FINAL TECHNICAL REPORT

Socio Economic Vulnerability of Himachal Pradesh to Climate Change

DST/CCP/PR-14/2012(G)

Supportted By

Department of Science and Technology, Government of India

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Socio Economic Vulnerability of Himachal Pradesh to Climate Change

DST/CCP/PR-14/2012(G)

Submitted to
Climate Change Program,
Department of Science and Technology (CCP-DST),
Government of India

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Dr. Jyoti Parikh
Executive director, IRADe

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Summary Findings

The Himalayan ecosystem is highly vulnerable to the stress caused by increased pressure of population, exploitation of natural resources and other related challenges. Climate change may adversely impact the Himalayan ecosystem through increased temperature, altered precipitation patterns, and drought. The Himalayan ecosystem is approaching towards a stage of disequilibrium and there are clearly visible negative changes in the resources and the environment. The fragility of the region stems mainly from geological history of its evolution and structural set-up of the rocks. Being located in the fragile Western Himalayan ecosystem, the state of Himachal Pradesh is highly vulnerable to climate change. Himachal Pradesh has a high dependency on climate sensitive sectors such as agriculture, horticulture and forestry. Incidences of floods, droughts, loss of biodiversity and poverty as a consequence of climate change are the biggest concern in these two states.

IRADe conducted a research study “Socioeconomic Vulnerability of Himachal Pradesh to Climate Change” (2015) supported by DST. The study examined the vulnerability of agriculture, water and forest sectors. IRADe developed and used a variety of data and methodologies for vulnerability assessment of the aforesaid sectors at different time scales, taking into account economic activities in future. The methodological approaches included in the projects were:

- Observation of various indicators, Sustainable livelihood observations
- IPCC projections of Climate (4th Assessment Report)
- Participatory Rapid Appraisal (PRA), primary surveys and multi-stakeholder consultations (including local people and Government Officials).
- **The criticality of the climate change, in context of Himachal Pradesh, was substantiated by future climatic projection, using RCP scenarios (IPCC AR5 Report) for 2050 and 2070**: Representative Concentration Pathways Scenarios (RCP) 2.61, 4.52 and 8.53 were mapped on Arc GIS (version 10.1) platform for state of Himachal Pradesh to understand the variation of different bioclimatic variables (Annual mean temperature, annual mean precipitation, temperature seasonality (standard deviation *100) and precipitation seasonality (Coefficient of Variation) to represent annual trends and seasonality

The Research Studies captured the status of local socioeconomic and ecological conditions, climate change trends, the local perception about climate change impacts, especially in terms of livelihood. The sectoral findings of the primary survey validated the secondary data analysis. The major findings of the project were:

Table.1: Summary of findings

Kind of Change	Evidence
Warming	Decline in snowfall period and persistence, decline in apple. • In some regions of Kullu district like Bhunter and other regions (eg: Hurla village, Kullu block) apple has failed, pomegranate orchards flourishing in these regions. • Increase in more tropical trees, In some regions of Mandi snowfall occurred before 2-3 decades back, now mango crop flourishing well. • Presence of low elevation weeds, pests & animals at higher elevations, invasion by Lantana camara, Ageratum sp. Increase in the number of low elevation, animal species like wild boars (Sus scrofa) in the higher elevations. • Early fruiting reported in stone fruits due to warm & prolonged summers. • Decline in some part of NTFP production. Drifting of medicinal herbs and plants in deeper and high altitude forests. • Drying of Kuhls and Chasmas
Decline in rainfall	Frequency of drought has increased, the same was observed in most of the areas. The situation is worst in areas where there is no provision for lift irrigation, during less; irregular and untimely rainfall there is a decrease in production and area under the crop in many regions eg: Basantpur, Mashobra blocks of Shimla.
Decline in snowfall	• Apple quality and quantity is directly affected by the chilling hours it receives, which in turn depend on the intensity and amount of snowfall received. In regions like Chandsari (Nagar Block) apple size is reduced due to less chilling hours (less snowfall), In Mandi in some regions snowfall occurred before 25-20 years ago, it has stopped now-Mango crop has started to flourish in the region, eg: Jarol (Padhar block, Mandi). • Apple size has become less prominent; shape deterioration has been reported in Chamba District. At lower altitudes the shelf life of apple has decreased. • In some areas like higher altitudes Kullu (Nagar, Manali) and Chamba (Bharmour, Tissa) apple area has increased as the climate become conducive
Decline in winter precipitation, winter precipitation in January-Feb instead of December and January and decline in intensity of snowfall	• Rabi crop negatively impacted • Wheat productivity is affected due to less rainfall. • Delayed sowing of winter crops, decline in wheat yields.
High rainfall during August, September instead of the normal peak in July-August	• Damage to rainy season crops when they are close to maturity. • Problem of flower setting in pomegranate crop due to erratic rainfall conditions.
Hot summers and long dry periods with less rainfall	Increase in prevalence of diseases and pests in the crop, increase in the incidents and severity of diseases, decrease in the grass in forests, droughts become frequent, tropical tree increase, increase forest fires, drying of Kuhls and Chasmas.
Increase in instances of hailstorms	Heavy loss of apple crop, increase in the use of hail nets in regions like Narkanda (block of Shimla).
Seasonal changes (earlier monsoons)	Decline in flora related NTFP output due to unsuitable seasonal variations. Decrease in availability of medicinal plants Banafsha (Viola serpens), Kadoo (PicrorhizaKurroa), Gucchi (Morchellaesculenta), Dioscorea (singli-mingli), Batch, Rakhal, Kakarsingi

Agriculture status in Himachal Pradesh

Change in crop patterns, shift of apple belt, increasing risks of crop failures, lowered productivity, increased cost of crop cultivation, and increased damage by wild/ stray animals, soil erosion and increased losses due to extreme weather events. The situation is further worsened due to the very low adaptive capacity of marginal and small farmers, poor accessibility of extension advices and government benefits. As a result, their condition becomes miserable, particularly in times of crop failures, disease outbreaks, and extreme climatic events.

Figure 1 presents that percentage land use classification in for the period 2000-14. It can be observed that net area sown of the total area shows a declining trend, permanent pastures and other grazing land also following a similar trend and land put to non-agricultural uses are increasing rapidly.

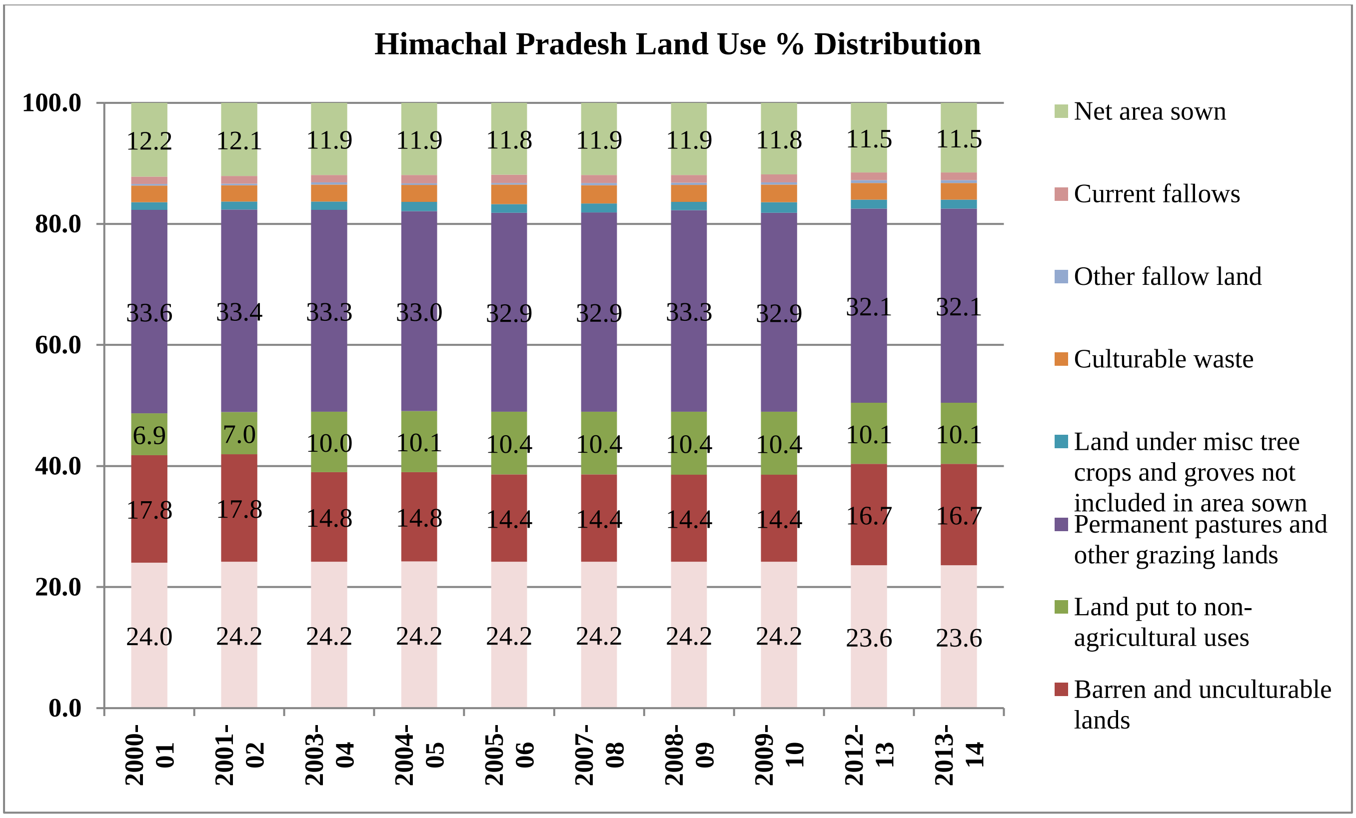


Figure 1: Land use Classification in Himachal Pradesh (% of Total area)
Data Source: State Statistical Abstract Himachal Pradesh for several years,

Rice, Wheat and Maize are important cereal crops of the State. Groundnut, Soyabeen and Sunflower in Kharif and Rapeseed/Mustard and Toria are important oilseed crops in the Rabi season. Urd, Bean, Moong, Rajmash in Kharif season and Gram Lentil in Rabi are the important pulse crops of the state which are mainly grown in the lower altitude districts. Lower altitude districts have high population density and higher dependence on the traditional agriculture. Figure 2 shows that the total area under foodgrains and oilseeds are declining in Himachal Pradesh. Area under major crops like Maize, Wheat, Paddy, Barley are also showing a declining trend. Moreover, the share of food grain in the total cropped area has also shown a declining trend which reflects that farmers are shifting to other crops in the State.

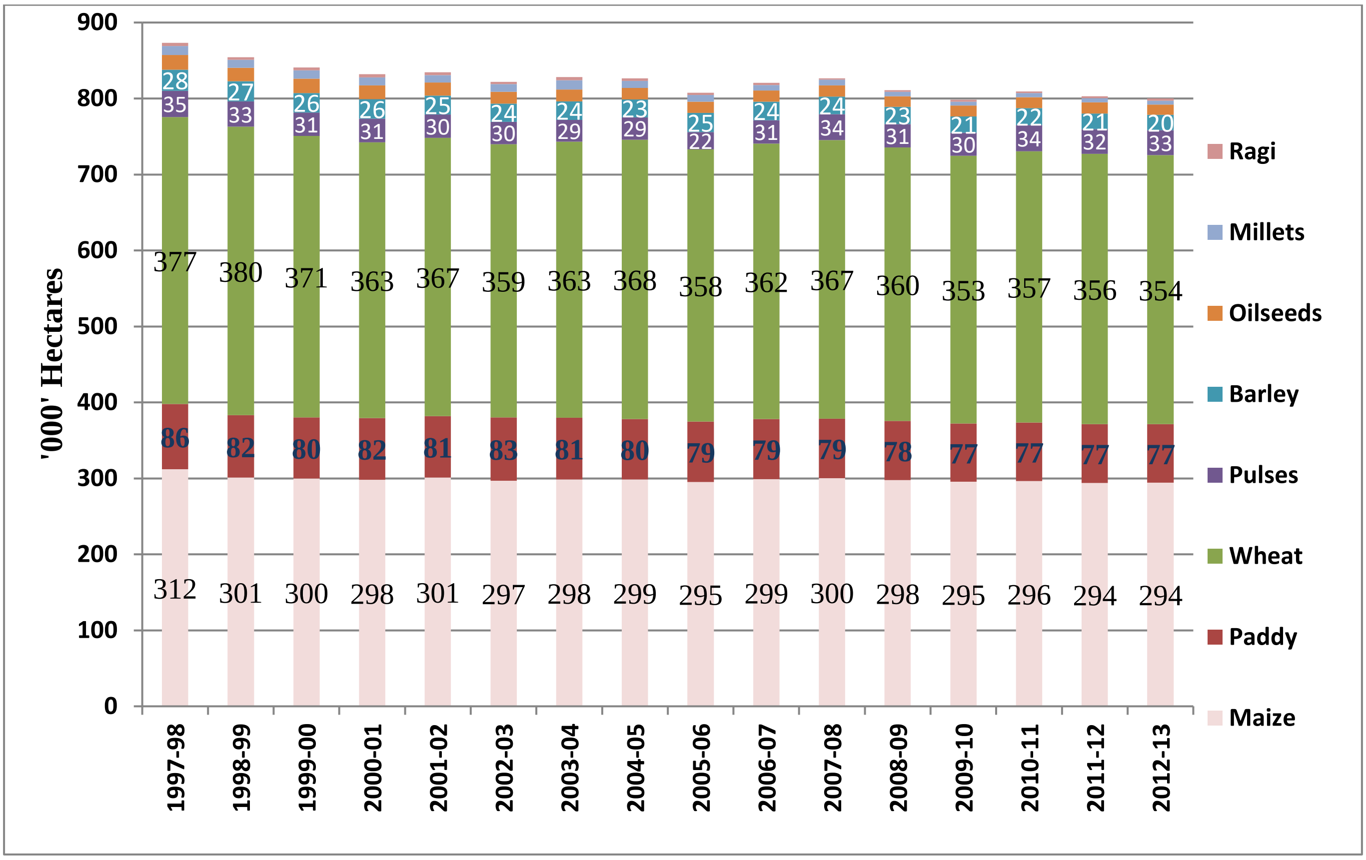
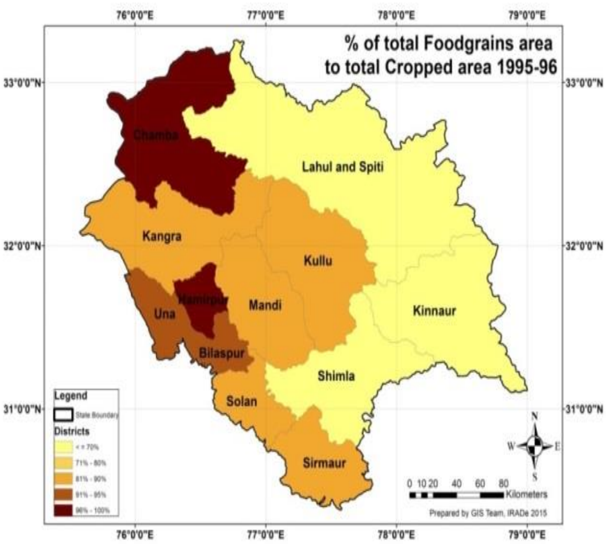
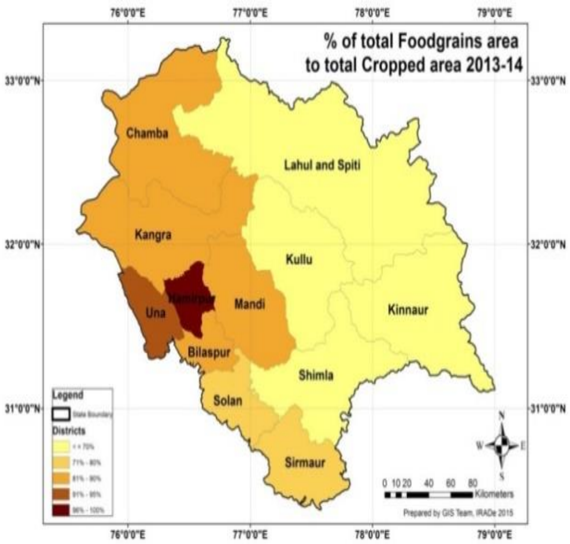


Figure 2 :Area under foodgrains and Oilseeds in Himachal Pradesh
Data source: Department of Agriculture, Himachal Pradesh

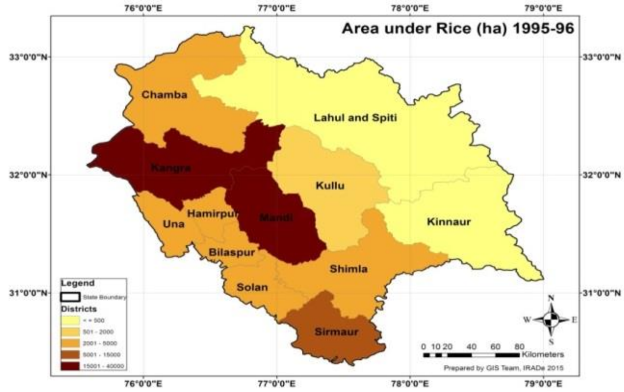
Map 1.a and 1.b show the total foodgrain area as percentage of total cropped area in 1995-96 and 2013-14 respectively. The comparison of map 1.a and 1.b suggest the changing share of foodrains in the total cropped area across districts. In districts like Kinnaur, Lahaul and Spiti, Kullu, Shimla, Chamba, Kangra, Sirmaur, Solan and Bilaspur farmers have shifted from food grains to other crops whereas in remaining three districts. In Hamirpur, Mandi and Una share of foodgrains in total cropped area had increased.



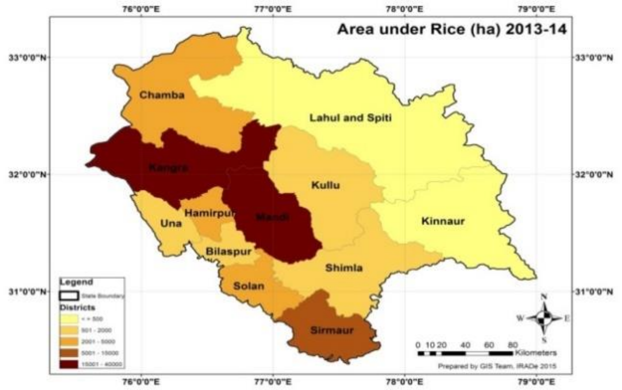
Map 1.a. Foodgrain share in total cropped area in 1995-96



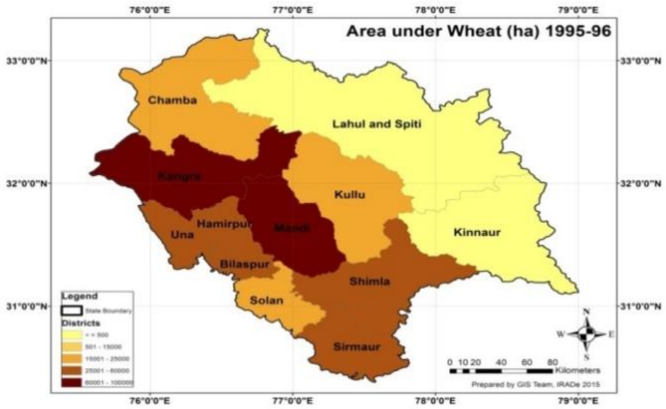
Map 1.b. Foodgrain share in total cropped area in 2013-14



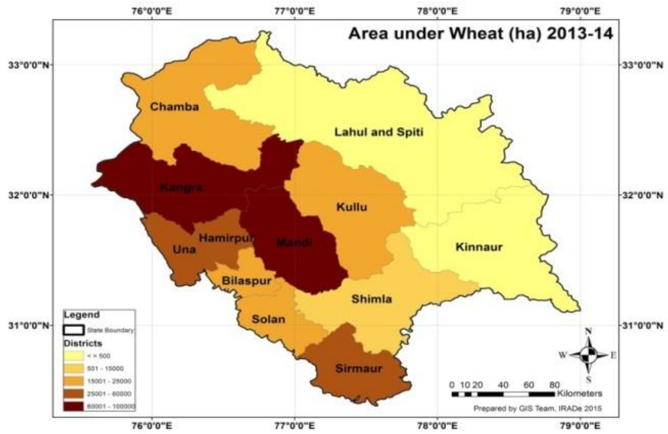
Map 2.a. Area under Rice in 1995-96



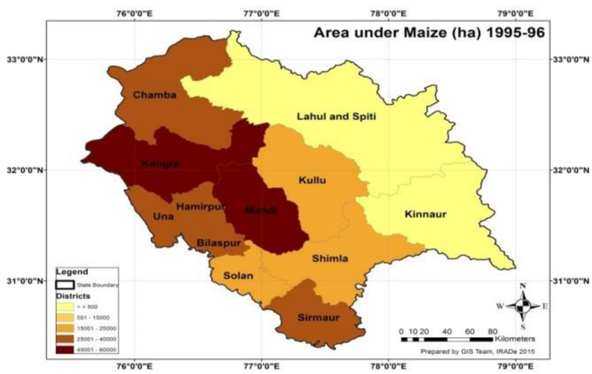
Map 2.b. Area under Rice in 2013-14



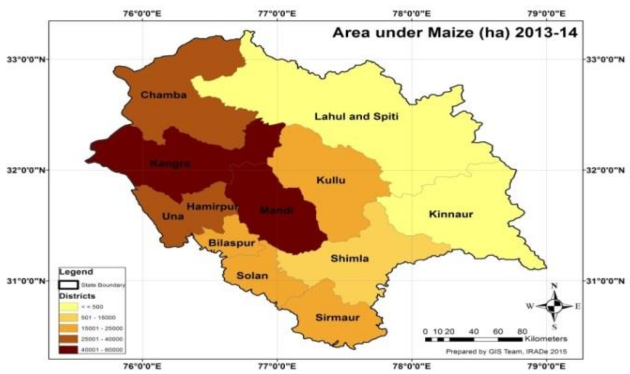
Map 3.a. Area under Wheat share in 1995-96



Map 3.b. Area under Wheat share in 2013-14



Map 4.a. Area under Maize in 1995-96



Map 4.b. Area under Maize in 2013-14

Climatic conditions prevailing in Himachal Pradesh are conducive for growing fruits ranging from apples and stone fruits in the Northern High Hills and Low Hills to citrus fruits which are grown in warm temperate and sub-tropical climatic conditions. A large proportion of operational holdings are being used for growing fruits in the Northern High Hills. The proportion of total operational holdings being used for growing fruits is relatively low in Low Hills. The climatic conditions in these two regions of the State are suitable for growing apple and fruits like plum, peach, apricot, pomegranate, pear, cherries and citrus fruits.

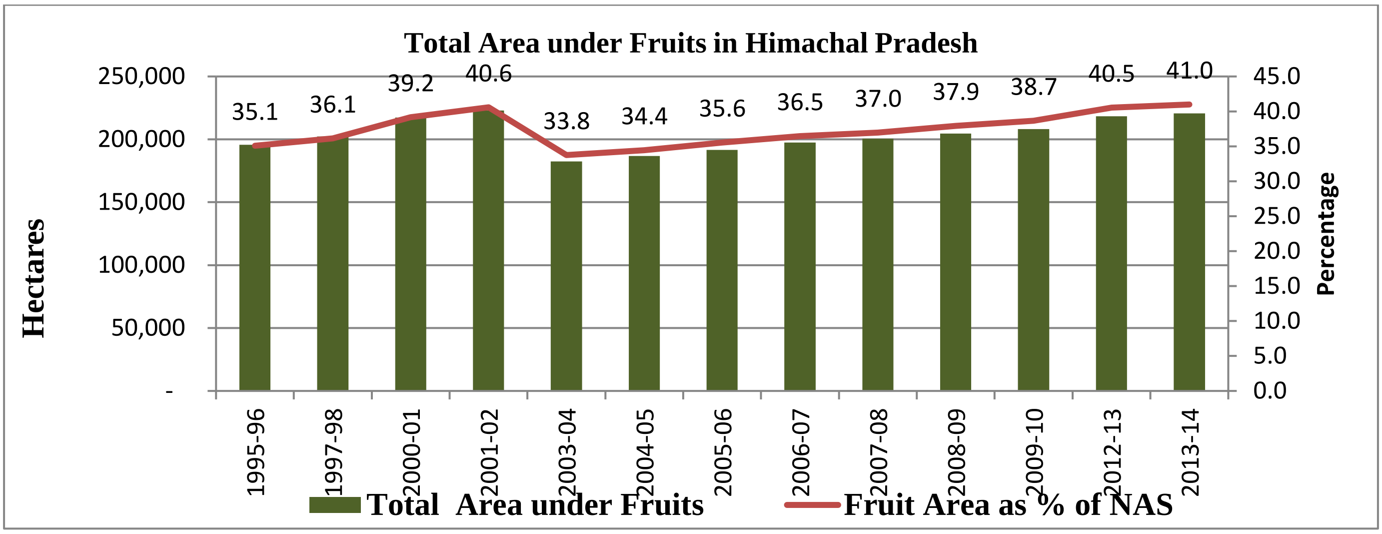


Figure 3: Area under Fruits and Fruit Area as a Percentage of Net Area Sown (NAS)

Data Source: Department of Horticulture, Himachal Pradesh

In higher altitudes districts like: Kinnaur, Kullu, Shimla the farmers have orchards of apple, pear and plum due to availability of suitable chilling hours and favorable climatic conditions, while in the lower areas people have shifted to the orchards of mangoes. In some places of Kullu pomegranate has replaced apple as the later crop failed in the area due unavailability of required chilling hours. Pomegranate requires less chilling hours as compared to apple.

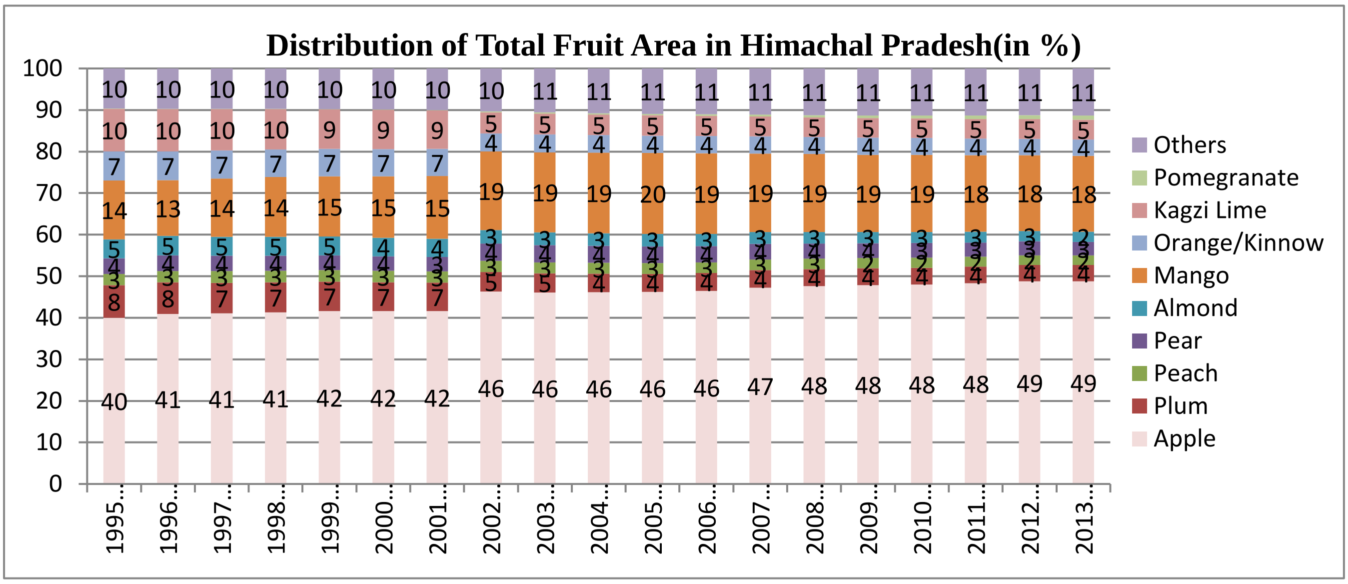


Figure 4: Distribution of fruit area

Data Source: Department of Horticulture, Himachal Pradesh

Apple and stone fruit trees develop their vegetative and fruiting buds in the summer and as winter approaches; the already developed buds go dormant in response to both shorter day lengths and cooler temperatures. These buds remain dormant until they have accumulated sufficient chilling hours of cold weather. When enough chilling hours accumulate, the buds are ready to grow in response to warm temperatures. As long as there have been enough chilling hours the flower and leaf buds develop normally. A simple and widely used method is the hours below 7°C model which equates chilling to the total number of hours below 7°C during the dormant period, autumn leaf fall to spring bud break. These hours are termed "chill hours". Research indicates fruit tree chilling 1) does not occur below about -1-1°C, 2) occurs also above 7°C to about 12°C, 3) is accumulated most effectively in the 1.5-10°C range, 4) is accumulated most effectively early in the dormant period, and 5) in early dormancy can be reversed by temperatures above 15.5°C. (www.davewilson.com).

A fruit tree's chilling requirements can vary widely from one variety to another. In general, except in the coldest climates, for best performance a variety's chilling requirement should approximately match the amount of chilling normally received where it is planted. Some highly productive varieties, however, will produce well over a wide range of climates and chilling.

The fruit trees requiring less chill hours are replacing those which require high chilling hours in the regions where climate has become hot as compared to what existed 1-2 decades back. So, pear & pomegranate are replacing the apple tree in lower altitudes of Kullu and Shimla. In lower regions of Himachal Pradesh that have become hotter, plantation of Mango orchards has increased. As per the agriculture department data, the area under Mango in the State has increased from 27,697 hectares in 1995-1996 to 40,298 hecatres in 2013-14. Moreover, at district level Kangra has witnesse the largest increase in mango plantation where area under mango had increase from 14,965 hectares in 1995-1996 to 20,963 hectares in 2013-14 i.e. nearly 50 percent of the State area under manago falls in Kangra district. Area under Mango had nearly dobled from 2,402 hectatres 1995-1996 to 4,680 hectares in 2013-14. In Hamirpur area under mango had increased from 1,656 hectatres 1995-1996 to 3,338 hectares in 2013-14. In Shimla 99 hecatres were under Mango cultivation in 1995-96 which has become 379 hectares in 2013-14. In Kullu district also Mango area had increase between 1995-96 to 2013-14.

The area under Pomegranate is also increasing in the State at a faster pace. In 1995-96 the area under Pomegranate was 111 hecatares which increased 410 hecatares in 2002-03 and by 2013-14 the area under Pomegranate stands as 2196 hecatres. In 2013-14 of the total area under Pomegranate in the State Mandi district share is 19 percent, Kullu 18 percent and Shimla and Hamirpur 10 percent each.

The cultivation of low chilling requirement fruits is increasing in State and this may be because the present availability of chilling hours during winters may not be sufficient for growing high chilling requirements fruits. Moreover, due to favorable conditions for vegetables mainly exotic vegetables many farmers have switch to vegetable crops. The shift to vegetables is primarily in areas with irrigation and where farmers have been able to adjust from subsistence food production to higher risk but better return cash crops. The success of the population earning handsome returns engaged in the production of off-season vegetables at large and fruits to some extent may have acted as a motivation for more and more people to adopt this activity as the means of earning their livelihoods.

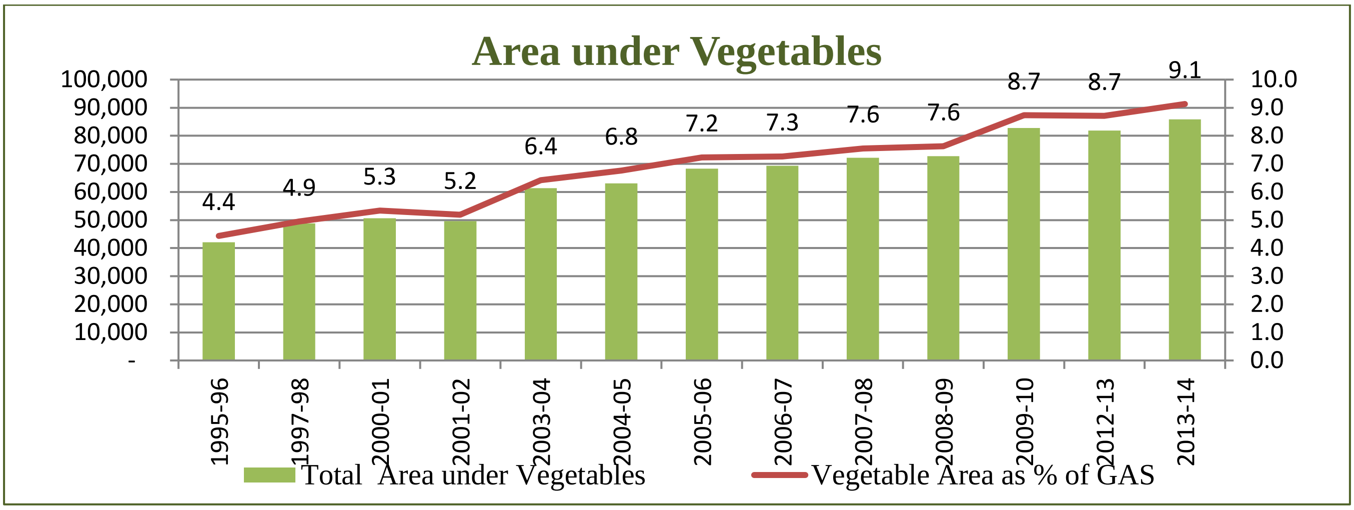
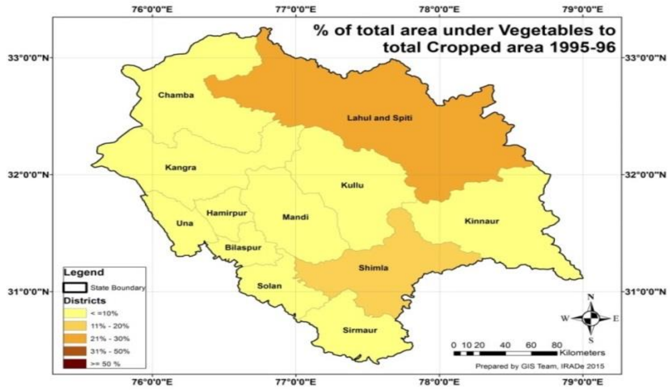
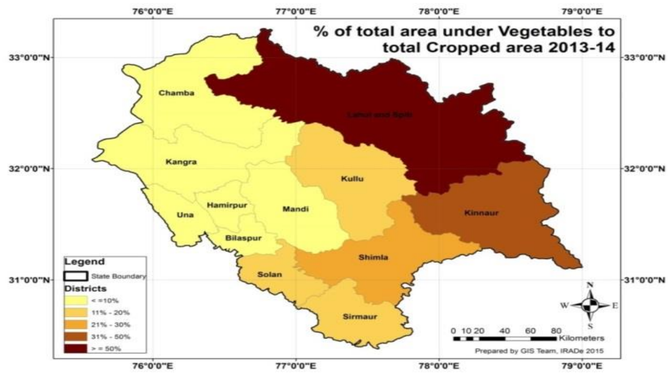


Figure 5: Total area under vegetable production and vegetable are as percentage of gross area sown
Data Source: Department of Agriculture, Himachal Pradesh



Map 5.a. Percentage vegetable area in 1995-96



Map 5.a. Percentage vegetable area in 2013-14

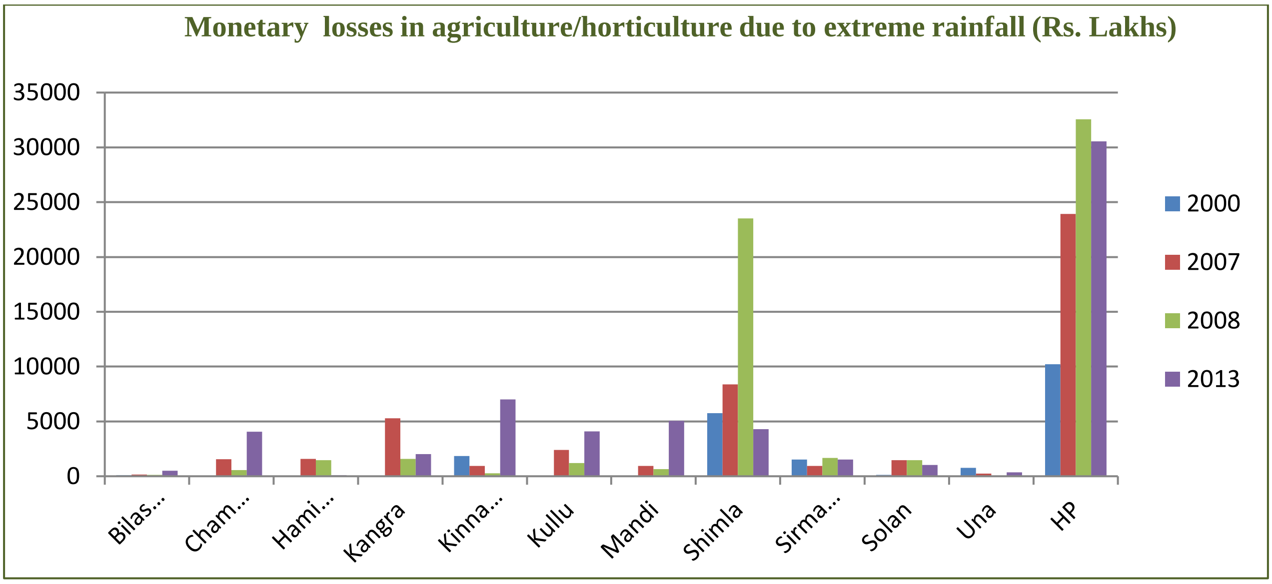
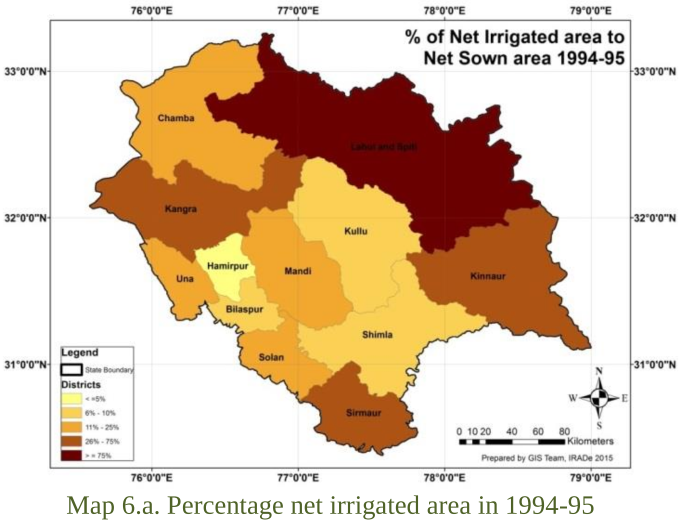
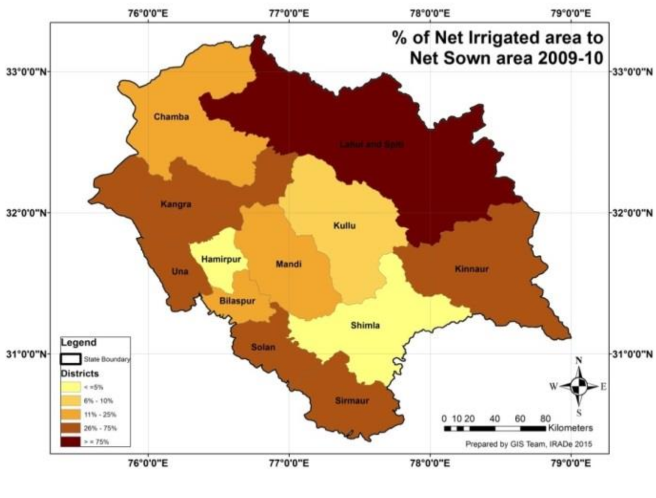


Figure 6: Economic losses due to extreme rainfall in Himachal Pradesh

Irrigation is the limiting factor that influences the production as well as area sown under wheat, maize and rice in all districts of Himachal Pradesh. In Himachal Pradesh 81.5 percent of the total cultivated area in the state is rain fed and therefore variation in rainfall adversely affects the State agriculture and horticulture. A very large proportion of irrigation is done either through irrigation canals or Kuhls. The uncertainty about weather conditions is one of the key risk factors associated with crop production. As per State center on climate change due to global warming the changes in the precipitation can be more complex as compared to the changes in the temperature, at the regional scale these changes in precipitation can be erratic despite of increasing or decreasing monotonically at the temporal scale. Climate change can alter the cropping calendar in some locations; shift the sowing months of the crop forward or back. Rainfall plays the most significant role than any other farm inputs and is one of the most uncontrollable climatic factors that affect the productivity of agriculture. The amount of rainfall received in a particular season or time is the most important determinant of inter annual fluctuations in national crop production levels. The impact that the rainfall has on crop production can be related to its seasonal amount received or its intra-seasonal distribution. Crop production suffers the most during extreme cases of droughts when the total seasonal rainfall received is very less. But subtler intra-seasonal variations in rainfall distribution during crop growing periods, without a change in total seasonal amount, can also cause substantial reductions in yields. It means that the number of rainy days received during the growing period of crop is also as important as that of the seasonal total. Even in wet locations rainfall variability at the daily time scale is critical to plant growth (Jackson, 1989), particularly in the early part of the rainy season before the soil moisture reserves have been built up. The effect of rainfall variability on the crop production varies with the type of crops cultivated in a particular area, the types and properties of soil and climatic conditions of the given area.



