IMPACT OF RAINFALL ON AGRICULTURE IN HIMACHAL PRADESH

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Introduction:

Climate is one of the main determinants of agricultural production. Climate change is any change in climate over time that is attributed directly or indirectly to human activity that alters the composition of global atmosphere in addition to natural climate variability observed over comparable time periods (IPCC, 2007). Since climatic factors serve as direct inputs to agriculture, any change in climatic factors is bound to have a significant impact on crop yields and production. Studies have shown a significant effect of change in climatic factors on the average crop yield (Dinar *et al*. (1998), Seo and Mendelsohn (2008) and Cline (2007).Throughout the world there is significant concern about the effects of climate change and its variability on agricultural production. Researchers and administrators are concerned with the potential damages and benefits that may arise in future from climate change impacts on agriculture, since these will affect domestic and international policies, trading pattern, resource use and food security. Agriculture typically plays a larger role in developing economies than in the developed world. For example, agriculture in India makes up roughly 20% of GDP and provides nearly 52% of employment (as compared to 1% of GDP and 2% of employment for the US), with the majority of agricultural workers drawn from poorer segments of the population (FAO, 2006). Furthermore, it is reasonable to expect that farmers in developing countries may be less able to adapt to climate change due to credit constraints or less access to adaptation technology. Many studies in the past have shown that India is likely to witness one of the highest agricultural productivity losses in the world in accordance with the climate change pattern observed and scenarios projected. Climate change projections made up to 2100 for India indicate an overall increase in temperature by 2-4^{o}C with no substantial change in precipitation quantity (Kavikumar, 2010). Studies by IARI and others indicate greater expected loss in Rabi crop. Every 1^{o}C rise in temperature reduces wheat production by 4-5 million tones. Variability in monsoon rainfall and temperature changes within a season. Global reports indicate a loss of 10-40% in crop production. Change in temperature and humidity may change the population dynamics of pathogens. Lower yields from dairy cattle, reduction in fish breeding, migration and harvests are the consequences of climate change. Lower yield of cash crop, fruits, cereals, aromatic and medicinal plants is also attributed to climate change. Agriculture is one of the most vulnerable sectors to the anticipated climate change. Despite the technological advances in the second half of 20th century, including the Green Revolution, weather and climate are still key factors in determining agricultural productivity in most areas of the world. The predicted changes in temperatures and rainfall patterns, as well as their associated impacts on water availability, pests, disease, and extreme weather events are all likely to affect substantially the potential of agricultural production.

Increases in atmospheric CO concentration can have a positive impact on crops yields by stimulating plant photosynthesis and reducing the water loss via plant respiration. This carbon fertilization effect is strong for so-called C_3 crops, such as rice, wheat, soybeans, fine grains, legumes, and most trees, which have a lower rate of photosynthetic efficiency. For C_4 crops like maize, millet, sorghum, sugarcane, and many grasses, these effects are much smaller. Other factors such as a plant's growth stage, or the application of water and nitrogen, can also impact the effect of elevated CO on plant yield.

The causes of climate variations

- The natural causes like changes in earth revolution, changes in area of continents, variations in solar system etc.
- Due to human activities the concentrations of carbon dioxide and certain other harmful atmospheric gases have been increasing.

Effects of Climate variations

- The increased concentration of carbon dioxide and other green house gases are expected to increase the temperature of earth.
- Crop production is highly dependent on variation in weather and therefore any change in global climate will have major effects on crop yields and productivity. The impact may be negative or positive.
- Elevated temperature and carbon dioxide affects the biological processes like plant respiration, photosynthesis, plant growth, reproduction, water use etc.
- However, in tropics and sub-tropics the possible increase in temperatures may offset the beneficial effects of carbon dioxide and results in significant yield losses and water requirements.

In the long run, the climate change could affect the agriculture in several ways

- Productivity, in terms of quantity and quality of crops
- Agricultural practices through changes of water use (irrigation) and agriculture inputs such as herbicides, insecticides and fertilizers
- Environmental effects, in particular in relation of frequency and intensity of soil drainage (leading to nitrogen leaching), soil erosion, reduction of crop diversity.
- Rural space, through the loss of previously cultivated lands, land speculations, land renunciation, and hydraulic amenities.

Most of the agricultural crops are sensitive to their growing conditions especially rainfall and temperature which consequently comes under the key factors influenced by the climate change. It is easily predictable therefore, how variation and annual weather and changing climate may affect their production and growth. The effect on agriculture and its consequences on society are likely to differ locally depending on the type of climate change that has taken place in that area and the options available to the farmers. It may well bring new agricultural systems to the area and replace the old crop and farming systems.

