</td></tr>
<tr><td>Agro Climatic Zone (NARP)*</td><td colspan="5">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%)</td></tr>
<tr><td>Irrigation</td><td>Net Irrigated Area ('000 ha) : 2.8</td><td colspan="2">Gross Irrigated Area ('000ha): 2.9</td><td colspan="2">Rainfed Area ('000 ha): 33.6</td></tr>
<tr><td></td><td rowspan="4">Sources of Irrigation:</td><td></td><td>Number</td><td>Area ('000 ha)</td><td>Irrigated Area (%)</td></tr>
<tr><td></td><td>Canals</td><td>7</td><td>0.1</td><td>14</td></tr>
<tr><td></td><td>Lift Irrigation Scheme</td><td>13</td><td>0.4</td><td>36.5</td></tr>
<tr><td></td><td>Kuhls</td><td>32</td><td>0.5</td><td>49.4</td></tr>
<tr><td>Major Crops</td><td colspan="5">Grain Crops: Wheat, Maize, Rice, Barley, Pulses (Rajmah, Blackgram etc.), Oil seeds (Mustard, other oilseeds)
Fruit Crops: Apple, Plum, Peach, Apricot, Pear, Cherry, Pomegranate
Veg. & Spices: Garlic, Onion, Green Peas, Cabbage, Cauliflower, Tomato, Brinjal, Radish, Capsicum, Chilies, Beans, Okra etc.</td></tr>
<tr><td>Crop Sowing Window</td><td colspan="5">Kharif – rainfed:
Maize – 2nd week of April (high hills), 1st week to 2nd week of July
Pulses – 3rd week of June to 3rd week of July

Rabi – rainfed:
Wheat – 1st week of October to 4th week of January
Barley - 1st week of October to 4th week of January

Rabi – irrigated:
Wheat – 1st week to 4th week of November
Barley – 1st week to 4th week of November</td></tr>
</table>

Source: Agriculture Contingency Plan, District Kullu, Himachal Pradesh (AGRICOOP, 2012)

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. 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 profile to pilot an assessment of climate change impact on agriculture 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 agricultural 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 agriculture.

CLIMATE DATASETS

The mean minimum, maximum, diurnal temperatures, and rainfall data for District Kullu was collected from India Meteorological Department (IMD), Shimla covering a time period of 1971-2016. This data was categorised for *Rabi* and *Kharif* crop seasons i.e. November to April for former, and May to October for latter.

AGRICULTURAL DATASETS

Wheat, Barley, Rice, Maize, Potato, and Millet Crops acreage and production data was collected from the Department of Land Records, Shimla covering the time period 1971 to 2010. Wheat and Barley are *Rabi* crops while the remaining crops are categorized as *Kharif* crops.

PRIMARY DATA PROCESS

Primary observations were collected between September 2017 and February 2018 by a team of 6 experienced surveyors in District Kullu. 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. First, the data on agriculture acreage and production for individual crops was available for time period 1966 to 2011 only; meanwhile the data on climatic parameters of temperature and rainfall was till 2016. Further, the land record data had several gaps and outlier values that were correct using estimates of historic data trend and mean values. Second, 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[2], where respondents could have given socially desirable and obvious answers.

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

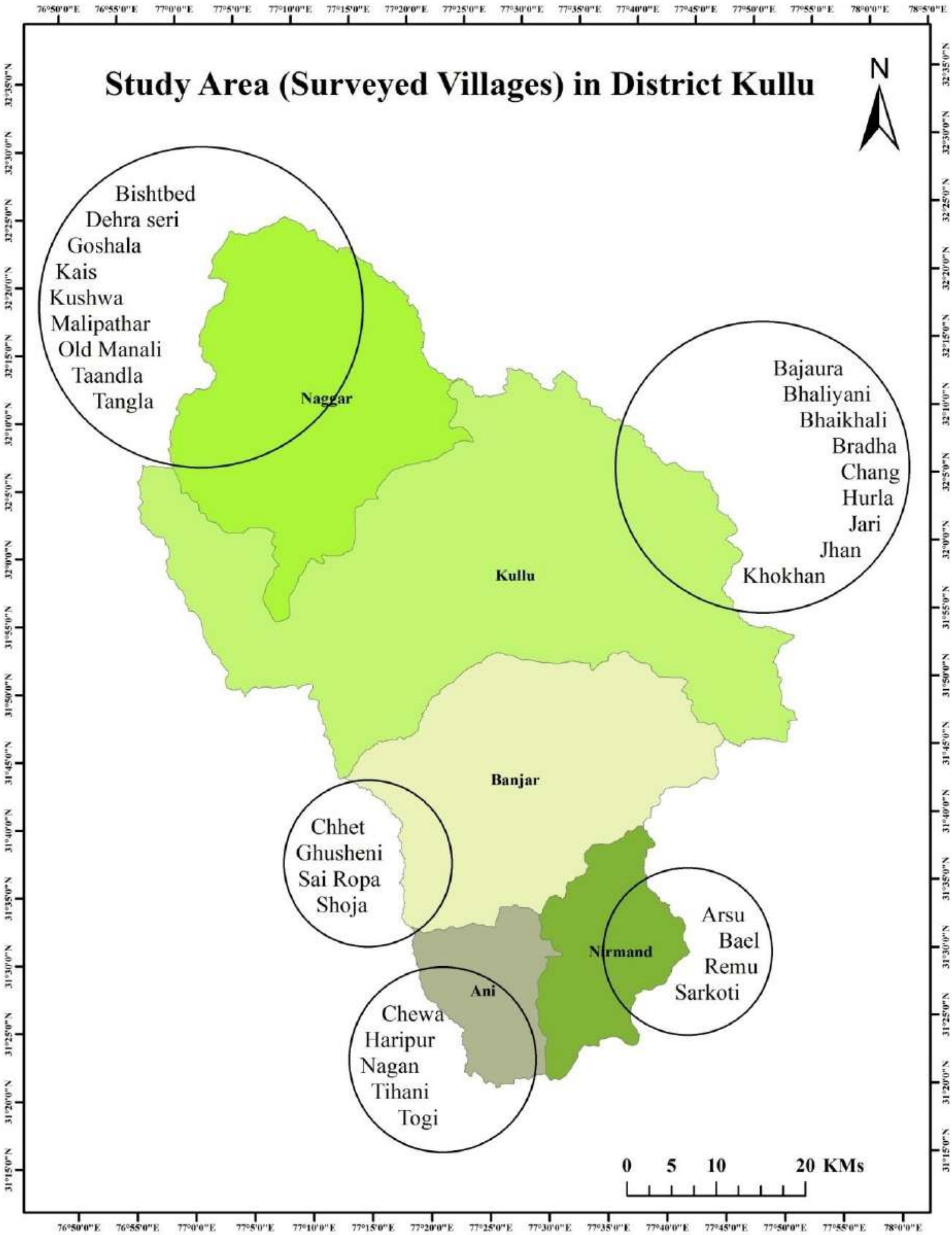


Figure 6: Study Area with Villages surveyed in Five Development Blocks, District Kullu, HP
Source: HPSCCC, 2018

CHAPTER 4 – CLIMATE TREND AND AGRICULTURE: 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, the minimum and diurnal temperature showed significant changes during the *Kharif* crop season for the study period spanned across 45 years, while for *Rabi* crop season, minimum temperature and rainy days exhibited statistically significant changes. 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 1971-2016.

Table 5: Mann Kendall Test Results – Climatic Trends for Kharif and Rabi Season (1971-2016)

	Mean	Sen's slope	p-value
Kharif			
Max T	30.7	0.01	0.25
Min T	16.1	**0.02**	**0.00**
Diurnal T	14.7	**-0.02**	**0.04**
Rainfall	475.0	1.24	0.45
Rainy Days	10.59	0.03	0.13
Rabi			
Max T	20.6	0.02	1.11
Min T	4.7	**0.02**	**0.00**
Diurnal T	15.9	0.005	0.68
Rainfall	457.1	-1.00	0.51
Rainy Days	6.86	**-0.07**	**0.01**

Source: HPSCCC, 2018

During the *Kharif* season, the minimum temperature rose at the rate of 0.02°C per year (as exhibited by Sen's slope), since 1971 After 2005, minimum temperature remained above the long term average except for the years 2009 and 2012, indicating an overall warming trend (illustrated in figure 7a). A continued warming trend at the same rate is expected to increase the minimum temperature in the district by 1.5°C by 2050. Meanwhile, the diurnal temperature exhibited a decreasing trend of 0.02°C per year, with prominent troughs post 1997, sparring the spikes in 2001, 2002, 2008, 2011, 2013, and 2016 (refer figure 8c). A steady trend for maximum temperature and inclining minimum temperatures resulted in a narrowing range for diurnal temperature during the *Kharif* season. Rainfall, on the other hand, did not show any significant variation from 1970 to 2016. Further, to better understand the variations in precipitation, changes in rainy days were analysed. However, no significant variations were observed for rainy days parameter during *Kharif* crop season as well.