Map 6.a. Percentage net irrigated area in 1994-95



Map 6.a. Percentage net irrigated area in 2009-10

The changes in the vegetation and trees in different regions of Himachal Pradesh over a period of time show that the climate of the region is changing with time and farmers are adapting to the change by making change in vegetation types. Some regions of Mandi used to get snowfall 3-4 decades back but now the climate has become hot and there are no snowfalls, Moreover the increase in the area under Mango plantation in Mandi and certain other districts as mentioned above is a clear indicator of warming conditions in the region. This change in the area of different fruits is the clear indicator of change in climate conditions. The sub-tropical climatic conditions are increasing in Himachal Pradesh while the temperate climatic conditions are receding and shifting to higher altitudes which are the major reason in shift of the apple belt to higher altitudes. These changes in climate conditions results in crop failure and make the farmers vulnerable. Farmers are forced to switch from one failed fruit crop to another (suitable to climate). Which poses a serious challenge for the sustainability of the farmers as a fruit plant has a gestation period of 4 to 5 years before its start fruit production and income generation for the farmer. We observed similar trend in Kullu where in certain regions the apple (high chilling hour's requirement) has failed and farmers have switched to pomegranate (low chilling hours' requirement).

Introduction

Climate and weather is related in the sense that climate is long-term average weather condition. Weather phenomenon like temperature and rainfall are typically controlled by cycles of seasons which get repeated every year. Climate change, which refers to the statistically significant change in either mean or variability of the weather variables like temperature, precipitation, has the potential to completely and adversely affect the ecology and human life.

Climate change has emerged as an important research area in global context. In 1988, the United Nations Environment Program and the World Meteorological Organization initiated a panel of experts, the Intergovernmental Panel on Climate Change (IPCC) to gather and evaluate scientific evidence of global warming, to identify the different causes and to monitor the development of human-induced global warming.

In the context of climate change there are many studies on vulnerability and its definitions vary according to the perception of the researchers. In this study we follow the IPCC Third Assessment Report (2001) according to which, "Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity".

Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. Climate-related stimuli encompass all the elements of climate change, including mean climate characteristics, climate variability, and the frequency and magnitude of extremes. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise).

Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences".

It has been widely accepted now that anthropogenic activities are directly or indirectly responsible for climate change. According to IPCC Fourth Assessment Report (2007) Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide, which are important factors for climate change/global warming, have increased markedly as a result of human activities since 1750.The schematic framework representing anthropogenic drivers, impacts of and responses to climate change, and their linkageshas been presented in figure 1.

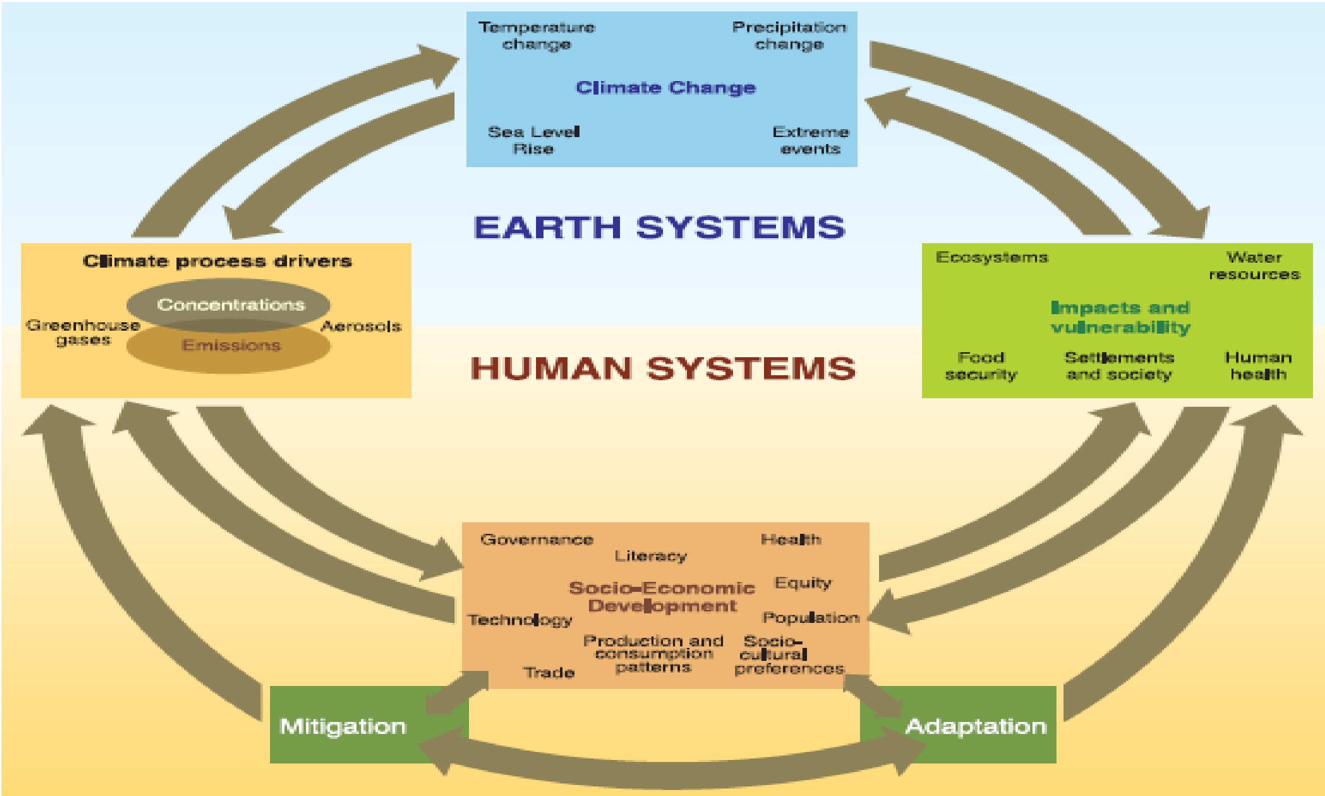


Figure 1: Schematic framework representing anthropogenic drivers, impacts of and responses to climate change, and their linkages

Note: Adopted from IPCC Fourth Assessment Report (2007)

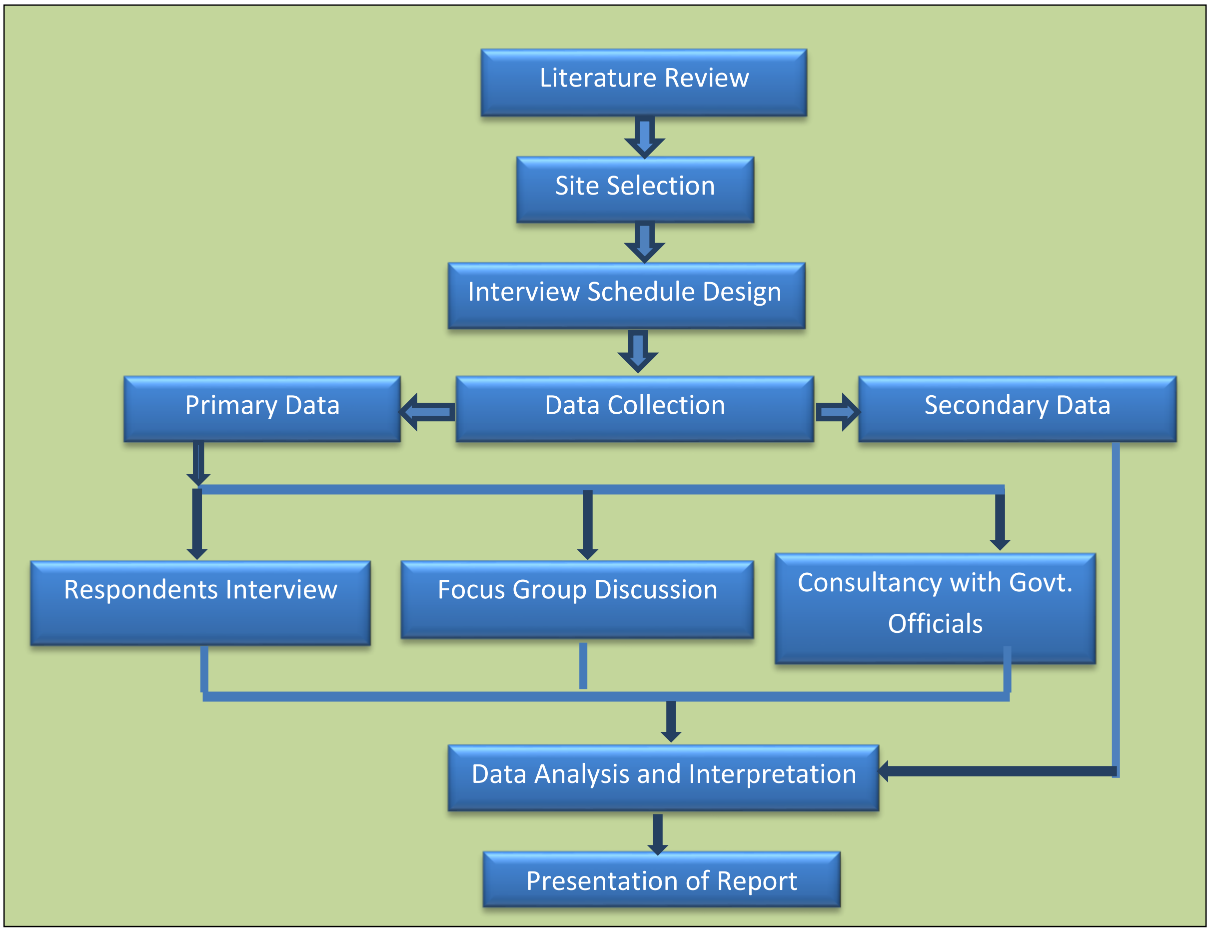
Climate-related risks come not only from direct exposure to natural hazards such as floods or droughts, but also from the vulnerability of social and economic systems to the effects of these hazards (Lemos and Tompkins, 2008). Climate change impact can be broadly classified into three categories namely ecological, social and economic. A brief description of climate change impact under these three categories has been presented in table

Table 1: Impacts of Climate change

Type of Impact	Phenomenon	Reference
Ecological Impact	• Shifts of vegetation types and associated impacts on biodiversity. • Change in forest density and agricultural production • Expansion of arid land • Decline in water quantity and quality • Effects on aquatic species and ecosystems • Stresses from pests, diseases and wildfire	• National Assessment Synthesis Team [NAST] 2001; Elliott and Baker 2004 • Adams et al. 1990; Smith et al. 2007 • Woodhouse and Overpeck 1998; Karl et al. 2009 • Gutowski et al. 2008; Milly et al. 2008 • Environmental Protection Agency [EPA] 2007, 2008 • Alig et al. 2004; Gan 2004
Social impacts	• Changes in equity, risk distribution, human health impacts, and relocations of populations	• Karl et al. 2009
Economic impacts	• Increased risk and uncertainty of forest and agricultural production • Alteration in productivity for crops and forest products • Changes in supply of ecosystem goods and services • Altered cost of utilities and services	• Smith et al. 2007 • Feng and Hu 2007 • Sohngen and Sedjo 2005; Adams et al. 2009 • Scott and Huang 2007

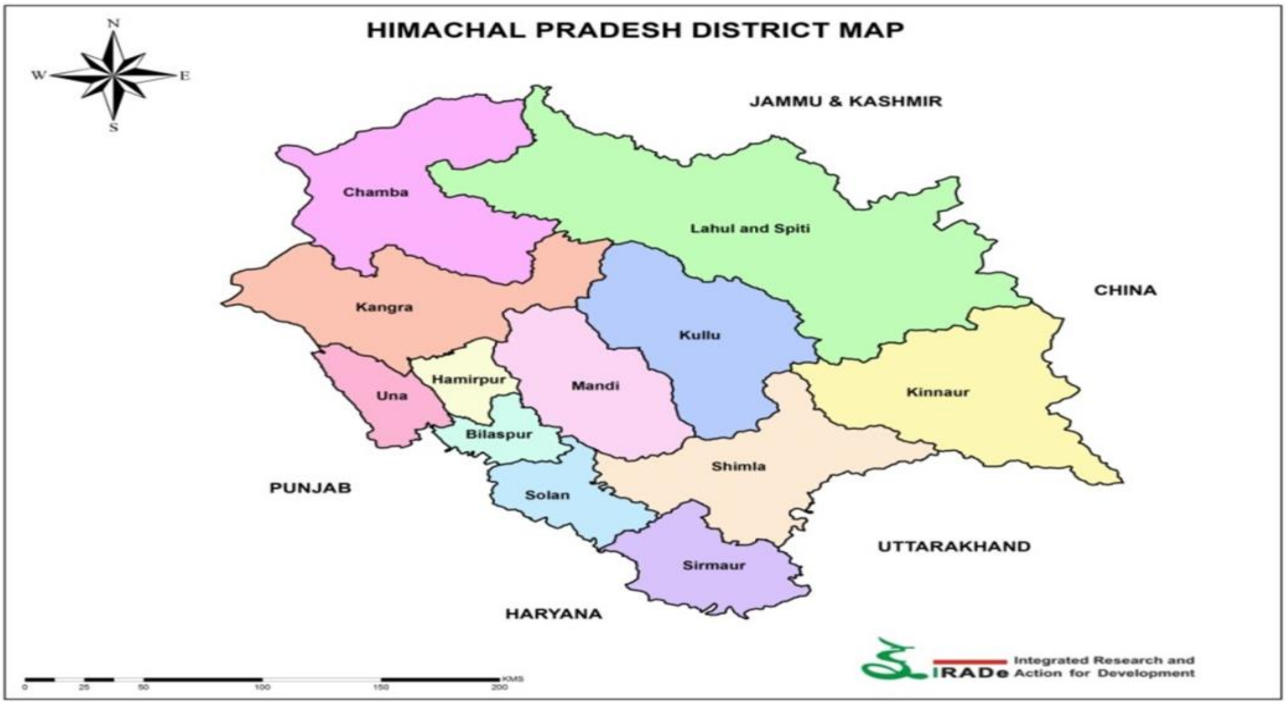
India is highly vulnerable to climatechange impacts (IPCC 2007). Climate change is expected to increase the severity and frequency of storms, rainfalls, floods, and droughtand temperature variability affecting agriculturalproduction (IPCC 2007)in the Indian sub-continent. For the Indian region (South Asia), the IPCC projected 0.5 to 1.2°C rise in temperature by 2020, 0.88 to 3.16°C by 2050 and 1.56 to 5.44°C by 2080, depending on the future development scenario (IPCC 2007).

The Himalayan ecosystem is highly vulnerable to the stress caused by increased pressure of population, exploitation of natural resources and other related challenges. Climate change may adversely impact the Himalayan ecosystem through increased temperature, altered precipitation patterns, and drought. The Himalayan ecosystem is approaching towards a stage of disequilibrium and there are clearly visible negative changes in the resources and the environment. The fragility of the region stems mainly from geological history of its evolution and structural set-up of the rocks. Himalayan ecosystem is vital to the ecological security of the Indian landmass. It provides forest cover, feeds perennial rivers that provide water for drinking, irrigation, and hydropower, and provides a home and a basis for sustainable biodiversity, agriculture, and tourism. Being located in the fragile Himalayan ecosystem, Himachal Pradesh is highly vulnerable to climate change. Incidences of floods, droughts, loss of biodiversity, health hazards and poverty as a consequence of climate change are the biggest concern in Himachal Pradesh. Climate change impact studies have shown that the productivity of agricultural activities is highly sensitive to climate change. Himachal Pradesh has high dependency on climate sensitive sectors such as agriculture, horticulture and forest for livelihood. Figure 2 below presents the flow chart of research methodology.



Profile of Himachal Pradesh

Himachal Pradesh a hilly state in North India in the western part of the Himalayan range has a geographical area of 55,673 km^2.It is situated between 30°22’40” to 33°12’20” N latitudes and 75°45’55” to 79°04’20” Elongitudes. The altitude in the Pradesh, a wholly mountainous region in the lap of Himalayas, ranges from 350 metres to 6975 metres above mean sea level. It is surrounded by Jammu and Kashmir in the north, Tibet on north east, Uttaranchal in the east/south east; Haryana in south and Punjab in south west/west.



Map 1: District Map of Himachal Pradesh

Himachal Pradesh comprises of four different agro-climatic zones :

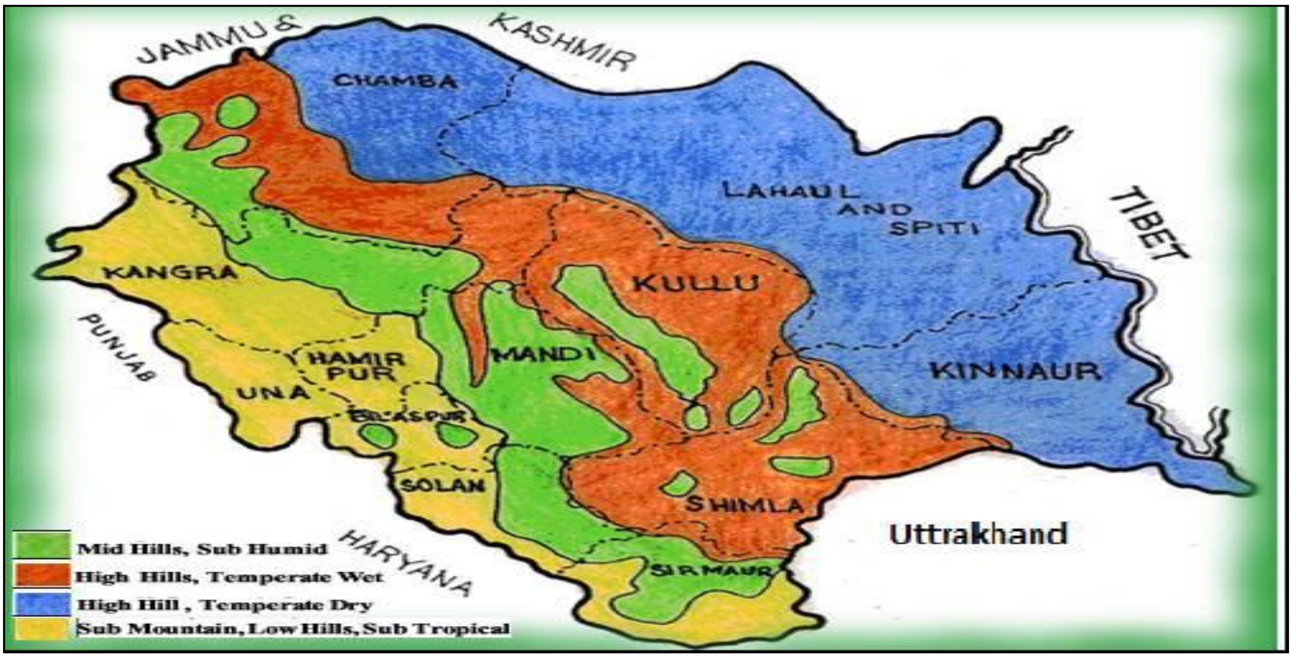
a) Shivalik hill zone: Climate subtropical consists of foothills and valley area from 350 to 650 meters above mean sea level. It occupies about 35% of the geographical area and about 40% of the cultivated area of the state. The major crops grown in this zone are wheat, maize, paddy, gram, mustard, potato, vegetables etc.

b) Mid hill zone: This zone extends from 651 meters to 1,800 meters above mean sea level. It has mild temperate climate. It occupies about 32 percent of the total geographical are and about 37 percent of the cultivated area of the state. The major crops are wheat, maize, barley, black gram, beans, paddy etc. This zone has very good potential for the cultivation of cash crops like off-season vegetables, ginger and production of quality seeds of temperate vegetables like cauliflower and root crops.

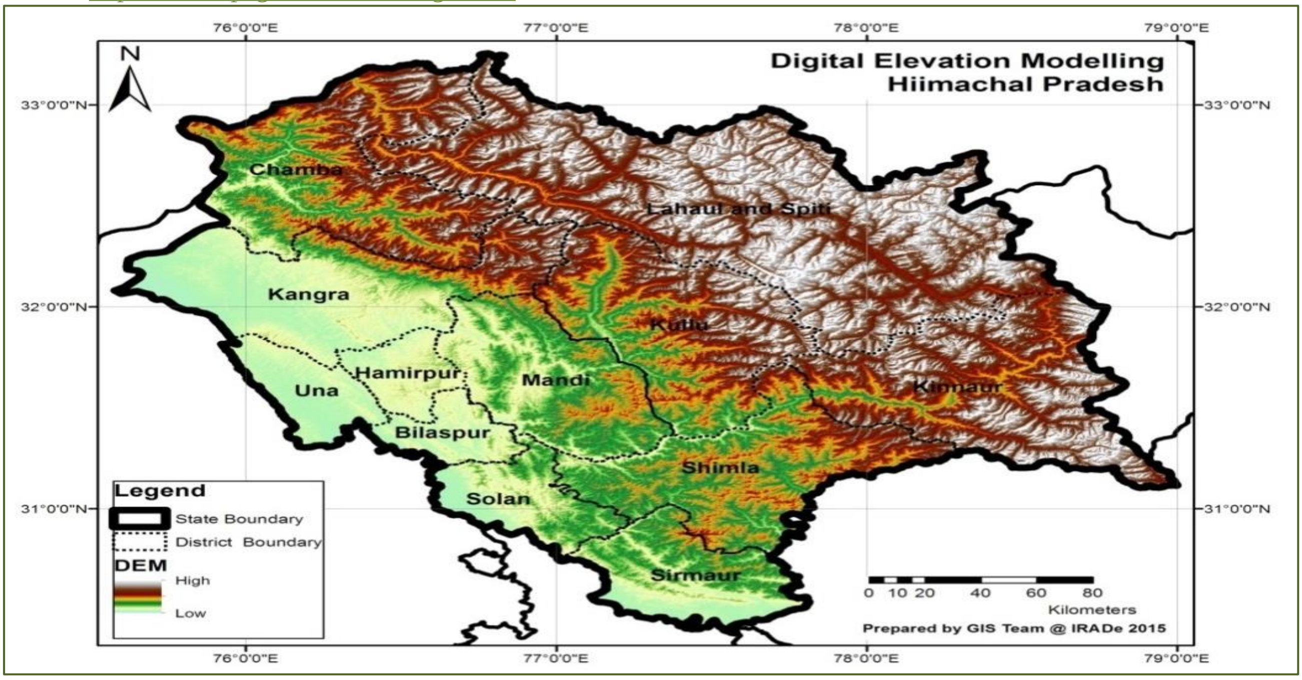
c) High hill zone: It lies from 1,801 to 2,200 meters above sea level with humid temperate climate and alpine pastures. This zone covers about 35% of the geographical areas and about 21% of the cultivated area of the State. The commonly grown crops are wheat, barley, lesser millets, pseudo-cereals (buckwheat), maize and potato etc.

The area is ideally suited for the production of quality seed potato and temperate vegetables. This zone possesses good pastures and meadows.

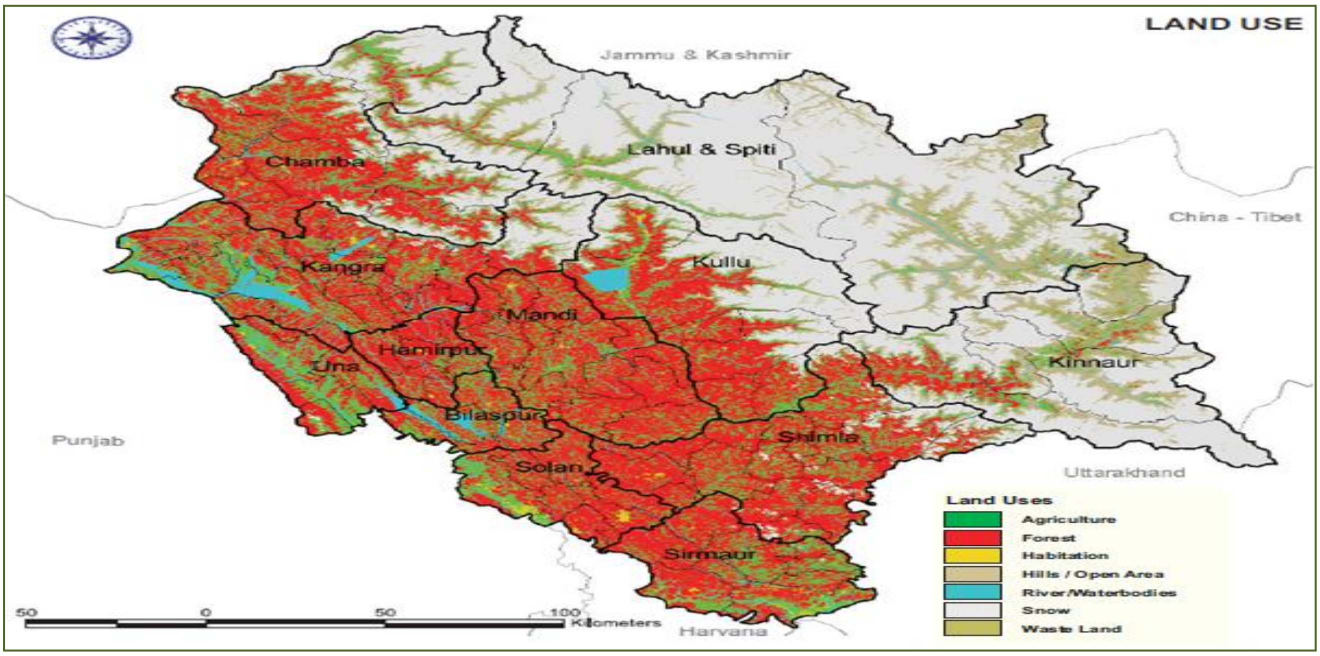
d) Cold dry zone: It comprises of Lahaul-Spiti and Kinnaur Districts and Pangi Tehsil of Chamba District lying about 2,200 meters above mean sea level. It occupies about 8% of the geographical and 2% of the total cultivated area of the state. The major crops grown are wheat, barley, and pseudo-cereals like buck wheat.



Map 2: Agro-Climatic Zone in Himachal Pradesh
Source: http://www.hpagriculture.com/agro.htm



Map 3: Himachal Pradesh digital elevation map
Source: Centre for Geo-informatics, CSK Himachal **Pradesh** Agricultural University, Palampur



Map 4: Land use and land cover of Himachal Pradesh
Source: Himachal Pradesh vulnerability Atlas SEEDS

2.1.Socio-economic profile

The total population of Himachal Pradesh is 68.64 lakh people (Census 2011). Decadal population growth rate in Himachal Pradesh is 12.94 percent which is much lower than all India average of 17.64 percent during same decade (table2). Rural regions contribute to 90% of the population and merely 10% people reside in the urban areas. The communities residing in rural areas differ from their urban counterparts in terms of occupations, earnings, literacy, poverty incidence, and dependency on government funds. These differences tend to shape economic and socio-cultural conditions across rural areas and provide insights on why rural populations may exhibit different vulnerabilities to climate change than their urban counterparts.

Table 2: Demographic details by districts

District	Area in Sq. Kms.	Total population		Decennial growth (2001-2011)	Density per Sq. Km. (2011 Census)
		Census -2001	Census -2011		
Bilaspur	1,167	3,40,885	3,81,956	12.05	327
Chamba	6,522	4,60,887	5,19,080	12.63	80
Hamirpur	1,118	4,12,700	4,54,768	10.19	407
Kangra	5,739	13,39,030	15,10,075	12.77	263
Kinnaur	6,401	78,334	84,121	7.39	13
Kullu	5,503	3,81,571	4,37,903	14.76	80
Lahaul-Spiti	13,841	33,224	31,564	-5	2
Mandi	3,950	9,01,344	9,99,777	10.92	253
Shimla	5,131	7,22,502	8,14,010	12.67	159
Sirmaur	2,825	4,58,593	5,29,855	15.54	188
Solan	1,936	5,00,557	5,80,320	15.93	300
Una	1,540	4,48,273	5,21,173	16.26	338
H.P.	55,673	60,77,900	68,64,602	12.94	123

Source: Census, 2011

Distribution of workers profile shows that nearly 58 percent workers in the State are cultivators and 5 percent are agricultural labour reflecting huge dependency on agriculture/horticulture sector for livelihood. District Kullu has highest dependency of workers on agriculture/horticulture (78%) for earning livelihood, followed by Mandi (70.5%), Chamba (70%), Sirmaur (69.2%), Hamirpur (64.5%), Shimla (64%), Bilaspur (63.8%), Kinnaur (63.1%) and Lahaul and Spiti (61.2%). In Kangra, Solan and Una workers (cultivators plus agricultural labour) dependence on agriculture/horticulture sector is less than the State average (Table 3).

Table 3: Distribution of workers -2011 census

District	Workers Percentage Distribution				
	Total	Cultivators	Agriculture Labourers	Worker in HH Industries	Other Workers
Bilaspur	205,871	61.8	2	1.2	35
Chamba	294,035	66.9	3.1	1.5	28.5
Hamirpur	241,931	60.8	3.6	1.4	34.2
Kangra	675,170	44.9	8.1	2.3	44.7
Kinnaur	56,273	58.6	4.5	1.7	35.2
Kullu	269,084	73.3	4.6	1	21.1
Lahaul-Spiti	19,295	58.2	3	0.9	38
Mandi	572,671	67.7	2.8	1.2	28.2
Shimla	430,926	58	6.1	1.8	34.1
Sirmaur	280,083	65.3	3.8	1.9	28.9
Solan	298,737	47.3	3.4	1.7	47.6
Una	215,346	39.4	9.1	1.6	49.9
H.P.	**3,559,422**	**57.9**	**4.9**	**1.6**	**35.5**

Source: Census, 2011

Table 4 presents the disaggregated gross value added (GVA) by agriculture and allied sector at constant 2004-05 prices. The table highlights that in 2010-11 GVA by agriculture and vegetables was nearly equal. GVA by horticulture was nearly 26 percent of agriculture and allied GVA. Together agriculture, horticulture and vegetables GVA accounted for 66 percent of of agriculture and allied GVA. Livestock contributed nearly 30 percent of of agriculture and allied GVA.

Table 4: Value Added from Agriculture and Allied Activities (at constant 2004-05 prices in Rs. Lakhs)

	Items	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
1	Gross Value of Output	5,78,054	5,91,372	5,51,286	6,34,370	6,18,044	5,35,802	6,88,541
1.1	Agriculture	1,38,487	1,15,716	1,47,986	1,39,375	1,34,395	1,06,363	1,39,089
1.1.1	Cereals	1,17,591	83,427	1,15,544	1,10,931	1,08,786	86,024	1,15,237
1.1.2	Pulses	2,622	2,285	8,085	8,284	8,410	4,692	9,536
1.1.3	Oilseeds	2,607	2,080	2,931	2,498	1,847	1,488	2,915
1.1.4	Sugar Group	2,012	1,328	2,055	1,789	1,671	1,476	1,197
1.1.5	Fiber Group	32	21	151	14	11	172	2
1.1.6	Dyes & Tanning	205	205	205	205	205	205	205
1.1.7	Drugs & Narcotics	753	496	739	395	739	739	739
1.1.8	Condimnts & Spices	5,859	19,067	11,499	8,483	6,345	4,792	2,483
1.1.9	Misce.Crops	6,806	6,807	6,777	6,777	6,382	6,777	6,777
1.2	Vegetables	86,487	1,02,135	1,17,230	1,22,264	1,28,955	1,42,017	1,38,920
1.3	Horticulture	1,62,999	1,78,021	89,619	1,75,014	1,53,666	91,226	1,76,389
1.3.1	Apple	1,39,181	1,42,546	73,636	1,56,322	1,34,580	73,893	1,55,049
1.3.2	Citrus Fruits	5,208	5,514	2,237	4,655	4,861	5,306	5,409

1.3.3	Nuts & Dry Fruits	2,460	2,613	2,419	2,444	2,413	1,948	2,480
1.3.4	Sub-Tropical Fruits	3,140	2,573	1,590	3,004	1,817	2,017	3,239
1.3.5	Other Temp. Fruits	3,821	3,083	2,860	2,999	3,045	2,522	3,624
1.3.6	Others Fruits	8,039	20,473	5,574	4,249	5,505	3,733	4,681
1.3.7	Mushrooms	1,151	1,220	1,303	1,340	1,443	1,806	1,907
1.4	Floriculture	1,292	1,460	1,790	2,004	2,458	3,761	6,949
1.5	Back Yard	1,287	1,267	1,259	1,267	1,327	1,649	1,867
1.6	By Products	27,800	26,600	26,841	26,965	27,990	26,135	26,367
1.7	Livestock	1,59,702	1,66,173	66,561	1,67,481	1,69,253	1,64,651	1,98,960

Source: Department of Economics and Statistics, Himachal Pradesh

2.2.Livelihoods

Himachal Pradesh is particularly vulnerable to climate change due to high dependence of rural population on agriculture and natural resources for livelihood; comparatively high exposure to extreme events. Nearly 63 percent of workers in the State are engaged in agriculture or horticulture for their day to day requirements.The livelihood strategies being followed by the people of the state are highly vulnerable to the suffering resulting from tough mountainous terrain, highly fragile environment and erratic behaviour of the weather. The average size of land holdings are small with many fields being on steep land that do not permit mechanisation of farming activity. High cost of creating and maintaining physical infrastructure for farming activity also act as constraints resulting in low resilience from weather vagaries.

Globally, the cropping areas are moving upwards because of general warming and availability of crop growth periods at higher altitudes, where it was not earlier possible to grow crops. Like wise, valleys & other such areas may become warmer, forcing several crops to be phased out of these areas. This situation is also getting evident in Himachal Pradesh. Temperate fruit belt has moved upwards by about 50-100kms. This has opened up new opportunities for high land farmers of Kinnaur and Lahul & Spiti but it also means that existing valleys of temperate fruits & vegetables are no longer the favourites. Farmers in these areas are looking for alternative options.

Increasingly, most rural families have access to off-farm incomes to supplement the shortfall from agriculture. Many families have one or more member working in urban centres out of the state, or in the military. Tourism and craft industries provide some supplementary income. Animal husbandry is another source of income; almost every family raises livestock for its day to day requirements for subsistence as well as for generating cash income. Owing to the very small land holdings, families rely heavily on natural fodder resources including the forest areas to feed their livestock. Livestock kept by tribal communities are subject to transhumance (seasonal movement to new areas) to get the best pastures. Economically vulnerable groups including the scheduled tribes and castes have high dependence on the forest resources including collection of fodder, medicinal plants, and firewood.

Himachal Pradesh has though emerged as one of the fast developing States of the country, the distribution pattern has been skewed against the rural population.The montly per capita expenditure in urban area was Rupees 3,173 and it rural areas it was only Rupees 1,801.

Table 5: District wise Poverty and Consumption

Sr No.	Districts/Sate	Poverty Rural (% headcount)	Poverty Urban (% headcount)	Overall (% headcount)	Rural MPCE (Rs.)	Urban MPCE (Rs.)
1	Chamba	7.00	7.83	7.06	1420	2728
2	Kangra	8.07	5.96	7.96	1651	2314

3	Lahul&Spiti	0.00		0.00	1711	
4	Kullu	9.66	7.88	9.50	1404	2397
5	Mandi	18.04	15.05	17.90	1470	1872
6	Hamirpur	4.29	0.82	3.99	2655	3779
7	Una	0.86	1.31	0.89	2110	2492
8	Bilaspur	9.69	1.57	9.11	2190	3549
9	Solan	10.31	4.98	8.55	1932	3600
10	Sirmaur	7.32	4.90	7.07	1811	3172
11	Shimla	4.43	0.00	3.48	1972	3571
12	Kinnaur	0.00		0.00	2456	
13	**Himachal Pradesh**	**8.48**	**4.33**	**8.03**	**1801**	**3173**

Data Source: Estimated using NSSO 68th roundhousehold consumer expenditure survey.

The monthly per capita expenditure in rural area was below the State average in Kullu Chamba, Mandi, Kangra and Lahaul and Spiti. The monthly per capita expenditure was highest in Hamirpur followed by Kinnaur, Bilaspur, Una, Shimla, Solan and Sirmaur. The gap between rural and urban monthly per capita expenditure at State level was Rupees 1,372 and in Solan and Shimla this gap was above State average. The gap between rural and urban monthly per capita expenditure was lowest in Una followed by Mandi, Kangra and Kullu.

Anciliaries agriculture activities and tourism are generating employment opportunities mostly for the urban population of the state. Tourism is one of the world's largest service industries with sizeable economic benefits and immense opportunities is constantly improving in Himachal Pradesh. Number of tourists arrival (domestic + international) in the state is increasing year by year, which is generating more employment opportunities for the local people in the state tourism industry (table 6). This accelerating tourism industry in state will proved to be one of the important drivers of growth and prosperity, employment generation and raises per capita income.Tourism sector is considered to be the backbone for allied sectors such as hospitality and transport which is likely to increase with tourism.

Table 6: Total tourist arrivals (domestic+foreign) in districts of Himachal Pradesh

District	2009	2010	2011	2012	2013
Bilaspur	8.87	9.63	10.93	9.78	11.45
Chamba	6.89	7.89	8.20	9.55	9.95
Hamirpur	4.33	5.55	6.30	6.83	7.29
Kangra	14.8	17.23	19.13	23.05	22.01
Kinnaur	2.85	4.03	4.85	4.60	1.26
Kullu	23.45	25.3	27.98	32.26	28.86
Lahaul & Spiti	3.16	4.22	5.44	4.44	1.20
Mandi	8.78	10.17	11.94	8.08	8.84
Shimla	22.84	26.14	29.52	33.54	31.57
Sirmaur	6.56	7.51	8.76	9.52	8.44
Solan	5.9	6.8	8.08	8.75	8.57
Una	5.95	8.19	9.77	11.06	11.86
TOTAL (State)	114.38	132.66	150.89	161.46	151.30

Source: Himachal Pradesh State statistical abstract

The increasing fruit production in the districts at higher altitudes are increasing demands for trucks (vehicle used for fruits transportation) which can be seen from the continuously increasing year on year number of registered trucks in the state. Total registered trucks in the state have increased more than 3 folds in the last decade from year

2002 to 2012. Number of registered trucks have increased across the districts of Himachal Pradesh during the same period with Solan is posting the highest growth in the number of registered trucks especially in 2011 and 2012 (Figure 3).