Assessment done by IARI of regional impact of climate change on rice yield using the Info Crop-Rice model projected that irrigated rice yields in India may decrease by ~4% in 2020, 7% in 2050 and ~10% in 2080 scenarios. Rainfed rice yields in India are likely to be reduced by ~6% in 2020 scenario, but in 2050 and 2080 scenarios they are projected to decrease only marginally (<2.5%). Adoption of the improved varieties with efficient input use and application of 25% of additional nitrogen can offset the adverse impacts of climate change, and increase the rice production by 6-17% in irrigated and 20-35% in rainfed conditions in future climate scenarios. Rice, chickpea, mustard, potato and green gram appears to be more suitable crops for future climatic scenarios with elevated temperature and CO. Growing of direct-seeded rice followed by zero-till wheat can reduce global warming potential by 41% as compared to the transplanted-rice followed by conventionally tilled-wheat. Zero tillage, integrated nutrient management, use of nitrification inhibitor and site-specific nutrient management are recommended to reduce GHG emission in the Indo-Gangetic plains.

During the recent past, weather patterns all over the world are changing and Himachal Pradesh (HP) state is no exception. Climate change may manifest most in HP through warming and rainfall changes. The impacts are likely to adversely affect a large percentage of the state's population dependent on natural resources. There is a clear indication of climate change having a direct impact on the vegetation, natural and cultivated, as also on the availability of water in the rivers and streams.

Impact of rainfall on agriculture

Agriculture is the largest occupation and source of livelihood to most people in Himachal Pradesh, about 66.71% of total population. Cultivation is mainly (80.9%) rain dependent. Rainfall is a crucial factor for the success of crop production. In Himachal Pradesh 31.3% of the area is still not irrigated and is totally rain dependent. The abnormal pattern of rainfall over the past few years has caused great fluctuations in crop production. The performance of crops is directly related to rainfall received during the crop season. The rainfall has shown variation in different districts, in some it was in excess whereas in others deficient. The climate has brought forward and reduced the Rabi season due to delayed and less rainfall. The yield of wheat crop has been affected owing to high maximum and minimum temperature. The area under rice crop has been diverted to maize crop due to irregular rainfall.

The effects of rainfall on agriculture are obvious. According to Ayoade (2004), water in all its forms plays a vital role in the growth of plants and the production of all crops. It provides the medium by which food and nutrients are carried through the plant. Ezedimma (1986) reported that water is the main constituents of the physiological plant tissue and a reagent in photosynthesis. Water is required for all metabolic reactions in plant. The concept of climate and agriculture has been extensively discussed. For example, Lema (1978), Oguntoyinbo (1986), Hartley (1999), Ayoade (2002; 2004) and Cicek and Turkogu, (2005) have all confirmed that climatic parameters (ie. rainfall, sunshine, temperature, evaporation, etc) are closely interrelated in their influence on crops . However, of all the climatic parameters affecting crop production and yield, moisture is the most important (Hodder, 1980). Moisture is primarily gotten from rainfall which in the tropics is cyclic and fairly dependable, (Ezedinma, 1986).

Rainfall is the major source of water which is essential for plant growth and development. Rainfall can be excess rainfall, scanty rainfall or Untimely. The total amount of rainfall in a season is not the criteria. But, its distribution over a large area is critical. Heavy rains with short frequencies will result in floods. If 125 mm of rain is received in two and half hours it is called as heavy rain.

Excess Rainfall

- Even though water in all its forms plays a fundamental role in the growth and production of all crops excessive amounts of water in the soil alter various chemical and biophysical processes.
- Free movement of oxygen is blocked and compounds toxic to the roots are formed, due to drainage problem.
- Soils with high rate of percolation are unsuitable for cultivation under rainfall conditions as plant nutrients can be removed rapidly.
- Heavy rains directly damage plants on impact or interfere with flowering and pollination.
- Top soil layers are packed or hardened which delays or prevents emergence of germinating seeds or emerging seedlings.
- Snow and freezing rain are threats to winter plants. The sheer weight of ice and snow may be sufficient to break branches of trees and shrubs.
- A thick ice cover on the ground tends, to produce suffocation of crop plants such as in winter wheat.
- Under excess rainfall conditions floods occurs, in areas drained by large river systems.
- Floods submerge crops; silt up fields; tank bunds and river embankments are washed off.

Management of excess rainfall (floods)

- By constructing multipurpose projects such as irrigation and electric systems.
- Planned afforestation.
- Keeping the field drains open
- By growing flood obstructing crops.