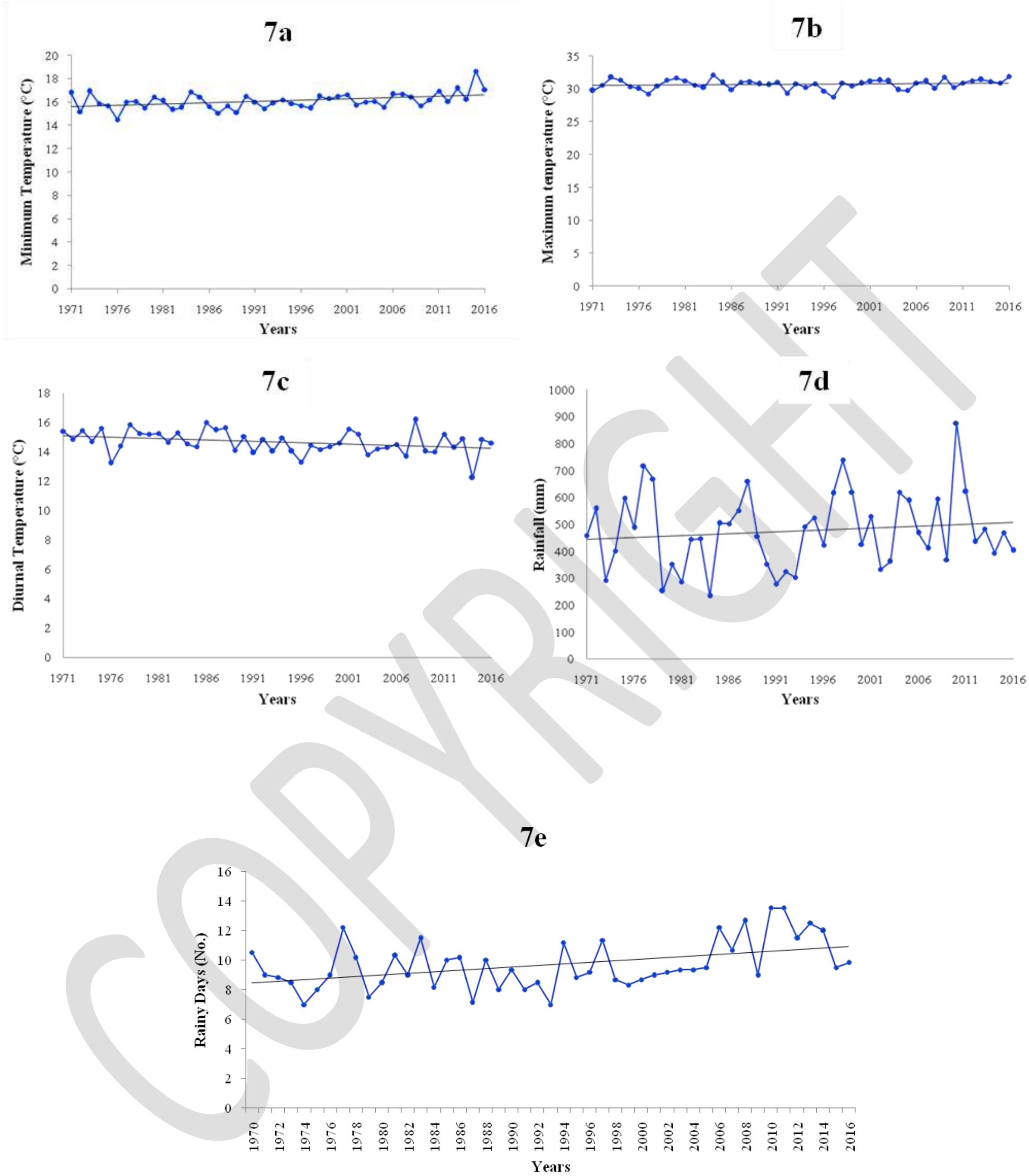


Figure 7: Variations in Climatic Parameters- Minimum T, Maximum T, Diurnal T, Rainfall, and Rainy Days during *Kharif Crop* season (1971-2016), District Kullu, HP
Source: HPSCCC, 2018

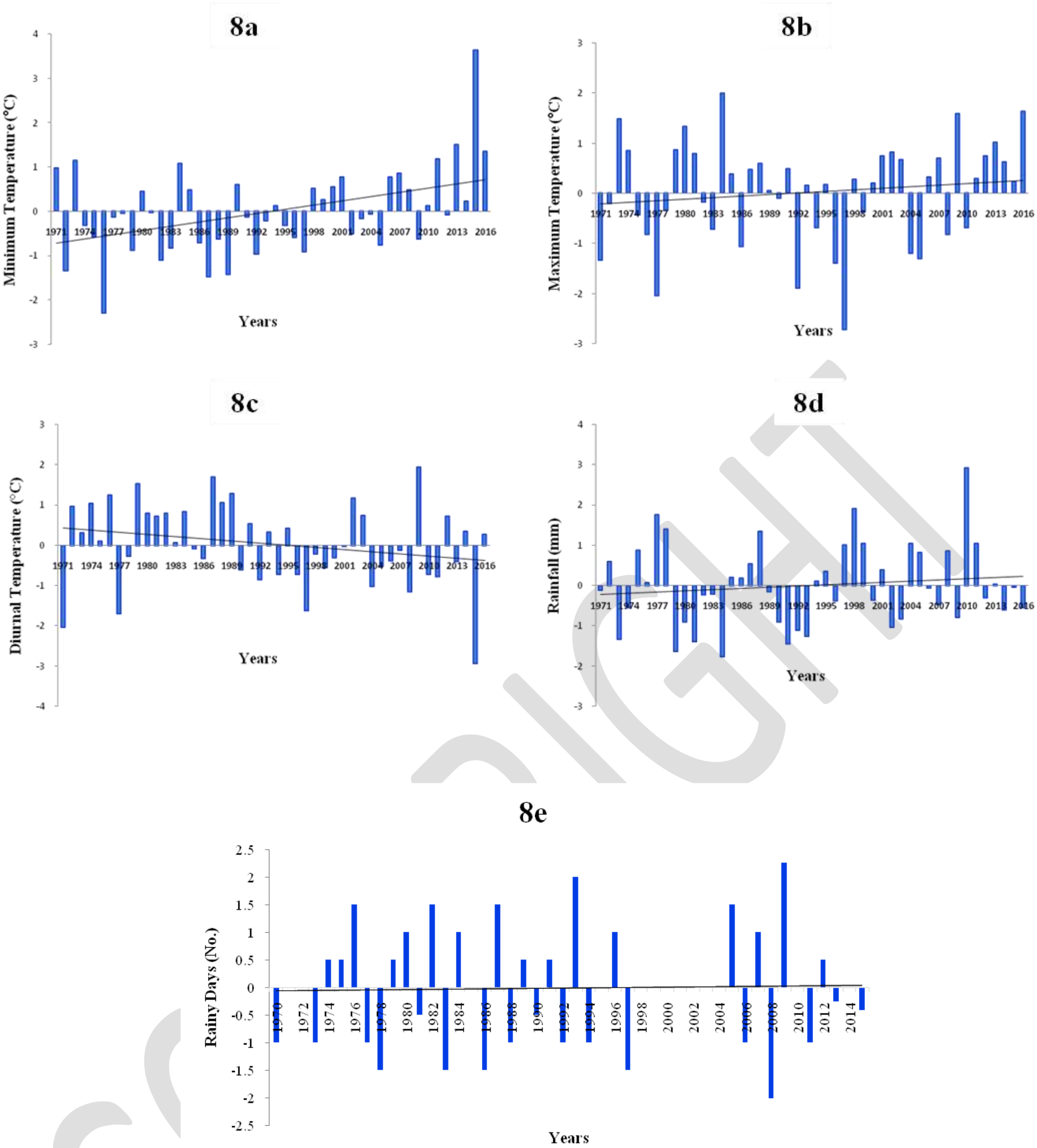


Figure 8: SAI for Climatic Parameters- Minimum T, Maximum T, Diurnal T, Rainfall, and Rainy Days during *Kharif Crop* season (1971-2016), District Kullu, HP
Source: HPSCCC, 2018

During the *Rabi* crop season, too, minimum temperature registered significant variation increasing at 0.02°C per year in District Kullu. Meanwhile, the maximum and diurnal temperature, and rainfall did not show substantial changes from 1971-2016. However, significant results were observed based for rainy days variations during the *Rabi* crop season signifying a decline of 0.07. Illustrated in figure 9(a-e) and table 5.

As per the outputs from SAI, minimum and maximum temperature showed a warming trend from 1998 onward, except dips in 2000 and 2001 (for minimum temperature), and

2003, 2005, 2014, 2015 for maximum temperature (figure 10(a-d)). Specially, for minimum temperature data, SAI highlighted an intense warming trend over the mean value since 2001. A dip in temperature below the average minimum temperature was observed in 2011, however for the subsequent years, consistent higher than average minimum temperatures were registered in the district. No significant patterns were observed from SAI of rainfall and for rainy days.