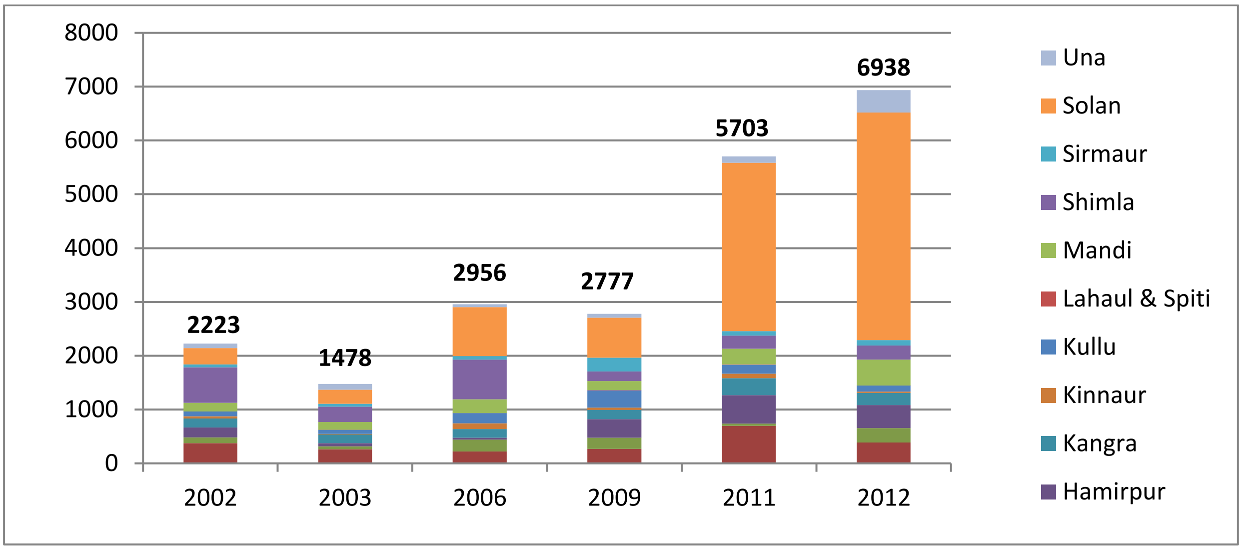


Figure 3: Numbers of registred trucks across districts
Source: Himachal Pradesh State statistical abstract

Climate change in context of Himachal Pradesh

The signals of climate change have clearly indicated towards increasing temperature, reducing rainfall and snowfall and shrinking winter season (Bhagat et al., 2007). The agricultural and fruit crops inHimachal Pradesh are mainly dependent upon the snow fed gravity flow channels (kuhls) and fresh snowfall.Therefore effect of climate change on agriculture is likely to increase the socio-economic vulnerability in the state. Moreover, since climate change does not occur uniformly, therefore given the topographical and socio-economic variations of Himachal Pradesh, climate vulnerability and risks may vary from one region to other.

Bhutiyaniet. Al. (2007) based on short term analysis observed that in different altitudinal zones in Himachal Pradesh , the rate of increase in maximum temperature at higher altitudes was more than that at the lower altitudes and in last century north western Himalayan region significantly higher than the global average. Bhutiyaniet. Al. (2009) using precipitation data from 1866-2006 showed that change in winter precipitation is minimum but there is significant decrease in monsoon precipitation. Bhan and Singha (2011) analysed twenty year data and revealed that the season tends to end 10-12 days earlier per decade leaving long term impact on agriculture-horticulture production in Himachal Pradesh. Kumar et. Al.(2009) reported that average annual minimum temperature has gone up 1.52°C over the yearsduring 1962–2004 in Kullu Valley. Shrestha et. Al. (2012) by analysing temperature datareportedincrease in average annual mean temperature during the 25 year period 1.5°C.

Himalayan glaciers have receded considerably and this is an important indicator of climate change. Nineteen glaciers in the Baspa basin were monitored over a period 1962 to 2001. The investigation showed that all the glaciers were receding and overall, 19 per cent deglaciation was observed in the period. Glaciers at around 5000 m elevation showed 24 per cent loss compared with 14 per cent loss for glaciers above 5400 m. The mean glacier terminus has moved vertically about 88 m[1] (The Glacier Study is not conceived in the project). The receding glacier may initially increase dry season flows and over the longer term, likely to reduce dry season flows. This may lead to uncertainty in supply of irrigation, water and may also cause loss of some perennial sources of potable water affecting the lives of millions of people residing in the regions. The rainfall and snowfalls are decreasing in Himachal Pradesh and so is the availability of water which further affects the irrigation system in the state. Himachal Pradesh State Action Plan on Climate change has explained the scenarios in detail. The climate trend analysis done in H.P State Action plan on climate change is taken from to support our observations. As per the analysis in the action plan the decreasing trend of snowfall has been observed on different altitudes (table7).

Table 7: Altitudinal variation in snowfall trends

Observation stn	Time period	Time period
	Observations based on depth of snowfall	
Bhang	(-) 1974-2005	(-) 1991-2005
Solang	(-)1982-2005	(-)1991-2005

[1]Government of Himachal Pradesh, Department of Environment, Science, and Technology. 2009. State of the Environment Report. Shimla.

Dhundi	(-)1989-2005	(-)1991-2005
Patseo	(-) 1983-2005	(-)1991-2005
(+) Increasing, (-) Decreasing trend		

Source: Himachal Pradesh State Action Plan on Climate Change

It has been observed that there has been about 40% reduction in rainfall over the last 25 years as it was 948 mm in 1987 which is reduced to about 470 mm during 2009. The table 5 below shows the trend analysis of climate variables (temperature and precipitation) at various altitudes in Himachal Pradesh over more than two decades.

Table 8: Trend analysis of climate variables

Altitude (amsl)	Obs Station	Annual Mean temp	Annual Mean Rainfall
1500-2400	Theog (Shimla)High Hill temperate wet	(+) 1.8 degree celcius (average database of 20 years)	(-) 127 mm (+) in Kharif season (average database of 20 years)
1200-1800	Kullu, High Hill temperate wet	(+) 2.8 degree celcius (average database of 34 years)	(-) 20.1 mm (+) in Kharif season (average database of 34 years)
700-1500	Palmpur (Kangra) Mid Hill sub humid	(+) 1.0 degree celcius (average database of 35 years)	(-) 1,000 mm exceptional decrease (+) in Kharif season (average database of 35 years)
Greater than 700	Fatehpur (Sirmaur) Low Hill sub Humid	(+) (average database of 23years)	(-) 29.4 mm (average database of 23 years)

The conclusions derived from the analysis of past temperature, rainfall and snowfall patterns are that the annual temperatures in Himachal Pradesh are set to rise, and temperatures are showing a rising trend in all seasons. There may be staggering decrease in snowfall patterns in mid-hills temperate wet agro climatic zones. The number of rainy days may increase with decrease in average intensity. Due to change in rainfall patterns with increased variability some regions may experience less rainfalls and drought like conditions may prevail. Projected increase in temperature, precipitation and variations in its intensities in the state may bring situations like flash floods in North-western parts of the State due to accelerated summer's flows.

3.1. Analysis of Temperature Data for Himachal Pradesh

Temperature is critical in determining plant water status, soil moisture status and irrigation practices. Since temperature is an important weather variable,therefore analysis of temperature is important to assess the impact of climate change. According to IMD climate summary (India meteorological department annual climate summary, 2009), analysis of data for the period 1901-2009 suggests that annual mean temperature for the country as a whole has risen by 0.560C over the period. Annual mean temperature has been generally above normal (normal based on period, 1961-1990) since 1990. Moreover, since 1990, minimum temperature is steadily rising and rate of its rise is slightly more than that of maximum temperature (IMD Annual Climate Summary, 2009). Given this background this study tries to analyse the variation in minimum and maximum temperature for the period 1969 – 2009. The idea is to assess whether the long term temperature trend has been constant or had shifted over time. The underlying assumption here is that the long term shift in tepratur trend up or down over time may be because of climate change.

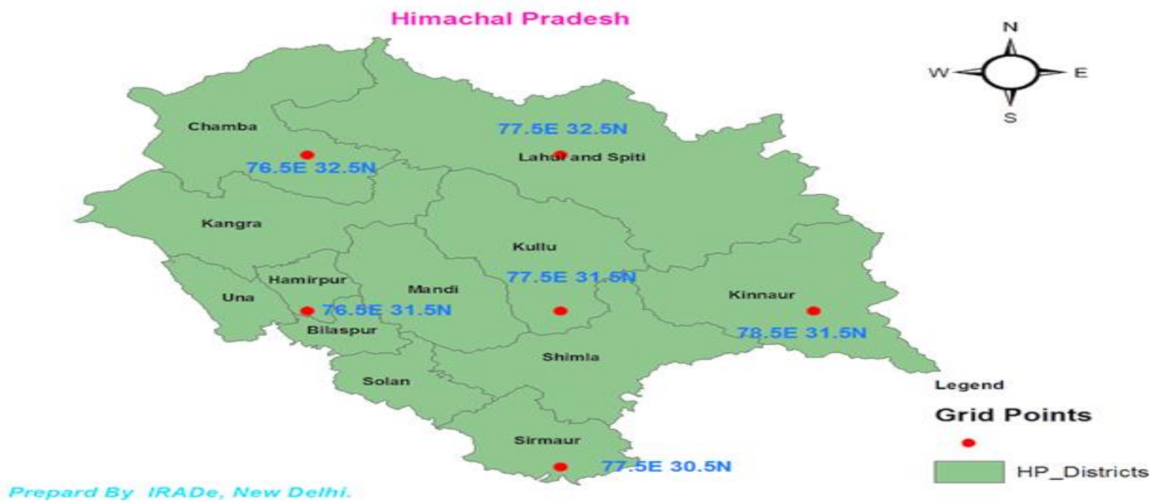
3.1.1. Data and Methodology

To carry out this analysis maximum temperature and minimum temperature data has been obtained from IMD. IMD had provided high resolution 1 by1 degree gridded daily temperature data (1969-2009). This data is arranged in 32x35 grid points. For this study, we have used those combinations of 1 by 1 degree grid data (latitude and longitude) which represents some location in Himachal Pradesh. The six different combinations of latitude and longitude which we have used have been presented in table 9.

Table 9: 1 by 1 degree grid representing Himachal Pradesh and their District wise location

Longitude	Latitude	District
76.5" E	32.5" N	Chamba
76.5"E	31.5" N	Hamirpur
77.5"E	32.5" N	Lahaul and Spiti
77.5"E	30.5" N	Sirmaur
77.5"E	31.5" N	Kullu
78.5"E	31.5" N	Kinnaur

Map 5 presents district and location in that district for which we have analysed the maximum and minimum temperature data. It is obvious that these six combinations of latitude and longitude represent widely varying geographical conditions.



Map 5:Combination of latitude and longitude and Location
Source: IRADe

We have used Bai and Perron test for detecting structural breaks in the time series temperature data. For a given time series it is reasonable to assume that there are m breakpoints, where the coefficients shift from one stable regression relationship to a different one. Thus, there are $m+1$ segments in which the regression coefficients are constant. Multiple structural breaks in time series can be identified using the econometric methods of Bai and Perron (1998, 2003). Their method locates and tests for multiple structural breaks within a time series and the null hypothesis is that there are no breaks in a data series. In our study, we consider the following mean-shift model with m breaks:

$$T_t = a_j + u_t, \qquad (t = t_{j-1}+1,...,t_j, \; j=1,...,m+1) \qquad (1)$$

where j is the segment index, $I_{m,n} = \{t_1,......,t_m\}$ denotes the set of the breakpoints ($I_{m,n}$ is also called m -partition), and by convention $t_0 = 0$ and $t_{m+1} = n$. In equation (1) g_t is the annual average minimum/maximum temperature, a_j is the mean temperature (minimum/maximum) during regime j, u_t is an error term and t is usual representation of time for $t = 1,2,...n$.

Given an m -partition $t_1,......,t_m$, this method consists of first estimating the regression coefficients a_j by minimising the sum of squared residuals $RSS(t_1,......,t_m) = \sum_{j=1}^{m+1} \sum_{t=t_{j-1}+1}^{t_j} [T_t - a_j]^2$. The estimated break dates $(\hat{t}_1,......,\hat{t}_m)$ are then determined by minimising the objective function

$$(\hat{t}_1,......,\hat{t}_m) = \arg\min_{(t_1,......,t_m)} RSS(t_1,......,t_m) \qquad (2)$$

over all partitions $(t_1,......,t_m)$ with $t_j - t_{j-1} \geq nh$. Here, n is the sample size and h is the "trimming" parameter, expressed as a percentage of the number of observations, which constrains the minimum distance between consecutive breaks[2] Bai and Perron (2003) developed a dynamic programming algorithm for obtaining the global minimisers in (2) for structural change models in an OLS regression context, which we adopt here. They implemented the Bayesian Information Criteria (BIC) to estimate the optimal break points. The number of breaks is selected for which BIC is at a minimum. If the BIC value is minimum for zero breaks then one cannot reject the null hypothesis of no breaks3.

3.1.2. Empirical Finding

Table 10 summarizes the results which shows that at all the selected locations the annual average temperature increase after 1997. The finding shows that an upward shift in average annual minimum temperature was higher in Kinnaur followed by Sirmaur. Moreover, only in Chamba average annual maximum temperature shifted upward by 0.52°C. Therefore, the finding of this essay suggests that in the last 40 years average annual minimum temperature in various parts of Himachal Pradesh had shifted upward, which reflects that long term weather trends had changed reflecting climate change. As per Commerce Department's National Oceanic and Atmospheric Administration the global mean temperature in 1998 was 0.66°C above the long-term average value of 13.8°C and this was the 20th consecutive year with an annual global mean surface temperature exceeding the long-term average (http://www.publicaffairs.noaa.gov/releases99/jan99/noaa99-1.html).

Table 10: Summary of Empirical Finding

Average annual minimum Temperature (in Degree Celsius)				
District	Breakdate	Change in Temperature	Change in Temperature	Confidence Interval (95 Percent)
Chamba	1997	*12.14→12.72*	*0.58*	(1993-2000)
Hamirpur	1997	*13.75*→14.41	*0.65*	(1993-2000)
Lahaul and Spiti	1997	*10.58*→11.27	0.69	(1993-1999)
Sirmaur	1997	14.70→ 15.45	*0.75*	(1994-1999)
Kullu	1997	13.13→13.85	0.72	(1993-1999)
Kinnaur	1997	12.77 →13.57	*0.81*	(1994-1999)
Average annual maximum Temperature (in Degree Celsius)				
District	Breakdate	Change in Temperature	Change in Temperature	95 Percent Confidence Interval
Chamba	1997	24.60→*25.12*	*0.52*	(1991-2007)

[2] In this study, the value we have used for h is 15 percent.
[3]Estimation of the breakdate(s) has been done using R package 'strucchange' developed byZeileis et al. (2003).

Our finding suggests the in all the six districts average annual minimum temperature increased in 1990's. However, only in Chamba average annual maximum temperature witnessed upward shift. In the remaining five districts we do not find a statistically significant shift in average annual maximum temperature.

3.2. Comparative Analysis of Current&Future Climatic Condition Based on RCPs

WorldClim4 is a set of Global Climate Layers (climate grids) with availability of 1 sq km spatial resolution which is available for use in mapping and spatial 30odelling in a GIS. The data layers were generated through interpolation of average monthly climate data from weather stations on a 30 arc-second resolution grid (often referred to as "1 km2" resolution). Variables included are monthly total precipitation, and monthly mean, minimum and maximum temperature, and 19 derived bioclimatic variables.

Two sets of bioclimatic variables which have been retrieved for climate change scenarios visualization for the project are as follows:

1. **Current conditions:** These conditions are obtained through interpolation of observed data and are representative of average from 1950 to 2000.
2. **Future conditions:** These conditions are downscaled global climate model (GCM)[5] data from CMIP5 (IPPC Fifth Assessment). The data available here are climate projections from GCMs for four Representative Concentration Pathways (RCPs)[6]. These are the most recent GCM climate projections that are used in the Fifth Assessment IPCC report.

To allow for relatively fast computations, the world is divided into a limited number of spatial units (grid cells). The resulting model output is therefore rather coarse, typically in the order of 2 to 3 degrees (one degree of longitude is ~ 111 km). This is problematic for studies considering variation at much higher spatial resolution with smaller size. To address this problem downscaled GCM output is available for different RCP scenarios under various models.

For purpose of this study, ESRI data for bioclimatic variables is downloaded at 2.5 minute spectral resolution (of a longitude/latitude degree) which is equivalent to about 4.5 km at equator. Time period of 2050 (average for 2041-2060) and 2070 (average for 2061-2080) are chosen to represent four bioclimatic variables which are of relevance for the study. These are Annual mean temperature, annual mean precipitation, temperature seasonality (standard deviation *100) and precipitation seasonality (Coefficient of Variation) to represent annual trends and seasonality. Bioclimatic variables are derived from the monthly temperature and rainfall values in order to generate more biologically meaningful variables. Only for temperature seasonality the standard deviation was used because a coefficient of variation does not make sense with temperatures between -1 and 1). AML (Arc-Info workstation

[4]WorldClim version 1 was developed by Robert J. Hijmans, Susan Cameron, and Juan Parra, at the Museum of Vertebrate Zoology, University of California, Berkeley, in collaboration with Peter Jones and Andrew Jarvis (CIAT), and with Karen Richardson (Rainforest CRC).

[5] The GCM output was downscaled and calibrated (bias corrected) using WorldClim 1.4 as baseline 'current' climate. The data is available at different spatial resolutions (expressed as minutes or seconds of a degree of longitude and latitude): 10 minutes, 5 minutes, 2.5 minutes, 30 seconds. The data available here are climate projections from GCMs that were downscaled and calibrated IPCC 5(CMIP5) data (bias corrected) using WorldClim 1.4 as baseline 'current' climate. The file format is GeoTIFF.

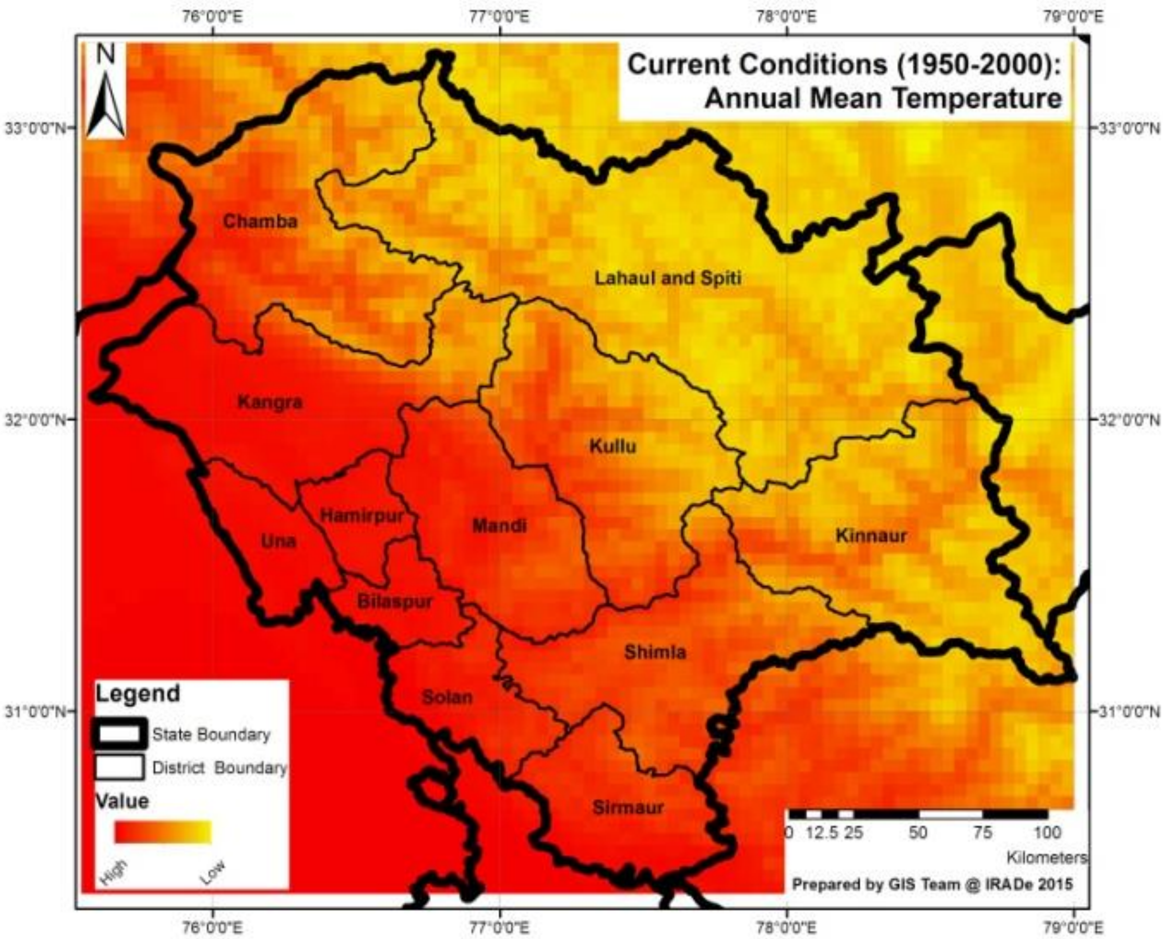
[6]RCPs represent pathways of radiative forcing, not detailed socio-economic narratives or scenarios. Central to the process is the concept that any single radiative forcing pathway can result from a diverse range of socio-economic and technological development scenarios. There are four RCP scenarios: RCP2.6, RCP4.5, RCP6.0 and RCP8.5.

script) was used to generate these layers. GCM used is GFDL-CM3 for near accurate results. (Rajiv Kumar Chaturvedi, 2012).

Adopting methodology explained in above section, RCP scenarios 2.6[7], 4.5[8] and 8.5[9] are mapped on ArcGIS (version 10.1) platform for state of Himachal Pradesh to understand the variation of different bioclimatic variables.

3.2.1. Annual Mean Temperature

Annual mean temperature is the mean of all the monthly mean temperatures. Each monthly mean temperature is the mean of that month's maximum and minimum temperature. There is a striking increase in temperature observed in North Eastern parts of state with Inner Himalayas and Alpine climatic zones. This region comprises of Lahaul & Spitti, Kinnaur, minor parts of Kullu, Chamba and Shimla districts with high altitude, cold-dry or humid continental climatic conditions, alpine and glacial mountain ranges. RCP scenarios depicted in map 7 to 12 shows extreme variability in terms of annual mean temperature for year 2050 and 2070. Projected annual mean temperature variable's values seem to shift tremendously towards higher side in future conditions in entire HP state.

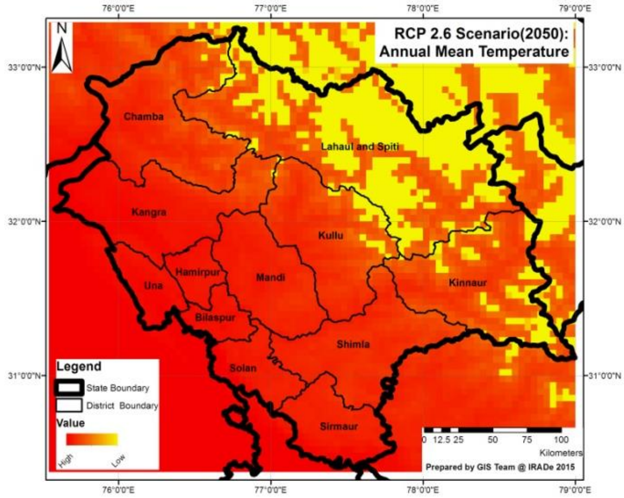


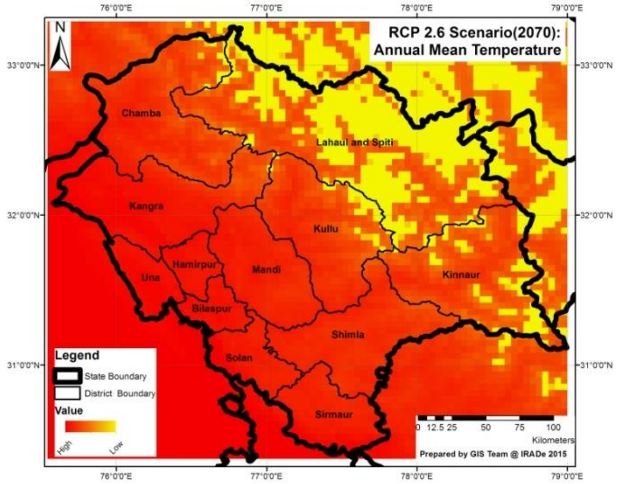
[7]Its radiative forcing level first reaches a value around 3.1 W/m mid-centuries, returning to 2.6 W/m2 by 2100. Under this scenario greenhouse gas emissions and emissions of air pollutants are reduced substantially over time

[8]It is a stabilization scenario where total radiative forcing is stabilized before 2100 by employing a range of technologies and strategies for reducing greenhouse gas emissions.

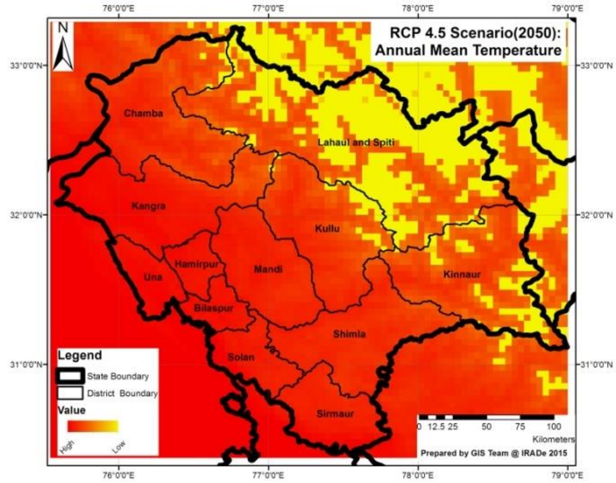
[9]It is characterized by increasing greenhouse gas emissions over time representative of scenarios in the literature leading to high greenhouse gas concentration levels.

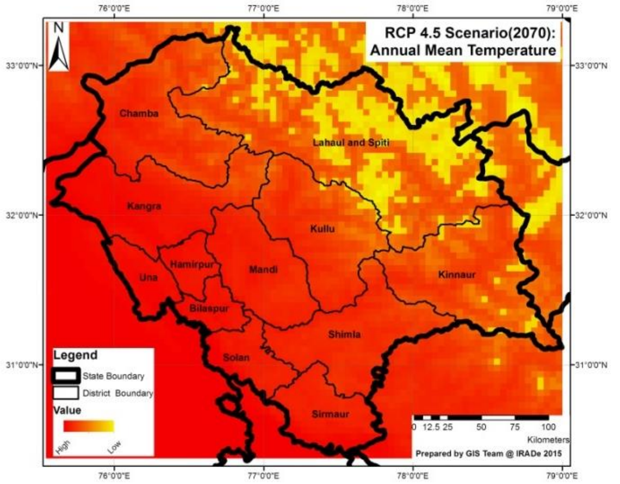
Map 6: Current Annual Mean Temperature (1950-2000)



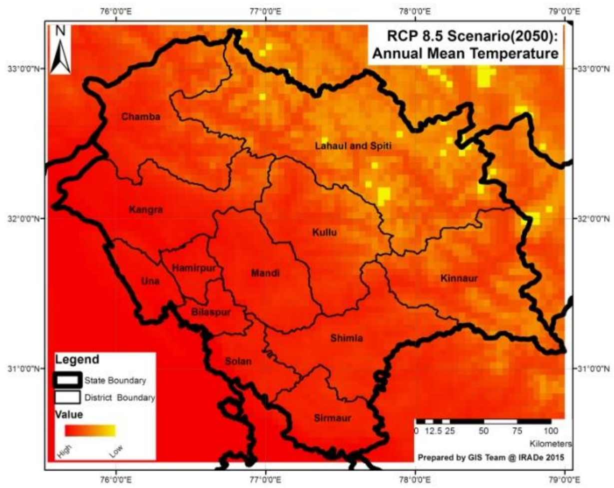


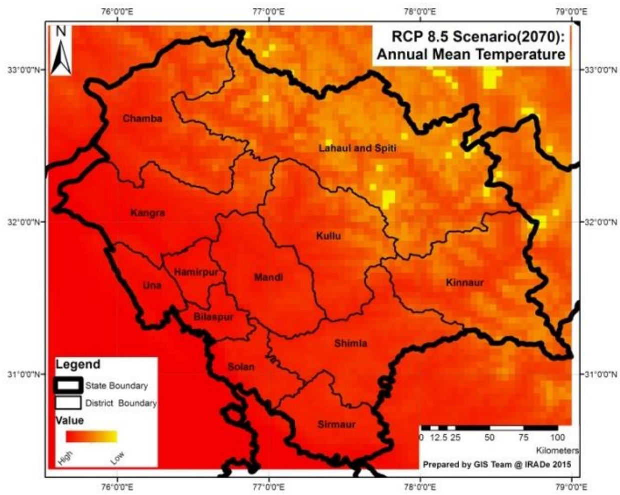
Map 7: RCP 2.6 Scenario (2050) AMT **Map 8: RCP 2.6 Scenario (2070) AMT**





Map 9: RCP 4.5 Scenario (2050) AMT **Map 10; RCP 4.5 Scenario (2070) AMT**

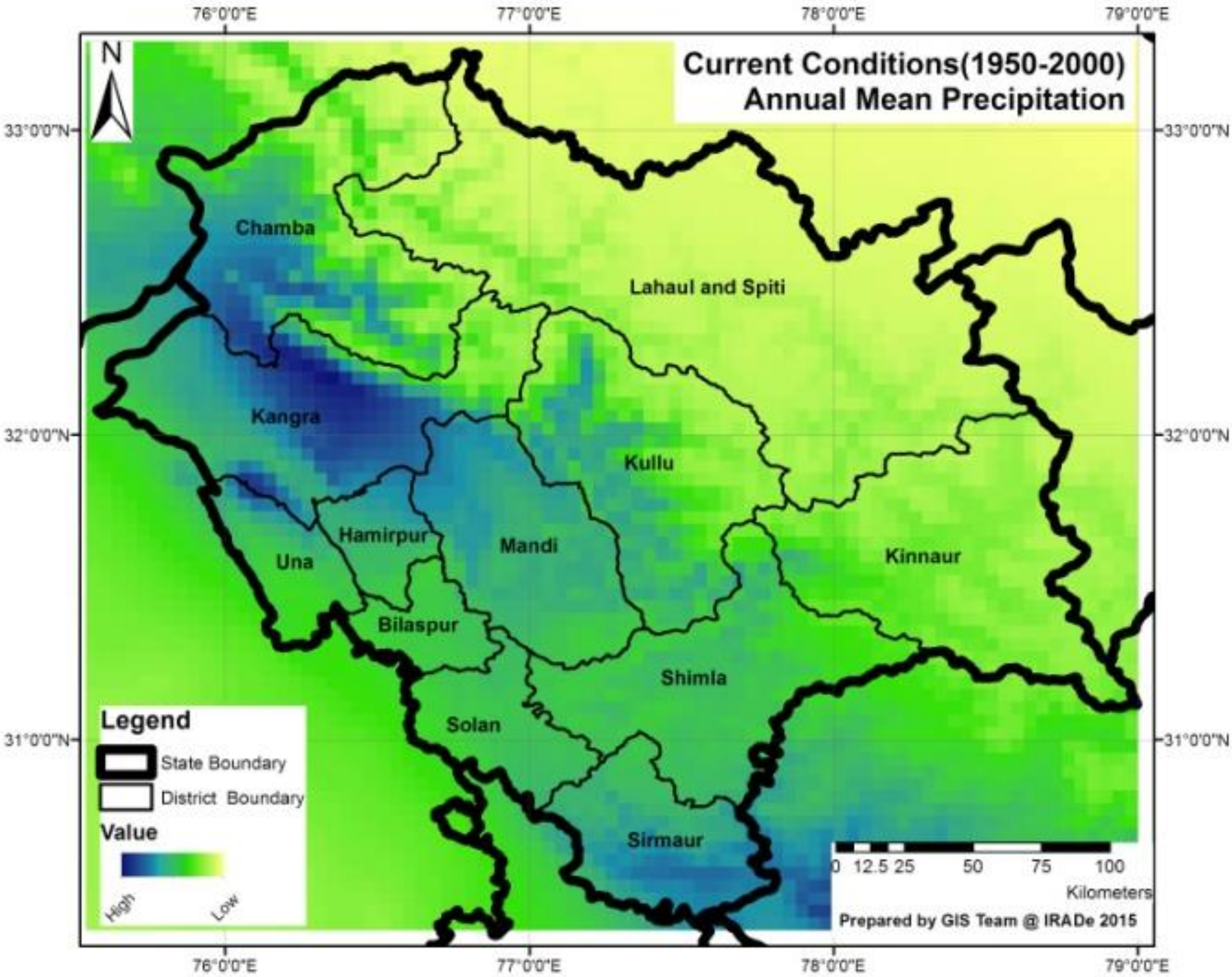




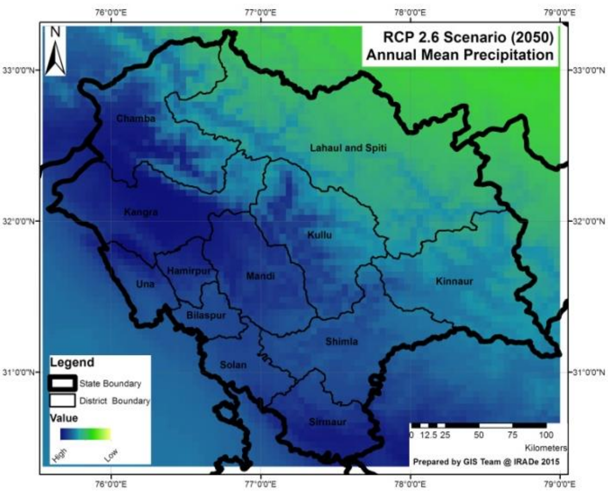
Map 11: RCP 8.5 Scenario (2050) AMT **Map 12: RCP 8.5 Scenario (2070) AMT**

3.2.2. Annual Precipitation

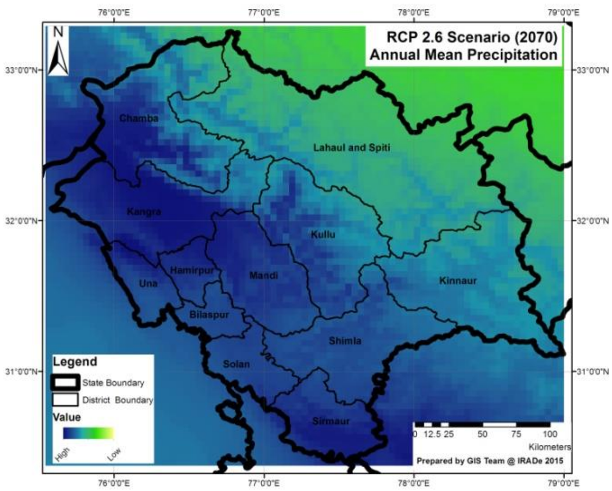
Also, Outer Himalaya and parts of Inner Himalaya zone in the southern tracts of the state with sub tropical monsoon currently receives high annual precipitation including districts of Chamba, Kangra, Mandi, parts of Kullu, Shimla, Una, Solan and Sirmaur. Annual precipitation is defined as the sum of all the monthly precipitation estimates. Map 14 to 19 shows RCP scenarios 2.6, 4.5 and 8.5 which indicates extreme conditions of rainfall in all the districts of Himachal Pradesh for 2050 and 2070 time periods. These extreme shifts in climatic conditions of state are depicted with the help of GIS maps 14 to 19, where each bioclimatic variable (Precipitation) value is represented using a color gradation scheme from its lowest to highest range.