Scanty rainfall

This is a synonym with "Inadequate rainfall" or `Drought'. The influence of drought can be observed not only on phenology but also on phenophases of crop plants.

- Water limitation from seedling emergence to maturity in all the cereals is very damaging.

- Water stress/drought during flowering reduces the size of inflorescence, affect fertilization, grain filling and reduce final yield.
- Plants show wilting symptoms
- Cell division and enlargement are very sensitive to drought stress, which results in stunted growth.
- Drought affects nutrient absorption, carbohydrate and protein metabolism and translocation of ions and metabolites.
- Abscission (falling off) of leaves, fruits and seeds can be induced by plant water deficit during droughts.
- Plant respiration is drastically reduced.

Management of drought / scanty rain

- Application of sufficient irrigation water negates the condition of insufficient or scanty rain.
- Estimate amount of water needed at various stages of crops by proper experimentation and adjust the sowing dates.
- Conserve water by suitable management of fallow and cropped field's viz., breaking up the surface to reduce runoff, removal of weeds, digging pits of small size which collects runoff water, etc.

Untimely rains: This refers to rainfall received too early or too late in the cropping season with the result that normal agricultural operations are upset.

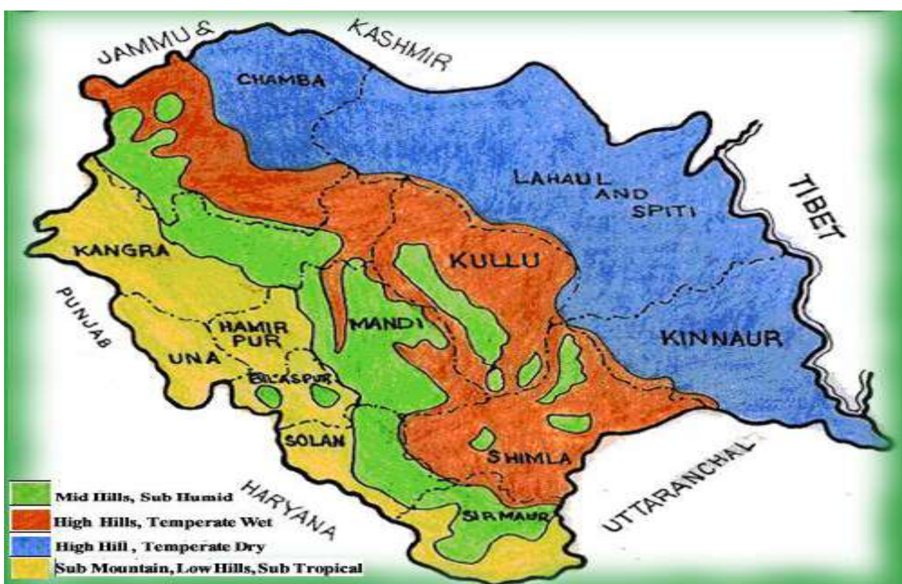
- Too early rains do not permit proper preparation of seedbed due to heavy rains.
- Too late rains delay sowings and pest attack cause colossal losses.
- Wet spells during flowering and harvesting results in poor fertilization and subsequent loss in yield.

Management of untimely rains

- Farmers need to be advised to follow the weather forecasting by IMD for proper management of their crops through crop-weather advisories.
- Contingency crop plans need to be developed to the needy farmers.

Impact of Rainfall on Agriculture in Himachal Pradesh

The effect of climate variations is also seen in Himachal Pradesh. The state is divided mainly in four agro-climatic zones viz. shivalik hill, mid hill, high hill and cold dry zones.



1. SHIVALIK HILL ZONE: Climate Sub Tropical 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, Sugarcane, Mustard, Potato, Vegetables etc.

2. MID HILL ZONE: This zone extends from 651 meters to 1,800 meters above mean sea level, having mild temperate climate. It occupies about 32% of the total geographical area and about 37% 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.

3. 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 and Amaranthus), 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.

4. 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 and Amaranthus. It is ideally suited for the production of quality Seed Potato, temperate and European type of Vegetables and their Seeds, Seed Potato, Peas as green and seed purposes.