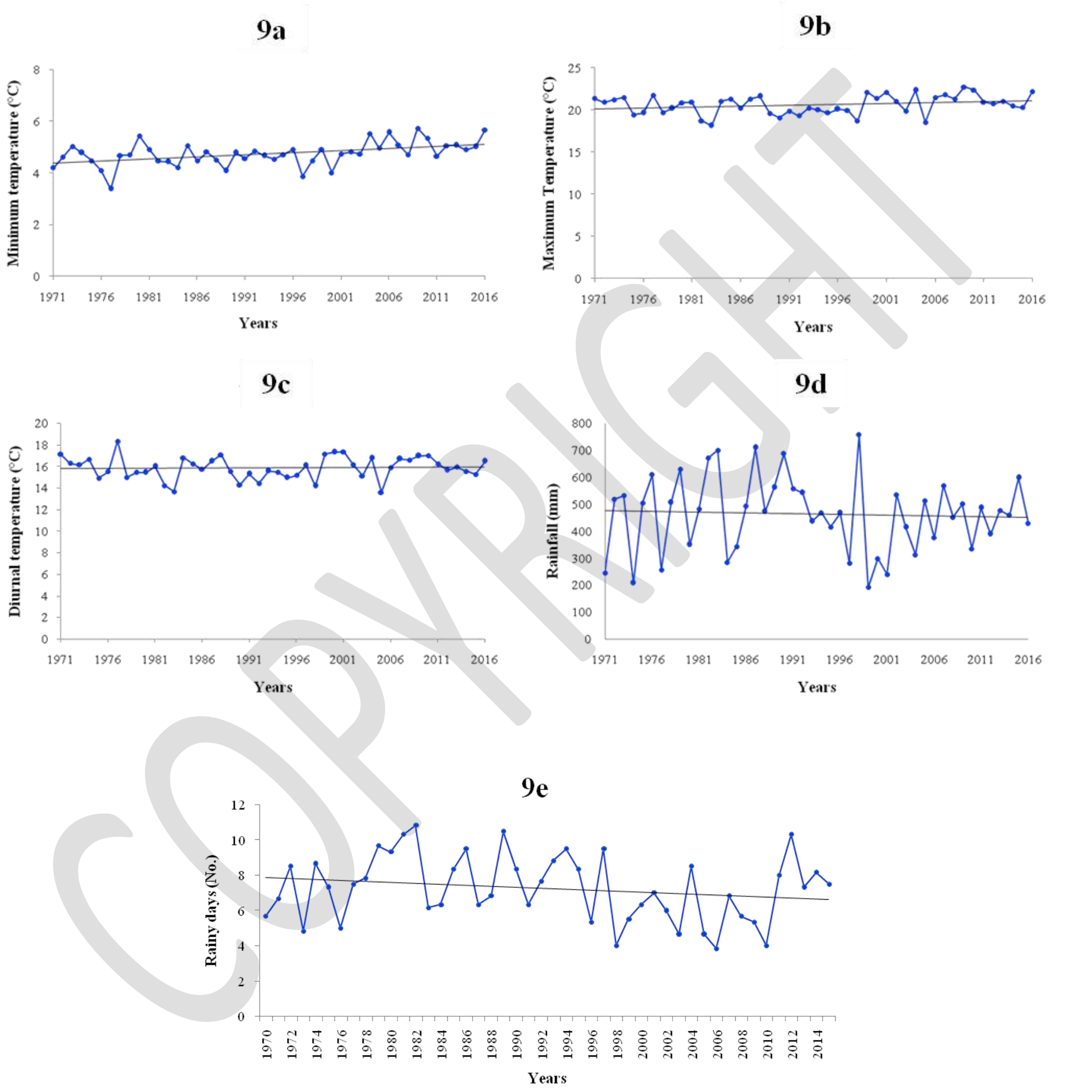


Figure 9: Variations in Climatic Parameters- Minimum T, Maximum T, Diurnal T, Rainfall, Rainy Days during *Rabi Crop* season (1971-2016), District Kullu, HP
Source: HPSCCC, 2018

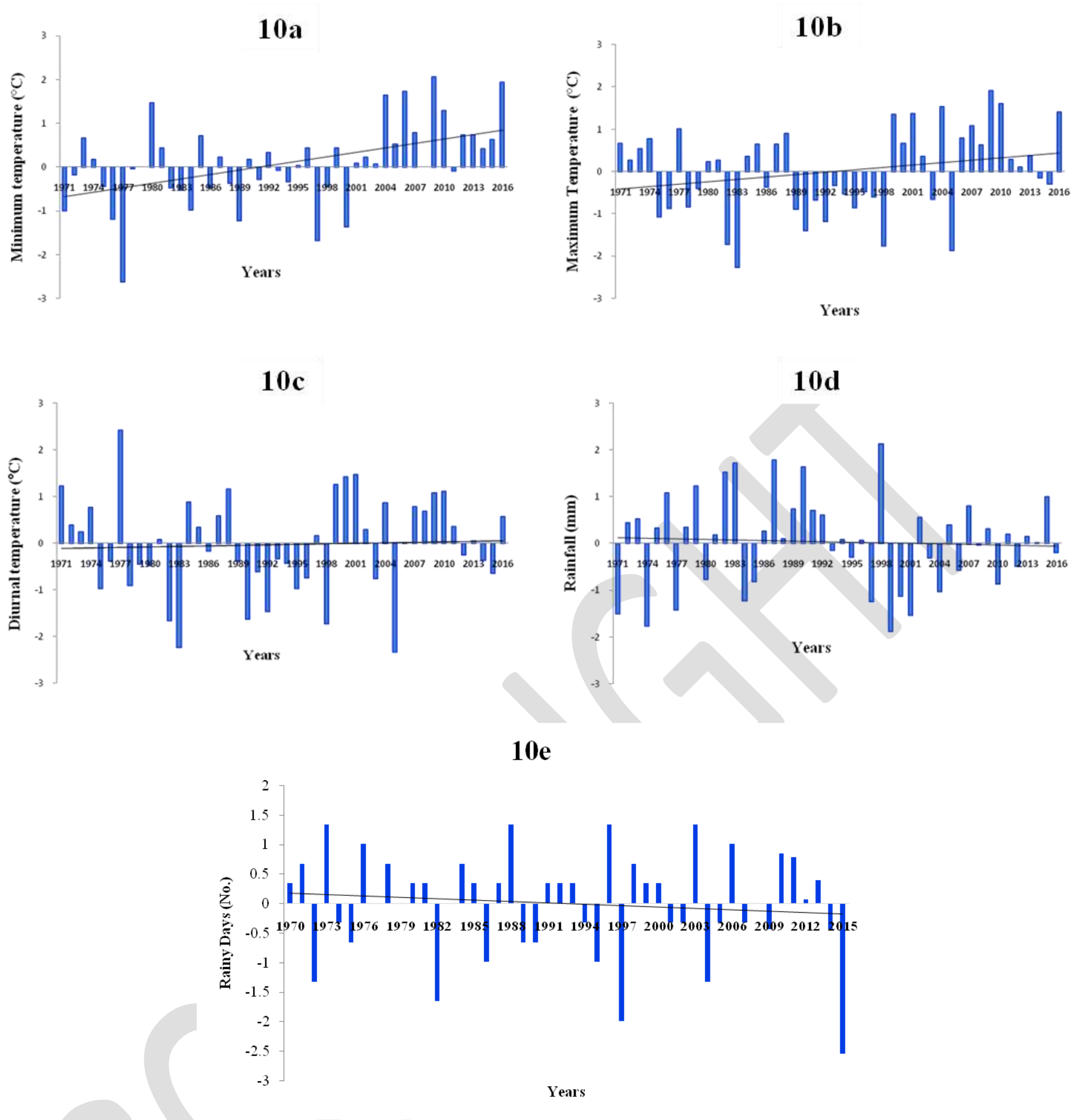


Figure 10: SAI for Climatic Parameters- Minimum T, Maximum T, Diurnal T, Rainfall, and Rainy Days during *Rabi Crop* season (1971-2016), District Kullu, HP
Source: HPSCCC, 2018

The discussed variations in temperature and rainfall patterns are not confined to District Kullu but are corroborated by various other observations from 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. 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). Rainfall patterns have been observed to remain steady in the Himalayan region (Joshi et al., 2011), as also observed in our study.

CROP PRODUCTIVITY – DISTRICT KULLU

While the total cropped area in Kullu, increased from 50,446 ha to 66,818 ha from 1965 to 2000 eventually decreasing to 59,597 ha in 2010, statistically significant changes were observed in movement of net sown area, increasing from 32,316 ha to 37,236 ha during the same time period. Meanwhile, cropping intensity exhibited an exceptional increase from 156.1 per cent in 1965 to 179.7 per cent in 2005 following which it displayed a sharp decline to 154 per cent in 2010. This decline in cropping intensity is expected to be linked to the reduction in total cropped area and culturable waste land in the district. Therefore, changes in the total cropped area were studied to understand the categorized shift in cropping patterns between food grains, vegetables, and orchard farming.

Based on the data from the Annual Crop and Season report by Directorate of Land Records, cropped area under food grains increased from 47,088 ha to 53,376 ha till year 2000 thereafter, drastically decreased by 16.24 per cent to 44,706 ha in 2010. Meanwhile, area under vegetable and orchards exhibited a sharp increase of 91.1 per cent from 1,563ha to 2,988 ha, and 1,304 per cent from 675ha to 9,477 ha respectively, from 1965 to 2010 (figure 11)

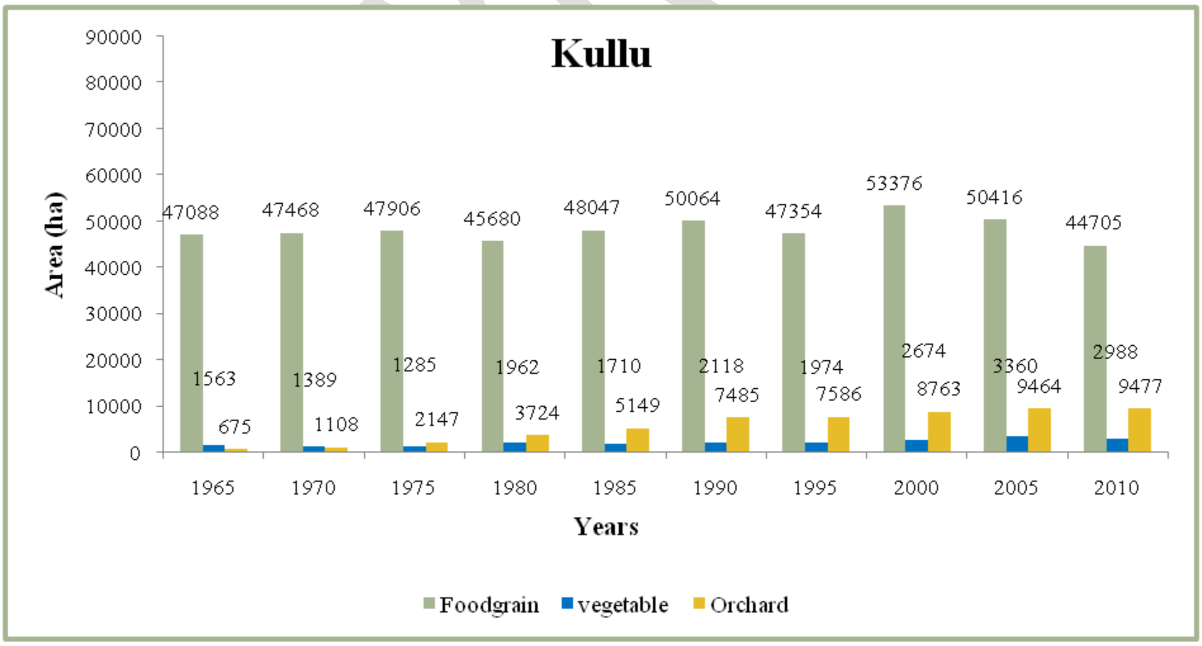


Figure 11: Changes in acreage under food grains, vegetable, and orchard farming (1965-2010), District Kullu, HP
Source: HPSCCC, 2018

A proportional shift from food grains towards vegetable and orchard farming could have suggested an absolute improvement through crop diversification and inherent economic attractiveness of cash crops. However, while orchard acreage reported a steady incline, vegetable showed fluctuated acceptance amongst the farmers in the district. Therefore, an understanding on the role of other influencing factors associated with variations in climatic conditions on individual crop productivity was deemed imperative. The next section explores the acreage and production trends for major crops of District Kullu before assessing the crop productivity and its relation to climate change variations.