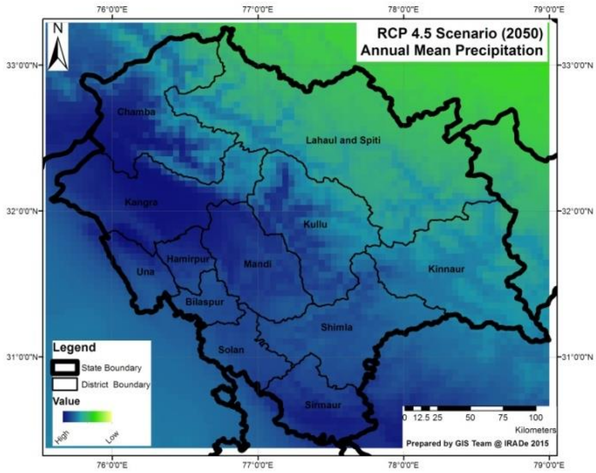
Map 13: Current Annual Mean Precipitation (1950-2000)



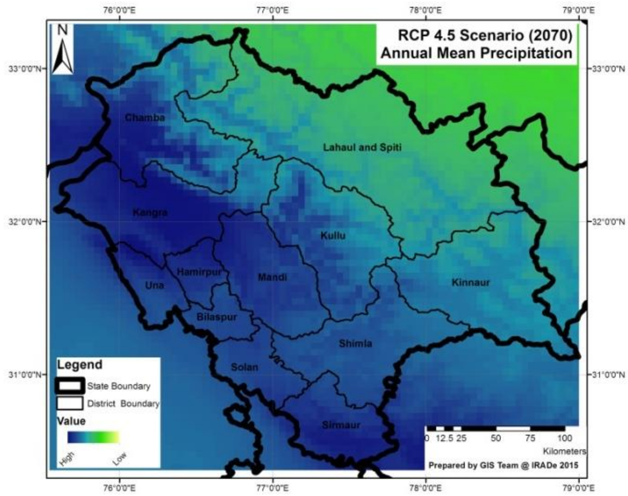
Map 14:RCP 2.6 Scenario (2050) AMP



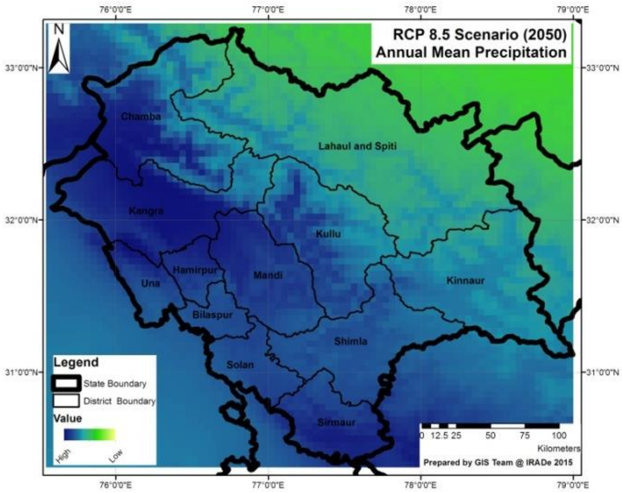
Map 15: RCP 2.6 Scenario (2070) AMP



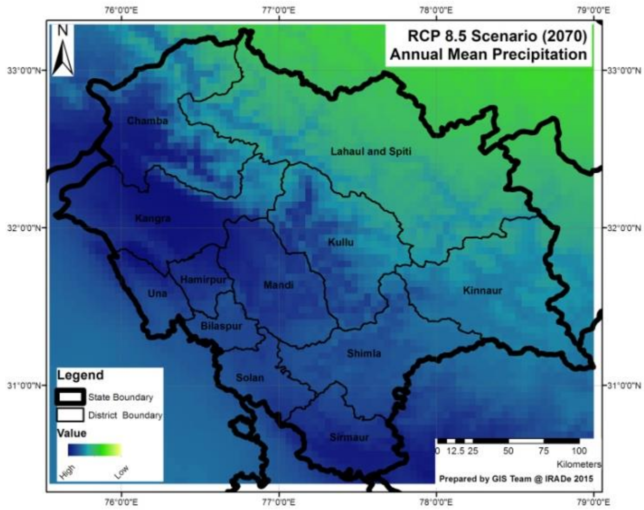
Map 16: RCP 4.5 Scenario (2050) AMP



Map 17:RCP 4.5 Scenario (2070) AMP



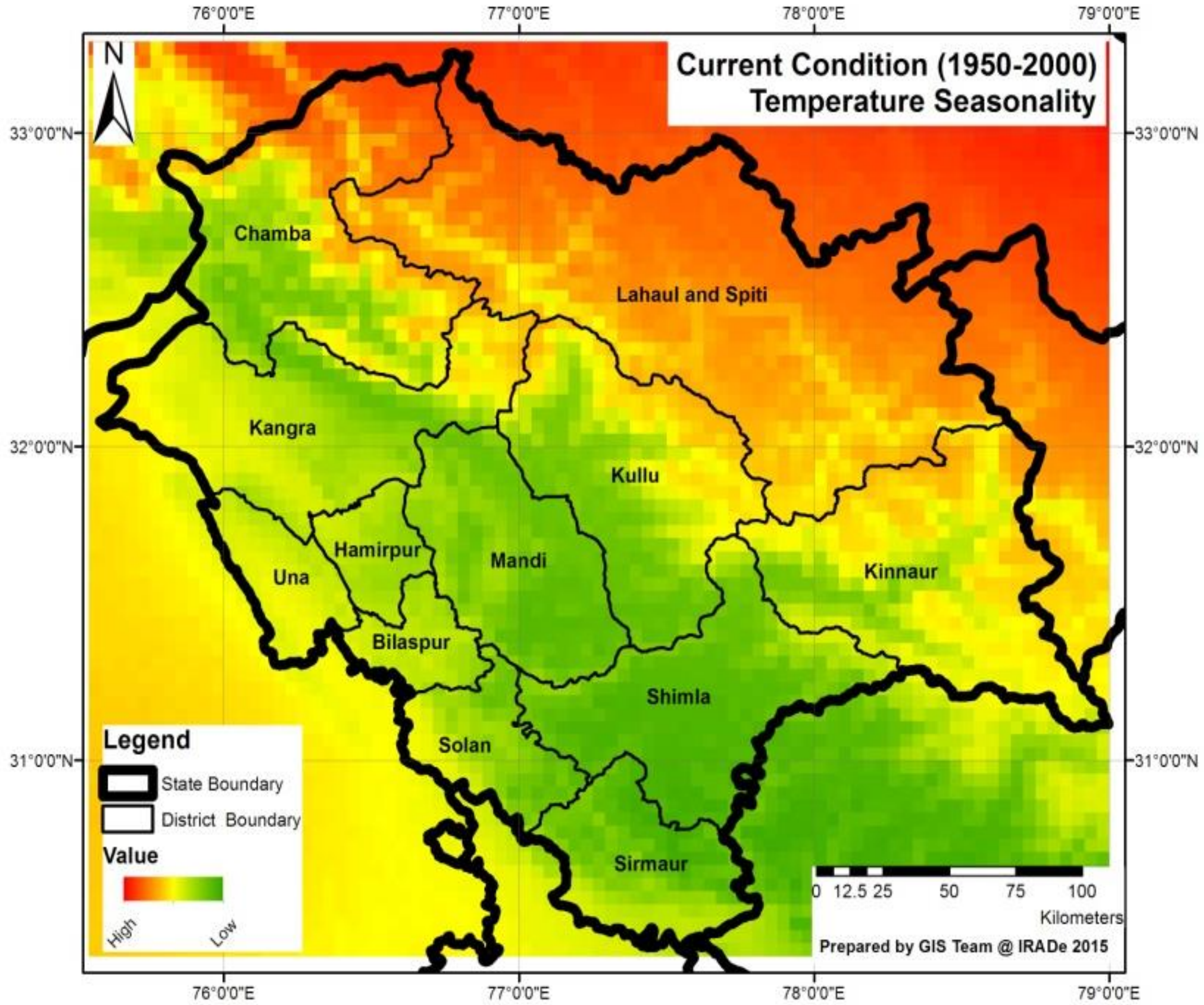
Map 18:RCP 4.5 Scenario (2070) AMP



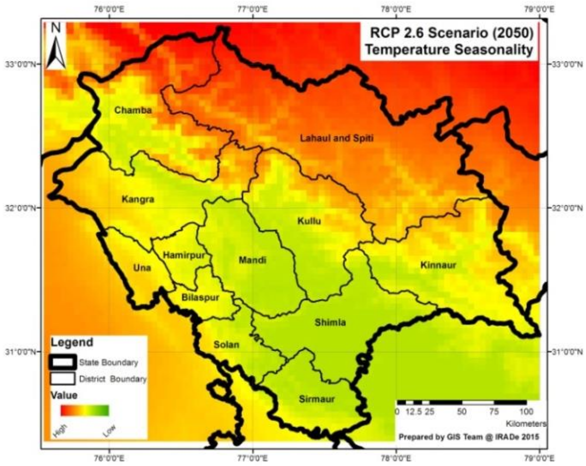
Map 19: RCP 4.5 Scenario (2070) AMP

3.2.3. Temperature Seasonality

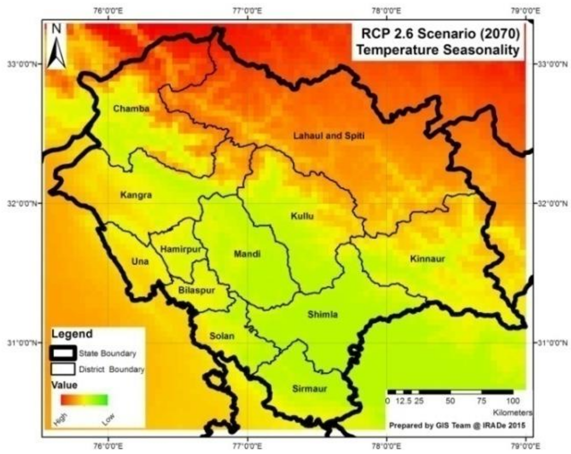
Temperature seasonality means the standard deviation of the monthly mean temperatures expressed as a percentage of the mean of those temperatures (i.e. the annual mean). For H.P., it is observed that in present climatic conditions, there is low seasonal variation in inner and outer Himalaya zones with sub tropical and humid continental conditions. This area spans geographically over districts of Kangra, Mandi, Hamirpur, Una, Bilaspur, Solan, Shimla, Sirmaur, major parts of Kullu, Chamba and minor parts of Kinnaur. However, there is high temperature seasonality observed in alpine zones of Lahaul and Spitti and major parts of Kinnaur. RCP scenarios in map 21 to 26 projects shift to higher side in all the districts of the state especially in the southern tracts of state with sub tropical climatic conditions.



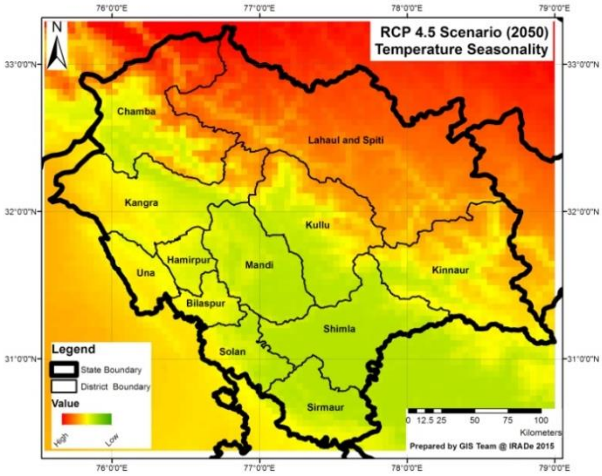
Map 20; Current Temperature Seasonality (1950-2000)



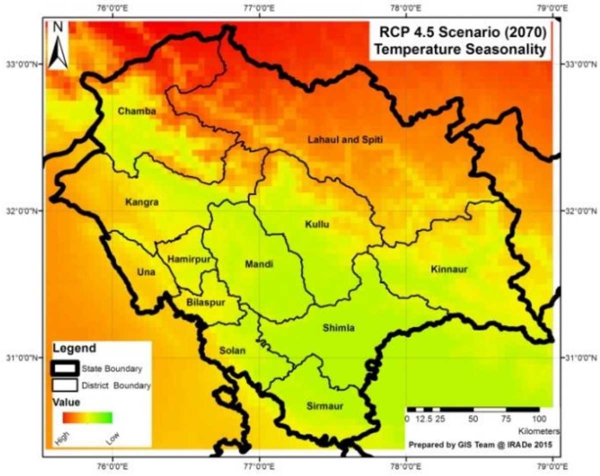
Map 21:RCP 2.6 Scenario (2050) TS



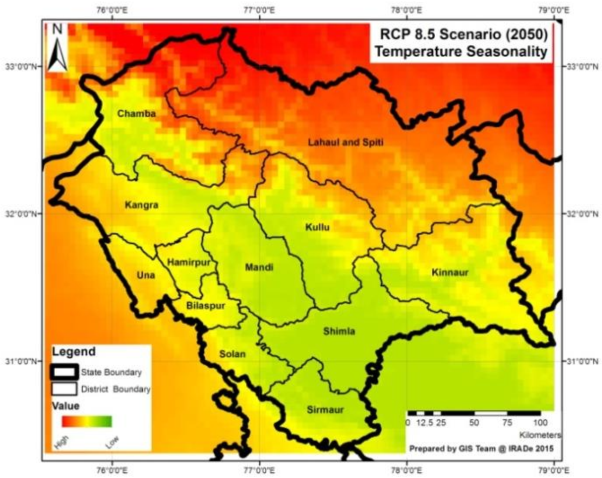
Map 22: RCP 2.6 Scenario (2070) TS



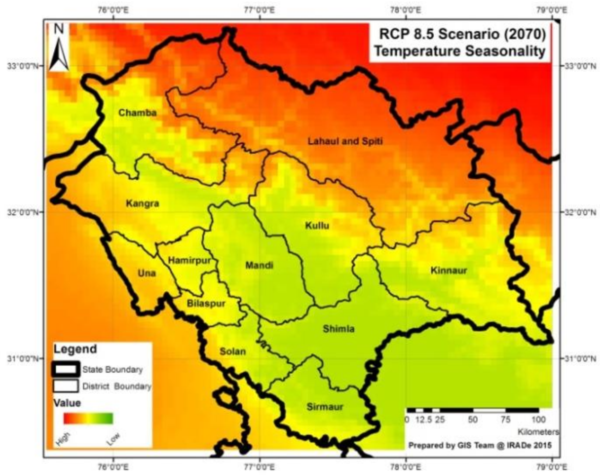
Map 23: RCP 4.5 Scenario (2050) TS



Map 24; RCP 4.5 Scenario (2070) TS



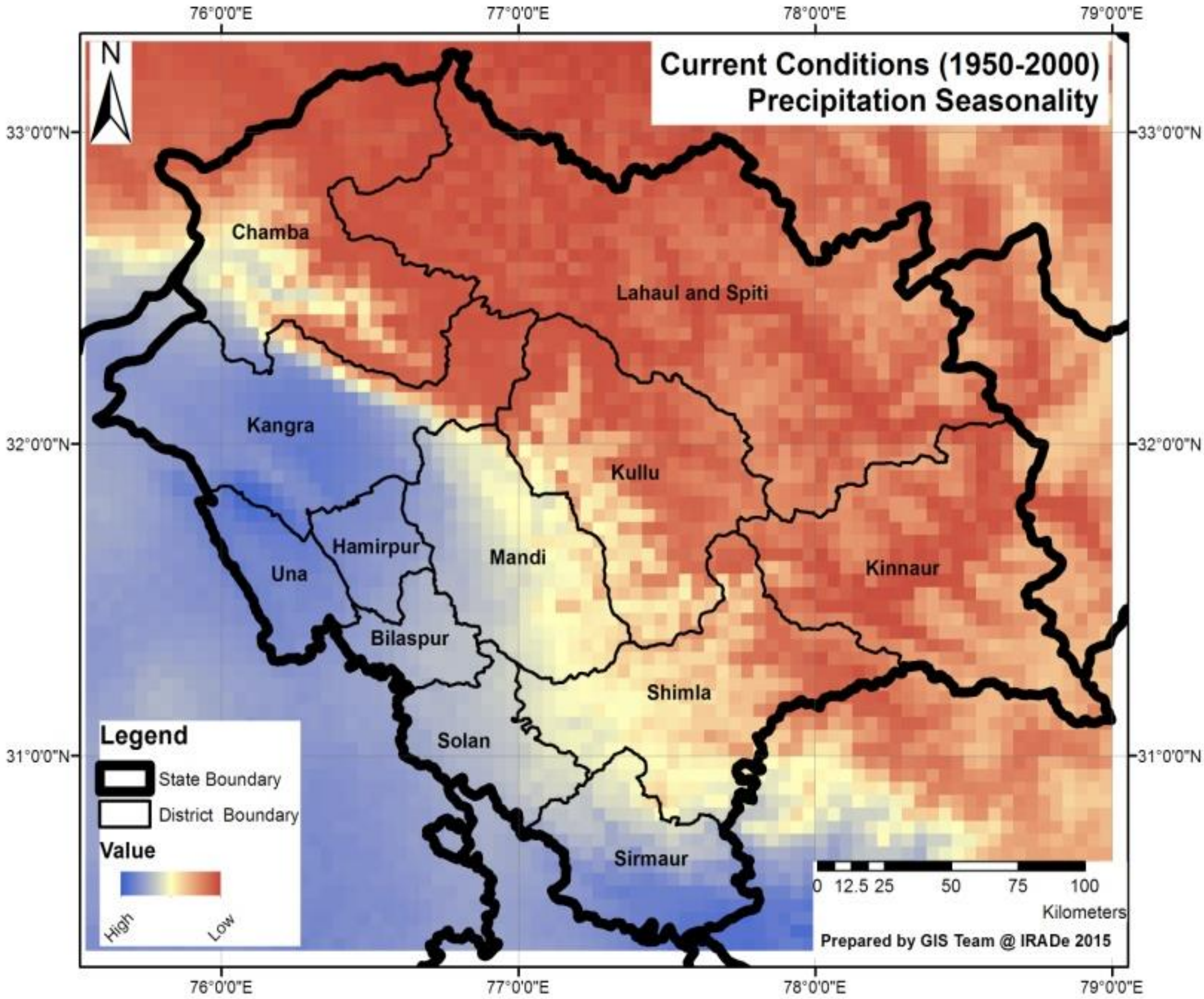
Map 25: RCP 8.5 Scenario (2050) TS



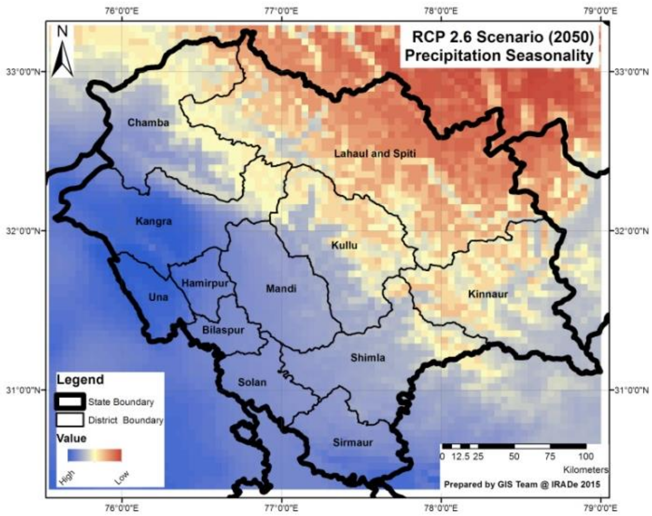
Map 26; RCP 8.5 Scenario (2070) TS

3.2.4. Precipitation Seasonality

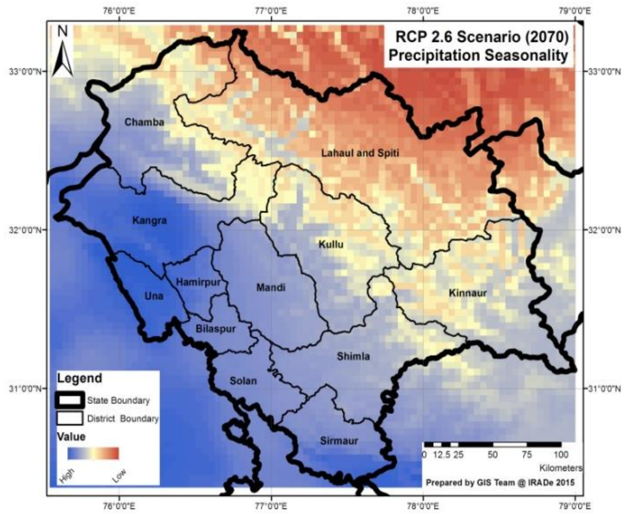
Precipitation seasonality is the standard deviation of the monthly precipitation estimates expressed as a percentage of the mean of those estimates (i.e. the annual mean). There is a low seasonal variation in rainfall conditions in inner Himalayas and alpine zones with humid continental and cold dry climate. These districts are Lahaul and Spitti, Kinnaur, major parts of Kullu, Chamba and Shimla. There is high precipitation seasonality observed in outer Himalaya zones in districts of Kangra, Hamirpur, Una, Bilaspur, Solan, Sirmaur, minor parts of Mandi and Chamba. But in the coming decades, RCP scenarios, shown in map 28 to 33 project high precipitation seasonality in almost all the districts of state except only few parts of alpine zone.



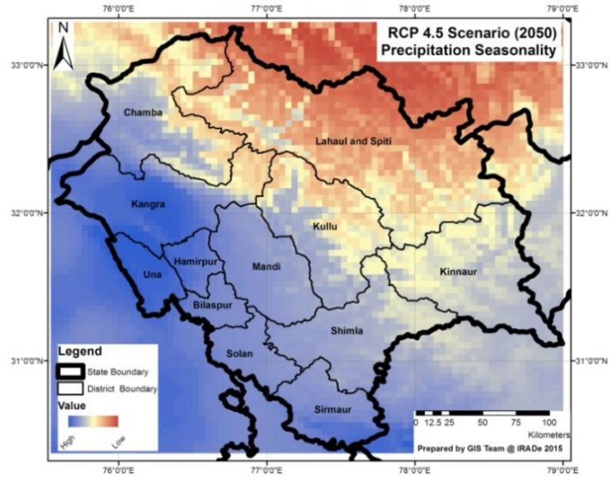
Map 27; Current Precipitation Seasonality (1950-2000)



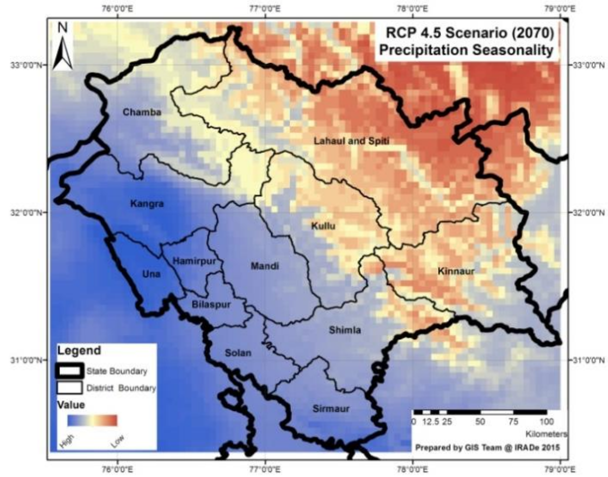
Map 28: RCP 2.6 Scenario (2050) PS



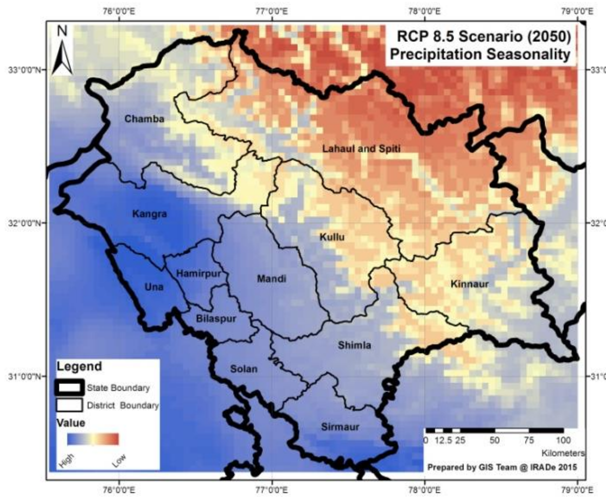
Map 29: RCP 2.6 Scenario (2070) PS



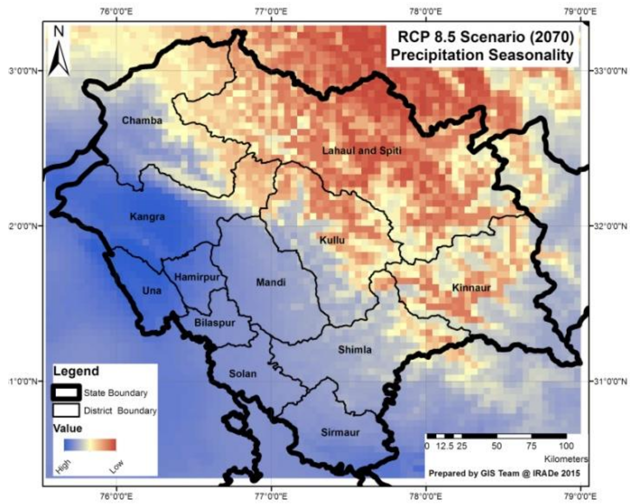
Map 30; RCP 4.5 Scenario (2050) PS



Map 31; RCP 4.5 Scenario (2070) PS



Map 32; RCP 8.5 Scenario (2050) PS



Map 33; RCP 8.5 Scenario (2070) PS

The share of agriculture, including horticulture and animal husbandry in Himachal Pradesh GSDP had declined from 26.5 percent in 1990-91 to 14.42 percent in 2012-13, yet the agriculture sector continues to occupy a significant place in the state economy and any unfavorable fluctuation in the production of food grains/fruits would adversely affect the economy (Economic Survey of Himachal Pradesh, 2013-14). The rise in average mean temperature, extreme precipitation conditions are going to affect state agriculture and horticulture more adversely in the future. There is a high dependence on primary sector (agriculture sector) for livelihood and any likely climatic shifts affecting this sector will have implications for other sectors through input linkages, employment, trade etc.The impact of climate change is likely to be severe for indigenous communities (having limited climate adaptive capacities) living in remote and ecologically fragile zones and relying directly on their immediate environments forsubsistence and livelihood (UNFCCC 2004).

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Status of Agriculture and Horticulture

Agriculture/Horticulture is important as it provides direct employment to about 65 percent of total rural workers. Chapter 3 had already discussed the current climatic condition and RCP scenario's in the State. Himachal Pradesh changing climatic conditions is affecting the horticulture and agriculture in the region. The high temperature in March 2004 adversely affected crops like wheat, apple, mustard, rapeseed, linseed, potato, vegetables, pea and tea across the State. The yield loss was estimated between 20% and 60% varing from crop to crop. Wheat and potato harvest was advanced by 15-20 days and the flowering of apple was early by 15 days. The optimum temperature for fruit blossom and fruit set is 24° C for apple, whereas state experienced above 26° C for 17 days. The entire region recorded between 2.10C and 7.90 C higher maximum temperature against the normal in March 2004 (Prasad and Rana, 2006).

Rice, Wheat and Maize are important cereal crops of the State. Groundnut, Soyabeen and Sunflower in Kharifand Rapeseed/Mustard and Toria are important oilseed crops in the Rabi season. Urd, Bean, Moong, Rajmash in Kharif season and Gram Lentil in Rabi are the important pulse crops of the state which are mainly grown in the lower altitude districts. These districts have high population density and higher dependence on the traditional agriculture.

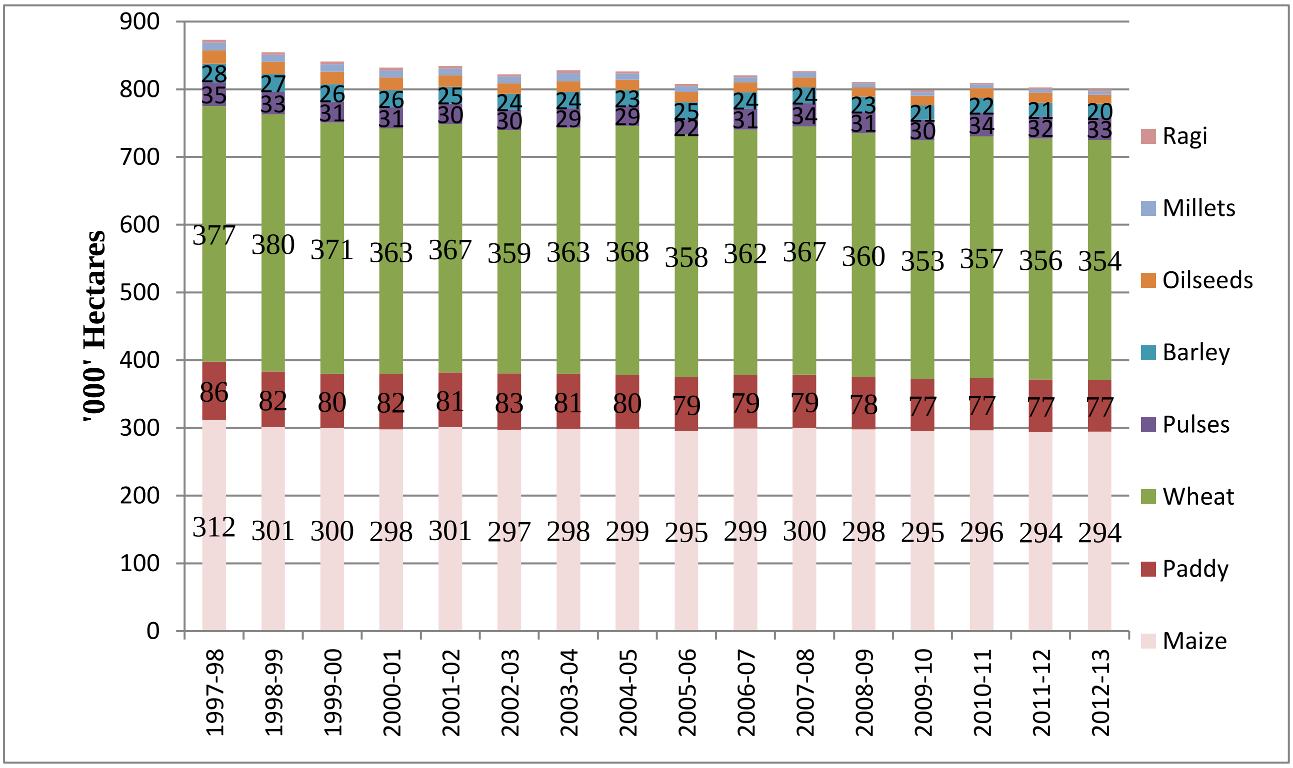
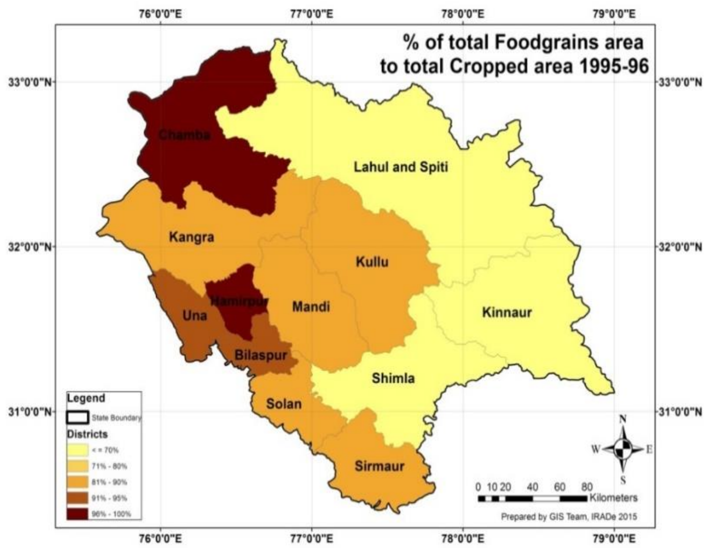
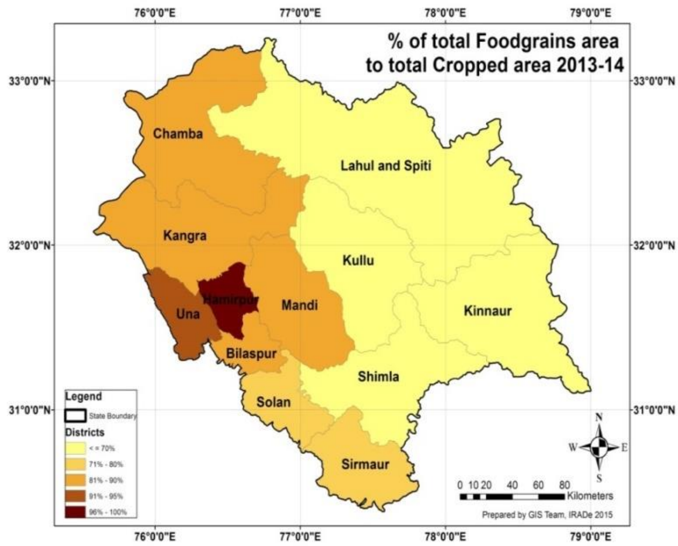


Figure 4 :Area under foodgrains and Oilseeds in Himachal Pradesh
Data source: Department of Agriculture, Himachal Pradesh

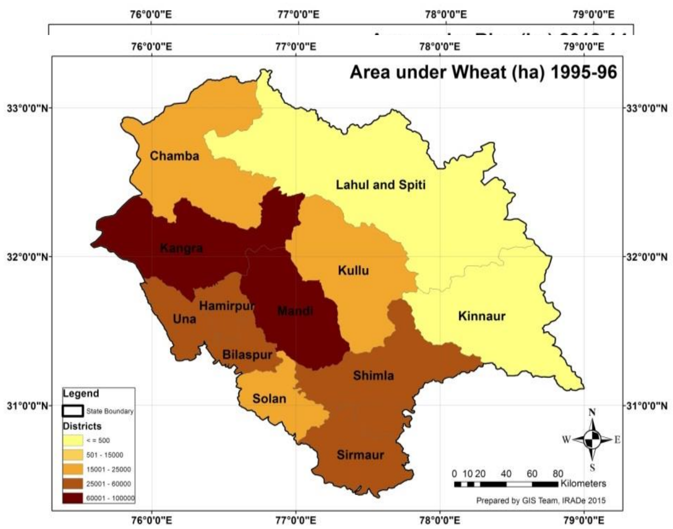
Figure 4 shows that the total area under foodgrains and oilseeds are declining in Himachal Pradesh. Area under major crops like Maize, Wheat, Paddy, Barley are also showing a declining trend. Moreover, the share of foodgraing in total cropped area has also shown a declining trend which reflects that farmers are shifting to other crops in the State. Map 34.a and 34.b shows the total foodgrain area as percentage of total cropped area in 1995-96 and 2013-14 respectively. The comparison of map 34.a and 34.b suggest the changing share of foodrains in the total cropped area across districts. In districts like Kinnaur, Lahaul and Spiti, Kullu, Shimla, Chamba, Kangra, Sirmaur, Solan and Bilaspur farmers have shifted from foodgrains to other crops whereas in remaining three districts. In Hamirpur, Mandi and Una share of foodgrains in total cropped area had increased.

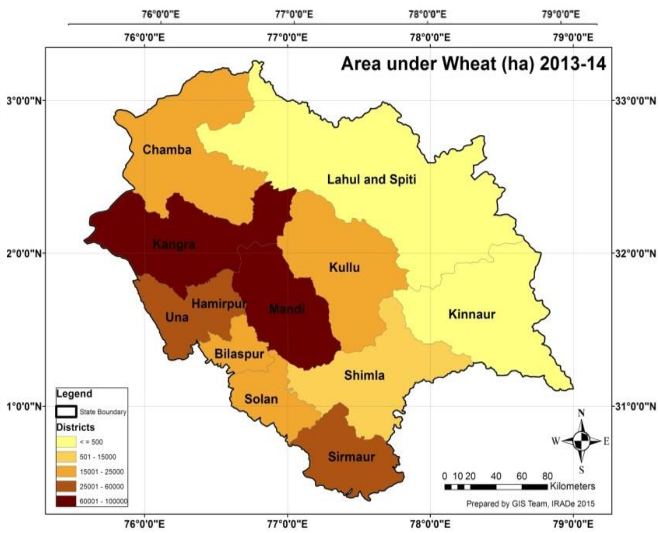


Map 34.a. Foodgrain share in total cropped area in 1995-96



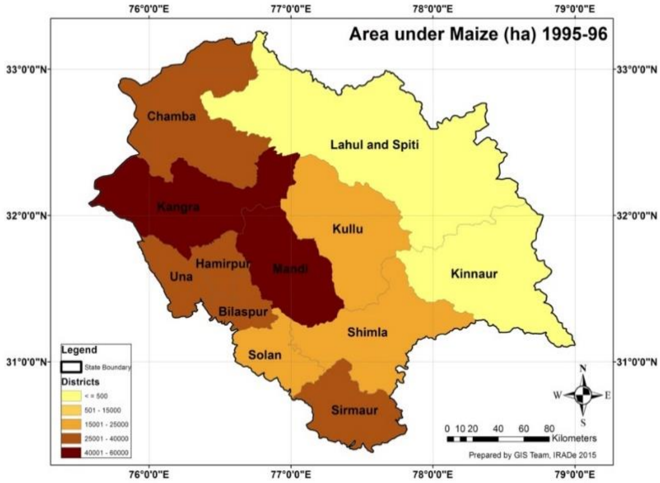
Map 34.b. Foodgrain share in total cropped area in 2013-14

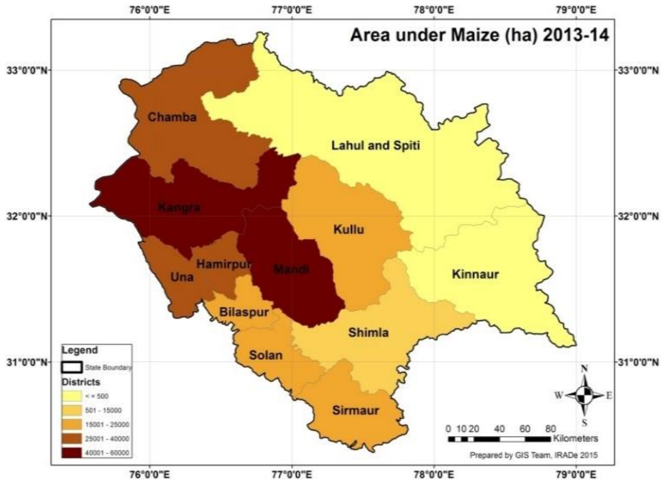




Map 35.b. Area under Rice in 2013-14
Map 36.a. Area under Wheat share in 1995-

Map 35.a. Area under Rice in 1995-
Map 36.b. Area under Wheat share in 2013-





Map 37.a. Area under Maize in 1995-96 **Map 37.b. Area under Maize in 2013-14**

Climatic conditions prevailing in Himachal Pradesh are conducive for growing fruits ranging from apples and stone fruits in the Northern High Hills and Low Hills to citrus fruits which are grown in warm temperate and sub-tropical climatic conditions. A large proportion of operational holdings is being used for growing fruits in the Northern High Hills. The proportion of total operational holdings being used for growing fruits is relatively low in Low Hills. The climatic conditions in these two regions of the State are suitable for growing apple and fruits like plum, peach, apricot, pomegranate, pear, cherries and citrus fruits.

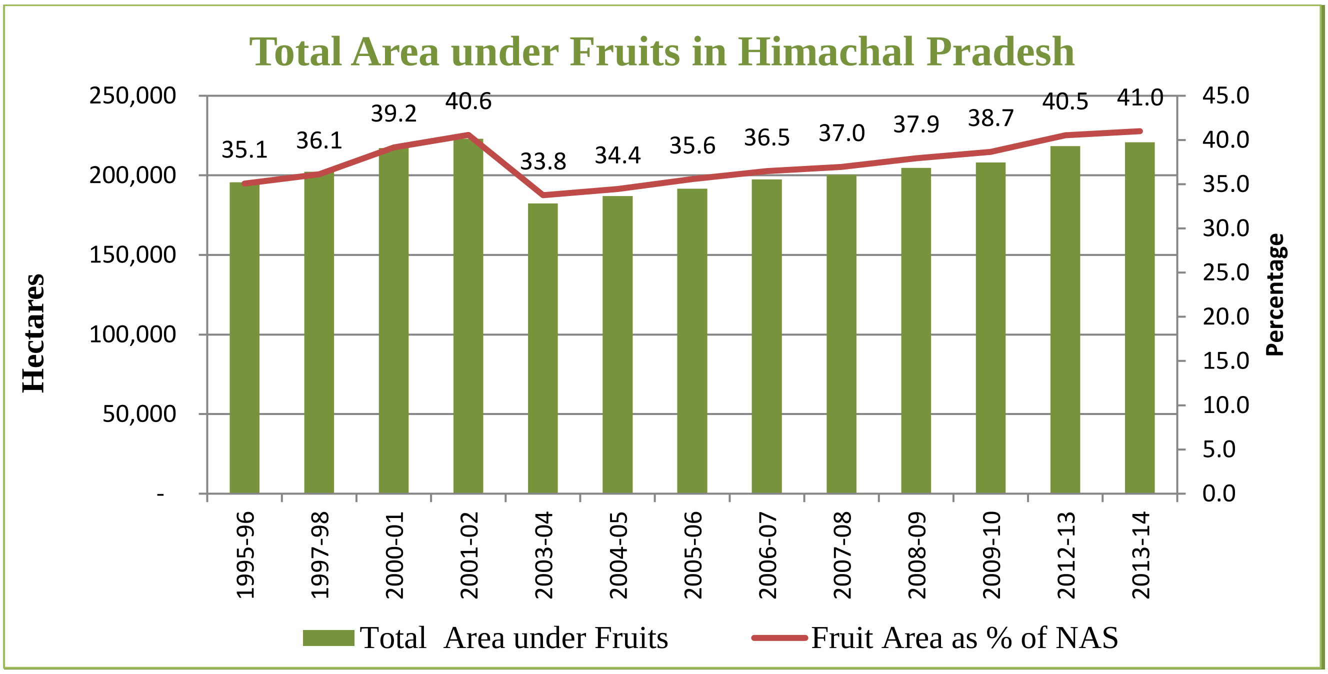


Figure 5: Area under Fruits and Fruit Area as a Percentage of Net Area Sown (NAS)
Data Source: Department of Horticulture, Himachal Pradesh

In higher altitudes districts like: Kinnaur, Kullu, Shimla the farmers have orchards of apple, pear and plum due to availability of suitable chilling hours and favourable climatic conditions, while in the lower areas people have shifted to the orchards of mangoes. In some places of Kullu pomegranate has replaced apple as the later crop failed in the area due unavailability of required chilling hours. Pomegranate requires less chilling hours as compared to apple.