LAND USE PATTERN IN HIMACHAL PRADESH:

Sr.No.	Head of classification	Area in hectare	%age to total
1.	Total Geographical area		
(A)	By Professional Survey	55,67,300	-
(B)	By Village Survey	45,44,400	-
2.	Forest	10,99,700	24.1
3.	Barren and Un-culturable Land	6,53,500	14.4
4.	Land Put to non-agricultural uses	4,71,600	10.4
5.	Permanent Pastures and other grazing land	15,14,000	33.3
6.	Land under misc. trees crops etc.	61,100	1.5
7.	Culturable Waste Land	1,28,000	2.8
8.	Other follows land	16,000	0.35
9.	Current Fallows	59,200	1.3
10.	Net Area Sown	5,41,400	11.9
11.	Area Sown more than once	4,10,900	9.0

Climate change is an increasingly significant global challenge and its negative impacts have been already felt in some regions of the world. The aggregate impacts of agricultural damages caused by climate change on the global economy are moderate. However, the impacts are not evenly distributed across the world. Developing countries would bear disproportionately large losses arising from climate change.

Increased concentration of greenhouse gases (GHGs) in the atmosphere resulted in warming of the global climate system by 0.74 °C between 1906 and 2005. The trends of rise in temperature, heat waves, droughts and floods, and sea level shown by the Indian scientists are in line with the Inter-Governmental Panel on Climate Change (IPCC) though magnitude of changes could differ. The mean temperature in India is projected to increase up to 1.7 ^{o} C in kharif (July to October) and upto 3.2^{o} C during rabi (November to March) season, while the mean rainfall is expected to increase by 10% by 2070.

Changes in precipitation under global warming can be more complex than temperature changes, and at a regional scale it is not necessarily always the case that precipitation will monotonically increase or monotonically decrease at the decadal temporal scale. Climate change will alter the cropping calendar in some locations, shifting the month in which a crop can be safely planted forward or back.

Agricultural production is affected by many uncontrollable climatic factors, the number one being rainfall. The role of rainfall as a resource in crop production has been an area of interest for many researchers. Rainfall plays a more significant role than other farm inputs. The amount and temporal distribution of rainfall is generally the single most important determinant of inter annual fluctuations in national crop production levels (Mulat et al., 2004). According to von Braun (1991), for instance, a 10% decrease in seasonal rainfall from the long-term average generally translates into a 4.4% decrease in the country's food production. Rainfall in much of the country is, on the other hand, often erratic and unreliable; and rainfall variability and associated droughts have historically been major causes of food shortages and famines (Wood, 1977; Pankhurst and Johnson, 1988).

The impact of rainfall on crop production can be related to its total seasonal amount or its intra-seasonal distribution. In the extreme case of droughts, with very low total seasonal amounts, crop production suffers the most. 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. This means that the number of rainy days during the growing period is as important, if not more, as that of the seasonal total. Jackson (1989) notes that even in wet locations rainfall variability at the daily time scale is critical to plant growth, particularly in the early part of the rainy season before soil moisture reserves have been built up. Generally, the effect of rainfall variability on crop production varies with types of crops cultivated, types and properties of soils and climatic conditions of a given area. The impact of rainfall on four major crops viz. wheat, barley, rice and maize was studied in the present work.

SOWING AND HARVESTING SEASONS OF CROPS IN HIMACHAL PRADESH

Crops	Sowing	Harvesting
Rice	May-July	September-October
Maize	May-July	September-October
Wheat	October-December	April-June
Barley	October-December	April-June

WATER REQUIREMENT OF MAJOR CROPS:

Crop	Rainfall required at time of sowing
Rice	1400-1800mm
Maize	500-800mm
Wheat	375-875mm
Barley	390-430mm

AVERAGE RAINFALL DURING THE YEARS 2001-12 IN HIMACHAL PRADESH

Year	Average rainfall (mm)	Year	Average rainfall (mm)
2001	1067.5	**2007**	1028.50
2002	984.8	**2008**	1238.87
2003	1131.7	**2009**	913.72
2004	906.46	**2010**	1322.03
2005	1012.25	**2011**	1169.37
2006	1104.90	**2012**	1131.33

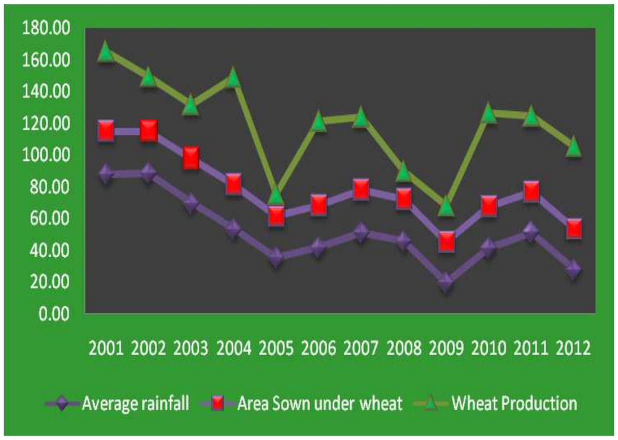
AREA UNDER MAJOR FOOD GRAINS IN HIMACHAL PRADESH ('000 ha)