ACREAGE AND PRODUCTION ASSESSMENT OF MAJOR AGRICULTURAL CROPS

Rice crop acreage witnessed a drastic decrease of 58.33 per cent from 3,590 to 1,496 ha during 1966 to 2010, while production decreased from 2,668 MT to 2,523 MT in 2010. Area and production of maize exhibited an increasing trend, moving from 11,547 ha in 1966 to 16,855 ha in 2010; whereas the production increased by 61.50 per cent. Wheat, too, experienced an increase in acreage from 15,268 ha to 19,278 ha in 2010; and in production by 172.95 per cent. However, Barley showed a consistent decline in acreage as well as production during the study period.

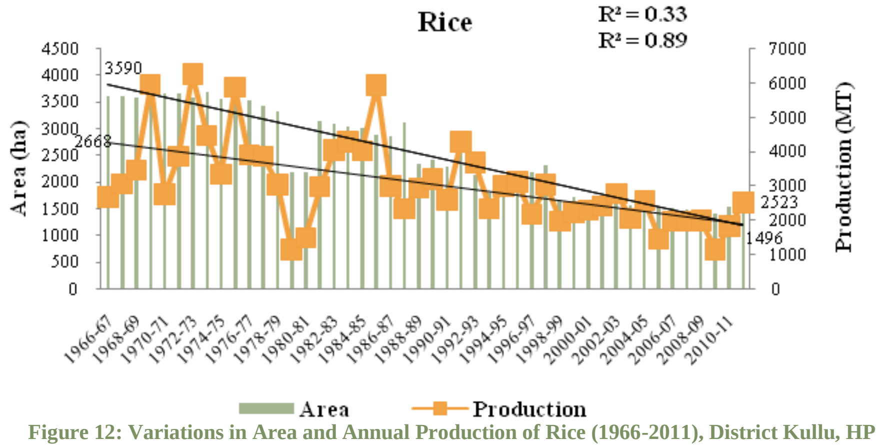


Figure 12: Variations in Area and Annual Production of Rice (1966-2011), District Kullu, HP

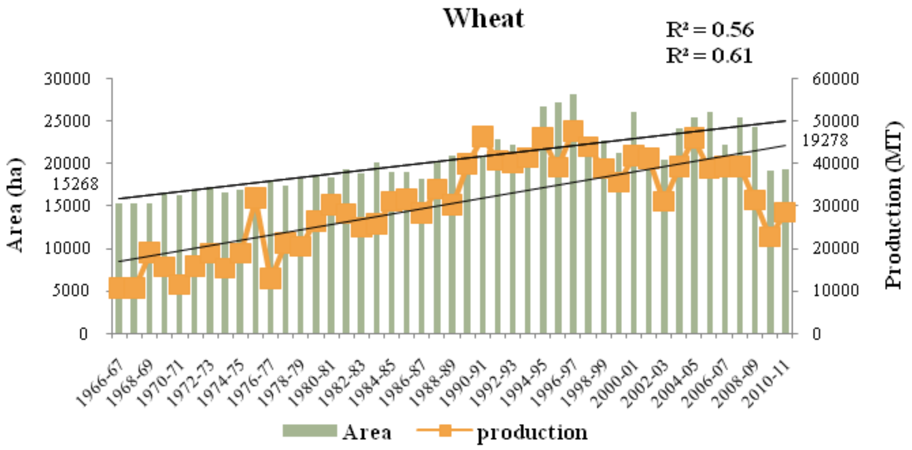


Figure 13: Variations in Area and Annual Production of Wheat (1966-2011), District Kullu, HP

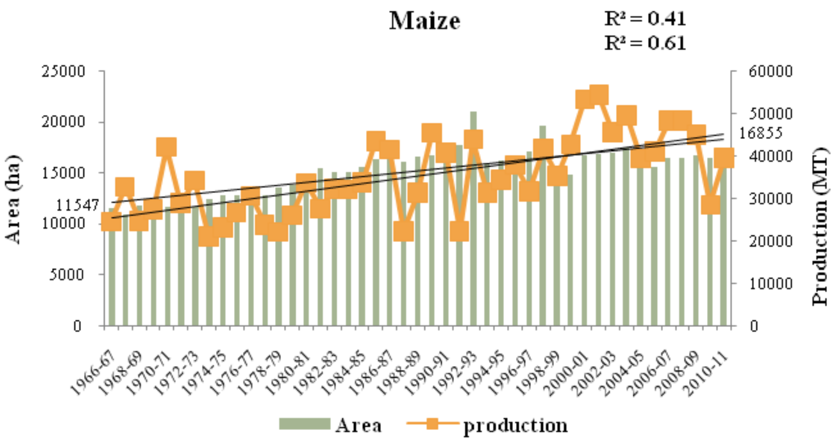


Figure 14: Variations in Area and Annual Production of Maize (1966-2011), District Kullu, HP

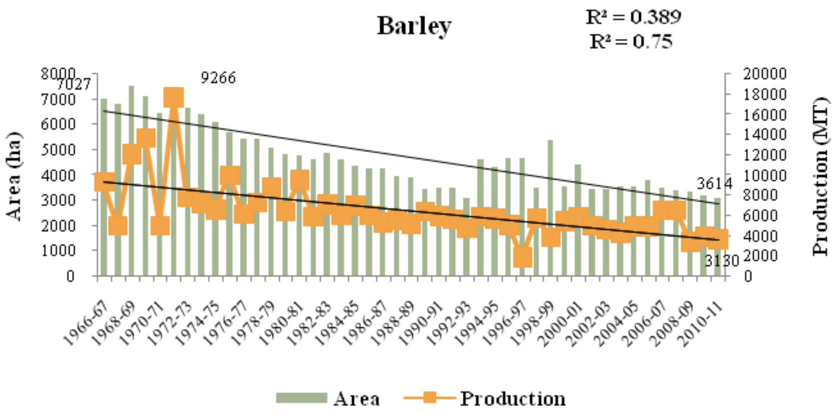


Figure 15: Variations in Area and Annual Production of Barley (1966-2011), District Kullu, HP

Analysis of productivity trends for Rice, Maize, Potato, Millets, and Wheat crops showed significantly changing yields during 1971-2010 time periods, except for Barley (illustrated in figure 16).

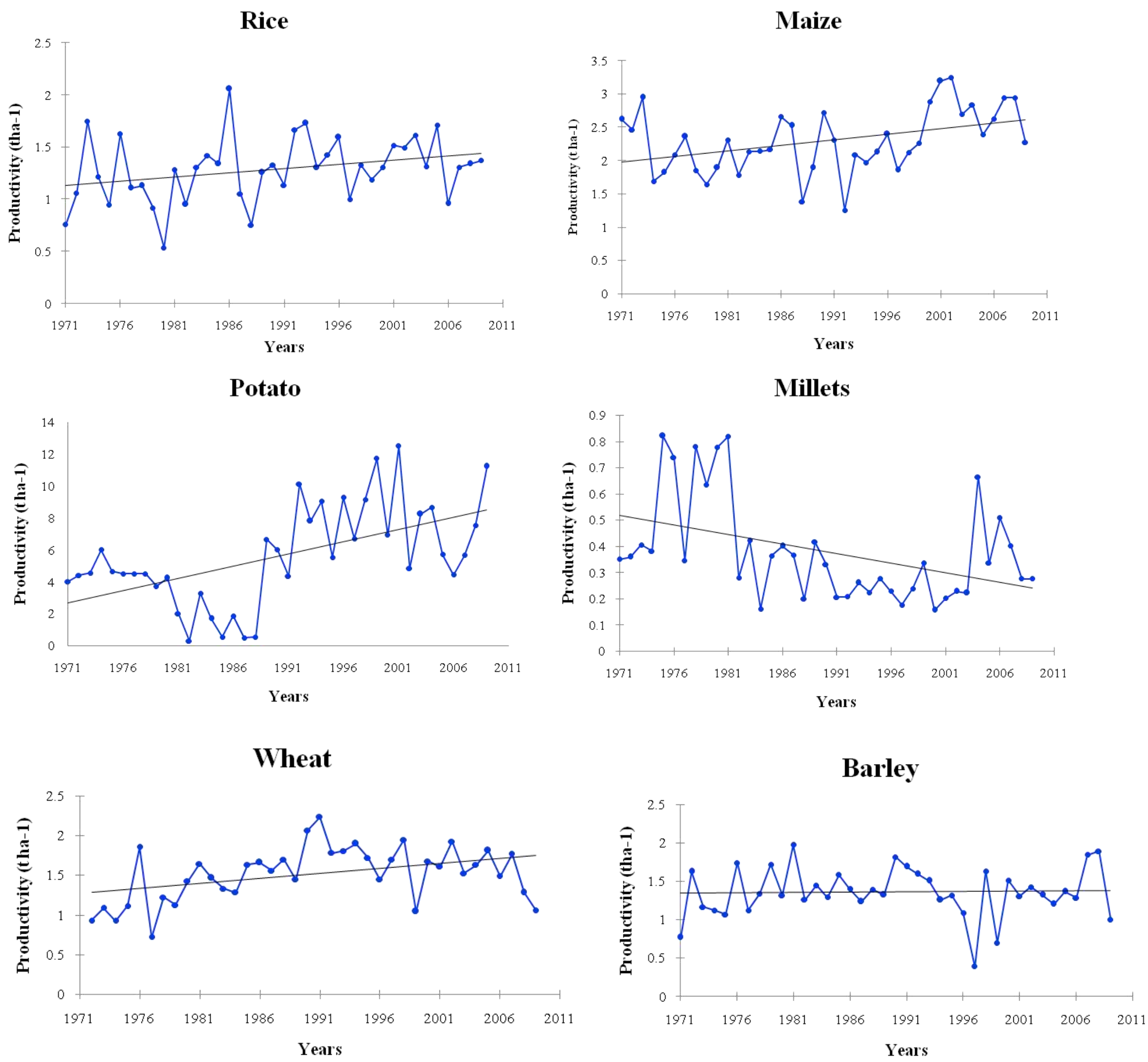


Figure 16: Variations in Productivity - Rice, Maize, Potato, Millets, Wheat, Barley (1971-2011), District Kullu, HP
Source: HPSCCC, 2018