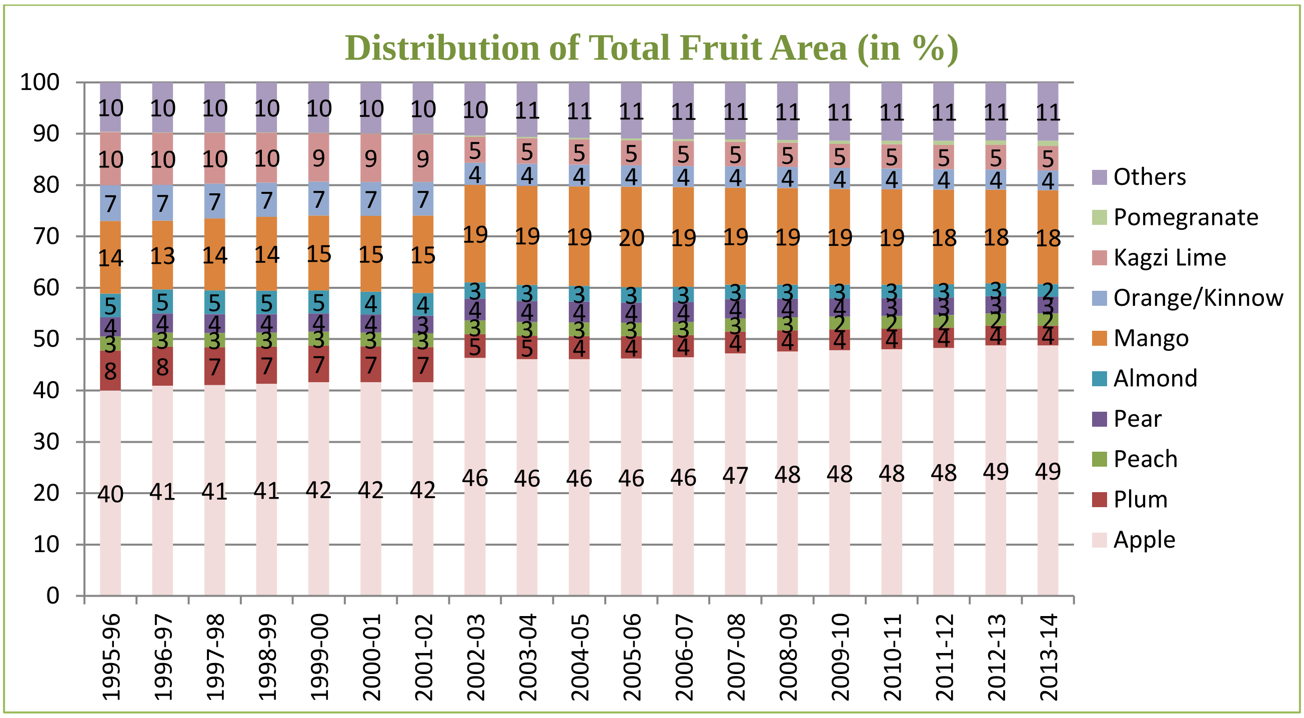


Figure 6: Distribution of fruit area
Data Source: Department of Horticulture, Himachal Pradesh

Apple and stone fruit trees develop their vegetative and fruiting buds in the summer and as winter approaches; the already developed buds go dormant in response to both shorter day lengths and cooler temperatures. These buds remain dormant until they have accumulated sufficient chilling hours of cold weather. When enough chilling hours accumulate, the buds are ready to grow in response to warm temperatures. As long as there have been enough chilling hours the flower and leaf buds develop normally. A simple and widely used method is the hours below 7°C model which equates chilling to the total number of hours below 7°C during the dormant period, autumn leaf fall to spring bud break. These hours are termed "chill hours". Research indicates fruit tree chilling 1) does not occur below about -1-1°C, 2) occurs also above 7°C to about 12°C, 3) is accumulated most effectively in the 1.5-10°C range, 4) is accumulated most effectively early in the dormant period, and 5) in early dormancy can be reversed by temperatures above 15.5°C. (www.davewilson.com).

A fruit tree's chilling requirements can vary widely from one variety to another. In general, except in the coldest climates, for best performance a variety's chilling requirement should approximately match the amount of chilling normally received where it is planted. Some highly productive varieties, however, will produce well over a wide range of climates and chilling. The chilling hours required by different fruit trees are as below:

- Apple 1000-1500 (Low chill varieties are less)
- Almond 500-600
- Japanese Pear 400-500
- Apricot 300-900
- Japanese Plum 300-500
- Kiwi 600-800
- Plum Cot 400
- Pomegranate 100-200

The fruit trees requiring less chill hours are replacing those which require high chilling hours in the regions where climate has become hot as compared to what existed 1-2 decades back. So, pear & pomegranate are replacing the apple tree in lower altitudes of Kullu and Shimla. In lower regions of Himachal Pradesh that have become hotter, plantation of Mango orchards are have increased. As per the agriculture department data, the area under Mango in the State has increased from 27,697 hectares in 1995-1996 to 40,298 hecatres in 2013-14. Moreover, at district level Kangra has witnesse the largest increase in mango plantation where area under mango had increase from 14,965 hectares in 1995-1996 to 20,963 hectares in 2013-14 i.e. nearly 50 percent of the State area under manago falls in Kangra district. Area under Mango had nearly dobled from 2,402 hectatres 1995-1996 to 4,680 hectares in 2013-14. In Hamirpur area under mango had increased from 1,656 hectatres 1995-1996 to 3,338 hectares in 2013-14. In Shimla 99 hecatres were under Mango cultivation in 1995-96 which has become 379 hectares in 2013-14. In Kullu district also Mango area had increase between 1995-96 to 2013-14.

The area under Pomegranate is also increasing in the State at a faster pace. In 1995-96 the area under Pomegranate was 111 hecatares which increased 410 hecatares in 2002-03 and by 2013-14 the area under Pomegranate stands as 2196 hecatres. In 2013-14 of the total area under Pomegranate in the State Mandi district share is 19 percent, Kullu 18 percent and Shimla and Hamirpur 10 percent each.

The above discussion reflects the cultivation of low chilling requirement fruits is increasing in State and this may be because the present availability of chilling hours during winters may not be sufficient for growing high chilling requirements fruits. Moreover, due to favourable conditions for vegetables mainly exotic vegetables many farmers have switch to vegetable crops.The shift to vegetables is primarily in areas with irrigation and where farmers have been able to adjust from subsistence food production to higher risk but better return cash crops. The success of the population earning handsome returns engaged in the production of off-season vegetables at large and fruits to some extent may have acted as a motivation for more and more people to adopt this activity as the means of earning their livelihoods.

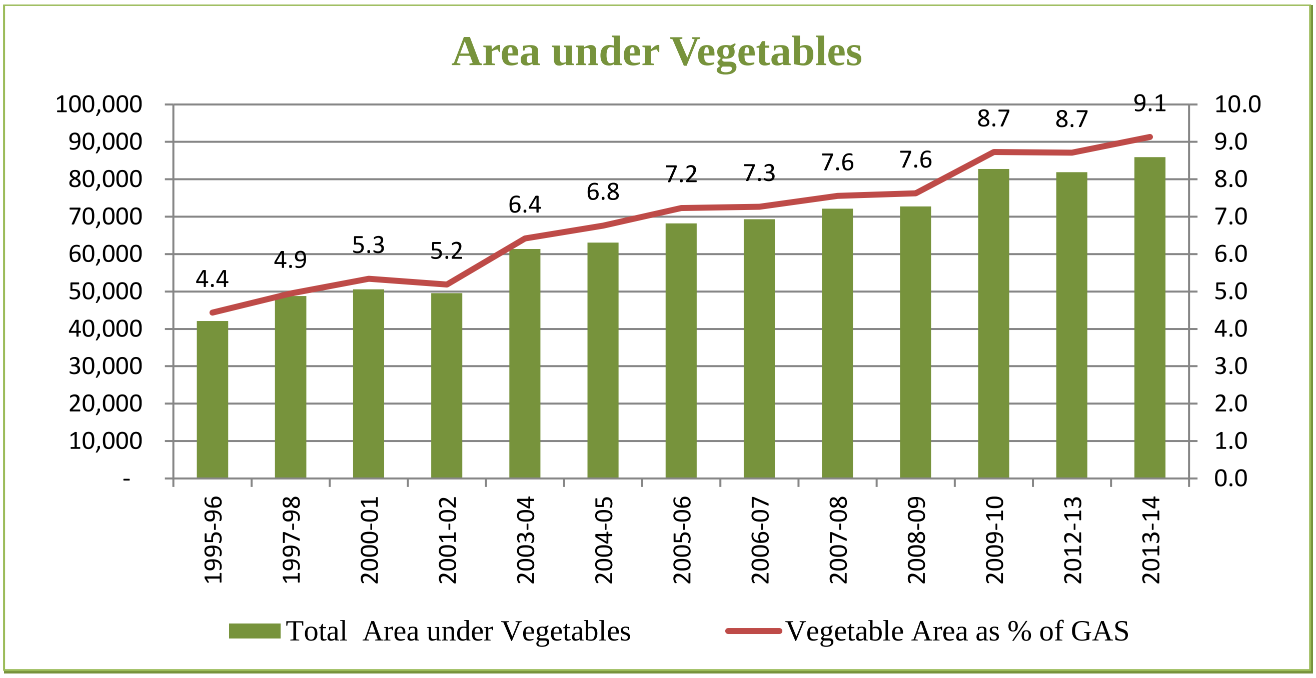
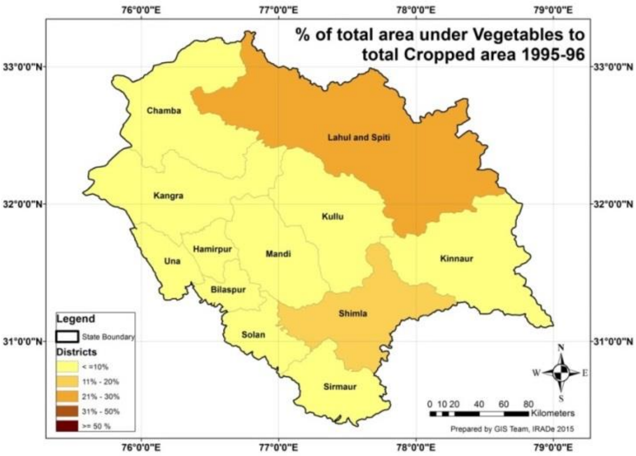
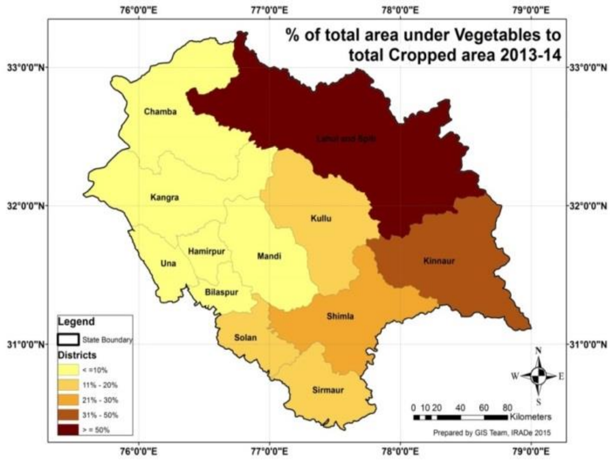


Figure 7: Total area under vegetable production and vegetable are as percentage of gross area sown
Data Source: Department of Agriculture, Himachal Pradesh



Map 38.a. Percentage vegetable area in 1995-96



Map 38.a. Percentage vegetable area in 2013-14

Figure 8 presents that percentage land use classification in for the period 2000-14. It can be observed that net area sown of the total area shows a declining trend, permanent pastures and other grazing land also following similar trend and land put to non-agricultural uses is increasing rapidly.

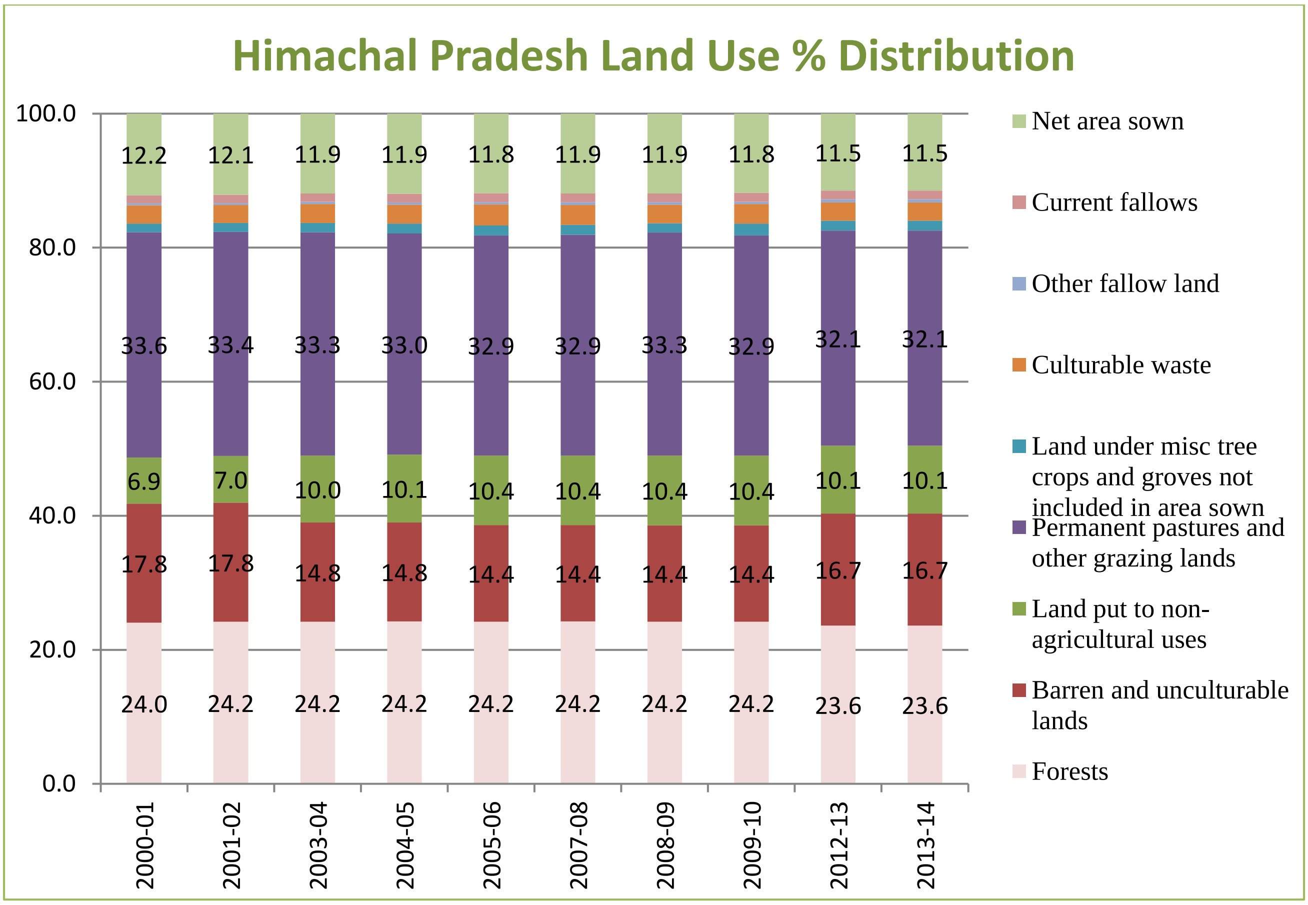
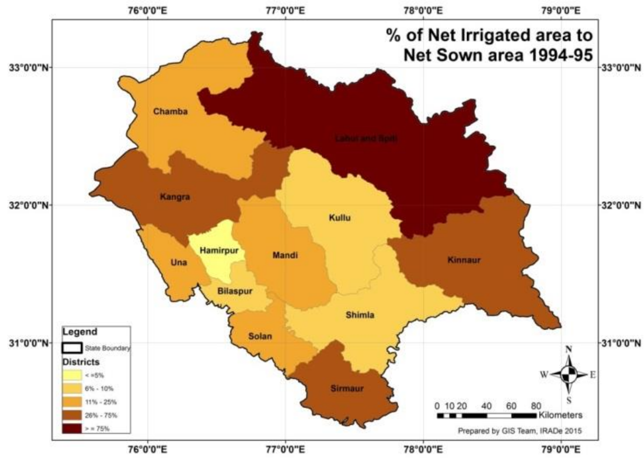
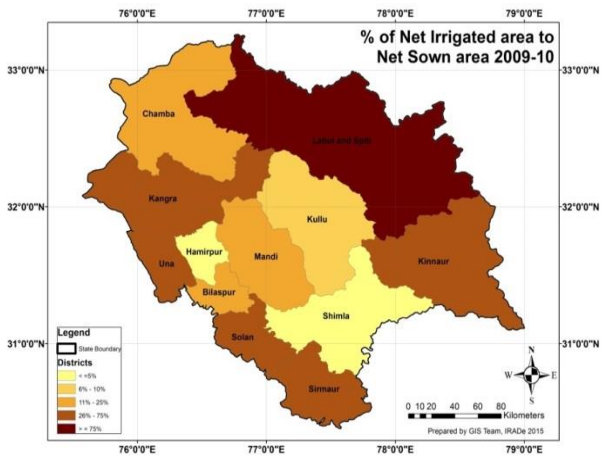


Figure 8: Land use Classification in Himachal Pradesh (% of Total area)
Data Source: State Statistical Abstract Himachal Pradesh for several years,

Irrigation is the limiting factor that influences the production as well as area sown under wheat, maize and rice in all districts of Himachal Pradesh. In Himachal Pradesh 81.5 percent of the total cultivated area in the state is rainfed and therefore variation in rainfall adversely affects the State agriculture and horticulture. A very large proportion of irrigation is done either through irrigation canals or Kuhls.The uncertainty about weather conditions is one of the key risk factors associated with crop production. As per State centre on climate change due to global warming the changes in the precipitation can be more complex as compared to the changes in the temperature, at the regional scale these changes in precipitation can be erratic despite of increasing or decreasing monotonically at the temporal scale. Climate change can alter the cropping calendar in some locations; shift the sowing months of the crop forward or back. Rainfall plays the most significant role than any other farm inputs and is one of the most uncontrollable climatic factors that affect the productivity of agriculture. The amount of rainfall received in a particular season or time is the most important determinant of inter annual fluctuations in national crop production levels. The impact that the rainfall has on crop production can be related to its seasonal amount received or its intra-seasonal distribution. Crop production suffers the most during extreme cases of droughts when the total seasonal rainfall received is very less. But more subtle intra-seasonal variations in rainfall distribution during crop growing periods, without a change in total seasonal amount, can also cause substantial reductions in yields. It means that the number of rainy days received during the growing period of crop is also as important as that of the seasonal total. Even in wet locations rainfall variability at the daily time scale is critical to plant growth (Jackson, 1989), particularly in the early part of the rainy season before the soil moisture reserves have been built up. The effect of rainfall variability on the crop production varies with the type of crops cultivated in a particular area, the types and properties of soil and climatic conditions of the given area.



Map 39.a. Percentage net irrigated area in 1994-95



Map 39.a. Percentage net irrigated area in 2009-10

The changes in the vegetation and trees in different regions of Himachal Pradesh over a period of time show that the climate of the region is changing with time and farmers are adapting to the change by making change in vegetation types. Some regions of Mandi used to get snowfall 3-4 decades back but now the climate has become hot and there are no snowfalls, Moreover the increase in the area under Mango plantation in Mandi and certain other districts as mentioned above is a clear indicator of warming conditions in the region. This change in the area of different fruits is the clear indicator of change in climate conditions. The sub-tropical climatic conditions are increasing in Himachal Pradesh while the temperate climatic conditions are receding and shifting to higher altitudes which are the major reason in shift of the apple belt to higher altitudes. These changes in climate conditions results in crop failure and make the farmers vulnerable. Farmers are forced to switch from one failed fruit crop to another (suitable to climate). Which poses a serious challenge for the sustainability of the farmers as a fruit plant has a gestation period of 4 to 5 years before its start fruit production and income generation for the farmer. We observed similar trend in Kullu where in certain regions the apple (high chilling hour's requirement) has failed and farmers have switched to pomegranate (low chilling hours requirement).

The above all discussions reveal that the crop pattern is changing in Himachal Pradesh. Farmers are moving towards fruits and vegetables more as they are able to get good return. Rise in temperature, scanty and erratic rainfalls are also the reasons behind the changes in the types of crop and fruits. The decrease in cereals and food grains cultivation is increasing the dependency of the farmers on the produce of other states.

4.1. Increase in pesticide and fertilizer usage:

The increase in use of pesticides in an area is an indicator of increased diseases in crops and trees. The fruit production of apple is declining every year in Himachal Pradesh ever since the crop has been hit by the diseases like Scab, and apple blotch. Pomegranate is suffering from canker, tomato from early & late blight and rottening disease, cauliflower from sclerotinia rot, black rust is prevalent in wheat. Apart from this various other diseases and pests like worms & mites are hampering the productivity of crops and fruits in Himachal Pradesh.

Table.11 Area under total pesticide usage in Himachal Pradesh

District	Total cropped area in 1996-1997	Usage of pesticides for all crops in 1996-1997 (Area in ht)	% of Area given pesticide treatment	Total cropped area for all crops in 2006-2007	Usage of pesticides for all crops in 2006-2007 (Area in ht)	% area given pesticide treatment
Chamba	59341	0	0	67571	1680	2.48%
Kangra	208980	0	0	241958	25433	10.51%
Hamirpur	73476	12	0.01%	76688	6246	8.10%
Una	77115	2656	3.44%	90004	25293	28.10%
Bilaspur	59992	124	0.20%	68557	1491	2.17%
Mandi	153760	4585	2.98%	186961	36458	19.50%
Kullu	61649	977	1.58%	64605	8852	13.70%
Shimla	109805	21520	19.59%	111660	37965	34.00%
Lahaul & Spiti	3073	1502	48.87%	4838	402	8.30%
Solan	63063	93	0.15%	68884	13723	19.92%
Sirmaur	75482	2015	2.66%	73286	13479	18.39%
Kinnaur	9251	2284	24.68%	10632	3191	30.01%

Source: Agriculture Census and Input Survey, http://agcensus.nic.in/

As per the agriculture census the usage of pesticides has increased in all districts of Himachal Pradesh accept Lahaul & Spiti. In Mandi, Kullu and Shimla the percentage increase in the area under pesticide usage in 2006-2007 is 16.52%, 12.12%, and 14. 41%. In Kangra district there was no usage of pesticides in 1996-1997, but in 2006-2007 the area under the pesticide usage increased to 25433 hectares. In other districts like Solan, Sirmaur, Una and Hamirpur (relatively hot as compared to other districts) there is major increase in the area treated with pesticides (table 11).

Table: 12.Apple area under pesticide usage in 1996-1997 and 2006-2007

District	Usage of pesticides for all crops in 1996-1997	Usage of pesticides for all fruit crops in 1996-1997	Usage of pesticide for Apple in 1996-1997	Usage of pesticides for total Food Grains in 1996-1997	Usage of pesticides for all crops in 2006-2007	Usage of pesticide for all fruits in 2006-2007	Usage of pesticide for Apple in 2006-2007	Usage of pesticides for total Food Grains in 2006-2007
Chamba	0	0	0	0	1680	147	147	1520
Kangra	0	0	0	0	25433	0	0	23849
Hamirpur	12	0	0	12	6246	0	0	6246
Una	2656	0	0	1994	25293	0	0	24770
Bilaspur	124	0	0	124	1491	0	0	1491
Mandi	4585	189	189	4394	36458	2501	2501	32575
Kullu	977	977	977	0	8852	6430	6430	2140
Shimla	21520	17323	17323	1497	37965	29783	29783	6070
Lahaul & Spiti	1502	78	78	216	402	100	100	17
Solan	93	22	22	0	13723	25	25	9178
Sirmaur	2015	0	0	1747	13479	787	787	9869
Kinnaur	2284	1572	1572	411	3191	2003	2003	1111

Source: Agriculture Census and Input Survey, http://agcensus.nic.in/

Above tables 12 show that area under apple treated with pesticides has increased from 189 hectares in 1996-97 to 2501 hectares in 2006-2007, while there is decrease in the food grain area that is given pesticide treatment. In Kullu from merely 977 hectares of pesticide treated area under apple the pesticide use was increased to 6430 hectares, the farmers also started using pesticides in food grains in a total area of 2140 hectares which was initially nil in 1996-1997. In Shimla the area under apple farms treated with pesticides increased to near about double in 2006-2007 , while the total area under food grains given pesticide treatment became 3 times i.e 6070 hectares from 1497 hectares in 1996-1997. The trends are nearly same in other districts also. In total the area under pesticide usage has increased tremendously in Himachal Pradesh.

Same is the case with the use of fertilizers in the soil. Due to soil erosion, increased use of chemical fertilizers & pesticides, loss in soil fertility, excessive use of chemical fertilizers, the fertilizers input has also increased in Himachal Pradesh (table 13).

Table 13: Area under fertilizer usage in Himachal Pradesh in 1996-97 & 2006-07

District	Total cropped area in 1996-1997	Usage of fertilizers for all crops in 1996-1997	% area given fertilizer treatment	Total cropped area for all crops in 2006-2007	Usage of fertilizers for all crops in 2006-07	% area given fertilizer treatment
Chamba	**59341**	**22987**	**38.73%**	**67571**	**33837**	**50.07%**
Kangra	208980	168046	80.41%	241958	224913	92.95%

Hamirpur	73476	57972	78.89%	76688	72942	95.11%
Una	77115	66347	86.03%	90004	77517	86.126
Bilaspur	59992	24097	40.16%	68557	67911	99.05%
Mandi	153760	90370	58.77%	186961	161160	86.19%
Kullu	61649	25563	41.46%	64605	27696	42.86%
Shimla	109805	69051	62.88%	111660	66761	59.78%
Lahaul & Spiti	3073	833	27.10%	4838	2255	46.61%
Solan	63063	46493	73.72%	68884	47872	69.49%
Sirmaur	75482	59538	78.87%	73286	47623	64.98%
Kinnaur	9251	2530	27.34%	10632	2239	21.05

Source: Agriculture Census and Input Survey, http://agcensus.nic.in/

The data from agriculture census shows that on an average the use of fertilizers has increased in Himachal except in Shimla and Solan district. In Kullu and Mandi there is increase in area under fertilizer treatment. In Kullu there is a small increase of 1.4% in the area treated with fertilizer while in Mandi there is an increase of 27.42% in the year 2006-2007.

The soils in the hilly regions are prone to erosion, poor cultivation practices, excessive input of chemicals make the soil less productive and deficient in minerals, this increases the need of using heavy dose of fertilizers to get a better yield. Increased use of pesticides and chemical fertilizers is putting an unnecessary pressure on the economic health of the farmers as it increases the cost of production, decreases the nutritional value of produce along with degrading soil & its productivity, this whole highlights the plight of the farmers and their vulnerability to changing climatic conditions.

Table 14: Changing agriculture landscape in Himachal Pradesh

Crops	Popular Belts	Remarks	
Apple	Shimla, Kullu, Sirmaur, Mandi, Kinnaur, Chamba	Farmers in HP are moving from tradition crops like apple to growing the Nectarine , Cherry, kiwi, apricots	Nectarine has proved better source of income. Cheery fruits required less care than apple and price of apple box on an average sell for Rs 400, whereas cheery fetches from Rs 200-300
Off Season Vegetable (Cabbage, cauliflower, tomato, peas)	Shimla, Solan, Sirmour, Kullu, Una	Off season vegetable production nearly increase 34-35 thousand to 10 lakh tonnes	Farmers are increasingly looking to off season vegetable as these fetch high prices when the production period is over.
Wheat, Rice, & other cereals	Shimla, Solan, Sirmour, Kullu, Una	The area under rice crop diverted to maize due to non availability of water	The uncertain weather patterns have kept the farmers guessing and there is no adaptive measure as this is a rainfed area and bringing in other crops would mean more investments and also know how. Ginger production in HP rose to 21,267 tonner in 2010-11 which is an increase of over 6000 tonner from the previous year

Source: Ray, Mukesh (et al): Climate vulnerability in North Western Himalayas –Environic Trust 2011

4.2. Losses due to extreme weather/climatic events

Most of the Himachal Pradesh state comprises of Himalayan ranges, which have a deeply dissected topography and complex geological structures. Being one of the youngest mountain ranges in the world, the Himalayas are very fragile and are prone to natural calamities of serious nature even under normal climatic conditions. The propensity gets pronounced when climatic factors behave abnormally. Due to extreme weather events which are attributed primarily to climate change, Himachal Pradesh economy has faced severe losses from time to time, both in terms of lives and infrastructural damages.

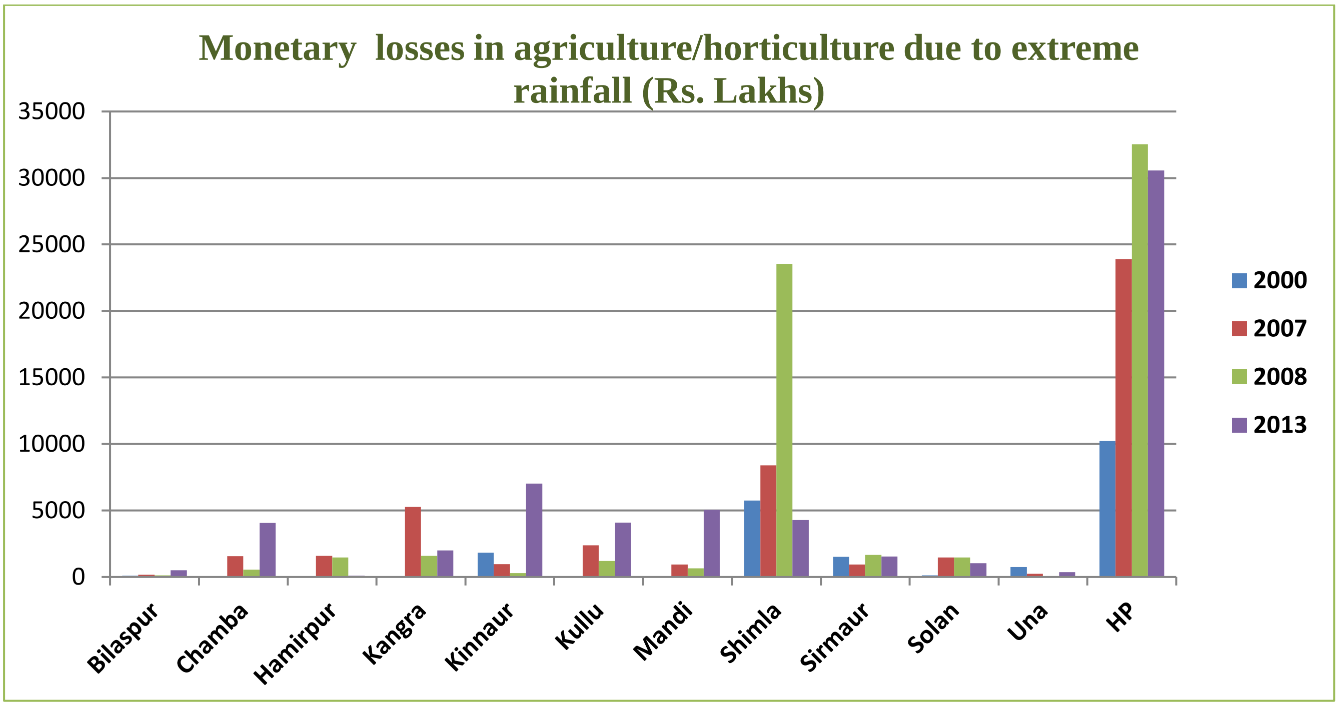


Figure 9: Economic losses due to extreme rainfall
Data Source: Revenue Dept., Memorandum on damages due to excessive rains, flash floods etc., Himachal Pradesh

Figure 9 shows distict wise economic losses of the agriculture/horticulture farmers due to extreme rainfall. Figure 9 suggets that in 2000, 2007 and 2008 Shimla districts farmers incurred the maximum lossess whereas in 2013 the highest economic losses where in Kinnaur followed by Mandi, Shimla and Kullu.

An analysis of Apple farming in Himachal Pradesh

Apple farming occupies a pivotal role in Himachal Pradesh agriculture. Area under apple has increased from 400 hectares in 1950-51 to 3,025 hectares in 1960-61 and 1,03,644 hectares in 2011-12 (Government of Himachal Pradesh, 2013).In 2011-12, apple constituted about 48 percent of the total area under fruit crops and about 74 percent of the total fruit production in Himachal Pradesh. In terms of value added at constant prices (2004-05) in 2010-11, apple contributed Rupees 1500.50 crore in Himachal Pradesh income. However, fluctuations in the apple production in recent years had gained attention and several researchers have argued that climatic change has demonstrated its impact on apple production.

5.1. Trend in Apple Area and Production Himachal Pradesh

Apple is the most important fruit crop of Himachal Pradesh. Area under apple has increased from 400 hectares in 1950-51 to 3,025 hectares in 1960-61 and 1, 03,644 hectares in 2011-12 (Government of Himachal Pradesh, 2013).In 2011-12, apple constituted about 48 percent of the total area under fruit crops and about 74 percent of the total fruit production in Himachal Pradesh. In terms of value added at constant prices (2004-05) in 2010-11, apple contributed Rupees 1500.50 crore in Himachal Pradesh income. However, fluctuations in the apple production in recent years had gained attention and several researchers have argued that climatic change has demonstrated its impact on apple production.

5.2. Data

District-wise annual apple production and area under apple in Himachal Pradesh was collected from National Horticulture Board, Government of India, New Delhi. The data for Lahaul and Spitiapple production is available from 1982-83 whereas for other apple growing districts it is available from 1973-74. Therefore, to keep our study period uniform across all apple growing districts we have used the time series data on apple production and area for the period 1982-83 to 2011-12. Table 15 presents district wise average annual apple yield (MT/ha), average annual share in total apple production and average annual share in total apple area. Table 15 highlight that the average annual apple yields during this period was highest in Shimla followed by Kullu & Kinnaur. Moreover, average annual apple yield in Shimla was higher compared to the Himachal Pradesh average annual yield and in the remaining eight districts it was lower compared to the State average. The average annual yield was as low as 0.21 MT/ha for Sirmaur. Shimla average contribution in total apple production was 63.68 percent (column 3, Table 15) & average contribution in total apple area was 38.14 Percent (column 4, Table 15) during 1982-83 to 2011-12.

Table15. District wise average annual apple yield, percentage production and percentage area in Himachal Pradesh for the period 1982-83 to 2011-12

District/State	Average Annual Yield (MT/Ha)	Average Annual Percentage Production	Average Annual Percentage Area
Shimla	7.32	63.68	38.14
Kullu	4.16	22.05	23.19

Mandi	1.06	4.06	15.77
Chamba	0.82	1.66	8.80
Kinnaur	3.65	8.07	7.48
Lahaul and Spiti (L&S)	0.30	0.03	0.47
Kangra	0.63	0.10	0.72
Solan	0.33	0.04	0.58
Sirmaur	0.21	0.29	4.85
Himachal Pradesh	4.26	100.00	100.00

The other major contributor districts in apple production are Kullu, Kinnaur and Mandi (column 3, Table 15). Apart from Shimla, Kullu, Mandi, Chamba and Kinnaur are the major contributor in apple grown Area (column 4, Table 15). Table 16 highlights that 95 percent of the total area under apple and 99 percent of the total apple production are concentrated in five districts namely Shimla, Kullu, Mandi, Chamba and Kinnaur in 2011-12.

Table 16 .District wise apple production and percentage area under apple in 2011-12

District	Percentage Production	Percentage Area
Shimla	61.31	34.52
Kullu	16.22	23.64
Mandi	1.61	15.29
Chamba	1.12	12.07
Kinnaur	19.38	9.74
Lahaul and Spiti	0.05	1.36
Kangra	0.15	0.41
Solan	0.01	0.08
Sirmaur	0.17	2.88
Himachal Pradesh	**100**	**100**

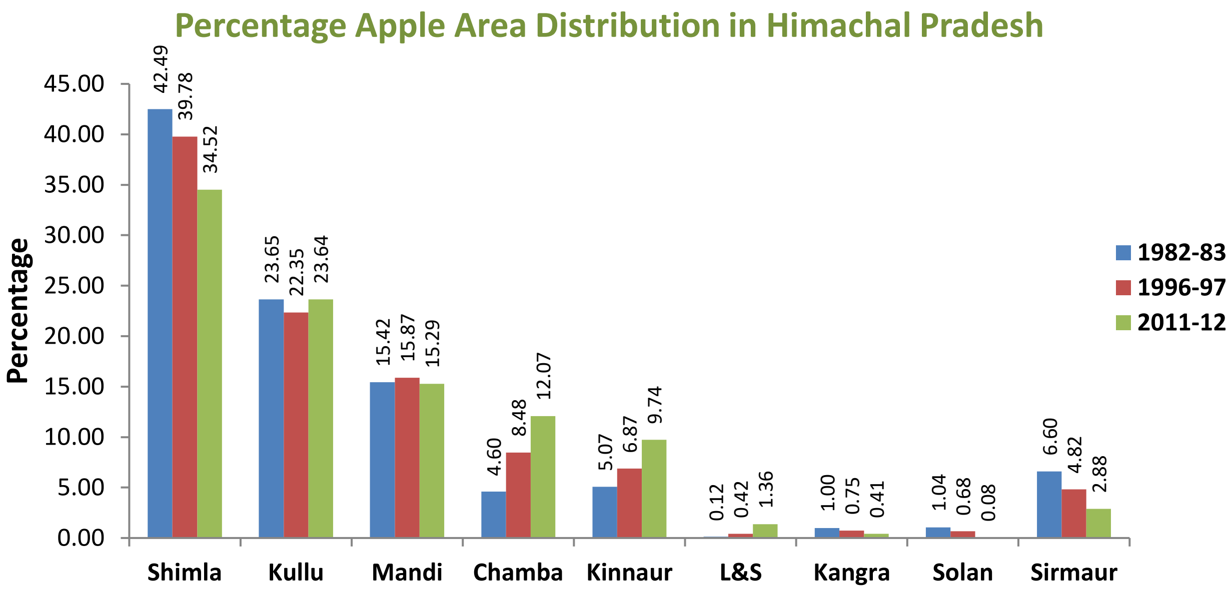


Fig.10 Percentage Apple area (of the total Apple Area in Himachal Pradesh)

Figure 10 presents the district wise percentage apple area trend in Himachal Pradesh. Figure 10 clearly points out that Shimla share in apple area is falling. Shimla apple area in 2011-12 was 34.78 percent in the total apple area of Himachal Pradesh. A significant fall compared to the year 1982-83. However, it is notable that the fall in Shimla share in total apple area is not due to falling absolute apple area in Shimla (Fig.11). This is attributed to rapid growth of apple area in other districts. For instance, compared to 1982-83 apple area increased by 119 percent in 2011-12 in Himachal Pradesh but in Shimla it increased only by 78 percent reflecting that Shimla was losing its share in total apple area. Kullu and Mandi roughly maintained their share in total apple area by keeping their growth rate of apple area close to the growth rate of total apple area in Himachal Pradesh for the period 1982-83 to 2011-12. Chamba, Kinnaur and Lahaul and Spiti (L&S) share in total apple area increased significantly during the period 1982-83 to 2011-12. This indicates that in Chamba, Kinnaur and Lahaul and Spiti (L&S) growth of apple area was at a faster rate compared to Himachal Pradesh total apple area. Kangra, Solan and Sirmaur share in apple area kept falling during the period 1982-83 to 2011-12. Kangra, Solan and Sirmaur also witnessed absolute fall in apple area in 2011-12 compared to 1982-83 (Fig.11) indicating that farmers were shifting away from apple production in these districts.