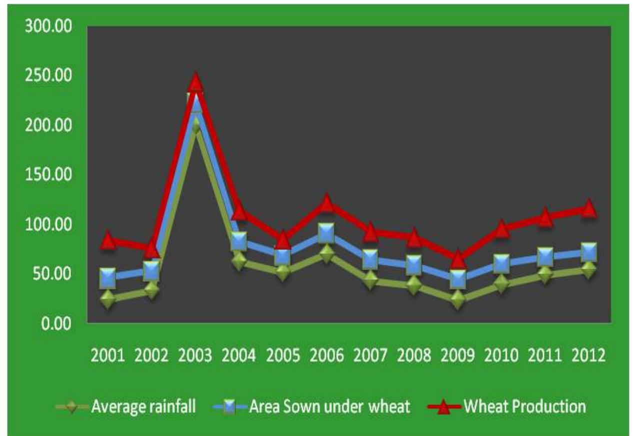
Year	Wheat	Barley	Maize	Paddy
2000-01	362.68	25.643	298.052	81.519
2001-02	366.518	25.017	301.282	80.579
2002-03	359.439	23.596	297.024	83.273
2003-04	363.359	24.324	298.467	81.335
2004-05	367.77	23.427	298.605	79.519
2005-06	358.45	25.24	295.35	79.37
2006-07	362.25	24.10	299.04	69.21
2007-08	366.59	23.51	300.15	78.57
2008-09	359.96	22.6	297.72	77.71
2009-10	352.52	21.24	295.44	76.7
2010-11	357.24	22.34	357.24	77.71
2011-12	356.58	22.06	356.58	76.7

PRODUCTION OF MAJOR FOOD GRAINS IN HIMACHAL PRADESH (000'mt)

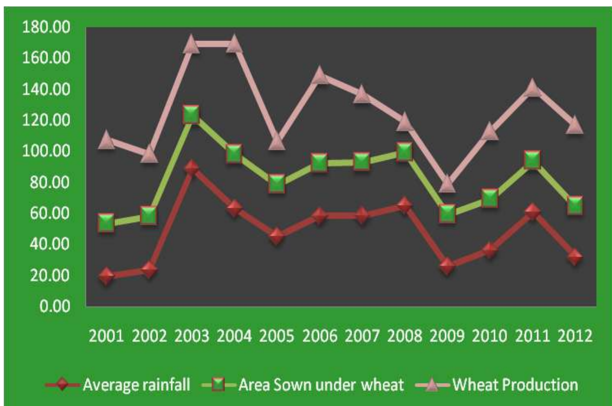
Year	Wheat	Barley	Maize	Paddy
2000-01	251.319	21.414	683.642	124.893
2001-02	637.068	34.685	768.198	137.418
2002-03	495.558	30.614	479.21	85.653
2003-04	496.93	28.139	729.571	120.624
2004-05	687.452	33.713	636.294	109.129
2005-06	365.88	29.36	543.06	112.14
2006-07	596.49	33.87	695.38	123.49
2007-08	562.01	30.67	682.62	121.45
2008-09	381.18	20.45	676.64	118.28
2009-10	414.41	22.94	543.19	105.9
2010-11	614.89	32.17	614.89	118.28
2011-12	595.78	30.39	595.78	105.9