An overall increased productivity trend is recorded for Rice, Maize, Potato, and Wheat (see table 6), where in Potato crop had the lowest p-value (0.002) exhibiting significant changes in productivity (with a factor of 0.13 as shown by Sen's slope) compared to the other crops. Maize, Rice, and Wheat showed an increased crop yield of 0.02, 0.01, and 0.01 t $ha^{-1}year^{-1}$ respectively. However, the productivity increase in wheat remained significantly below the national average of 3.07 t ha^{-1}.

Only Millet crops registered a decline in productivity by 0.005 t ha^{-1} $year^{-1}$. Traditionally the staple crop, millet production has been significantly neglected in favour of relentless advance of high-yielding varieties of wheat and rice. Millet cultivation now is limited to remote patches of tribal and hilly areas as part of subsistence farming.

Table 6: Mann Kendall Test Results – Crop Yields for Kharif and Rabi Season (1971-2011)

Crops	Sen's slope	p-value	Confidence interval
Wheat	0.01	**0.04**	0.01, 0.02
Barley	0.02	0.78	-0.001, 0.004
Rice	0.01	**0.02**	0.01,0.01
Maize	0.02	**0.01**	0.02, 0.02
Potato	0.13	**0.002**	0.11, 0.15
Millets	-0.005	**0.01**	-0.01, -0.004

Source: HPSCCC, 2018

From the table above it can be seen that except for Barley, all crops showed significant variations in productivity (as per interpretation of p-values at 95% confidence intervals). Changes in climate system are quite complex to show immediate impact on any sector. Agriculture stands to witness exacting economic impact of climate change, especially with the continuous passage of time under 'as is' scenario. Various studies aimed to predict future course of climatic impact on agriculture have forecast for decline in grain yields with warming temperatures in many developing countries, even though they may be witnessing growth as per census data (Mendelsohn & Dinar, 1999) (Kumar & Parikh, 2001) (Mendelsohn et al., 2011). Further, it is estimated that while an overall increase in mean temperature is certain, its impact on agricultural productivity remains highly subjective to magnitude and timing of extreme temperatures (Gornall et al., 2010). Therefore, it is imperative and suggested to explore the reasons for changes in crop productivity in District Kullu by establishing the correlation of climate change in the equation. The next section explores this relationship using correlation and multivariate linear regression analysis between agriculture productivity and climatic parameters.

CLIMATE-CROP JUXTAPOSITION

To ascertain the relationship between climatic variability and crop productivity, a correlation analysis was performed using the statistical tool – *Pearson's coefficient*. The results revealed a strong relationship between climate variability and productivity of *Rabi* crops such as wheat and barley, whereas negligible association was observed for the *Kharif* crops (rice, maize, potato and millets) in District Kullu (Table 7). While testing the effects of variability in minimum temperature a significant and positive trend (0.37) was observed for Maize crop productivity (with a p-value of 0.02). For variability in maximum temperature, Wheat and Barley showed a negative correlation coefficient of -0.31 and -0.30, i.e. an increase in maximum temperature is expected to result in a decline in their productivity, as corroborated from Mann Kendall trend test results. Secondary literature also supports these findings in certain cases. Singh et al. (2015), Mishra et al. (2015), and Gammans et al. (2017) reported similar trends for wheat, barley, maize, and paddy crops. Rainy days variations did not hold statistically significant relationship with variability in productivity for any of the crops during the study period.

Table 7 illustrates the regression outcome of detrended[3] climatic variables of minimum, maximum, diurnal temperature and rainfall with the productivity of selected crops. For all assessed crop varieties viz. barley, maize, rice, millets, wheat, and potato only 26.8%, 24%, 18.4%, 11.9%, 11.3% and 9.3% of productivity variability could be explained from temperature and rainfall variations in the district. With respect to individual crops, this means that the observed increase in productivity for Maize, Rice, Wheat, and Potato from 1965-2011 is explained by the variations in climatic parameters only to the extent of 24%, 18.4%, 11.3%, and 9.3% respectively. Similar interpretation stands for the decline in productivity for Barley and Millets. Factors of access to improved seed varieties, extensive fertilizer application, and better farm practices are touted to be the explanatory reasons for remainder variations in crop yield (Sharma, 2011).

With respect to rainfall variations, divergent but statistically significant outcomes were observed for barley and rice yield, with coefficients of correlation 0.49 and -0.34 respectively. While rice production is known to be water intensive with direct and positive relation with rainfall performance especially in rain-fed areas, the test result showed that with a positive change in rainfall variation, rice productivity will decrease by 0.34. One possible

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

reason for the decline in crop productivity can be attributed to the occurrence of *neck blast* and *shoot borer* diseases during heavy rainfall or high moisture conditions. *Neck Blast* is found to affect the panicle directly leading to high and significant losses in rice yields. Barley, on the other, struggles with simultaneous occurrence of high temperatures and high humidity. While concurrent results were seen for rising temperature, with positive changes in rainfall, the barley production should have shown a negative relation (as *rabi* crops require less moisture content for production). This inconclusive output can be attributed to inherent variations and gaps in data that were unable to capture minute changes in rainfall frequency and intensity. In absence of scientific evidence and field-based experiments conclusion on direct sensitivity to rainfall cannot be drawn.

Table 7: Multivariate Linear Regression Analysis – Crop Yields and Climatic Parameters, (1971-2011)

Crop	Variable / Statistics	Minimum temperature	Maximum temperature	Diurnal temperature	Rainfall	Rainy Days	R^2	Change (%)
Wheat	Coefficient	-0.02	**-0.31**	**-0.31**	0.22	-0.15	0.113	**11.3%**
	p-value	0.46	**0.03**	**0.02**	0.09	0.18		
Barley	Coefficient	0.00	**-0.30**	**-0.29**	**0.49**	-0.09	0.268	**26.8%**
	p-value	0.50	**0.03**	**0.03**	**0.00**	0.27		
Rice	Coefficient	-0.10	0.05	0.20	**-0.34**	-0.03	0.184	**18.4%**
	p-value	0.53	0.74	0.47	**0.04**	0.43		
Maize	Coefficient	**0.37**	0.11	-0.19	-0.21	0.06	0.24	**24.0%**
	p-value	**0.02**	0.53	0.25	0.20	0.35		
Potato	Coefficient	-0.01	-0.17	-0.15	0.09	-0.03	0.093	**9.3%**
	p-value	0.97	0.31	0.34	0.60	0.42		
Millets	Coefficient	-0.01	-0.01	-0.01	0.10	-0.03	11.9	**11.9%**
	p-value	0.47	0.48	0.47	0.27	0.44		

Source: HPSCCC, 2018

CONCLUDING POINTERS

Crop Variations:
Rice, Wheat, Maize, and Potato witnessed increased productivity expect for Barley and Millets, from 1971 to 2010.
Only Rice and Barley crop registered reduced acreage.

Climatic Variations:
Increase in Mean minimum temperature by 0.02 degree C during Rabi and Kharif crop season from 1971 to 2016
Decrease in Diurnal temperature by 0.02 degree C owing to plateaued mean maximum temperature
Rainy days during Rabi crop season declined by 0.07

Climate Crop Juxtaposition:
Strong relationship between climate variability and productivity of Rabi crops such as wheat and barley, whereas negligible association observed for Kharif crops (rice, maize, potato) in District Kullu i.e. variations in productivity of both Wheat and Barley were explained by statistically significant changes in climatic parameters of Maximum and Diurnal Temperature, and Rainfall. Whereas for Kharif crops, only Rice (with Rainfall), and Maize (with Minimum Temperature) reported statistically significant results.

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

The outcomes from the statistical analysis only gave a plausible variation in agricultural 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 District Kullu 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 8 below gives details on socio-economic status of farmers in District Kullu.

Table 8: 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 also captured individual farm data from the 210 surveyed farmers on temporal changes in acreage (1988-2018) for cultivation of *rabi and kharif* crops.

Farmers' preference for different *rabi* crops and its acreage during past 30 years plotted in figure 17 and 18 illustrates a substantial shift in acreage per HH from all cereals (wheat, barley) and other crops such as mustard and masoor (pulses) toward vegetable crops of peas, cauliflower, cabbage, carrot, radish, spinach, and garlic. Statistically, acreage under different *rabi* grain crops declined by 60 per cent (from 8.2 to 3.2 bigha/ HH). Maximum decline was recorded in case of wheat where cultivated area fell by 72.7 per cent (from 5.5 to1.5 bigha/HH) followed by mustard (50%) and barley (36.4%). No change was observed in acreage under masoor between 1988 and 2018.