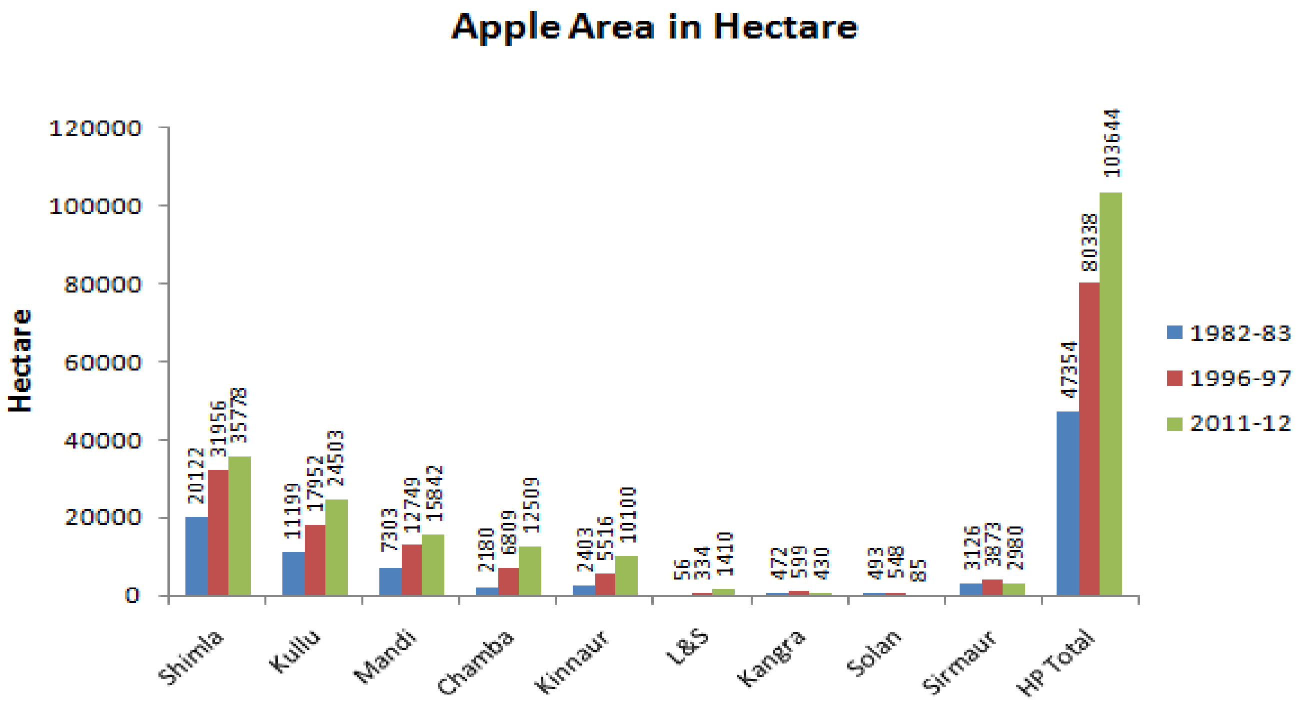


Fig.11 District Wise Apple Area Trend in Himachal Pradesh (in Hectare)

Figure 12 presents the districts share in apple production. Although these are point estimates[10] of the year 1982-83, 1996-97 and 2011-12, still we can see some clear trends. For instance the share of Kullu, Mandi and Chamba in total apple production had gone down in 2011-12 compared to 1982-83. As discussed above,Kullu and Mandi share in total apple area roughly remained constant still their share in total apple production had shown a falling trend (Fig.12). Moreover, though Chamba share in total apple area had shown an increasing trend but its share in total apple production had gone down in 2011-12 compared to 1982-83 (Fig.12). Kinnaur share in total apple production had shown a rising trend (Fig.12). The rise in Kinnaur share in total apple production is relatively higher than the rise in its share in total apple area.

[10] If apple production was abnormal in any of the districts during the reference year then point estimates may give us misleading results.

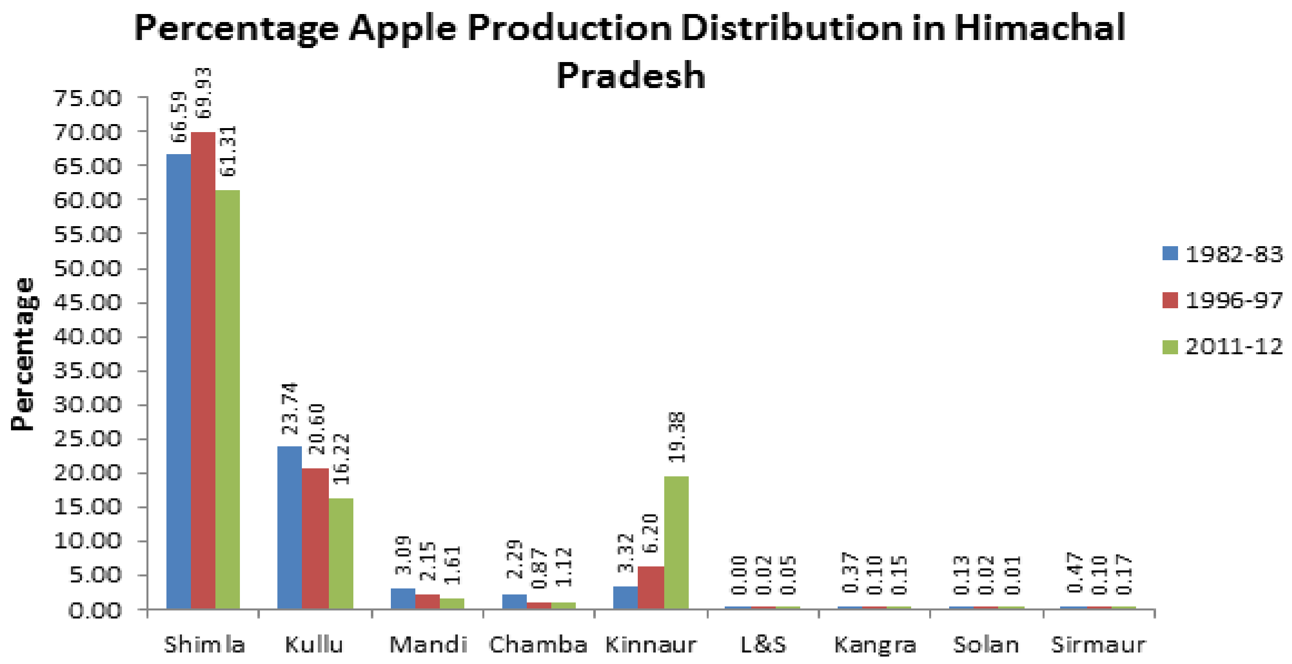


Fig.12: Percentage Apple Production (of the total Apple Area in Himachal Pradesh)

Prima facie the above discussion suggests that the apple area, production and yield were shifting over the period of time across Himachal Pradesh. In the next section we discuss the methodology to detect the shift in apple belt in terms of average yield by means of time series analysis.

5.3. Methodology

Binary Segmentation (BS) is arguably the most established search method used within the change point literature. Early applications include Scott and Knott (1974) and Sen and Srivastava (1975). In essence the method extends any single change point method to multiple change points by iteratively repeating the method on different subsets of the sequence. Binary Segmentation first applies a single change point test statistic to the entire data, if a change point is identified the data is split into two at the change point location. The single change point procedure is repeated on the two new data sets, before and after the change. If change points are identified in either of the new data sets, they are split further. This process continues until no change points are found in any parts of the data (Killick and Eckley, 2013; Killick*et al.*, 2012).Our objective of this section is to see whether the average yield had remained constant, shifted down or had gone up. Therefore, this methodology is suitable for our analysis since it detects multiple breaks in time series data. It is possible that in few districts yield had gone down, in few districts yield may have gone up and in the remaining districts no shift occurred in the mean apple yield. Moreover, it is also possible that few districts may have witnessed multiple breaks in the mean apple yield may be only positive reflecting improvement in yield or only negative reflecting falling yield or a mix of this. A limitation of this study is that we have only 30 observations of yield data. Next section we present our empirical finding based on binary segmentation analysis for mean break.

5.4. Empirical Results

We try to see whether mean yield of apple had remained constant or it has been changing over time. We apply the Binary Segmentation method to the apple yield data for the period 1982-83 to 2011-12 to identify the change point in means of annual yield of apple across Himachal Pradesh districts. Mean shift and results of change point in mean are summarized in table 17.

Table.17 Change Point in Mean Apple Yield for the Period 1982-83 to 2011-12

District/State	First Change Point	Second Change Point	Third Change Point	Fourth Change Point	Fifth Change Point	Sixth Change Point
Shimla	1985-86(+)	1992-93 (-)	1998 -99(-)	2001-02 (+)	-	-
Kullu	1984-85 (+)	1993-94 (-)	1996-97 (+)	1998-99 (-)	2001-02 (+)	2005-06 (-)
Mandi	-	-		-	-	-
Chamba	-	-		-	-	
Kinnaur	2002-03 (+)	-		-	-	-
Lahaul and Spiti (L&S)	-	-	-	-	-	-
Kangra	2002-03 (+)	-		-	-	-
Solan	-	-	-	-	-	-
Sirmaur	-	-		-	-	-
Himachal Pradesh	1993-94 (-)	2002-03 (+)		-	-	-

Note: The (+) and (-) sign in parentheses represents acceleration and deceleration. (-) represents no change point.

The results of shift in mean highlights that in Himachal Pradesh average yield of apple went down after 1993-94 and remained low till 2002-03. After 2002-03 Average yield has improved significantly in Himachal Pradesh. The average apple yield in Himachal Pradesh was 4.51 Mt/ha during 1982-83 to 1993-94 which became nearly 3 Mt/ha during 1994-95 to 2002-03 was, a significant fall. Awasthi et *al.* (2001) rightly pointed out that that although the production of apple was increasing but the productivity was falling. For the period 2003-04 to 2011-12 average apple yields in Himachal Pradesh had become nearly 5 Mt/ha which reflects a significant improvement compared to 1994-95 to 2002-03 period.

The falling yield of apple was also visible in Shimla. Shimla is the largest contributor in apple Production and average yield in Shimla started falling after 1992-93. Shimla average apple yield further went down after 1998-99. The average yield of apple in Shimla improved only after 2001-02. For the period 2002-03 to 2011-12 average apple yields in Shimla was above 9MT/ha. It is important to note that in Shimla in the year 2002-03 area under apple came down by 22 percent compared to 2001-02[11]. In 2001-02 area under apple was 35,905 hectare which came down 27,678 hectare in 2002-03. It appears that low yield apple orchards were cut down in Shimla in this year which significantly improved the yield in this district after 2001-02. However, after 2002-03 area under apple started increasing and in 2011-12 it stands at 35,778 hectares which is still lower than 2001-02 level.

In Kullu also average apple yield was falling in 90's. However no clear conclusion can be drawn for Kullu as the mean was shifting frequently. The last break in average yield occurred in the 2005-06 in Kullu after which Kullu average yield had shifted down to 4 Mt/ha for the period 2006-07 to 2011-12. The average apple yield in Kullu prior to this break was more than 5.5 Mt/ha for the period 2002-03 to 2005-06. Kullu never witnessed any downward shift in area under apple during the period of analysis. The average apple yield had remained constant in Mandi which is close to 1 MT/ha; very low compared to Himachal Pradesh apple yield. However, the area under

[11] In the year 2002-03 area under apple in Himachal Pradesh came down by 12 percent compared to 2001-02.

apple in Mandi district has increased significantly from 7,303 hectare in 1982-83 to 15,842 in hectare in 2011-12. Despite, low yield the area under apple is growing in Mandi and had nearly maintained its share in total apple area (15 percent) in Himachal Pradesh for the period of analysis. The reasons for growth in apple area in Mandi with relatively very low yield compared State average needs to be investigated in depth.

Kinnaur and Kangra witnessed improvement in apple yield in the year 2002-03. Although Kangra had witnessed upward shift in apple yield after 2002-03, still the apple yield in Kangra post acceleration is very low; nearly 1 MT/ ha. Prior to 2003-04 i.e. for the period 1982-83 to 2002-03 average apple yield in Kangra was nearly 0.40 MT/ha. A look at the apple area data in Kangra suggests that apple area in Kangra fell sharply after 2001-02. In 2001-02 apple area in Kangra was 603 hectare which stands at 430 hectare in 2011-12. Therefore, probably low yield orchards in Kangra were removed after 2001-02 and which improved the apple yield in that district. After 2002-03, Kinnaur average apple yield has increased by nearly 2 MT/ha. For the period 1982-83 to 2002-03 average apple yield in Kinnaur was 3 MT/ha which shifted to nearly 5 MT/ha after 2002-03.The area under apple had also been growing in Kinnaur and share in total apple production had also increase significantly over time.

Table.18 Geophysical Profile of Apple Growing Districts of Himachal Pradesh

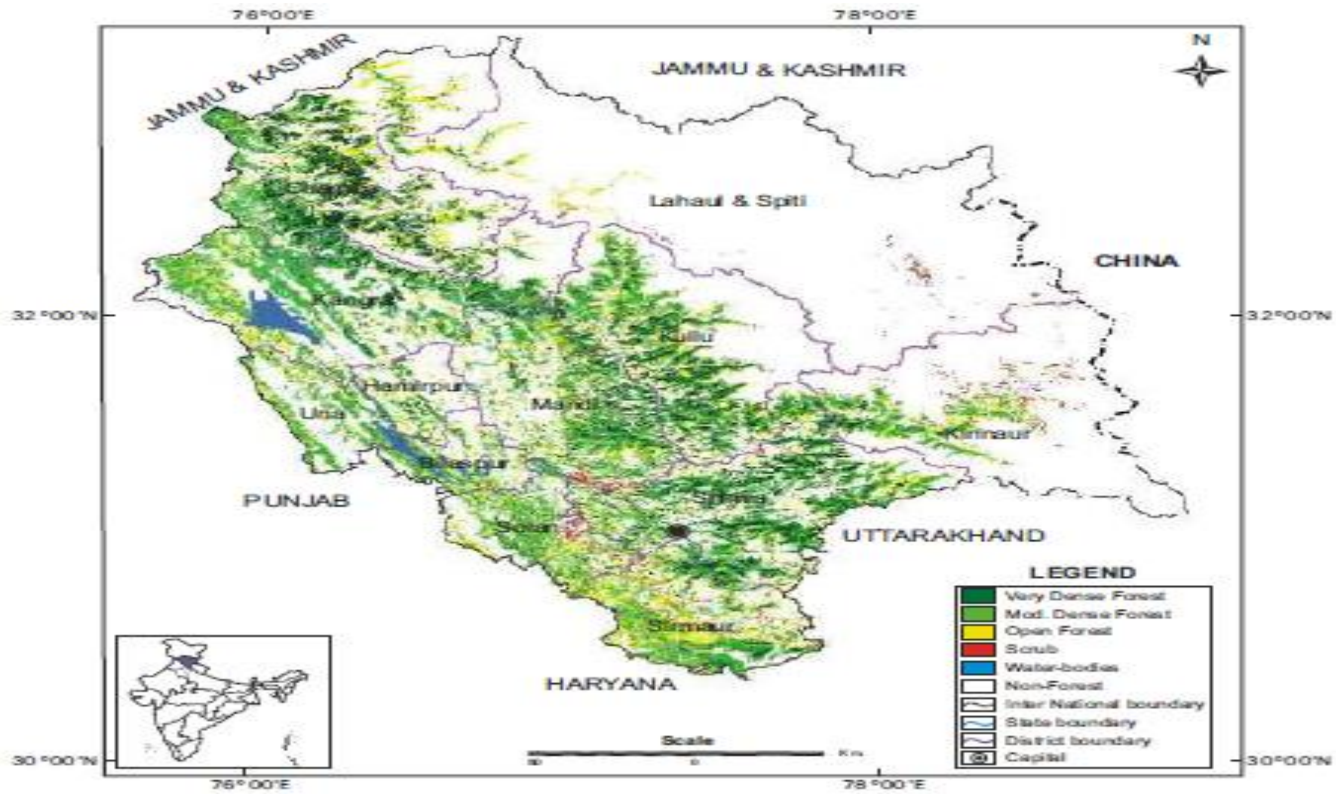
District	Altitude (height from MSL in mts.)	Climate
Shimla	1500- 3200	Cold temperate and Warm temperate
Kullu	1500-4800	Alpine, Cold temperate and Warm temperate
Mandi	1200-3000	Warm temperate
Chamba	1000-5000	Alpine, Cold temperate and Warm temperate
Kinnaur	1800-4800	Sub-arctic, Alpine and Cold temperate
Lahaul and Spiti	3000-4500	Sub-arctic and Alpine
Kangra	500 to 1000 and 3000 to 6000	Cold temperate and Warm temperate
Solan	300-2100 to 150 to 1500	Warm temperate and Sub tropical
Sirmaur	300-450 to 3000-3300	Warm temperate and Sub tropical

Source: State of Environment report Himachal Pradesh, Department of Environment, science and Technology, Government of Himachal Pradesh, (2009).

Table 18 presents the altitude and climate for nine districts. The table highlights that Kinnaur lies on relatively higher altitudes and possess sub-arctic, alpine and cold temperate climate. The rising increase in yield and increasing area in this districts points out that this region may be becoming more conducive for apple cultivation.We find that apple belt in Himachal Pradesh had shifted over time in term of area and production. We further find that in 1990's apple yield went down in Himachal Pradesh. In Kinnaur the yield has increased by more than 2 MT/ha and area under apple had also increased significantly in this district. This indicates that apple cultivation is becoming more profitable at higher altitudes and in sub-arctic, alpine and cold temperate climate. The rising apple area in Chamba and Mandi despite low productivity is an area which needs to be investigated during primary survey. It is important to understand the drivers of rising area under apple in these districts and why farmers are not switching to other crops. In Lahaul and Spiti despite constant lower yield area under apple is rising. There also the reason for this needs attention during primary survey. Since, the limitation of our data and method does permit us to understand the changes in the apple quality and diseases. Therefore, farmers should be also interviewed on these issues.

Forests in Himachal Pradesh

The total area under forests in Himachal Pradesh is 37,033 sq km which is 66.52 % of the total geographical area of the state (SFR, 2013). The Forest Cover of the state is shown in map 40. The forests in Himachal Pradesh have been classified on an ecological basis as laid down by Champion and Seth (1968), and can be broadly classified into Coniferous Forests and broad-leaved Forests. Distribution of various species follows fairly regular altitudinal stratification. The vegetation varies from Dry Scrub Forests at lower altitudes to Alpine Pastures at higher altitudes. In between these two extremes, distinct vegetation zones of Mixed Deciduous Forests, Bamboo, Chil, Oaks, Deodar, Kail, Fir and Spruce, are found.The richness and diversity of our flora can be gauged from the fact that, out of total 45,000 species found in the country as many as 3,295 species (7.32%) are reported in the State. More than 95% of the species are endemic to Himachal Pradesh and characteristic of Western Himalayan flora, while about 5% (150 species) are exotic, introduced over the last 150 years.The forest wealth in the state is extremely diverse as a result of the huge variation in the topography of the state.

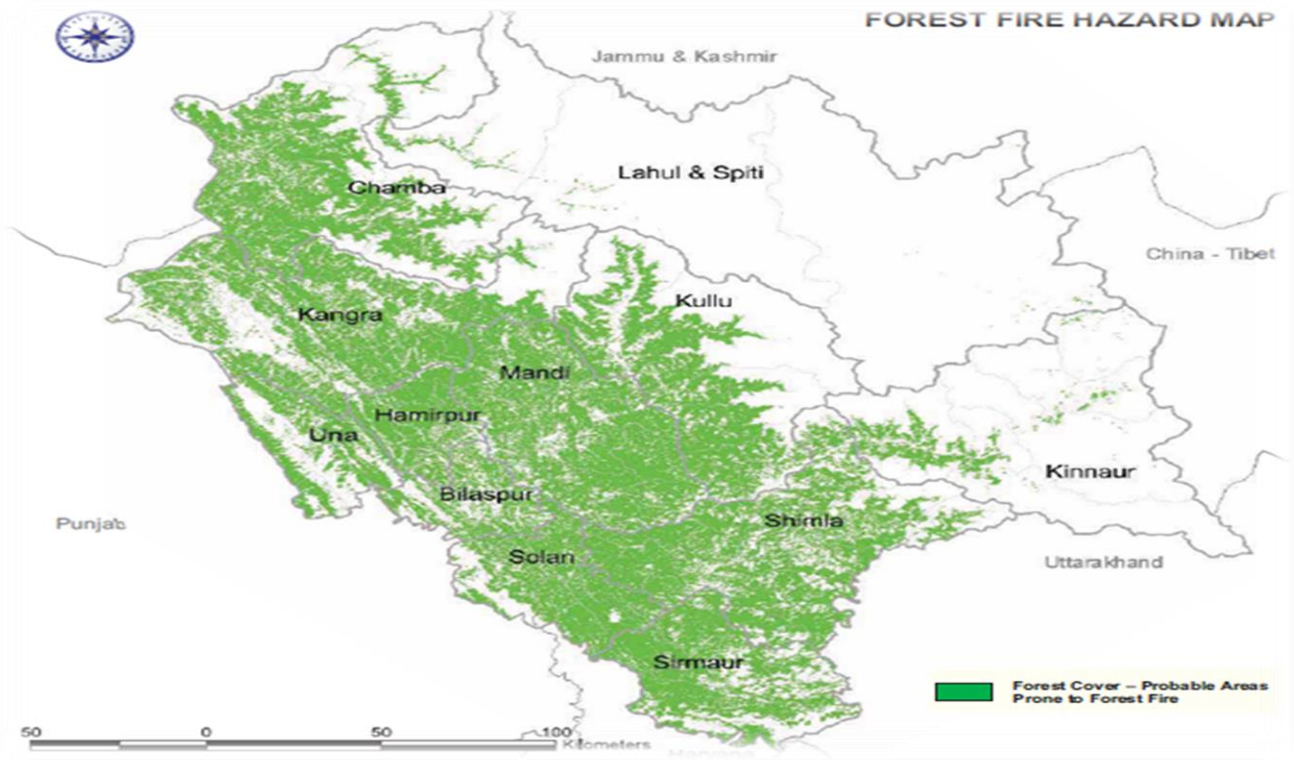


Map 40. Forest Cover Map of Himachal Pradesh
Source: State of Forests Report, 2013

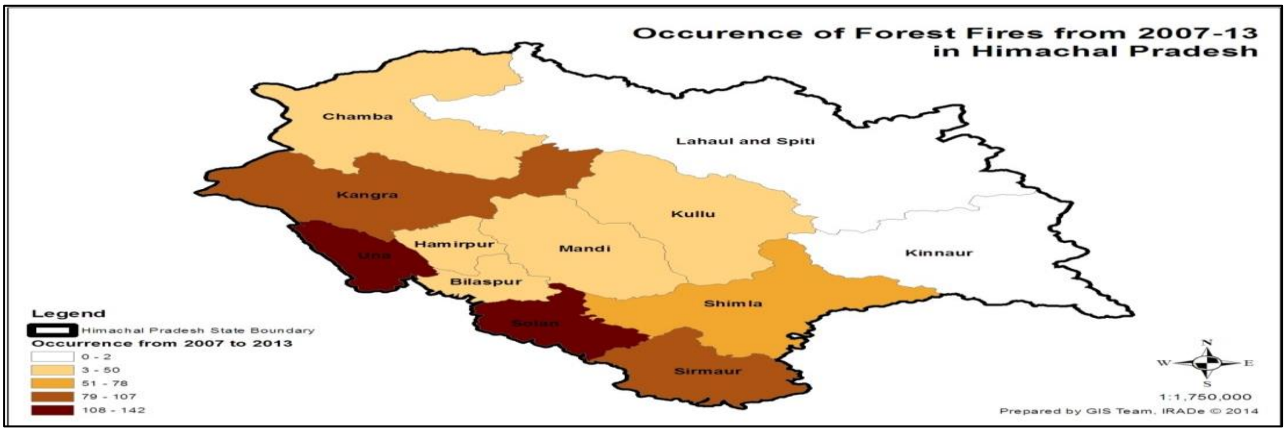
Due to the impact of biotic pressure on the forests, many forest areas spread across the state has been depleted and degraded which is a serious concern (SFR, 2009).The rapidly changing climatic conditions make plant species more prone to disease and pests, contributing to the degradation and fragmentation of forests. Mountain ecosystem is highly vulnerable to climate change and there may be a large shift in the vegetation boundary, large scale forest dieback or mortality may occur in the transient period. Likewise the species which are already threatened are at greater risk and some of the species are currently classified as critically endangered. The forests are also affected by fire, grazing, pest and invasive species and are also the primary targets for agricultural and urban expansion.

6.1. Forest Fire in Himachal Pradesh

In the recent years, forest fires have increased enormously due to human induced factors. Approximately, 90% of the forest fires are human induced, both intentional and unintentional. Most of the forest fires are caused by negligence and poor knowledge of the people. Collections of forest produce, shifting cultivation, throwing smouldering smoking products are the basic anthropogenic causes that ignite forest fires.



Map 41. Forest Fire Hazard Map of Himachal Pradesh



Source: Climate Vulnerability Atlas

Map 42. Occurrence of forest fires 2007-13
Source: Prepared by IRADe

According to the Forest Survey of India, an average of 54.7% of forests are affected by fire and more than 95% of the forest fire incidents in India are human caused (Srivastava; 1999).

In comparison with other parts of the country, the forests fire in the Himalayan region has been increasing due to various biotic and geographical reasons. The forest of Himachal Pradesh is rich in vascular flora, which forms the conspicuous vegetation cover. But over the years the forest wealth of the state is being destroyed by the incidences of frequent forest fire attributed to both anthropogenic and other reasons (table 18 presents the no of cases of forest fire in last 3 decades and areas affected). The destruction of rich flora and fauna of the state due to forest fires will have serious repercussions on the ecological balance of the state. Forest fires that are natural or manmade play a significant role in ecosystem dynamics. Forest fire is important cause for forest degradation and it is most important factor that affects natural regeneration in the forests.

Table 18: Forest Fire Incidences in Himachal Pradesh

Year	No. of Cases	Area Burnt (in ha.)
1980-81	478	21646
1981-82	64	1283
1982-83	22	358
1983-84	46	960
1984-85	1497	50364
1985-86	325	7713
1986-87	33	310
1987-88	123	3243
1988-89	821	20854
1989-90	168	2292
1990-91	115	1447
1991-92	532	6325
1992-93	325	7779
1993-94	586	10170
1994-95	1706	10850
1995-96	1669	53174
1996-97	240	6052
1997-98	67	2174
1998-99	533	8128
1999-00	1900	36887
2000-01	362	6216
2001-02	104	1684
2002-03	818	12828
2003-04	697	12303
2004-05	400	6319
2005-06	Not Available	Not Available
2006-07	270	5170
2007-08	550	8393
2008-09	1039	13358
2009-10	1852	23935
2010-11	870	7837
2011-12	168	1758

Source: Forest Department, Himachal Pradesh

6.2. Climate Change and Forest Fire

When vegetation burns, the resulting release of stored carbon increases global warming. The black carbon that is released into atmosphere by fires causes global warming. Forest fires causes global warming by three ways, first, fire releases large quantities of carbon into the atmosphere through the combustion of plant material and surface soil organic matter, second, fire killed vegetation decompose over time emitting carbon and third, the vegetation on newly burned sites may not absorb as much carbon from the atmosphere as the decaying vegetation emits. Thus, fires are an important part of the global carbon cycle (Forest Disaster Management; 2012).

Forest fires in India have environmental significance in terms of tropical biomass burning, which produces large amounts of trace gases, aerosol particles, and play a pivotal role in troposphere chemistry and climate. Thus, there is a need to carry out operational fire monitoring to concerns over the loss of forests and effects of widespread burning on global atmosphere. Among the various tropical forests in the Indian subcontinent deciduous forests are largely prone to forest fire and account for approximately 40% of all forest fire. Forest Survey of India showed that on average of 54.7% of forestis affected by fires and 72.1% of the forest area is subjected to grazing. Annually 3.73 million hectares of the forest area are burnt, resulting in economic losses of approximately USD 110 million in India.

Table.19: Types of Forest and causes of forest fire

State Profile	Forest Type	Fire Situation & Seasons	Causes of Forest Fire	Prevention & Preparedness
Hilly terrain, including snow covered high peaks and glaciers. Climate varies from Temperate to Alpine Cold. Annual rainfall- 900 mm.	Around 26.35% of GA under forest covers. Forest types; Tropical deciduous, Tropical thorn, Moist Temperate and Sub Alpine to Alpine.	Main fire season is between March to June. Forest fires are annual phenomena in the State; the major fires took place during 1995 and 1999. During 1995 forest worth Rs. 1750 million was lost due to fire.	Main causes are manmade such as; Collection of fuel wood, NTFP collection, shifting cultivation, throwing burning smoking products, burning Farmresidues are some of the common causes in HP.	Forest department has taken many initiatives under Forest Fire Control Scheme of Central govt.

Source: Forest Disaster Management; 2012

More than ninety five percent forest fires are caused either by the negligence or unknowingly by the human being (table 19). People have been clearing and burning forests for shifting cultivation and forest continue to burn. Forest fires are calamity that causes damage to the forest economy which is considerably greater than all damages caused by the harmful insects and diseases. Its cause’s substantial damage whether caused by natural or anthropogenic factors. Grazing and fire are linked to plant invasions. Gaps created by high-intensity fires are particularly susceptible to invasion by exotic species e.g. Imperata cylindrica quickly recovers after fire and may respond with an increase in cover. Invasive species depletes the biodiversity of an area through allelopathic path ways.

Therefore the problem of controlling forest fire is making its important place in issue of economic development. So there is a need for rethinking the forest policy and making adjustment between forest policy and human activities.

6.3. Increase in Invasion by alien species

Out of total 37,033 Sq KM forests area in Himachal Pradesh 6506 Sq Km forests are under Tropical and Sub-Tropical Forest (H.P forest department). Mainly in these forests biological invasions (due to anthropogenic or climatic factors) are posing threat to native biodiversity, result in changing the structure and composition of the community by hindering the ecological successions in the forests and affect the ecosystem services. The alien species invading forests land in the state are:

- **Lantana camara:** This Tropical American species belongs to family Verbenaceae and has been declared as Weed of National Significance by more than 60 countries across the globe. It has come to occupy almost all the forest and non-forest areas in the sub-tropical belt in the State. It is one of the most important invasive alien species of Himachal Pradesh Forests badly affecting the native floral diversity, availability of grass. Moreover Lantana is highly combustible species and hence, the increase in presence of Lantana in forests makes them vulnerable to fires.Tropical and sub-tropical lands are the main invasive grounds for Lantana.
- **Parthnenium hysterophorus L. (Carrot Weed, Congress Grass, Gajar ghas,):** It is a member of family Asteraceae and a native species of Tropical America, Parthnenium is an aggressive invader of degraded areas having inadequate ground cover and exposed soil such as agricultural fallows, wastelands, roadsides, soil dumps, overgrazed pastures and degraded forests. Apart from causing severe ecological impacts Parthnenium causes serious health hazards (allergic reactions) in human beings.
- **Ageratum Conyzoides L. (Goat Weed, Neel-phulnu):** It's a member of family Asteraceae and native of Tropical America. It has agricultural fields, wastelands, plantations, pastures and all forest types, thus has threatened all the indigenous vegetation in the State.
- **Eupatorium adenophorum Sp. (Crofton Weed):**It's a native of Mexico and member of family Asteraceae. It causes infestation in wastelands, fallow lands, degraded forests and forest fringes impacting growth of indigenous species negatively. The weed causes allergies and other potential health hazards in human and animals.

The poorly managed agricultural lands, fallow lands, wastelands, pasture lands, degraded forest cover and land cover are most vulnerable to weed invasions. The tropical and sub-tropical areas of Himachal Pradesh are invaded by all the above mentioned alien species which has affected the quality of forest and pasturelands. The weed infestation is increasing at a very faster rate and the "speed of spread" is an issue of concern (Himachal Pradesh State Forest Department).

6.3.1. Extent of Invasion:

As per the H.P state forest department survey Lantana alone has invaded 1.5 lakh hectares of forest lands. The other main exotic weeds -Parthnenium, Ageratum, Eupatorium have been recorded to occur over 0.50 lakh hectares of forests, especially pastures. The invasion of exotic weeds in different forest circles is shown below:

Table 11 Invasion of exotic weeds in different forest circles of H.P

Circle	Forest Area under the Invasion of				
	Lantana	Ageratum	Parthnenium	Eupatorium	Total
Nahan	21,456.99	4,302.51	4,260.73	595.87	30,616.10
Bilaspur	55,941.55	0.00	0.00	0.00	55,941.55

Mandi	7,900.00	2,360.00			10,260.00
Hamirpur	12,680.00	0.00	0.00	0.00	12,680.00
Dharamshala	47,403.00	12,810.00			60,213.00
Shimla	4,060.89	0.00	1,100.00	0.00	5,160.89
Rampur	0.00	0.00	0.00	0.00	0.00
Chamba	4,631.77	132.91	68.50	85.40	4,918.58
Kullu	575.70	0.00	284.30	137.25	997.25
WL (S)	475.06	683.98	611.44	190.50	1,960.98
WL (N)	1,160.00	54.00	0.00	1,239.00	2,453.00
WL (GHNP)	0.00	0.00	0.00	0.00	0.00
	156,284.96	**20,343.40**	**6,324.97**	**2,248.02**	**185,201.35**

*Source: H.P Forest Department,*http://hpforest.nic.in

The invasion of exotic weeds is also prominent on road sides and waste land. More than 80% of the exotic weed infestation along road sides is on account of *Parthenium*, *Ageratum* and *Eupatorium* (H.P Forest Department).The rate at which these species are invading is an issue that has emerged from the recent survey of forest department invasive alien species, with more than 40% of the infestation reported as having taken place over the past decade only. There being little control over the various extraneous factors contributing to the spread of exotic weeds, viz. cutting of lands for roads and projects, muck dumping, uncontrolled grazing, innate biological traits of weeds, etc. the infestation is still continuing at an alarming rate.

6.4. Non Timber Forest Product (NTFPs)

The geographical location of Himachal Pradesh, a north-western Himalayan state, with agro climatic zones varying from sub-tropical towards its boundary with Punjab and Haryana and temperate in the middle Himalayan zone to alpine in the inner Himalayas, endows it with a rich and unique natural diversity. In Himachal Pradesh NTFPs plays an important role in the day-to-day life of the people whether in the form of household use or as a source of cash income. NTFPs are defined as "all tropical forest product (plants and animals, or parts therefore), other than industrial timber, which are harvested for human use or self-support and for commercial purpose". This includes products which are used for as food, cosmetics (oils), herbs, aromatic substances and flavourings, feed for animals, medicines, ornamental plants, paint and rubber, and also animal products , for food, medicines, trophies and international trade (Rijsoort, 2000). However, NTFPs have become a major source for employment and income generation due to several reasons; Firstly, NTFPs is viewed as a means of improving the rural economy and the livelihood of the rural economy. Secondly, rural communities basically rely on a variety of plant and animal species for their livelihoods. In other words the variety of miscellaneous forest has been providing an immediate and direct use in the day-to-day life of the people. Thirdly, many species that yield NTFPs are assumed to be potential sources of new genes as well as new products and it is used as a raw material for and pharmaceutical industries.

6.4.1. Sources and categories of Non Timber Forest Product (NTFPs)

NTFPs are an important source of livelihood for forest-based poor people in Himachal Pradesh. NTFPs include fodder and grasses; raw materials like bamboo, cane and babbar grass; herbal medicinal plants, leaves, gums, waxes, dyes and resins; and many forms of food including nuts, wild fruits, roots, honey and etc. Sources or species of NTFP could be categorized into Edible plant products, Edible animal products, Medicinal products, Non-edible plant product and Non-edible animal products. However, this can be further sub categorized which is showed in below (table 21).

Table 21: Categories and Sources of NTFPs

Categories	Sources
Plant products	Edible oils, Herbs, Spices, Bamboo shoot, Fodder, Rattan, Bamboo, Ornamental plants, Gums and Resins, Tannins and Dyes, Essential Oils and Fibbers and Flosses and leaves.
Animal products	Animal products (birds, honey), Insect products like (wax, lacquer, mainly collected), Silk, Horns, Ivory
Medicinal products	Plants and Animal products

6.4.2. NTFP Species with High Socio-Economic Impact

Having diversified from agriculture, the NTFP is assuming the prime role in raising the potential income of the people and important source of trading. The villagers collect most of these species (NTFPs) from the forests and alpine pastures of the state. Collection and selling of these species and medicinal plants (NTFPs) occupy an important place in the household economy in some parts of rural Himachal Pradesh.

6.4.3. Contribution of HMPs (Herbal Medicinal Plants) in the Rural Economy

HMPs are the important source of income and livelihood in Himachal Pradesh. Dependence on Medicinal plants varies from region to region depending upon the nature of forest, nature of terrain, and cultivable land and accessibility of that particular area. It has been observed that the dependence on medicinal plants and other non-timber forest produce is comparatively more in those areas where food and cash crops do not grow sufficiently due to soil and other factors; and also in those remote areas where orchards are not profitable due to high transport cost. These types of regions mostly fall either in high hill areas or in the alpine zones (Nandi, 1999).The extraction season for medicinal plants starts in the month of March. The collection of different species in different areas continues for three to four months. Children and women are involved in collecting the medicinal plants. Nandi (1999) found in her research that the commercial extraction of herbs depends on several factors; (a) the herb should be available abundantly, so that the villagers can collect and sell it to the local traders. If the herb is scarce in that case the trader would not be interested to buy that particular item from that region. As a result, the villagers collect those herbs only for home uses, if necessary, (b) the traders should be known about the availability of a particular herb, and (c) Price of the herb at village level should be economically profitable to the villagers so that they can extract that item from the forest. Table 22 below shows the year wise quantity (in quintal) of Medicinal Herbs collected by the rural households.

Table 12: Quantity of medicinal herbs collected in H.P

Name of Species	1987-88	2000-2001	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13
Muskbala/Nihani	499.14	1023	315	455	471	163	196	105
Dioscorea	2071	9						
Neoza		303	597	291	481	167	227	303
Patlain roots		530	1040	406	623	306	160	39
Dhoop	5927.35	399	96	75	106	15	24	7
Riyondchini			--	125	123	14	24	--
Thuth	463.5	87	43	43	62	7	19	1
Kaur/Karu	1243.47	68	265	418	287	156	58	12

Gucchi	1280.34	50	11	8	15	7.3	17	13
Bankakri	1.38	3	--	315	112	101	18	4
Kakarsingi	173.06	10	8	96	1	4	1	--
Bhutkesi		12	101	25	36	192	31	21
Mithi Patish/MithaTelia	122.63		--	5	--	--	7	22
Kauri Patish	4.51							
Kuth		50	--	22	--	--	20	--
Berberies roots			4521	--	10418	9921	5171	600
PathanBel			841	590	400	492	675	190
Chukri/Rewardchini		462	348	69	200	40	78	12
TalisPatra		313	24	35	4	6	23	--
Bach	67	45	4	2	--	--	18	--
Rhododendron Flower			41	329	352	495	112	77
Birch/ Bhojpatra	138	32	556	158	25	--	--	--
Marrygold				--	100	90	--	200
Somlata			360	270	--	120	--	101
Mousgrass			--	--	--	67	2	--
Brans Flower			--	--	--	7	--	--
Bitherpatta			--	--	--	6	--	--
Bichhubutti			--	--	--	10	--	--
Kaparkachari			--	--	--	18	--	--
AltimisiaChhamber			--	--	--	2	--	--
Nagchatri			--	--	--	--	31	--
Chariyata			--	--	--	--	26	--
Brahmi	562.65	275	--	--	--	--	7	--
Datishan root			239	--	--	--	--	--
Chalora			8	--	--	--	--	--
TejPatta	83.31	680	--	--	--	--	--	215
Horse chestnut			--	--	--	--	--	180
Banafsha	84.05	4						
Dorighas	167	1027						
Jarka	59.7							
Baryan	116.4							
Balchhar	7.2							
Rakhal			--	--	--	--	--	35
Nihani	4							
Viola flowers	32.85							
Kail Cones	641							
Kala Zira	18.23							
Panja	16							
Salam misri	65.2							
Anjwan	65.6							
Lichens								
Marigold		2194						
Berberries roots	450	6135						
Patishan Roots		767						

Mehandi		692						
Ephedra		349						
Sath Jalari		246						
Baryan/Bajh		32						
Chora		51						
Others	700.6	3883	93	22	121	--	--	111
Total	15717.64	19719	9511	3759	13937	12406.3	6945	2532

Source: Himachal Forest Department

The quantity of HMPs collected in various years given in table does not show any particular trend but it has been observed that prices of medicinal plants and increase in awareness about their market value among the local people are the important factors that affect the collected quantity, availability and distribution of the medicinal herbs. Excessive extraction by human, forest fires and invasion by alien species negatively affect the availability and distribution of medicinal plants and herbs in the Himalayan regions, for example *Terminalia chebula, T. bellirica, T. tomentosa* which are having highly commercial and medicinal value respectively and are facing severe problems due to forest fire leaving behind poor stocking. Species like *Lantana camara, L. indica, Eupatorium glandulosum, Parthnenium hysterophorus*, Cassia tora; C occidentalis, etc. have invaded several of the significant sites of forest biodiversity conservation and are posing a threat to the native biodiversity. Source: (Parashar Amit, Biswas Sas, The impact of forest Fires on Forest biodiversity in the Indian Himalayas).