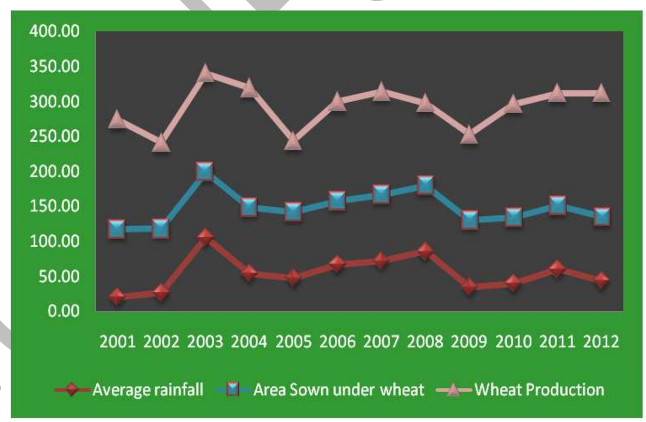
Impact of rainfall on wheat



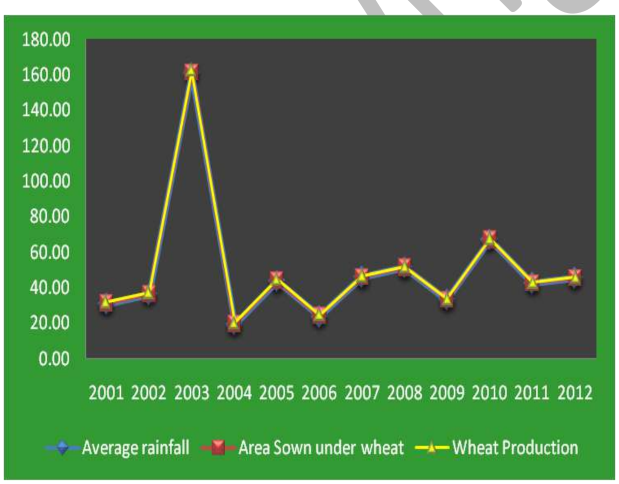


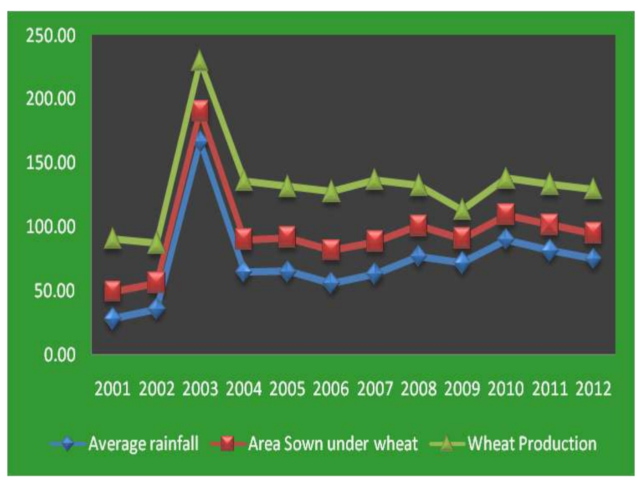
Bilaspur **Chamba**



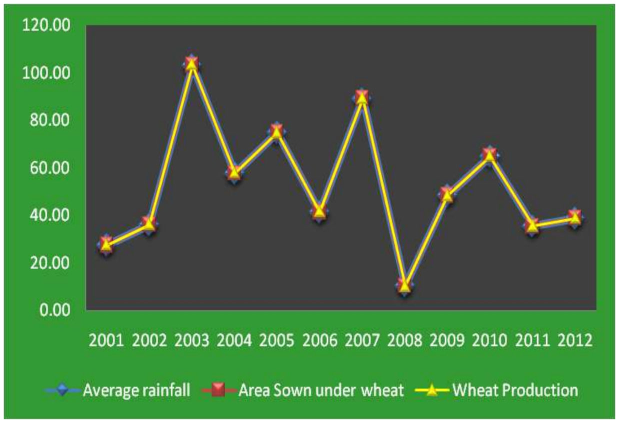


Hamirpur **Kangra**

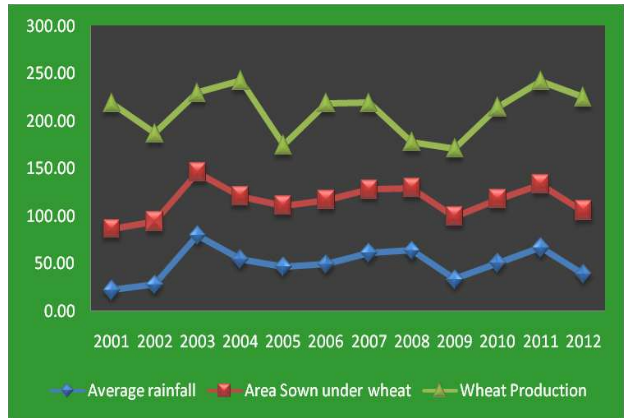




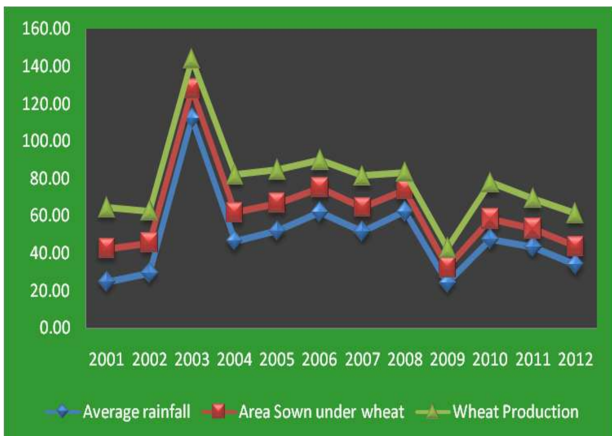
Kinnaur **Kullu**



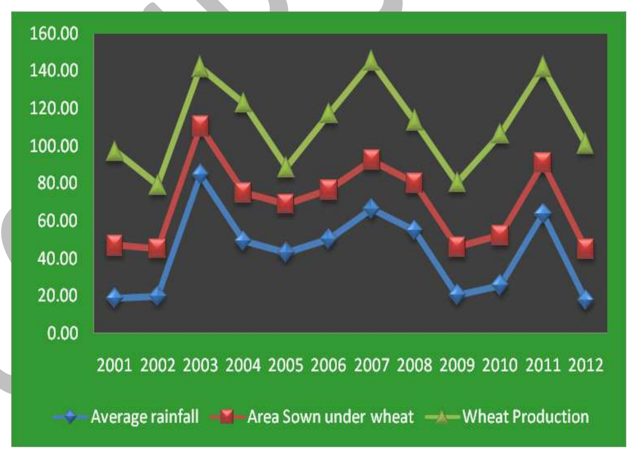
Lauhal & Spiti



Mandi

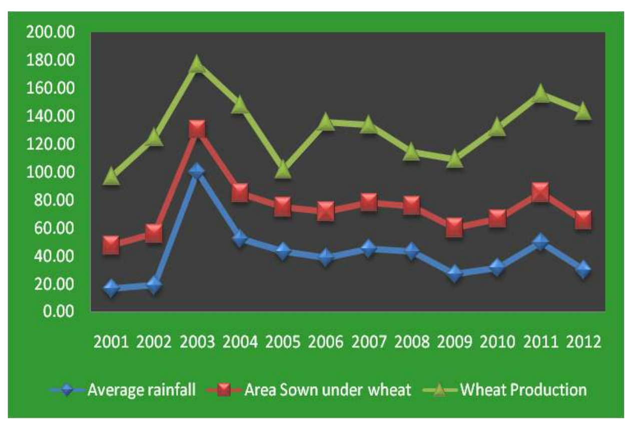


Shimla



Sirmaur

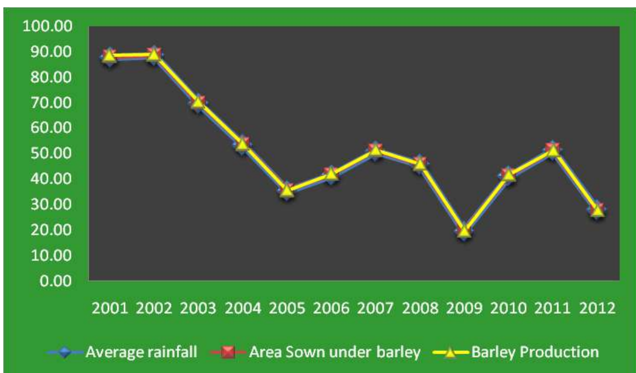
Solan



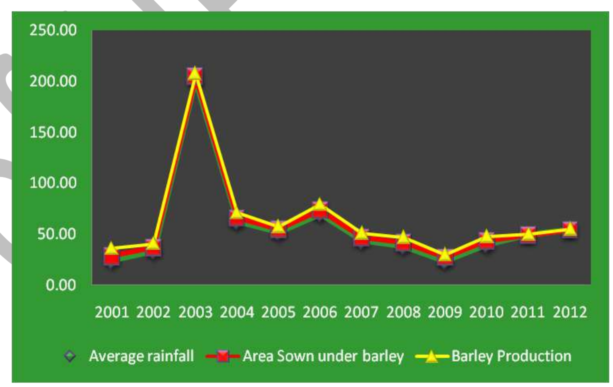
Una

There is positive correlation between the rainfall and the production as well as area sown under wheat crop which showed that rainfall is the major factor influencing the production as well as area sown under wheat in all districts. The area sown under the wheat was increasing or decreasing according to the occurrence of rainfall during the growing season of wheat. Maximum production was in the year 2003 when there was sufficient rainfall while minimum production was in the year 2004 in Kinnaur, 2008 in Lahaul & Spiti and 2009 in rest of the districts when there was less rainfall during the growing season of wheat. However the production was not increasing and the trend showed downfall in the year 2012 in almost all the districts due to irregular, less and untimely rainfall during the growing season.