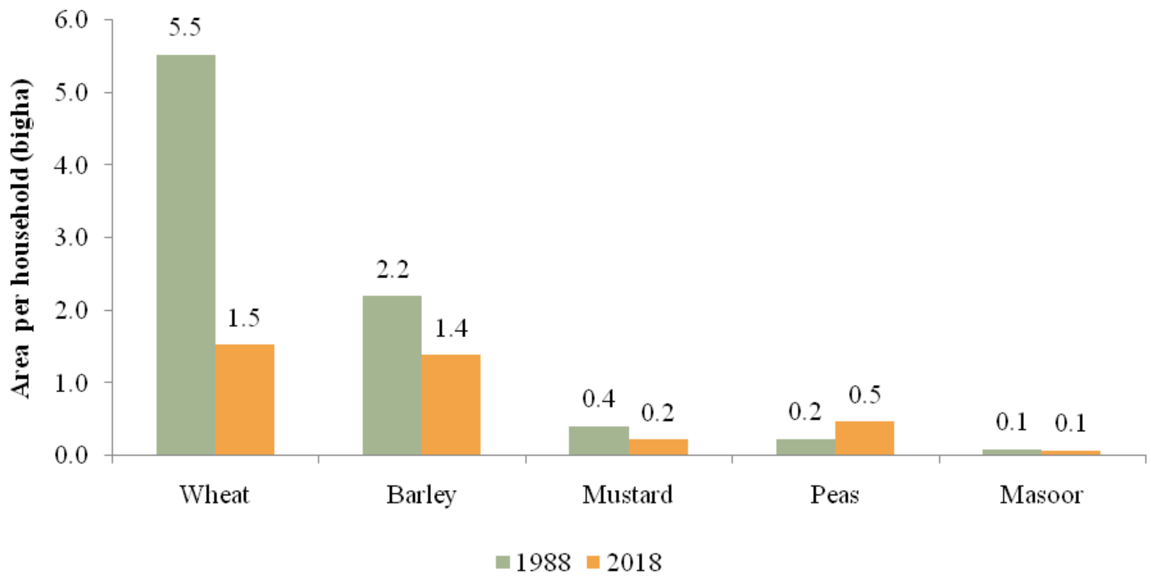


Figure 17: Acreage under different Rabi Grain Crops, Field Survey, District Kullu, HP
Source: Field Survey, HPSCCC, 2018

Rabi vegetable crop cultivation exhibited four-fold increase from 1988 to 2018, growing from 0.6 bigha to 2.3 bigha/ HH. Acreage under pea, cauliflower and cabbage doubled from 0.2 to 0.5, 0.2 to 0.4 and 0.1 to 0.2 bigha/ HH respectively. In Himachal Pradesh, crop diversification toward fruit and vegetable crops commenced in the late sixties that garnered pace in 1970s and 1980s. By 1990s, new crops such as carrot, spinach, and garlic had gained further momentum in low and mid-hill districts as well. Move towards these high-value cash crops was for their ability to stabilise farm incomes, increase employment, and natural resource conservation. Nevertheless, during initial phases the higher adoption rate could have been attributed to demonstration effect[4] rather than result based outcomes. However, since then these crops witnessed stark increase in acreage for all surveyed farming HH. The above observations signify a shift in acreage toward commercial crops, which could be attributed to adaptation to changing sowing and cultivation conditions and/or pure economic reasons.

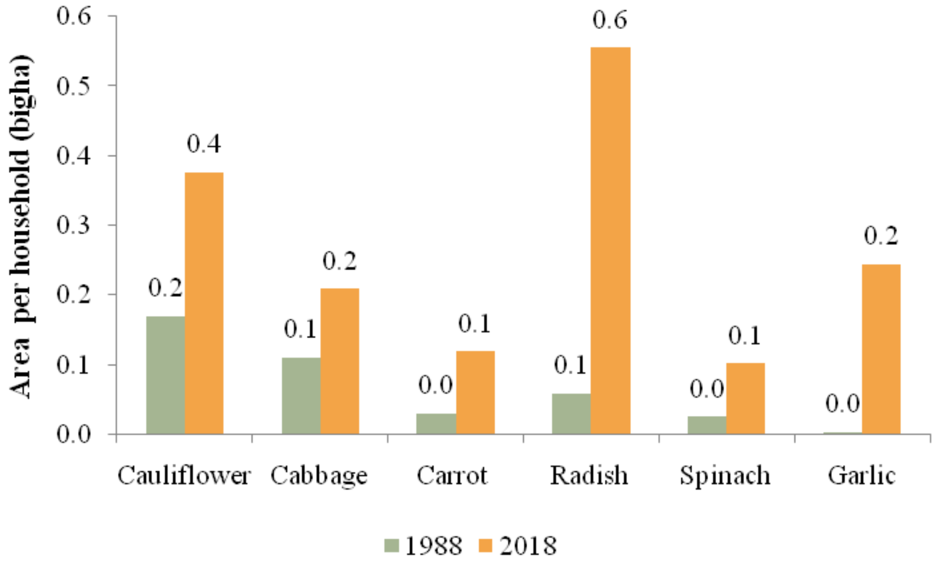
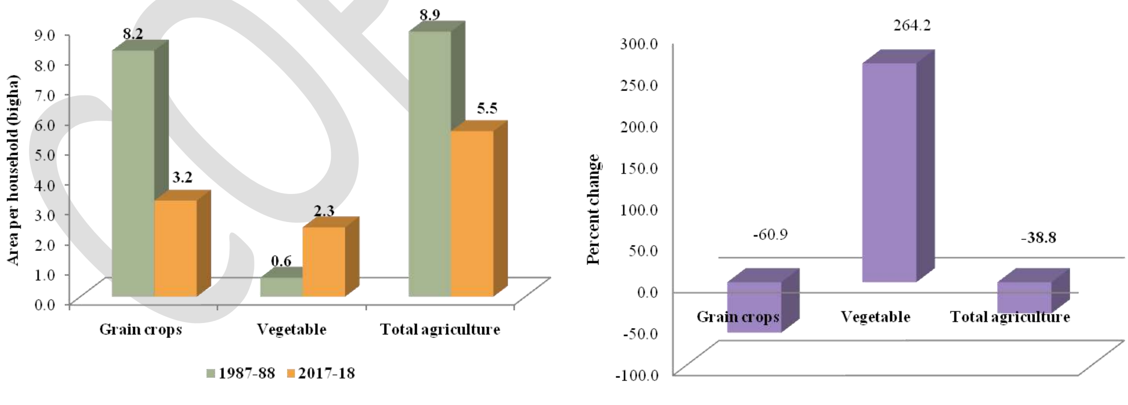


Figure 18: Acreage under different Rabi Vegetable Crops, Field Survey, District Kullu, HP
Source: Field Survey, HPSCCC, 2018



(a) Acreage under agriculture crops of Rabi season in Kullu district

(b) Percentage change in acreage under Rabi crops in Kullu district

Figure 19: Acreage (absolute and percentage change) under Rabi Crops, Field Survey, District Kullu, HP
Source: Field Survey, HPSCCC, 2018

[4]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.

Nevertheless, total area under agriculture decreased by 38.8 per cent (as per surveyed HHs) moving from 8.9 bigha to 5.5 bigha per HH, indicating a shift to non-agriculture activities and field fragmentations linked to family expansions (figure 19).

Meanwhile, area under *Kharif* grain crops decreased by 58.4 per cent from 9.6 to 4.0 bigha/ HH) (figure 20). Maximum decline was observed for paddy cultivation (81.6%) followed by maize (52.4%), finger millet (77.8%), Amaranth (85.3%), Buckwheat (41.3%), Rajmah (35.4%) and Blackgram (66.7%).

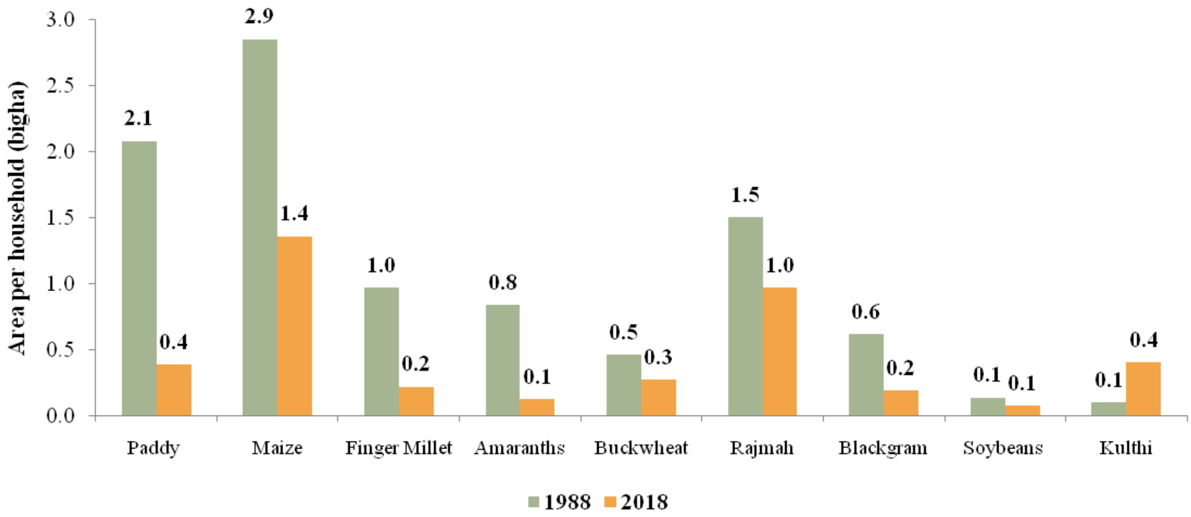


Figure 20: Acreage under different Kharif Grain Crops, Field Survey, District Kullu, HP
Source: Field Survey, HPSCCC, 2018

Similar to the trend under *rabi* vegetable crops, *kharif* vegetable crop registered a twin-fold increase from 1988 to 2018. Except for potato (2.1 to 0.4 bigha/ HH), every other crop such as chillies, tomato, capsicum, brinjal and beans had increased acreage (figure 21).