Socio-economic vulnerability assessment

Primary survey was conducted in 5 districts of Himachal Pradesh to asses the socioeconomic vulnerability to climate change. The purpose of the survey was to capture the status of local socio-economic and ecological conditions, climate variability and trends, perceived changes and impacts especially in terms of livelihood of the local people. The study employs a mixed method- qualitative and quantitative, to explore the multiple aspects of the study. The primary survey used structured questionnaire for local community,interviews,desk study, field observations and focus group discussions. An integrated questionnaire covering demographic profile, socio-economic characteristics and dominant natural disastersaffecting the local people's livelihood was used in five districts namely **Shimla, Kullu, Mandi, Kangra and Chamba.** The structured questionnaire included questions on socio-economic parameters, agriculture and livelihood, climate change perceptions, evidences of climate change impact and indigenous coping mechanisms.During the field visit IRADe's project team interacted withGovernment officials and Scientists in Himachal Pradesh to understand their views on the study theme. Table 23 enlists the officials with whom consultation and interviews have taken place during the project survey.

Table 23: List of officials with whom consultation was done

S. No.	Name and Designation	Address
1	Mr. Pramod Shah Divisional Horticulture Officer	Department of Horticulture, Bharmour. Contact no: 09418570508
2	Mr. Shiv Kumar Divisional Forest Officer	Forest division Bharmour, Bharmour, Chamba
3	Dr. M. Kirupashanka, IFS Divisional Forest Officer, Chamba	Forest Department Chamba Chamba. 0919418443600, kirupasha@gmail.com
4	Mr. ARM Reddy, IFS Chief Conservator of Forests, Chamba Circle	Forest Department Chamba Circle Chamba (H.P): 176310
5	Dr. Rajiv Raina Senior seed research officer, Programme Coordinator, S KVK Chamba	Krishi Vigyan Kendra, Chamba
6	Sh Rajiv Chandra Subject Matter Specialist Dept of Horticulture, Chamba	Dept of Horticulture, Chamba Saluni, Chamba. 09418041886
7	Dr. Rajinder Kumar Sharma District Horticulture Officer, Dharamshala	Department of Horticulture, Dharamshala, Kangra, 09418395034
8	Dr. Kamal Sheel Negi Subject Matter Specialist, North Zone horticulture Department, H.P	North Zone Controlling Office Horticulture Department.
9	Dr. Suresh Upadhyay Professor of Horticulture	CSK-H.P agriculture university Palampur, Kangra Contact no: 09418015729.
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7.1. Questionnaire Design

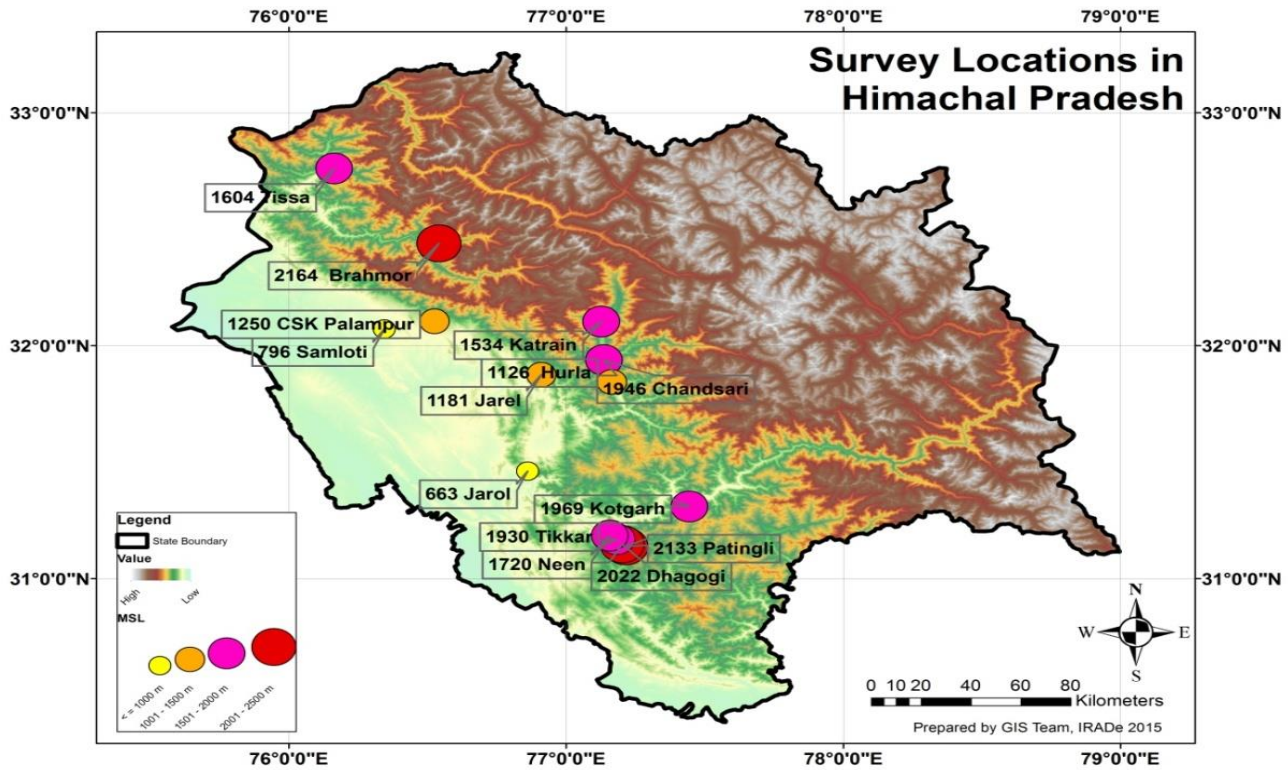
The survey was exploratory in nature as it sought to investigate the views of the farmers and agricultural workers on climate change and its impact on their livelihood. The central focus was to get an insight into the local perceptions about climate change and its impact on their sources of livelihood. A purposive sampling technique was used to select respondents (farmers or agricultural workers) in the afore-mentioned regions for the survey.

The household questionnaire for the study was categorised into 7 sections. Section 1 dealt with the general information of the household, occupation and issues of income and food. Section 2 focused on health sensitivity.Section 3 collected data on agricultural practices, and crop related information and constraints. Section 4 dealt with the livestock and related constraints Section 5 looked at the forestry related issues.Section 6 focused on markets and sales of farm produce and extension services availability andsection 7 dealt with losses due extreme weather events.

7.2. Sample Composition and Survey Locations

The primary survey was conducted in 5 selected districts of Himachal Pradesh *viz*.**Shimla, Kullu, Mandi, Kangra and Chamba**. As there is great altitudinal, regional and climatic variations within these five districts, IRADe team chose different altitude locations for primary surveys in these districts. The villages selected are given here as under and their respective locations are represented in the Map 43:

1. **Shimla:** Neen, Tikkar (Basantpur block), Patingali, Dhagogi (Masobra block), Kotgarh, Batari (Narkanda block)
2. **Kullu:** Hurla (Kullu block) Katrain (Nagar block), Chandsari (Nagar)
3. **Mandi:** Jarol (Sundernagar Block) Jarel (Padhar Block), Balha (Padhar)
4. **Chamba:** Bharmour, Jasorgarh (Tissa)
5. **Kangra:** Samloti



Map 43: Survey Locations in Himachal Pradesh

The above locations are categorized into four groups on the basis of their elevation. The data analysis for each group of survey location is done separately to bring out the impact of climate change at diferent elevations.

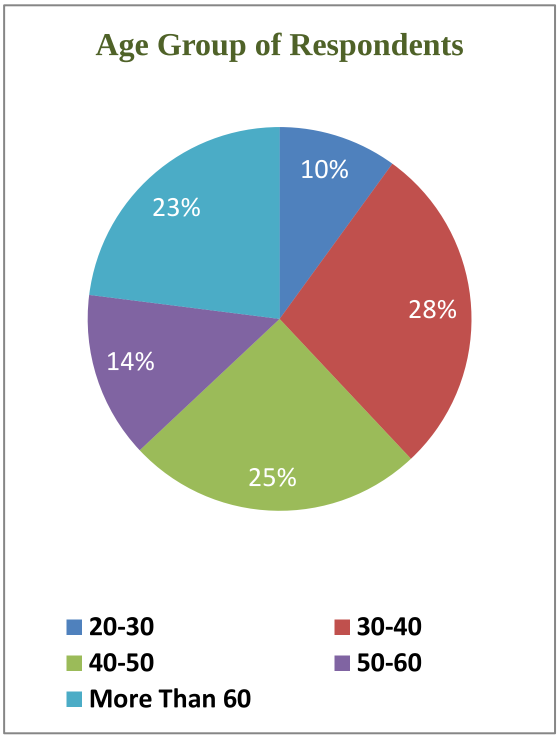
The different sets of elevation in which the survey locations are listed as following:

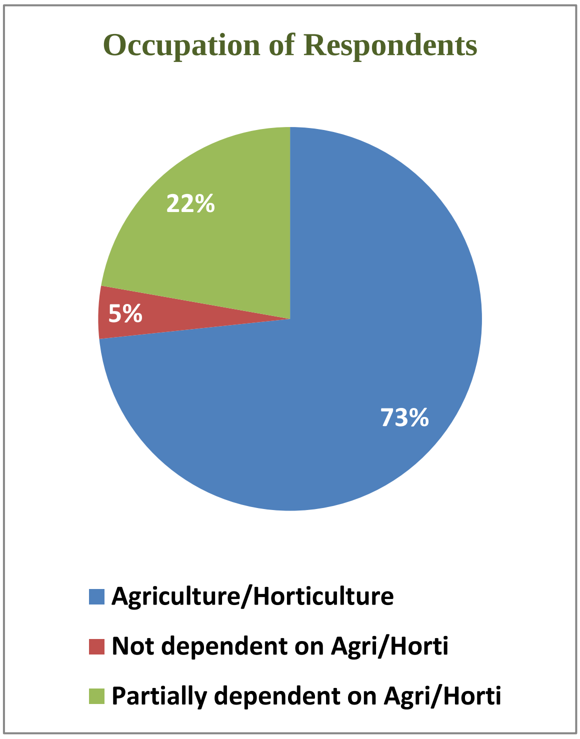
1) **<1000 m**
   - Village 1: Samloti, 796 m (District Kangra)
   - Village 2: Jarol , 663 m (District Mandi)
2) **1001m -1500 m**
   - Village 1: Hurla, 1126 m (District Kullu)
   - Village 2: Jarel , 1181 m (District Mandi)
3) **1501-2000m**
   - Village 1: Chandsari (1946 m, District Kullu)
   - Village 2: Katrain (1534m, District Kullu)
   - Village 3: Kotgarh (1969m, District Shimla)
   - Village 4: Neen (1720 m, District Shimla)
   - Village 5: Tissa (1604m, District Chamba)
4) **2001-2500m**
   - Village 1: Patingli (2133 m, District Shimla.
   - Village 2: Dhagogi (2022m, District Shimla)
   - Village 3: Bharmor (2164 m, Chamba)

A total of 200 household surveys and 15 focused group discussions (FGDs) were conducted. Also, 4 local agriculture and fruit markets were surveyed from the selected districts to analyse the impact of climate change on the local markets and livelihood of the people.

Samples were chosen from different age groups tohave a representative sample**(fig.5).** Maximum numbers of people interviewed werein the age group of 30 to 40 years which is 28% of the sample. The most important source of information for this study was local farmers as they are the most vulnerable group to climate change. In the sample 72% of the respondents were male and 28 % were female respondents.

66% of the respondents were found to be totally dependent on agriculture or horticulture sector while 20% were partially dependent on agriculture/ horticulture sector. Poor people having small land holdings between 0-5 bigha[12] consists of 40% of total respondents where as the proportion of rich farmers having land holdings more than 15 bigha was merely 13%. Figure 13 show the proportion of the respondents as discussed above.





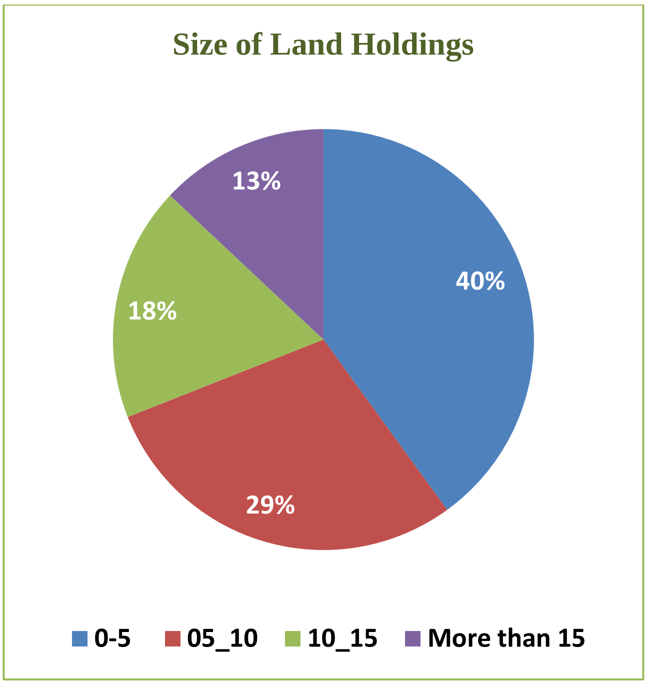


Fig.13: Distribution of sample households
Source: IRADe primary surveys, 2014

[12]5 Bigha is equal to 1 acre

7.3. Survey Findings

Based on the perception of the people and the survey observations the findings of the study are as discussed below:

7.3.1. Inadequate/ Insufficient irrigation facilities

In Himachal Pradesh agriculture/horticulture is mainly rainfed. As per the farmers the poor irrigation facilities is one of the major problem that they face in crop cultivation. Due to increased temperature the traditional sources of water (Kuhls, Baolis) have also dried up.The Kuhls built for irrigation in some areas have problems of leakage and are not maintained properly. In some areas (eg: Katrain, Kullu) people also complained that water is not being supplied regularly to the canals, whereas in some regions the old canals made by Britishers are damaged and needs maintenance. The people's response at various altitudes with respect to the availability of water for irrigation is shown in table 24:

Table 24: Farmers's response regarding availability of water

Range of Elevation	Sample 1: Elevation: <1000 m	Sample 2: Elevation: 1001-1500	Sample 3: Elevation: 1501-2000 m	Sample 4: Elevation: 2001-2500 m
Surveyed Locations	Village 1: Samloti, 796 m (District Kangra) Village 2: Jarol , 663 m (District Mandi)	Village 1: Hurla, 1126 m (District Kullu) Village 2: Jarel , 1181 m (District Mandi)	Village 1: Chandsari (1946 m, District Kullu) Village 2: Katrain (1534, District Kullu) Village 3: Kotgarh (1969, District Shimla) Village 4: Neen (1720, District Shimla) Village 5: Tissa (Chamba)	Village 1: Patingli (2133 m, District Shimla) Village 2: Dhagogi (2022m, District Shimla) Village 3: Bharmour (2164 m, Chamba)
	Response			
No of respondents in each sample dependent on agriculture/horticulture sector for their livelihood	85%	92%	97%	71%
Inadequate irrigation facility and less rainfall as a reason behind decreased agricultural productivity	80%	42%	13%	20%

As per the primary survey, at the lower elevations such as Hurla and Samloti majority of the respondents experienced decrease in rainfall and rise in temperatures during both summer and winters over the last 10-15 years which has further aggravated the situation of scarcity of water for irrigation. As per the respondents at higher altitudes like Kothgad, Katrain, Bharmor they have not witnessed severe change in rainfall pattern however they felt thatexpanding the irrigation facilities can play an important role in improving farm productivity.

The Kuhls and Baolis were serving the main purpose of irrigation so far but with increase in hot and dry spells, drying up of these sources has been observed. This has not only created problem in irrigation of crops but also in availability of drinking water in many areas like Hurla, Jarel, Chandsari. This has resulted in an increased workload on female members of the family because now they have to travel longer distances to fetch water for drinking and other household purposes. The majority of the surveyed households are solely dependent on the

Agriculture/Horticulture sector for their livelihood. Hence, lack of sufficient water for irrigation (behind which one of the reasons can be attributed to decreased rainfall with rise in summer temperature and increase in glacial flow due to climate change, increase in drought frequency) is making farmers more vulnerable.

7.3.2. Decline of Apple farming in lower altitudes and Increase in higher altitudes

Based on the people's perception the primary survey results related to major fruits' farming are shown in table 25:

Table 25: Farmers's response regarding horticulture activity

Range of elevation	Sample 1: Elevation: <1000 m	Sample 2: Elevation: 1001-1500	Sample 3: Elevation: 1501-2000 m	Sample 4: Elevation: 2001-2500 m
	% of Respondents			
Change in Area under fruits crops over last 10-15 years • Apple • Pomegranate • Plum	Apple not present	87% farmers in Kullu have cut their apple orchards. All the apple cultivators in Kullu shifted to pomegranate 14% farmers have increase area under plum cultivation as the fruit give very good returns	18% of the respondents stated that area under apple has increased. The change was observed mainly in upper regions of Kullu valley.	30% of the respondents stated that area under apple has increased. Particularly in upper regions of Chamba district. Apple cultivation has increased as the climate conditions have becomeconducive for apple. Bharmour is known for best quality apple in Chamba.

The survey observations suggests that apple orchards were gettingseverely affected in areas receiving delayed/less snowfall and increased temperature. The reported problem by farmers in these areas was apple flowering was not followed by fruiting. Farmers reported this happenedbeause the required chilling hours for apple was no more available in these regions. In these areas, farmers have cut their apple orchards and have started growing other fruits like Pear,Pomegranate or particularly those fruits which need less chilling hours. For instance, it was observedthat in lower altitudes of Kullu regioni.e. in Hurla village, apple orchards existed some 30 years ago butas the temperature became warmer, the apple tree failed to produce fruits. This has resulted into farming of fruits like pear, plum and pomegranate now as these fruits need very less chilling hours. It's one of the adaptive measures taken by the local farmers to combat the changes of the climate. Although pomegranate fetches good returns and produces sample in lesser time as compared to apple tree; but the lean years (when the switch in crop was taking place) were really awful for them as they had to incur losses and thus became vulnerable to changing climatic conditions. In other areas of Kullu like Chandsari, a village in Nagar block, farmers are getting good returns from apple orchards, but they reported the fruit is not growing well in size. They fear that if the conditions will keep on prevailing and become intense with time then the apple orchards may fail in the region in the coming next 20-25 years.

In contrast to this, it was found that in higher altitudes of Kullu (Manali& Nagar) and even higher ranges of Chamba (Bharmour & Tissa), farmers are very much content with the productivity of apple orchards that have become more productive overthe last 25-30 years. This indicates comparatively conducive climatic conditions for apple growth at higher altitudes. These regions at higher altitudes are gaining prosperity due to boom in apple production. Most of the farmers in the region own apple, pear orchards and other cash crops (vegetables). However, in higher altitudes of Shimla in Narkanda district (Kothagad) apple production had suffered in the pastfew years due to less and delayed snowfall. There have been instances of dying apple trees due to prevalence of drought conditions.The fruit shrinks in absence of rainfall and farmers fetch less prices for their produce. Moreover, frequent hailstorm is also one of the major causes of damage to apple crop in the area.

7.3.3. Increase in Area under Horticulture crops and decrease in area under cereals or decrease in area under Rabi crops and other cereals

The farmers at lower altitudes areless interest in cultivation of cereals like Rice, Wheat and Maize. The majority of the agricultural land is rainfed, so in areas where the scarcity of rainfall is major issue, people have stopped cultivating rice. The farmers at higher altitudes of Kullu (Nagar), Shimla (Narkanda), Mandi and Chamba (Bharmour and Tissa) regions, where climate is temperate, have deviated towards growing orchards of- apple, pear and plum along with vegetables, while in lower altitudes of Kullu, Shimla and Chamba districts, farmers are having orchards of pomegranate or pear along with other cash crops like vegetables (tomato, cabbage, cauliflower and potato). In lower areas of Mandi (Padhar, Sundernagar) and Kangra there is increase in orchards of Mango and Citrus fruits as the climate has become comparatively warmer in these areas. The response of the people with regards to the change in area under cereals and vegetables are discussed below:

Table 26: Farmers's response regarding cereal crops

Range of elevation	Sample 1: Elevation: <1000 m	Sample 2: Elevation: 1001-1500	Sample 3: Elevation: 1501-2000 m	Sample 4: Elevation: 2001-2500 m
	% of Respondents			
Change in Area under Major Cereals over last 10-15 years • **Wheat**	Farmers crops are getting severely affected due to excessive damage by stray cattle.	• 14% farmers have decreased the area under wheat cultivation. The reasons being increased fruit orchards, unfavorable climate conditions, and damage by wild animals.	• 10% farmers stated that wheat cultivation has decreased.	• 18 % of the surveyed farmers stated that wheat cultivation has decreased.
• **Maize**		• 28% farmers said that the area under maize cultivation has decreased due to unavailability of timely rains.	• 4% farmers said the maize cultivation has decreased	• 19% farmers said the maize cultivation has decreased.
• **Rice**		• Rice not cultivated by majority of the farmers	• Rice was not cultivated by majority of the respondents/farmers.	• Rice was not cultivated by majority of the respondents/farmers.
• **Vegetables**		• 28 % of the farmers have decreased the area under vegetables, due to increase in disease incidences and unavailability of water, Tomato cultivation has become very tedious as is excessively damaged by pest diseases.	• 22% farmers stated that the area under off-seasonal and seasonal vegetables has increased.	• 47% farmers stated that the area under off-seasonal and seasonal vegetables has been increased.

As per the farmer's response the area under cereals had shown declining trendsirrespective of the altitudinal variations, but the reasons for this trend varies at the various altitudes. In the lower altitude regions –Samloti and Jarol, the foodgrain crop cultivation is declining due to increase in damage by stray cattle and monkeys, whereas at mid altitude regions damage by wild animals, scarcity of water and increase in orchard planting (due to conducive climate) are the primary reasons behind decrease in area under cereals. At further higher altitudes, the increase in farmer's interest in apple, fruits and vegetable cultivation was found to be the main reason. Another important observation was that majority of the farmers (nearly in all the altitudes) have either left or reduced ricecultivation. The reason stated lesser/erratic rainfalls and was lack of irrigation facility.

Analysis of vegetable cultivation shows that the area under both seasonal and off-seasonal vegetables have increased at higher altitudes (1800-2500 m) while in Hurla region majority of the farmers responded that they have decreased area under vegetables because of less availability of erratic rainfall, rising temperature and increase in pest diseases. In addition to this they have almost stopped tomato cultivation as the crop is excessively damaged by pest diseases. Farmers responded that during June and July month pest attack was more frequent due to rising temeperature and erratic rainfall. However, it cannot be concluded that climate change is the sole reason behind these crop shifts. The other prime drivers for these crop shifts can be summed up as following:

- Farming of fruit and vegetables is more profitable and gives good economic returns in comparison to the cereals.
- Accessibility to market facility for fruits and vegetables had provided opportunity to farmers to grow cash rich crops.
- Arrival of low chilling requirements varieties of fruits suitable for lower altitudes has also motivated farmers to shift to fruit cultivation. For instance, their effort under JICA (Japan International Cooperation Agency) project has resulted in cultivation of low chill varieties of apple in the lower regions of H.P. In January 2012, 2000 saplings of low chill apple varieties (Dorset golden & Anna) which needs only 200-300 chilling hours were imported from France by H.P Horticulture Department under this project. After an year's quarantine, the samples were distributed to farmers from January to March 2013 and the trees produced fruit sample in 2014.
- Chamba district was once known for Maize production but now the area under maize crop is declining. As per the Chamba *Krishi Vigyan Kendra*(KVK) officials, they areencouraging cultivation of apple and other fruits and vegetablesto get better farm value. Unlike Kullu and Shimla, Apple cultivation is not very old in Chamba region as it has gained popularity in the recent past only. Low chill varieties of apple (Spur, Red Chief, Super red chief, Oligan spur, Gala Gala, Gibson Jordan, Vast Delicious & Red Spur) which needs 400-800 hrs & Anna Varieties which needs around 400 hrs, are being cultivated in the lower altitudes of Chamba; whereas the high chill traditional varieties of Apple (Royal Delicious, Richa Red, Red Gold, Golden delicious, Winter Banana) are being cultivated in Tissa and Bharmour(higher altitudes)where climatic conditions are conducive climatic and the apple trees receives adequate chilling hours.

7.3.4. Increase pests and weeds

Based on the response of the farmers in the state, it was observed that the cost of crop production has increased. Theresponse of farmer's suggest that primary factors responsible for rising cost of cultivation are increasing usagesof pesticide due to risein pest attack and increasing dose of fertilizer dose.

Prevalence of pest diseases was found quite common in all the five sample districts. Diseases affecting apple are Apple blotch complex (caused by Marssonina and Alternaria sp). It is an important disease manifested recently in all apple growing states of India. The fungal disease appears in the form of dark brown blotch on the upper side of the leaf in the second week of June under humid weather conditions which causes premature yellowing and abscission of leaves, due to whichthe apple tree becomes dry. Scab, Blight diseases and Canker are other important diseases. Scab disease has been controlled in some parts of Narkanda district of Shimla but is still occurring in apple in other parts of Himachal Pradesh. The other pests attacking apple are wooly aphids (mainly in Bharmour and Tissa),borer worms and mites.

Farmers informed that in order to control the pest attack they have increased the pesticide sprays in apple during summers to nearly 6 times which was earlier 1-2 times. Due to rise in temperature and prolonged dry summer periods,the apple fruit starts shrinking initially and the tree dies later. The diseases in Pomegranate are canker, borer worms and fruit blasting; due to prevalence of long hot and dry period. Fruit blasting in Pomegranate is increasing over the years which occurs due to long dry spells days followed by heavy rainfall.

In lower regions of Shimla, Kullu Mandi& Kangra, wheat is damaged by black rust disease. In tomato, early blight, rottening disease (viral disease that results in development of a black line in the stem of tomato which causes death of plant), powdery mildew and borer worms are causing major damages. In Kullu district, tomato crop is heavily damaged by pest diseases and in some regions (Hurla village) the cultivation has become really tedious. In cauliflower, Sclerotinia rot and black rot are attacking. Canker is another diseasequite common in vegetables.

As reported by the farmers, the disease incidences have increased over last 15-20 years and so is their pesticide input, which has resulted into increase in the cost of cultivation.

Table 27: Farmers's response regarding pests, weeds and fertliser

Range of elevation	Sample 1: Elevation: <1000 m	Sample 2: Elevation: 1001-1500 m	Sample 3: Elevation: 1501-2000 m	Sample 4: Elevation: 2001-2500 m
	% of Respondents			
• **Response in support of increase in pests or insect diseases over the last 10 years.** • **Major reason behind increase in pest/insect diseases.**	• 71% of the respondents said the pest and insect attacks/diseases have increased in the crops, also the growth of alien species has increased • As per 70% respondents the major cause was	• 86% of the respondents said the pest and insect attacks/diseases; weeds have increased in the crops. • As per 85% respondents the major cause was less rainfall and	• 82% of the respondents said the pest and insect attacks/diseases; weeds have increased in the crops. • As per 44% respondents the major cause was less rainfall and rise in	• 82% of the respondents said the pest and insect attacks/diseases have increased in the crops. • As per 65% of the respondents less rainfall and hotter summers are responsible.

• Name of the main pest diseases/pests/insects damaging crops and invasive species **• Period during which diseases mainly occur.**	less rainfall and increased hot conditions during summers. • Black rust in wheat. Ageratum Conyzoides, lantana Camara are the main weeds. • June-August	warmer & prolonged summers. • Rottening disease of Cabbage, Tomato Black rust in wheat, and canker in all the vegetables, Fruit Blasting in Pomegranate, mites and borer worms are the insects in fruit crops. • June-August	temperature, especially the summers have become hotter. • Marssonina Blotch in apple. Rottening in vegetables, and canker in all the vegetables. Mites and borer worms are the insects damaging fruits and vegetables. Eupatorium, Lantana Camara are the main weeds • June-August	• Marssonina Blotch and woolly aphids in apple. Mites and borer worms are the insects damaging fruits and vegetables.Lantana Camara is the main weeds • May-November
Reason for increase in Fertilizer input in farms	• Decrease in soil fertility28% • 72% respondent said for increasing crop yield	• Decrease in soil fertility 42% • 35%respondent said for increasing crop yield.	• Decrease in soil fertility 31% • 49% respondendent said for increasing crop yield	• Decrease in soil fertility 20%. • 60%respondendent said for increasing crop yield

Majority of the farmers stated that rise in temperature especially during summers, decreased or erratic rainfall, and prolonged drought periods are the primary causes of increase in pest diseases in the crops. The period of occurrence of most of the diseases is in summers (mainly May-August) except for the wooly aphids which occur in the month of November at higher altitudes of Chamba.

Uncontrolled growth of weeds is an important issue of concern among farmers in the State. The unwanted plant species like Lantana Camara, Parthnenium and Ageratum (Neelaphool) are obstructing the cropsgrowth. These weeds compete with the crops for nutrients and water uptake resulting in poor growth of the crops. These weeds become dominant species in farms as well as forests and inhibit the growth of the useful species. These weeds are not required and cause health problems both in man and animals. Lantana Camara is inflammable and catches fire easily, hence is responsible for increasing the vulnerability of forests to fires. Allergens released by Ageratum causes dizziness and nausea in the farmers when they work in the fields.

As per the farmers' responses, prevalence of weeds have increased considerably over the last 15-20 years; the reason can be attributed to the increase in temperature and prevalence of warmer conditions which are suitable for the growth of these weeds. In response to this unwanted growth of weeds, farmers either remove the weeds manually or spray weedicides. Apart from using weedicides, farmers spend on labours to uproot weeds and other invasive plants. This is a serious area of concern of the farmers as it increases thecost as well as mandays (of household/hired labour) requiredfor crop cultivation. Moreover, as the manual labour started becoming expensive over the years, farmers started using more weedicides, which cost less compared to manual labour. As per the consultation with the officials in pesticide department of H.P (Directorate of Agriculture, H.P), maximum amount of pesticides (weedicides) is used to control weeds.Though using weedicides has merits in terms of economic cost but the way weeds are increasing as well as the use of weedicide is increasing it will pose serious challenge to sustainable agriculture in the State.

The traditional manure used by the farmers were cow dung, pine leaves or residues of trees, but now spread of chemical fertilizers is gaining more importance in the state. Normally, at all the altitudes, over the years farmers have formulated a schedule for pesticide and fertilizer usage and without actually knowing the real need, farmers religiously follow their routine. Majority of the farmers use chemical fertilizers just to increase the crop yield without assessing the nutrient requirement of soil and crop. It has been evident that the incidents of pest diseases have increased in the crops and the soil fertility may have also decreased over the years but without understanding the soil nutrients requirement, use of pesticides and fertilizers is inappropriate and may adversely affect the soil fertility. This situation can lead to problems in the long run like diseases in human beings and animals, , deteriorating soil quality and fertility, killing soil micro flora and fauna, polluting water resources, increasing toxic chemical levels in fruits/food grains/food chains & webs and many more.

7.3.5. Increase in crop damage by animals (wild and stray cattles) and rise in man animal conflicts.

Severedamage to crops by animals is the one of the major problems faced by majority of the villages in the three districts of Kullu, Shimla and Mandi. Monkeys from cities are left in the forests near the villages which destroy their crops and fruits. Along with monkeys, wild boars are also becoming threat to framers. Farmers reported that before 15-20 years, the wild boars interferencein the farmlands was not as severe and frequent as it is now. The reasons of their encroachment can be the increase of unfavourable climatic conditions (hot) in the low lying areas which used to be their original habitats.In quest of a better and suitable Habitat the boars' population have moved to higher altitudes. Besides this destruction of their native habitats/forests due to deforestation, forest fragmentation and forest fires are also pushing them towards the fields/orchards for food and shelter. For instance, in Sundernagar (Mandi district) farmers reported that before 20-25 years, snowfall used to occur in the region and leopards& bears were the main animal species in the regional forests but gradually as the climatic conditions became warmer and snowfall stopped, bears have shifted to higher altitude forests while the wild boars from the low lying areas replaced them. The boars are present in large numbers and are huge in size also, the forest department has given the people liberty to kill the wild boars but it's very difficult for the farmers to protect their crops and trees from wild boars as they attack severely.

Apart from wild animals, an increase in population of stray cattles has also tremendously increased. The reasons behind are increased in orchard culture which has resulted in shortage of grass to feed cattle, increase in cost of rearing and occupational shift of people. This is adversely affecting the agriculture/horticulture sector as the animals cause heavy damage to crops and trees. The problem of animal encroachment has become so severe in some regions (Samloti-Kangra, Neen-Shimla, Jarel-Mandi) that farmers out of fury and losses have stopped crop cultivation. The increase in incidences of crop damage by animals has resulted to man-animal conflicts in the state and has become difficult for the people to live in harmony with the animals, thereby posing a threat to the biodiversity. The analysis of farmers' responses is given in table 28.

Table 28: Farmers's response regarding economic loss due to extreme weather condition

Range of elevation	Sample 1: Elevation: <1000 m	Sample 2: Elevation: 1001-1500	Sample 3: Elevation: 1501-2000 m	Sample 4: Elevation: 2001-2500 m
	% of Respondents			
No of respondents faced Economic lossess due to wild animals, stray cattle	• 80% due to stray cattle, one of the major reason for decrease in	• 7% due to Monkey and Wild boars	• 37% due to monkeys , wild boars & bears	• 23% due to monkeys, bears maize cultivation badly affected.

7.3.6. Decrease in domestic cattle count

From the table 29, it is clear that the count of domestic cattle has decreased in all the survey regions. In higher altitudes, the primary reasons behind the decrease are increase in area under fruit orchards which has ultimately decreased the area under fodder, shortage of grass/fodder in the forests, increased cost of animal rearing, prolonged and dry summer spells, while in lower altitudes the main reasons are scarcity of water, prolonged and dry summer spells and less rainfalls. Apart from these, the other significant reasons behind decrease in cattle count are shift in occupation of people and division of cattle during family divisions. In some areas, people reported that farmers left their cattle stray when they grow old and become unproductive (stop yielding milk, unable to work in fields). This has increased the count of stray cattle which again poses a threat to the crops because these stray animals encroach the fields for food and cause heavy damage to crops/trees.

Table 29: Farmers's response regarding livestock

Range of elevation	Sample 1: Elevation: <1000 m	Sample 2: Elevation: 1001-1500	Sample 3: Elevation: 1501-2000 m	Sample 4: Elevation: 2001-2500 m
	% of Respondents			
Status of cattle count(in the sample households) in comparison to last 10-15 years **Reasons for decrease**	56% of the respondents said that the cattle count in their households has been nearly constant. While in 44% of the households the no of cattle have decreased. lack of water, grass and high cost of animal rearing are the mains reasons for decline in the cattle count. Shift in occupation is another reason	In 64% of the households the no of cattle have decreased. 28% stated the Unavailability of grass in the forests (due to decrease in rainfall, forest fires), less pasture in fields due to increase in orchard culture that results in increased cost of animal rearing 7% stated that division of cattle during family division is the reason behind cattle count fall. 7% said they had occupational shift in the family which leads to decreased cattle count.	In 40% of the households the no of cattle have decreased. The major reason found was increase in Orchard culture, increased duration of hot and dry spell during summers and third being forest fires.	In 42% of the households the no of cattle have decreased. Major reason found was shortage of grass due to increased orchard cultivation and lack of grass in forests due to fires.

7.3.7. Increase in agriculture/horticulture crop lossess due to extreme climatic/weather events.

The agriculture/horticulture sector has always been vulnerable to the extreme weather events and climate vagaries, but due to change in the climate the crop lossesses incurred by farmers due to extreme climatic/weather events have increased over last 15-20 years. 50% of the farmers reported losses to crop (apple and other fruits) due to hailstorms, while 26% have incurred losses (cereals and fruits) due to extreme rainfall events. This problem was found to be severe, particularly in higher altitudes of Chamba, Shimla, Kullu, Mandi and Kangra.

On the other hand, 24% of the farmers inHurla, Chandsari (Kullu), Samloti (Kangra) and Jarol incurred losses due to prolonged drought periods. Although the loss in agriculture/horticulture sector due to extreme weather events is not new but the issue of concern is that the frequency of these events has increased over the years and so is thevulnerability of the farmers. It is essential that suitable adaptation and mitigation strategies should be formulated to increase the adaptive capacities of the farmers to reduce the impact of these losses. As per the primary survey's observations, the adaptive capacity of farmers to minimize the impacts of climate change is very low; also the extension advices and other benefits provided by the government are not accessible to majority of the farmers which adds to their sufferings. For example in Narkanda block, Shimla farmers are aware of anti-Hail-nets and can afford them or are getting Hailnets from government on subsidy but in other regions like Chandsari block in Kullu district, farmers are less informed about hailnets and therefore the use is also very less.

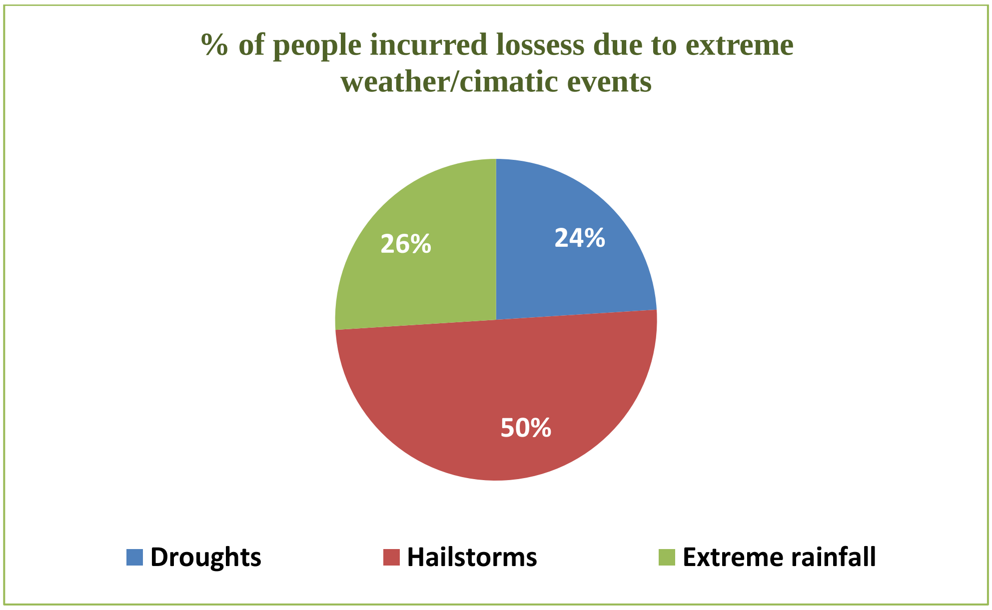


Fig.14: Percentage respondent incurred losses due to extreme events
Source: Primary Survey by IRADe, 2014

7.3.8. Low adaptive capacity of farmers to climate change and limited accessibility of government benefits and extension advice.