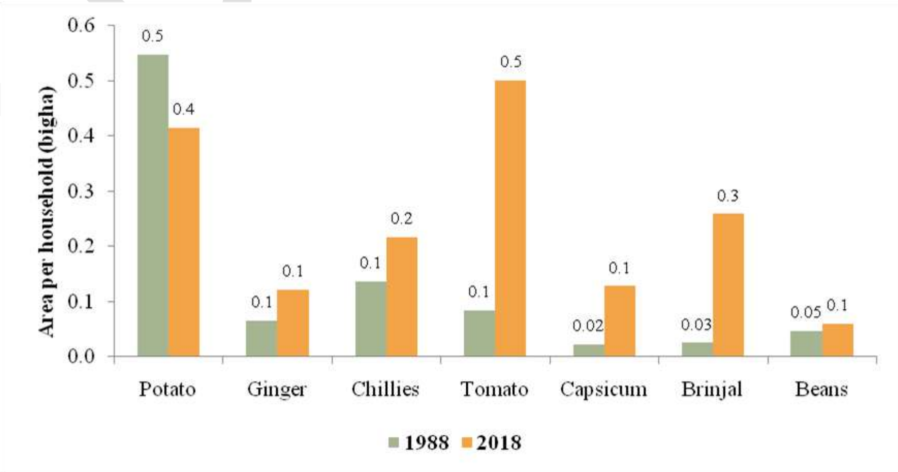
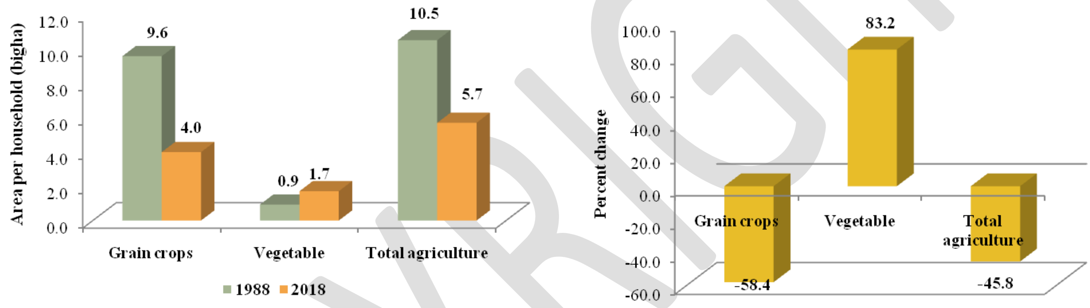


Figure 21: Acreage under different Kharif Vegetable Crops, Field Survey, District Kullu, HP
Source: Field Survey, HPSCCC, 2018

For the interviewed HHs, total area cultivated under *kharif* season crops decreased by 45.8 per cent. A total area of 4.8 bigha/ HH shifted to non-agriculture activities, showing decrease in cereals by 58.4 per cent. Acreage under *kharif* crop for the 210 HHs showed a shift from grain crops to vegetable crops (except for potato), as exhibited in trend assessment of acreage and productivity data from the Directorate of Land Records[39]. While as per the productivity trend analysis, potato yield registered a surge from 1971 to 2016, it showed contrasting results for acreage as per surveyed HHs. Reasons apprised were linked to the shift from seed potato to table potato variety that fetched low market price compared to former.[5]

Field survey revealed plausible reasons for this drastic shift in crop cultivation choices. As per the insights, vegetable crops are expected to involve low sowing effort and cost intensity with relatively high remunerative returns when compared to *kharif* grain crops.



(a) Acreage under agriculture crops of Kharif season in Kullu district **(b) Percent change in area under Kharif crops in Kullu district**

Figure 22: Acreage (absolute and percentage change) under Kharif Crops, Field Survey, District Kullu, HP
Source: Field Survey, HPSCCC, 2018

[5]Seed potato cultivation is more prominent in Lahaul & Spiti district shifted from District Kullu

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

***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 9: Shifting Cropping Patterns – Reasons and Response, Field Survey, District Kullu, HP

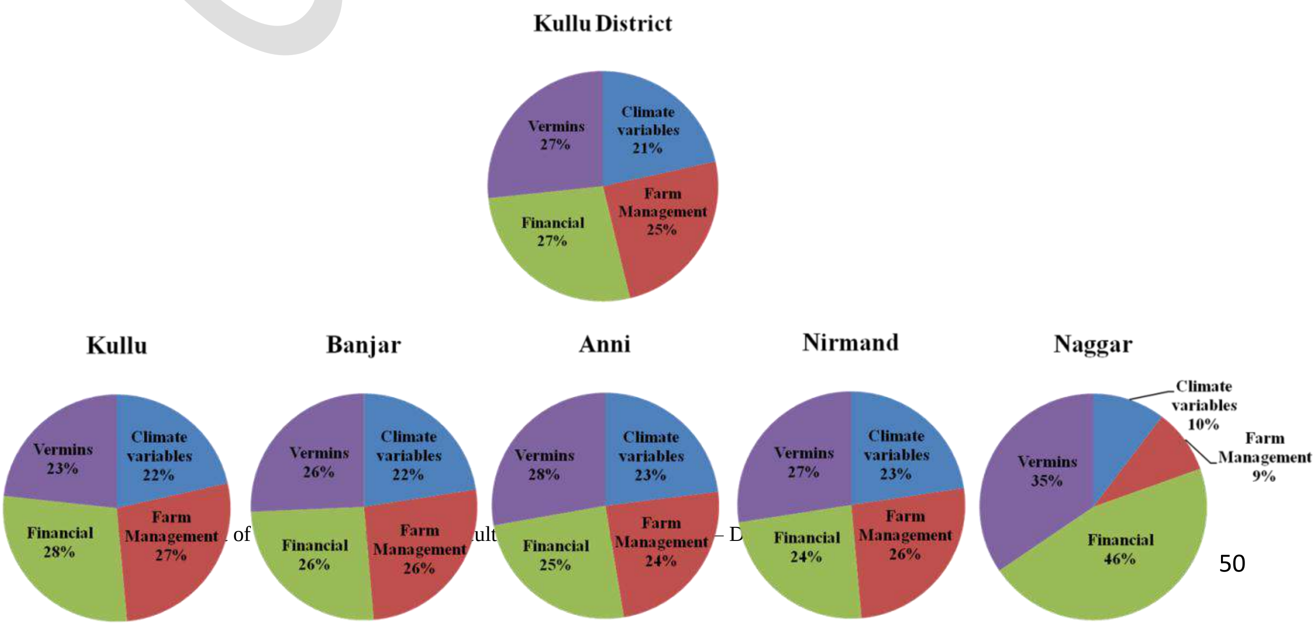
Variables	Factors	Kullu	Naggar	Banjar	Anni	Nirmand	Total
Climate	Increasing temperature	84.0	15.0	72.0	65.0	87.5	64.7
	Abnormal rainfall	85.7	12.5	100	60	55	62.6
	Drought	84.5	12.5	96.7	100	87.7	76.3
	Hail	35.7	5	76.5	90	70.6	55.6
	Average	**72.48**	**11.25**	**86.30**	**78.75**	**75.20**	**64.80**
Farm 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

graphical representation (figure 23).

Figure 23: Intervening factors for shifting cropping patterns for individual blocks and district Kullu, HP
Source: Field Survey, HPSCCC, 2018

Within climatic patterns, droughts were cited as the major reason for a shift in cropping patterns for farmers across five blocks in District Kullu, followed by increasing temperatures,



abnormal rainfalls, and hailstorms. However, for the farmers in the Naggar block the predominant factor to changing cropping patterns was availability of cash crops (for economic benefits through easy market accessibility). 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 23). 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[26] 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 10 summarises the output of PCA for block-wise variations in Exposure indicator.

Table 10: Block-wise scores and variations in Exposure Indicator, District Kullu, HP

Exposure Indicator	Scores	Kullu	Naggar	Banjar	Anni	Nirmand	p-value
Flash flood frequency	***0.64***	0.45	0.05	-0.48	-0.28	-0.27	**0.00**
Strong Winds	***0.56***	0.004	0.17	-0.14	-0.19	0.07	**0.04**
Hail frequency	***0.53***	0.05	0.06	-0.07	0.04	-0.12	0.40
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**
Temperature	***0.20***	0.03	0.02	-0.005	-0.06	-0.02	0.37

Source: Field Survey, HPSCCC, 2018

All the weights of climate variables were positive thereby indicating a direct relationship with the overall exposure index and a perceived exposure of surveyed population to increased frequency of climatic events – floods, hail, rainfall, snowfall, and droughts. A further investigation revealed 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 exposure 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). Dependence on rainfed agriculture in these blocks increases their exposure to rainfall variability. However, in Naggar (-0.19) and Banjar (-0.17) blocks presence of perennial rivulets and natural water sources reduces their perceived exposure to rainfall led variability to crops success. Highest exposure to drought in Kullu block was accounted to limited support of irrigation water and higher dependence on rain-fed agriculture, 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 than for agricultural crops owing to direct loss exposure (physical appearance of cash crops such as apples and vegetables is linked to their 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 agriculture 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 11 summarises the output of PCA for block-wise variations in Sensitivity indicator.

Table 11: 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 detail, the 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). 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, (exhibited in table 12)

Table 12 : 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 13 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 13: 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 by following the logic of ***Adaptive Capacity net of Exposure and Sensitivity*** to Climate Change, which varied significantly across the blocks (Table 14). On the collective perception for vulnerability, farmers' community in Nirmand block exhibited highest value on vulnerability index (2.44). Farmers appeared least equipped on front of all asset classes of human, natural, physical, and financial capacity. They had high perception on exposure to rainfall and hailstorms (owing to growing share of orchard and vegetables 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 24)

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 agriculture activity, 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 databases at global level.

Table 14: Block-wise Vulnerability Index, 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

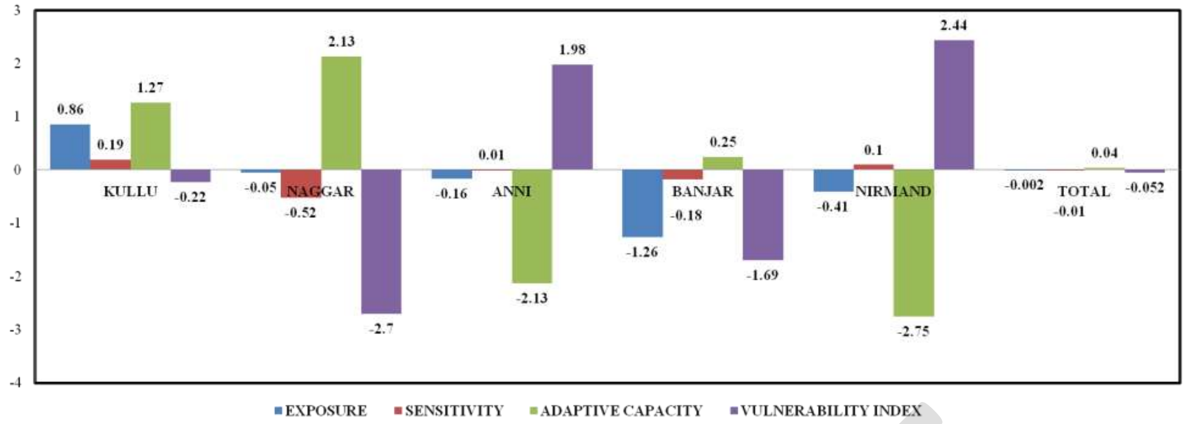


Figure 24: Block-wise Vulnerability Index – Exposure and Sensitivity net of Adaptive Capacity, District Kullu, HP
Source: Field Survey, HPSCCC, 2018

CONCLUDING POINTERS:

Crop Acreage:
Shift in acreage from all cereal crops to vegetable crops
Rabi Vegetable Crop cultivation witnessed four-fold increase, for interviewed farming HHs
Kharif Vegetable Crop cultivation witnessed two-fold increase, for interviewed farming HHs
Decrease in agriculture area to non-agricultural activities

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

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

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*
Sensitivity: *Climate Change induced sensitivity affects land size and availability to agriculture, pest population, crop diseases, and irrigation support*
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 was 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 agriculture 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 agriculture practices. The Table 15 below summarises the adopted adaptation strategies, where in major approaches are highlighted.

As discussed earlier as well, 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. Extensive use of fertilisers to maintain and perhaps, increase agricultural 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 15: 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 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.

The mean minimum temperature increased by 0.02°C during *Rabi* and *Kharif* crop seasons, the diurnal temperature decreased by 0.02°C during the *Kharif* crop season, and rainfall quantity did not register any statistically significant results. Moreover, the Standardized Anomaly Index of temperature depicted a warming trend from 1998 onwards with heightened intensity over the mean value since 2001. Further, to better understand the variations in precipitation, changes in rainy days were analysed. However, no significant variations were observed for rainy days parameter during *Kharif* crop season. While during *Rabi* crop season a decline of 0.07 in rainy days was recorded from Mann Kendall Test.

The statistical assessment of variations in climatic parameters of temperature and rainfall with changes in agriculture crop productivity registered maximum impact on *Rabi* crops (wheat and barley), whereas negligible association was observed for *Kharif* crops (rice, maize, potato) i.e. variations in productivity of both Wheat and Barley were explained by statistically significant changes in climatic parameters of Maximum and Diurnal Temperature, and Rainfall. Whereas for Kharif crops, only Rice (with Rainfall), and Maize (with Minimum Temperature) reported statistically significant results. Rainy days did not show any statistically significant correlation with crop productivity for both crop seasons.

For all assessed crop varieties viz. Barley, Maize, Rice, Millets, Wheat, and Potato only 26.8%, 24%, 18.4%, 11.9%, 11.3% and 9.3% of productivity variability could be explained from temperature and rainfall variations in the district. With respect to individual crops, this means that the observed increase in productivity for Maize, Rice, Wheat, and Potato from 1965-2011 is explained by variations in climatic parameters only to the extent of 24%, 18.4%, 11.3%, and 9.3% respectively. Similar interpretation stands for the decline in productivity for Barley and Millets.

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 ongoing shift from all cereal crops to more attractive vegetable crops. These shifts in crop cultivation was 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.

This study qualified the results of statistical trend of climatic variables vis-à-vis crop productivity (*rabi and kharif*) juxtaposed with a perception-based assessment, however, it demands field based experimental validation and simulation exercises to validate individual crop based outcomes, 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 agriculture, 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 on clarity on policies and schemes, latest technology and crop varieties, subsidies and credit facilities. Departments are urged to applying 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, cauliflowe)	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					
	Pests	Increased	Decreased	No change	Remarks
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 Agriculture Crops
Nirmand	Nirmand	Sarkoti	1550	6593	1513	Wheat, Paddy, Bajra, Ginger, Potato
	Gadej	Bael	950	877	214	Wheat, Paddy, Barley, Bajra, Peas, Mustard, Maize, Rajmah, Tomato, Brinjal, Potato, Cabbage, Cauliflower
	Twar	Remu	1500	1498	358	Wheat, Paddy, Maize, Rajmah, Tomato, Bajra, Potato, Cabbage, Cauliflower
	Arsu	Arsu	1950	1657	346	Wheat, Paddy, Barley, Rajmah
	Kot	Dhar	NA	4400	900	Wheat, Paddy, Barley, Rajmah, Ginger, Chillies, Tomato, Capsicum, Potato
Anni	Dalash	Chewa	1850	2850	650	Potato, Tomato, Peas, Cabbage, Carrot, Spinach, Reddish, Amaranth, Brinjal, Beans, Chillies
	Behna	Tihani	1300	1977	529	Wheat, Barley, Maize, Rajmah, Potato
	Dhingidhar	Togi	NA	2250	601	Barley
	Taluna	Nagan and Haripur	1000	805	194	Wheat, Barley, Maize, Paddy, Bajra, Rajmah, Moong, Masoor, Blackgram, Kulthi, Peas, Soybean
Banjar	Sharchi	Gushaini	1600	NA	NA	Barley, Wheat, Maize, Finger Millet, Mustard, Blackgram, Massoor, Rajmah, Potato, Carrot,, Peas, Radish, Spinach, Tomato, Capsicum, Cauliflower, Cabbage, Chillies,
	Kandi Dhaar	Sai Ropa	1450	NA	NA	Barley, Wheat, Maize, Finger Millet, Fagopyrum, Rajmah, Potato, Peas , Mustard, Cauliflower, Cabbage, Carrot, Radish, Spinach,
	Chaini	Chhet	1620	NA	NA	Wheat, Paddy, Bajra, Maize, Barley, Rajmah, Blackgram, Potato, Peas, Cauliflower, Cabbage, Carrot, Radish, Spinach
	Khadagaad	Shoja	2550	2720	650	Wheat, Barley, Maize, Paddy, Finger Millet, Amaranath, Rajmah, Blackgram, Potato, Carrot, Radish, Spinach, Peas, Cauliflower, Cabbage

Kullu	Bhaliyani	Bhaliyani	6360	2600	526	Wheat, Barley, Paddy, Maize, Finger Millet, Amaranth, Fagopyrum, Rajmah, Black Gram, Peas, Potato
	NA	Madgaon	NA	NA	NA	Wheat, Barley, Maize, Finger Millet, Balckgram, Amaranth, Kuttu, Rajmah, Potato, Peas
	Koti Sari	Bhaikhali	NA	2100	550	Wheat, Barley, Maize, Finger Millet, Amaranth, Kuttu, Rajmah , Blackgram, Potato, Peas
	Khokhan	Khokhan	7923	3193	692	Wheat, Barley, Paddy, Maize, Finger Millets, Mustard, Black Gram, , Amaranth, Rajmah, Peas, Potato,
	Hurla	Hurla	7601	1805	400	Wheat, Paddy, Maize, Blackgram, Rajmah, Peas, Cauliflower, Cabbage, Radish
	Jari	Jari	4991	2725	584	Wheat, Barley, Paddy, Maize, Mustard, Saliara
	NA	Jhan	NA	NA	NA	Wheat, Barley, Maize, Mustard, Blackgram
	Jha	Bradha	8168	2619	527	Wheat, Barley, Maize, Rajmah
	Haat	Bajaura	3625	5852	1255	Wheat, Barley, Paddy, Maize, Rajmah, Potato
	NA	Phatnaal	NA	NA	NA	Wheat, Barley, Paddy, Maize, Mustard, Saliara
	Chang	Chang	NA	1900	441	Wheat, Barley, Paddy, Maize, Finger Millet, Amarnath, Mustard, Blackgram, Rajmah, Peas, Potato
	Ratocha	Ratocha	6525	1468	265	Wheat, Barley, Maize, Mustard, Blackgram
	Karzan	Sajla	6039	622	144	Wheat, Barley, Paddy, Maize, Rajmah, Potato
Naggar	Kais	Bishtbed	NA	NA	NA	Wheat, Barley, Paddy
	Kais	Taandla	NA	NA	NA	Wheat, Barley, Paddy, Maize, Finger Millet, Amaranth, Rajmah, Blackgram, Mustard, Potato
	Shanag	Goshala	5493	850	181	Wheat, Barley, Paddy, Maize, Finger Millet, Saliara, Rajmah, Mustard, Potato, Peas
	NA	Kushwa	6719	NA	NA	Wheat, Barley, Paddy, Maize
	Manali	Old Manali	6530	831	178	Paddy, Maize, Barley, Mustard, Potato, Peas, Spinach, Ginger
	Benchi	Malipathar	NA	2102	559	Wheat, Barley, Maize, Mustard, Rajmah, Potato
	Raison	Dehra Seri	NA	1061	NA	Barley, Chillies, Tomato
	Malipathar	Malipathar	NA	NA	NA	Wheat, Barley, Paddy, Maize
	NA	Tangla	NA	NA	NA	Wheat, Barley, Paddy, Maize