On the basis of the information provided by the farmers during the primary survey, it was found that majority of the farmers in all the sample districts were not aware of the necessary adaptive and mitigation measures to reduce their vulnerability to Climate Change. Only 50% of the total farmers were using improved varieties of crops/fruit saplings/vegetables while 46% were still not using. The reason for not using improved varieties are lack of awareness and poor extension advice. The awareness and benefiaciaryof government schemes are found to be at higher altitude regions above 2000 m; 42% of the people are getting improved variety of seeds subsidies on fertilizers, pesticides and Hailnets from H.P government departments, while the percentage in other altitudinal regions was merely 14% and 10%.

Another noticeable observation is the poor accessibility/availability of extension advice; only 14% of the farmers in survey sample 1 and 2 admitted that they are getting extension advice while in rest of the regions it was almost zero. The lack of extension advices and other government aid reduces the adaptive capacity of the farmers and results in making them further vulnerable to vagaries of climate. As already discussed above in absence of proper guidance and extension advice, farmers use the chemical fertilizers and pesticides blindly leading to increased cost of production and increase in level of toxic chemicals in the ecosystem. Use of improved/ hybrid crop varieties, innovative farming practices, appropriate use of chemicals and cultivation of right crops are necessary to build the capacity of farmers to combat the circumstances of crop failures, pest infestations, weed invasions and decreased fertility of soil.

While in absence of apt extension advices and government aids, **farmers try to survive with their own experiments and intuitions**. Also, subsidies help farmers in managing the cost of cultivation but it is necessary to build awareness among people about the government programmes and aids so that maximum can take benefit of the same and needless to say that the process of granting government aid (subsidies, distribution of seeds/saplings) should be made simple and quality of products should not be compromised.

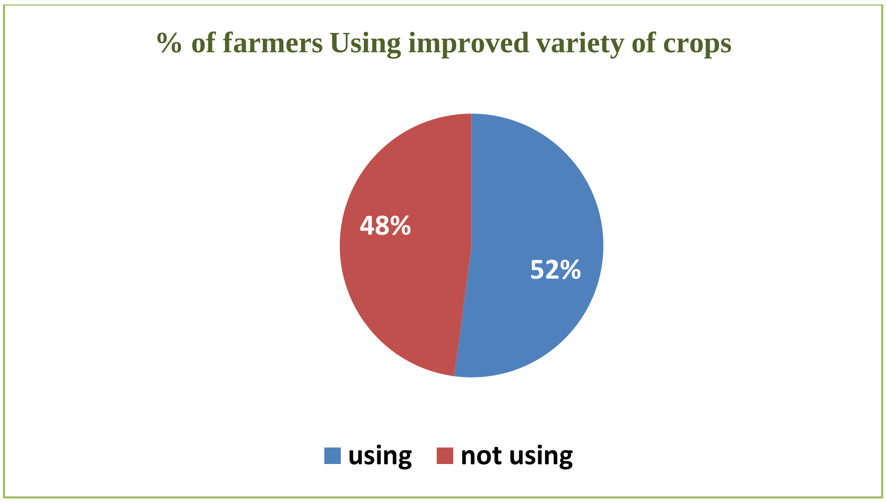


Fig.15: Percentage respondent using improved variety of seed/saplings
Source: Primary Survey by IRADe, 2014

Table 30: Farmers's response regarding benefits from Government schemes

Range of elevation	Sample 1: Elevation: <1000 m	Sample 2: Elevation: 1001-1500	Sample 3: Elevation: 1501-2000 m	Sample 4: Elevation: 2001-2500 m
	% of Respondents			
Benefits/ aid from government in agriculture/horticulture	• 84% people denied any kind of government aid in agriculture/horticulture. • 14% of the respondents said they are getting aid in form of fertilizer/pesticides, improved variety of seeds/seedlings and extension advices.	• 72% people denied any kind of government aid in agriculture/horticulture. • 14% are getting aid in form of fertilizer subsidies, subsidy on pesticides and Extension advices.	• 90% people denied any kind of government aid • 10% of the respondents get subsidy on fertilizers, pesticides, Hailnets and improved variety of seeds/saplings	• 58% people denied any kind of government aid in agriculture/horticulture. • 42% of the respondents get subsidy on fertilizers, pesticides, Hailnets and improved variety of seeds/saplings.

7.4. Market development

To know the status of ancillary activities and livelihood opportunities based on agricultural sector we did primary survey of 4 fruits and vegetable markets in the Shimla, Kullu, Kangra and Chamba districts. The markets visited are as follows:

1) Patli Kuhal Fruit and Vegetable market, Kullu (Qualitative survey)
2) Dhali fruit and vegetable market, Shimla
3) Palampur vegetable market, Kangra
4) Balu fruit and vegetable market, Chamba

The regional observations (qualitative & quantitative) based on our survey are as discussed below:

7.4.1. Easy transportation of horticulture produce

In Patni Kuhl market, Kullu the fruit traders reported that the increased production of fruits and vegetables in the districts have led to emergence of new local fruits/vegetable markets in the district viz Patni Kuhl, Bandrol, Bhuntar.Local farmers prefer to sell the fruits (mainly apple, pomegranate and plum) and vegetables now in the local markets as it is more convenient. Moreover many times the farmers had to incur lossess when their transported produce used to get perish before reaching in the market. The development of new market facility had improved the market accessabilty of farmersand this has also resulted in cultivation of more vegetables in the region. Same was reported in Dhali market, Shimla where fruits (mainly apple, plum & peach) and vegetables from Kinnaur (Apple), Shimla, Kumarsain and Narkanda districts are brought for sale. Earlier farmers transported their produce to Azadpur Mandi, Delhi. In Chamba district, not much change have taken place as the traders informed that the apple produce of major areas like Bharmour and Tissa is still transported to distant markets in Punjab (Pathankot and Jalandhar). The reasons for this was less arrivals of fruit traders in this market.However, apple production in the district has increased over last 15-20 years (when climate of Chamba became conducive). In the lower altitudes like Kangra production of mango, citrus and vegetables has increased, the local Sabji Mandi of Palampur is very well developed and most of the farmers prefer to sell their produce here, earlier transportation of crop was not as easy and profitable for farmers as they had to look for distant markets in Punjab. Moreover, most of the traders replied that the cash flows have also become easier and faster for the farmers, as they get their money within 4-5 days of selling their produce in the local markets, on the other hand they had to wait for longer periods for their money to come from distant markets of Delhi and Punjab.

7.4.2. Increase in ancillary activities and livelihood opportunities

It was observed that the increase in productivity of horticulture sector is boosting up the ancillary livelihood opportunities like transportation, trading and packaging in the state.The primary response of the *arhatiyas* (local market traders) are presented in table 31. From the primary data given above in the table it is clear that the no. of vehicles (both small and big), labours engaged in fruit loading/unloading, packing, traders, accountants have increased in all the markets (in Dhali market alone tremendous change has been observed). Also the increase in no of Dhabas, eateries shows that more of the people are getting employment opportunities. Majority of the surveyed traders in the markets reported that there income from fruit/vegetable business has become twice to what it used be 10-15 years ago. Hence, it can be said that Climate Change is not only a menace in Himachal Pradesh, because the increase in productivity of apple/other low chill needing fruits along with vegetables is bringing prosperity and positive socio-economic growth in the state. Even the major crop shifts behind which climate is the important driver have proved to be economically viable in some regions of state as, the new crop is fetching better prices (like shift from apple to pomegranate in lower regions of Kullu and Shimla, increase in production of plum in lower altitudes, increase in production of apple in higher altitudes of Chamba and cold deserts like Lahaul Spiti).

Table 31: Arhatiya/Traders response during primary survey

Surveyed markets	No of vehicles carrying fruits and vegetables in and out of market daily now/10 years ago	No.of labours/employees engaged in the market head loading, packaging, accountancy now/10 years ago	Dhaba /Eateries in and around market region now and 10 years ago	No of Arhatiya/Middle Man, Outside traders now/10 years ago
Dhali market, Shimla	Now- • 200 small vehicles (pick-ups, jeeps). • 60 trucks 10 years ago- • 50 small vehicles (pick-ups, jeeps). • 5-7 trucks	Now- • 500 total labours 10 years ago- • 100 total labours	Now • 40 dhabas and eatries 10 years ago • 2 dhabas	Now • 40 Arhatiya/Middle man • 100 outside traders 10 years ago • 12 rhatiya/Middle man • 10 outside traders
Palampur vegetable market, Kangra	Now- • 50 small vehicles (pick-ups, jeeps). • 5 trucks 10 years ago- • 10-12 small vehicles (pick-ups, jeeps). • 1-2 trucks	Now- • 70 total labours 10 years ago- • 30 total labours	Now • 3-4 dhabas and eatries 10 years ago • none	Now • 25 Arhatiya/Middle man • No outside traders 10 years ago • 10Arhatiya/Middle man

Balu fruit and vegetable market, Chamba	Now- • 5 small vehicles (pick-ups, jeeps). • 5 trucks 10 years ago- • 2-3 small vehicles (pick-ups, jeeps). • 1-2 trucks	Now- • 12 total labours 10 years ago- • 1-2 total labours	None	Now • 25 Arhatiya/ Middle man 10 years ago • none

7.5 Forestry and Non Timber Forest Produce (NTFP)

The villagers in sample districts collect fodder and leaf litter from the nearby forests. Apart from this, the other NTFP's collected by the people are:

i. Medicinal plants (at higher altitudes)
ii. Edible oils, Herbs, Spices, Bamboo shoot, Rattan, Ornamental plants, Gums and Resins, Tannins and Dyes, Fibers, Flosses and leaves.
iii. Animal products (birds, honey), Insect products.

Due to deforestation, forest fires, climate change and excessive anthropogenic pressure, the availability and distribution of the NTFP's have been affected in Himachal Pradesh. The status of the various NTFP's on the basis of the perception local people is as below:

7.5.1. Shortage of Fodder/grass

The availability of the fodder for animals has reduced considerably due to increase in the intensity of summers, less rainfalls, overgrazing by the cattle/ livestock and forest fires. Normally people face fodder shortage in summers and in winter seasons in higher altitudes when due to extreme temperature the grass dries and become sparse. The observations were same nearly for all the regions (except in those where the farmers are taking fodder from their own orchards/farms). Usually the farmers keep a part of their field fallow for the fodder; but the marginal small land holders can't afford to do so and are totally dependent on the forests for the fodder. Hence, during the dry seasons when there is extreme shortage of fodder, these people have to purchase it, which puts additional pressure on their pockets. For instance, in Sunder nagar block of Mandi, farmers reported that their cost of animal rearing has increased nowadays, because they have to purchase animal feed as enough grass is not available in the forests. The problem is severe in Basantpur (Shimla), Mashobra (Shimla), Sunder nagar (Shimla) Kullu and Nagar blocs. Due to increase in area under orchards, decrease in the fodder in forests, high cost of animal rearing and decrease in milk productivity of the cattle, the number of stray cattle have also increased in these regions, which is another problem for the farmers causing mass destruction of their standing crops

7.5.2. Shortage of Leaf Litter

The leaf litter covering the forest ground is collected by the village people to use it as manure on the cultivated land as a fertilizer to replenish the soil with nutrients. Forest fires and deforestation have increased the workload on females as they need to travel longer distances to collect the materials making. Trade–offs are generally felt by the poor; the forest department and its policies favour the most vulnerable commercial species and the promotion of high-biomass trees. This leads to neglect of food, fodder and building materials needed by rural poor.

7.5.3. Decrease in availability of Medicinal –Herbs and drifting of medicinal plants to higher and deeper forests

The availability of medicinal plants in certain areas of Himachal Pradesh has reduced. The right holders collect these herbs from the forests and sell them to petty contractors/purchasers. A nominal export and collection fee is realized from traders for exporting various medicinal herbs outside Himachal Pradesh. But excessive and illegal collection of medicinal herbs by the people has resulted in decreased availability. Alteration of climatic conditions needed for the growth of herbs is another reason for this. In Chamba, Kullu, Kangra, Mandi and Shimla, the availability of medicinal plants is moreat the higher altitudes of Chamba (Pangi, Killar) and Kullu (Nagar, Manali). As the villagers do not admit the collection of medicinal herbs and plants in open, hence it was difficult for us to capture the quantitative picture of the status of medicinal herbs and plants. That's why, a qualitative analysis is presented in this section. Table 32 shows the availability of all the medicinal herbs collected in the districts surveyed.

Table 32: Availability of medicinal herbs in the surveyed districts

Place	Name of medicinal-herbs found	Reasons for decrease (based on people's perception)
Hurla village (Kullu)	Dioscorea (Singli-Mingli). Panja, Bethar , Kadoo, Bhutkesi, Tejpata, Gucchi, and Banafsha	Increase in anthropogenic pressure and forest fires, increase in temperature and less rainfalls
Chandsari (Nagar, Kullu)	Patish, Dioscorea, Gucchi, Nagchatri, lingerie, Google, Banafsha	Increase in anthropogenic pressure and forest fires, hot summers and less rainfall
Katrain (Nagar, Kullu)	Motashia (Mushroom), Mushkbala, Chora, Kadoo, Patish, Dioscorea, Gucchi, Nagchatri, kakarsingi, pathanbel, Horse chestnut, Rakhal (TaxuswallichianaZuec.)	Increase in anthropogenic pressure by Nepal migrants and forest fires
Chamba (Bharmour, Pangi, Killar)	Guchhi, Nagchatri, Kadoo, Dhoop, Mushkbala, Patlain roots, Bankakri and many more	Over extraction, Higher prices, drifting of species to higher and deeper forests, rise in temperature one of the reason.

As per the information collected from forest department about licensed traders, it was observed that the quantity of extracted medicinal herbs is greatly affected by the market value and commercial demand of the herb. The same is discussed in the **table** below. People collect the herbs from forests only if the market prices of the product are economically viable because of a tedious and time taking task. Also, the awareness about high market values of these herbs has increased among these people leading further to increase in legal as well as illegal extraction.

Table 33: Regional availability, Market Values and Status of the medicinal herbs

Name of Species	Regional Availability	Market Values	Status (availability in the region as compared to 10-15 years ago)
Muskbala /Nihani	Mid and higher altitudes	80 Rs/kg	Present in abundance, due to less rates people are not extracting much of it.
Banafsha	Kullu in Banjar region, cold areas	500 Rs/Kg	Less available, due to alteration in climatic conditions.
Neoza	Chamba in Killar & Pangi region, mountain peaks of Manali& Nagar blocks	400 Rs/Kg	Less available, due to deforestation the quantity has reduced.
Patlain roots	In Kullu and lower altitudes of Himachal	40 Rs/Kg	Available in abundance, due to low rates not extracted.
Chora	Kullu and cold areas	100 Rs/Kg	Available in abundance as people are not extracting because of less market rates.
Dioscorea	Kullu and colder areas of Himachal		Before 10-15 years its availability was reduced due to over extraction as it was high in demand for commercial use of 16 DPA formed from it, but now 16 DPA is imported from China.
Kadoo	Grows at higher altitudes	800 Rs/Kg	Less available due to change in climate conditions, prevalence of long and hot summers, scanty & untimely rains.
Mendi	Grows at higher altitudes	100 Rs/Kg	Present in abundance, less extraction due to less prices.
Panja	Grows at very high altitudes in Pangi & Lahaul.	200 Rs/Kg	Less available due to change in climate conditions, drifting to higher and deeper forests.
Dhoop	Found in mid Himalayan regions	190 Rs/Kg	Demand has decreased in the market, availability and abundance is nearly same.
Riyondchini	Grows in mid and high altitudes of Himachal.	90 Rs/Kg	Availability is same as it was earlier.
Guchhi	High and in some low altitude regions	13000 Rs/Kg	Availability decreased in some region due to change in climatic conditions while present in abundance in some. Drifting to high altitudes and deeper forests
Bankakri	Higher altitudes	100Rs/kg	Its very less in demand in market, very less extraction
Kakarsingi	In lower Himachal – Kangra, it's a tree crop.	900 Rs/kg	Less available due to change in climate conditions.
MithiPatish /MithaTelia	Available in Chamba in Killar & Pangi region, and other colder region.	700 Rs/Kg	It is available as wild in forests and also cultivated by people. Quantity available in Himachal is almost same as it was before 10-15 years ago.
Kuth	Cultivated only in Lahaul and Spiti	250 Rs/Kg	Present in abundance.
TalisPatra	Lower Himalayas	-	-
Bach	Water logged and marshy regions near the river banks, in Manali and higher altitudes	120 Rs/Kg	Reduced due to floods in the river.
Nagchattri	Mid and higher altitudes- Bharmor, Killar, Pangi	2000Rs/Kg	Less available due to change in climate and excessive extraction. Also Extracted illegally. Drifting to higher and deeper forests.
Horse chestnut	Killar, Pangi, Bharmor and other higher altitudes		Reduced due to deforestation, forest fires and climate changes.
Rakhal	Mid –Higher altitudes	70Rs/Kg	Less available, in Himachal Pradesh its cultivation is banned. Used for treatment of cancer.

From the above table 33, it is clear that the availability and distribution of medicinal herbs and species have changed. Many of the species have drifted to higher altitudes and to deeper forests because of over extraction leading to regional extinction of species and rise in temperature which hinders the growth and regeneration of these rare species. The alteration in the climatic conditions in a particular area affects the life cycle, phenology and flowering time of the plants affecting their growth & distribution. Deforestation and uncontrolled fires are other reasons behind the issue. The repeated fires decrease the soil nutrients (Nitrogen), growth of grasses, herbs and shrubs resulting into erosion and killing of essential micro-organisms.

7.5.4. Increase in vulnerability of forests to fire

Forest fires are a common phenomenon and frequent fires occur in almost all the surveyed districts - Shimla, Chamba, Kullu, Kangra and Mandi, with usually 2-3 incidences of forest fires occurring annually. In lower regions of Himachal Pradesh, the fires in forests occur in summers while in the higher altitudes they occur during winters. Majority of the forests fires are anthropogenicin nature and are set by people while burning dried grass and agriculture wastes near the forests and sometimes unknowingly when smouldering smoking products are thrown on the forest land. In most cases, fires are controlled by local people and the forest department, but in some cases fire become uncontrollable due to dry vegetation and high wind velocities, and thus taking toll on life and property. Climate change is also a significant reason for increasing the vulnerability of forests to fires and increasing the frequency/incidences of fires:

- As a result of rise in temperature in the state, the ignition temperature of the forests has decreased making them inflammable to slight anthropogenic activities**.**
- With rise in temperature, higher altitudes have further become conducive for growth of easily inflammable Chir pine (Pinus Rouxburghii) which has invaded greater height forests resulting in increasing number of incidences of forest fires
- Increase in invasion of forestlands by highly combustible alien species like Lantana Camara is also increasing the vulnerability of forests to fires.

The season in which fires normally occur vary from region to region. In Shimla and Mandi, frequent fires occur during the summers due to rise in temperature and long dry spells, whereas in Kullu and Chamba fires occur during winters when people try to burn the dried and lifeless grass. Severe cases of uncontrolled fires were reported in Basantpur block of Shimla where people incurred huge losses of life and property. Forest fires damage the humus on the top soil that has been collected over the years; this affects the relief of the ground, water conserving capacity and fertility of the soil. Forest fires not only damage the biomass of the forest and the ground, but also disrupt the cultural, social, economic, agricultural and environmental networking of the region. Observations based on primary survey findings in sample districts, discussing the problems caused by forest fires are given in **table.**

Table 34: Primary observations regarding forest fire

	Sample 1: Elevation: <1000 m	Sample 2: Elevation: 1001-1500	Sample 3: Elevation: 1501-2000 m	Sample 4: Elevation: 2001-2500 m
	% of Respondents			
Impact of forest fires on the life of people	• 42 % of the respondents get problem in getting grass to feed cattle and fuelwood for cooking due to forest fires.	• 50 % get problem in getting fodder grass and fuelwood due to forest fires. • This has resulted into increased workload on the females as they have to travel longer distances to collect grass and fuelwood.	• 25 % get problem in getting grass and fuelwood • Increased workload on the females. • No pasture land left for the cattle to graze • Cost of animal rearing increased, decrease in domestic cattle count.	• 47 % get problem in grass to feed cattle and fuelwood for cooking due to forest fires. • increased workload on the • Cost of animal rearing increased.

Major problems observed by the local community due to forest fires are listed below:

i. Shortage of fuel wood and fodder in the forests.

ii. Loss of NTFP, timber and medicinal plants resulting into loss of livelihood based on them.

iii. Villagers especially women have to travel to long distances in search of fuel wood and fodder. Sometimes they even have to purchase grass to feed their animals and fuel wood to cook; thus, putting pressure on their pockets.

iv. Burning of grass in the forests leads to increased cost of cattle rearingresulting in decrease of domestic cattle count.

v. Wild animal lose their habitats due to forest fires and start encroaching into the villages causing damage to their crops and thus giving rise to man-animal conflicts.

vi. Health problems like eye irritation and suffocation are prevalent because of forest fire. 57 percent people complaint of health issues due to forest fires **(fig.).**

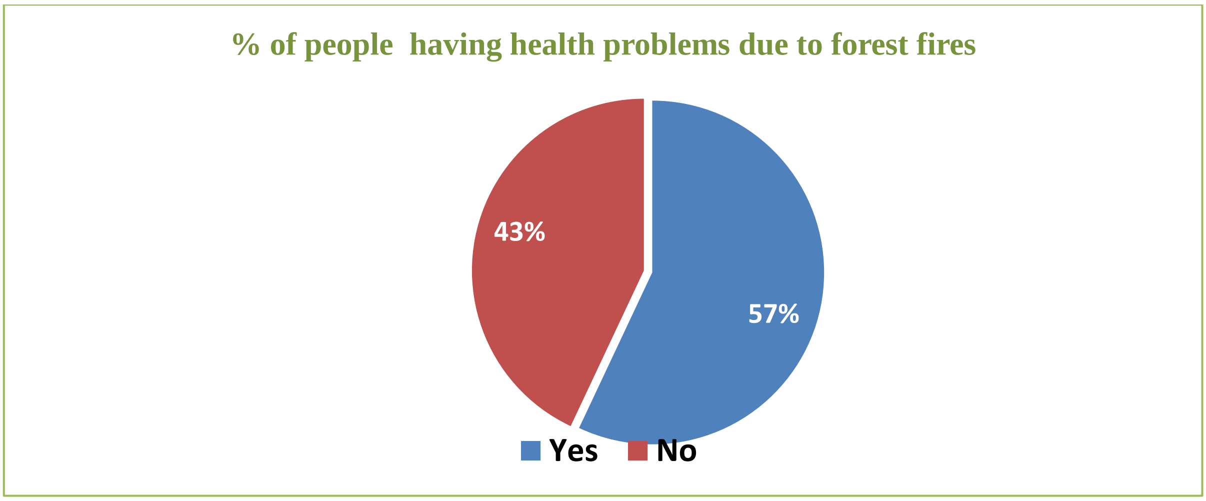


Fig.16: Percentage respondent family members got affected due to forest fire
Source: Primary Survey by IRADe, 2014

Local people suggested that forest fires can be minimized by controlling the growth of unwanted weeds, human activities leading to fires, plantation of deodar, walnuts.

Table.35: Climate Change and Evidence

Kind of Change	Evidence
Warming	Decline in snowfall period and persistence, decline in apple. • In some regions of Kullu district like Bhunter and other regions (eg: Hurla village, Kullu block) apple has failed, pomegranate orchards flourishing in these regions. • Increase in more tropical trees, In some regions of Mandi snowfall occurred before 2-3 decades back, now mango crop flourishing well. • Presence of low elevation weeds, pests & animals at higher elevations, invasion by Lantana camara, Ageratum sp. Increase in number of low elevation animal species like wild boars (Sus scrofa) in higher elevations. • Early fruiting reported in stone fruits due to warm & prolonged summers. • Decline in some part of NTFP production. Drifting of medicinal herbs and plants to deeper and high altitude forests. • Drying of Kuhls and Chasmas
Decline in rainfall	Frequency of drought has increased, the same was observed in most of the areas. The situation is worst in areas where there is no provision for lift irrigation, during less; irregular and untimely rainfall there is decrease in production and area under the crop in many regions eg: Basantpur, Mashobra blocks of Shimla.
Decline in snowfall	• Apple quality and quantity is directly affected by the chilling hours it receive, which in turn depend on the intensity and amount of snowfall received. In regions like Chandsari (Nagar Block) apple size is reducing due to less chilling hours (less snowfall), In Mandi in some regions snowfall occurred before 25-20 years ago it has stopped now-Mango crop has started flourishing in the region, eg: Jarol (Padhar block, Mandi). • Apple size has become less prominent; shape deterioration has been reported in Chamba District. At lower altitudes the shelf life of apple has decreased. • In some areas like higher altitudes Kullu (Nagar, Manali) and Chamba (Bharmour, Tissa) apple area has increased as the climate become conducive
Decline in winter precipitation, winter precipitation in January-Feb instead of December and January and decline in intensity of snow-fall	• Rabi crop negatively impacted • Wheat productivity is affected due to less rainfall. • Delayed sowing of winter crops, decline in wheat yields.
High rainfall during August September instead of the normal peak in July-August	• Damage to rainy season crops when they are close to maturity. • Problem of flower setting in pomegranate crop due to erratic rainfall conditions.
Hot summers and long dry periods with less rainfall	Increase in prevalence of diseases and pests in the crop, increase in the incidents and severity of diseases, decrease in the grass in forests, droughts become frequent, tropical tree increase, increase forest fires, drying of Kuhls and Chasmas.
Increase in instances of hailstorms	Heavy loss of apple crop, increase in the use of hail nets in regions like Narkanda (block of Shimla).
Seasonal changes (earlier monsoons)	Decline in flora related NTFP output due to unsuitable seasonal variations. Decrease in availability of medicinal plants Banafsha (Viola serpens), Kadoo (PicrorhizaKurroa) , Gucchi (Morchellaesculenta), Dioscorea (singli-mingli), Batch, Rakhal, Kakarsingi

Conclusion and Recommendations

This study focused on sectors where there is high significance for socioeconomic vulnerability due to climate change. In Himachal Pradesh, rural regions constitutes 90% of the population and has very high dependency on agriculture and allied activities for their livelihood. They are highly vulnerable to climate change and differ from their urban counterparts in terms of occupations, earnings, literacy. Huge dependency on agriculture and allied sectors, rising temperature, changing prepitation pattern and their seasonal variability will adversely affect the agriculture/horticulture and allied sectors productivity and therefore State's prosperity. The ancilliary industry like packaging, transportation, food processing will also get affected.

Himachal Pradesh has micro climatic conditions and the varying elevation level plays pivotal role in deciding the area suitability for growing cash rich temperate fruits like apple and other stone fruits. Earlier at elevation level above 1000 msl. was suitable for growing apple and other stone fruits. However, the rising temperature had started altering the crops landscape in the State. Due to changing weather conditions as elaborated in the above sections, the rural folks at the lower elevations have started descending to low chilling requirement stone fruits, pomegranate and mango. On the other hand, at higher elevations the rising temperature is making those regions suitable for growing temperate fruits like apple and other stone fruits cultivation and the area under these crops are also expanding. This is an alarming situation as farmers at lower elevations finds it difficult to cope up with changing climatic conditions. Moreover, there is a significant gap between plantation of new orchards (low chilling requirement fruits) and its fruit bearing phase which makes the farmers economically vulnerable.

Recommendations:

- Irrigation is major challenge in the State and more than 80 percent net sown area are rainfed. The geographical conditions in the state does not permit bore wells irrigation in most of the locations. Therefore, restoration and maintenance of traditional *Kuhls* will improve the resilience of the farmers during dry spells. The technologies for managing water scarcity, such as the conservation of water sources and the promotion of water harvesting tanks can be constructed to provide supplementary irrigation.
- The availability of extension services should be strengthen for adaptation as well as increasing the resilience of farming sytems. It was felt that local farmers have though taken some adaptive measure measure like shifting to new crops but they still lack the proper knowledge to overcome the problem of changing climate. The extension advice will help the farmers to adopt integrated nutrient management, integrated pest management and suitable crop plantation which will reduce their cost of cultivation on one hand and improve the farm value on the other.
- As discussed above that Himachal Pradesh has a micro climatic conditions which varies depending upon the the altitudes. Therefore, government needs to support strategic research to improve the understanding for development of crop varieties, soil and water management and disease mitigation in different regions and

more specifically at different elevations. Such research will facilitate developing package of adaptive measures suitable for a regions categorized according to elevation levels.

- The replacement of the fruit orchard with more adaptive varieties, better suited to the climate conditions, is a primary necessity for local people. The traditional varieties of fruits like apples, pears are no longer suitable for areas where chilling hours have reduced. Therefore, as a means of adaptation new varieties/other fruits which requires low chilling hours should be distributed among farmers. The horticulture department had though taken initiatives to distribute low chilling varietis of apple (spur variety) to the farmes but it still the measures are not adequate given the size of affected farmers. Moreover, to improve the agriculture/horticulture productivity distribution of improved and suitable varieties of seeds and sapling should be carried out at Panchayat level.
- The government is providing hailnets at subsidised rate to orchard farmers. However, the benefits of this scheme had only reached to few farmers. The government should prepare work-plan for generating awareness among needy farmers through horticulture extension officials. There is need to generate awareness among farmers regarding State and Central Government run schemes to improve the adaptive capacity of farmers in wake of climate change.
- Sustainable development of agriculture/horticulture will largely depend upon the farming practices in the State. Earlier farmers were using less chemical inputs in their farm and more organic inputs. But this trend had reversed in the recent years with the increased occurrence of new pests and weeds. This trend needs to be reversed and farmers should be promoted to use more organic inputs for sustainable hilly agriculture.
- Capacity-building activities of local extension officials and field workers in the extension of agriculture/horticulture, livestock, soil conservation needs to be developed. The capacity building for farmers also needs more attention to take on climate change adaptation such as use of new varieties of sapling, seeds and cultivation practices.
- Post harvest management and efficient marketing system needs to be encouraged. The sizable part of the horticultureproduce is lost for want of proper storage and processing facilities. To overcome such problems, the State Government with involving private partners should work for expanding the cold storage facility in various parts of the State. This will help in improving the farm income in the State through reducing the losses.
- The problem of wild boars, monkeys and stray cattles needs to be tackled through a coordinated effort of the State government departments. In many places the menace of wild boars, monkeys and stray cattles had forced the farmers to either shift to other crops or even leave the farmland barren.
- Keeping livestock is very common in Himachal Pradesh. Livestock sector offers great opportunity for the State rural economy where over 92% of the holdings in the State are classified as small or marginal and a large proportion of population is dependent upon agriculture. Therfore, upgrading the indeigenous cattles and buffaloes stock by extension services from veterinary department will improve the breed as well as their productivity. It will improve the livelihood of the poors as well as help them in diversifying their source of income. The disaster management programme in the state should incorporate providing quality feed and fodder in drought like situation. Such initiatives will help the poors from destitution and will improve their livelihood.

- Himachal Pradesh has a rich resource of medicinal plants and in the past few years their rising demands from the industry is putting great pressure on natural sources and leading to unsustainable extraction. This over exploitation of medicinal plants (mainly which has higher market value) is posing a serious risk to their regeneration. An integrated initiative by including the local communities to protect the inherent potential of wild habitats which provides a range of potent medicinal raw drugs in a sustained manner will benefit the local communities particularly the poor and women. It will also help in conserving the natural medicinal plant diversity and their habitat sustainably. The involvement of local community in forest management is beneficial during occurrence of forest fires as their involvement will help in quickly responding to extinguishing the fire.
- As projected, with increase in warming condition and advent of more dry spells the forest fires may increase resulting in increased losses (Timber, biodiversity etc.). Therefore emphasis should be given to such practices where involvement of local in the forest resource management shold be increased such as joint forest management.
- Occupational diversification is another important area where government should focus actively to smoothen the consumption and overall livelihood.

References

- Aggarwal, P. K. (2008). "Global Climate Change and Indian Agriculture: Impacts, adaptation and mitigation", Indian Journal of Agricultural Sciences, 78(10): 911 -19.
- Aggarwal, P. K. (2009), "Global climate change and Indian Agriculture: Case Studies from the ICAR Network Project". Indian Council of Agricultural Research, New Delhi. 148p.
- Annual Report 2008-09, ICAR Network Projection Impact, Adaptation and Vulnerability of Indian Agriculture to Climate Change.CSK Himachal Pradesh Agriculture University, Palampur. Pg. 67-68
- Asian Development Bank (ADB) Report (2010), "Climate Change Adaptation in Himachal Pradesh– Sustainable Strategies for Water Resources".http://www.adb.org/.
- Bhagat, R. M., Rana, R. S., Prasad, R., Lal, H., Kalia, V. and Sood C., (2007), "Project Progress Report (2004-07) of project entitled, Impact Vulnerability and Adaptation to Climate Change" submitted to Network project on climate change, ICAR, New Delhi, 1-2.
- Bhagat et al (2009), "Impact of climate change on shift of apple belt in Himachal Pradesh". ISPRS Archives XXXVIII-8/W3 Workshop Proceedings: Impact of Climate Change on Agriculture.
- Bhan, S. C. and Singh, Manmohan, 2011, "Analysis of total precipitation and snowfall patterns over Shimla", J. Agrometeorol., 13, 2, 141-144.
- Bhutiyani M.R., Kale,V.S and Pawar, N.J. (2007). Long-term trends in maximum, minimum and mean annual air temperatures across the northwestern Himalaya during the 20th Century. Climate Change, 85:159–177.
- Bhutiyani M.R., Kale,V.S and Pawar, N.J. (2010). Climate change and the precipitation variations in the northwestern Himalaya: 1866-2006 – Paper published online now in International Journal of Climatology, Vol.30, Issue 4, pp 535-548.
- Champion, H. G. and Seth, S. K. (1968) A revised survey of forest types of India, Govt. of India Press, Delhi.
- Datta, S. (2013), "Impact of climate change in Indian horticulture: A review", International Journal of Science, Environment, 2(4): 661– 671.
- Forest Fire Disaster Management report (2012), Government of India
- Government of Himachal Pradesh, (2009), State of Environment Report Himachal Pradesh. Department of Environment, Science and Technology
- Gopalakrishnan et al (2011), "Climate Change and Indian Forests", Current Science, Vol. 101, No. 3, 10 August 2011
- Himachal Pradesh Mid-Himalayan Watershed Development Project http://hpmidhimalayan.org/NTFP%20Study.pdf
- Himachal Forest Statistic 2010
- IPCC. 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability- Contribution of Working Group II to the IPCC Fourth Assessment, Cambridge University Press, Cambridge Intergovernmental Panel on Climate Change (IPCC, 1995).

- IPCC Second Assessment Climate Change: A report of the Intergovernmental Panel on Climate Change.Indian State of Forest Report 2010
- Killick.R. and Eckley. I.A. (2013), "Changepoint: An R Package for Changepoint Analysis
- Kumar, S., Barik, K. and D. Parashar (2012), "Cropping and Land Use Pattern in Himachal Pradesh: Case of District Solan", International Journal of Current research and Review, 2012; 4(3): 19-25.
- Kullu District Disaster Management Plan Report, 2011
- Mishra & Reddy (2009), "Mining in Forest Areas - Problems, Causes and Concerns: A Review" RULNR-CESS Working Paper Series No. 1.
- Murthy el at (2006), "Sustainable Community Forest Management Systems: A Study on Community Forest Management and Joint Forest Management Institutions from India", International Review for Environmental Strategies, Vol. 6, No. 1, pp. 23–40.
- OECD (2002). Organization for Economic Cooperation and Development 2002: Climate change: India's perceptions, positions, policies and possibilities. Available at http://www.oecd.org/dataoecd/22/16/1934784.pdf
- Oberoi, R. C. and K. K. Raina (1991). "Growth and Diversification of Food grains in Himachal Pradesh", Economic Affairs, 1991; 36 (3): 155-160
- Parkash and Sharma, "Determining People's Participation in Forest Fire Control: A Study of Himachal Pradesh"
- Patwal and Bharat (2010). "A Himalayan village under climate change microscope: A case study", in Reflections of Climate Change Leaders from the Himalayas - Case Studies Detailed, Thematic Group, Livelihood and People's Perceptions", published by LEAD India, 2010, New Delhi.
- Parashar Amit, Biswas Sas, The impact of forest Fires on Forest biodiversity in the Indian Himalayas (Uttaranchal),0358-B1, FAO (http://www.fao.org/docrep/ARTICLE/WFC/XII/0358-B1.HTM)
- Prasad, R and Rana, R. 2006. A study on maximum temperature during March 2004
- and its impact on rabi crops in Himachal Pradesh. J. of Agrometeorology, 8(1): 91-99
- Ravindranath et al (2006), "Impact of Climate Change on Forests in India. Current Science, 90: 354 361"
- Rajib Nandi (1999). "Herbal Medicinal plants in Himachal Pradesh: An Analysis of Income and Employment Potential"http://www.isst-india.org/PDF/HMP_in_HP.pdf
- Rana et al (2009), "Impact of Climate Change on shift of apple belt in Himachal Pradesh", ISPRS Archives XXXVIII-8/W3 Workshop Proceedings: Impact of Climate Change on Agriculture, Space Applications Centre (ISRO), Ahmedabad, India, 17-18 December 2009.
- State of Environment Report Himachal Pradesh,http://himachal.nic.in/environment/pdf/SOER.pdf
- State Strategy & Action Plan on Climate Change Himachal Pradesh – 2012 http://himachal.nic.in/environment/pdf/HPSCCAP1.pdf
- Sharma el at (2011), "Geospatial Approach for Forest Fire Risk Modelling: A Case Study of Taradevi Range of Shimla Forest Division in Himachal Pradesh, India".
- http://environmentportal.in/files/file/forest%20fire.pdf
- South Asia Disaster Report 2007

- Sharma, D. D. (2010). "People's Perception on The Effect of Climate Change – A Case Study of Tribal District of Himachal Pradesh" , in Reflections of Climate Change Leaders from the Himalayas - Case Studies Detailed, Thematic Group, Livelihood and People's Perceptions, published by LEAD India, 2010, New Delhi.
- Sharma, H. R. (2011). "Crop Diversification in Himachal Pradesh: Patterns, Determinants and Challenges", Proceedings on the workshop on Policy options and Investment Priorities for Accelerating Agricultural Productivity and Development in India, November 10-11, 2011, Organized by Indira Gandhi Institute of Development Research, Mumbai and Institute for Human Development, New Delhi.
- Scott, A. J. and Knott, M. (1974), "A cluster analysis method for grouping means in the analysis of variance", Biometrics, 30(3):507-512.
- Tambe et al (2011), "Rapid, cost-effective and high resolution assessment of climate-related vulnerability of rural communities of Sikkim Himalaya, India", Current Science, Vol. 101, No. 2, 25 July 2011.
- UNFCCC (2004) The First Ten Years. Climate Change Secretariat, Bonn, Germany
- Vedwan, Neeraj and Robert E. Rhoades (2001), "Climate change in the Western Himalayas of India: a study of local perception and response", Climate Research, Vol. 19: 109-117, 2001.
- Verma et al (2001), "Causes of low Productivity in Apple orchards and suggested remedial measures: In Productivity of temperate fruits". Edited by Jindal and Gautam: 1-8.

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