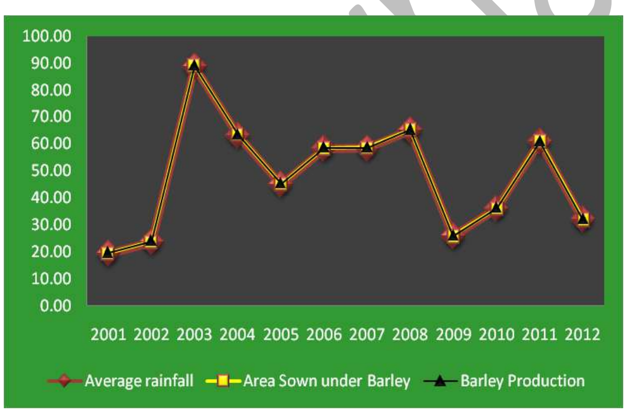
Impact of rainfall on Barley:



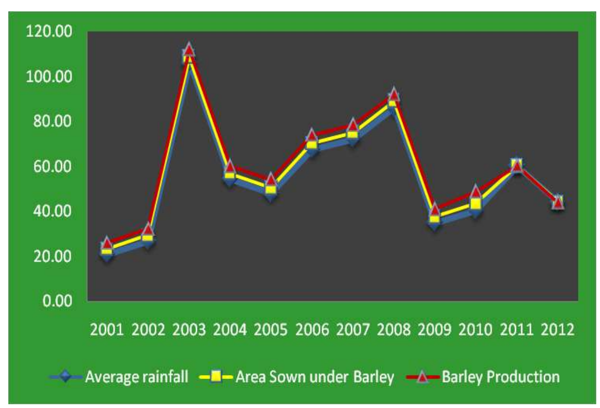
Bilaspur



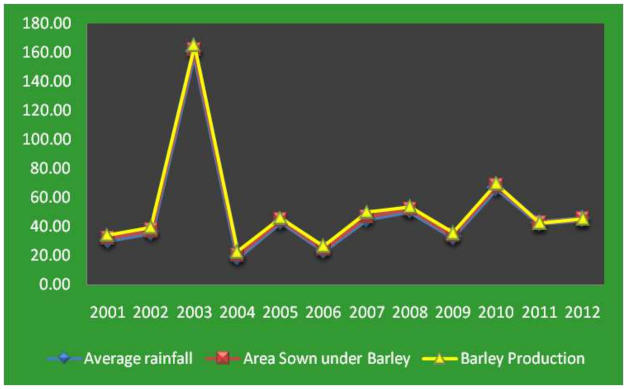
Chamba



Hamirpur

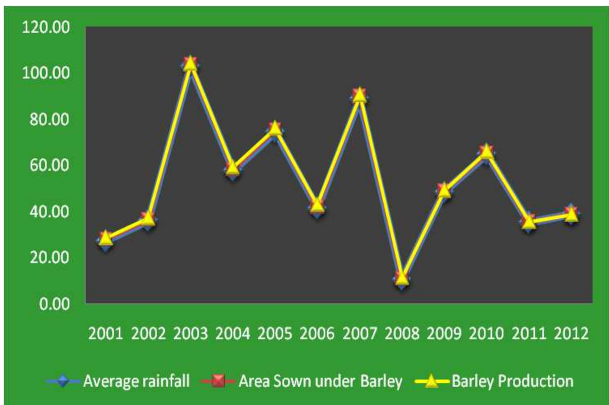


Kangra



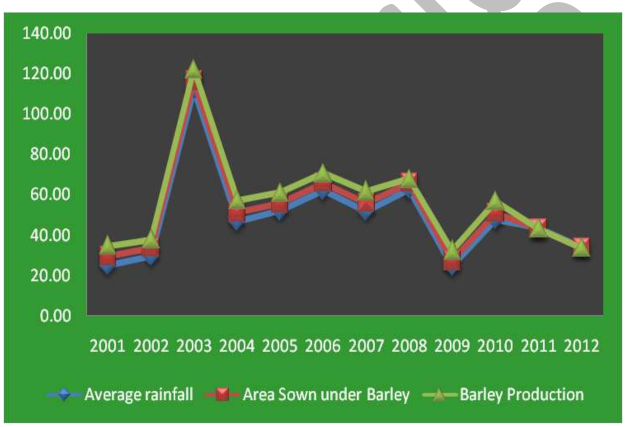
Kinnaur

Kullu



Lauhal & Spiti

Mandi



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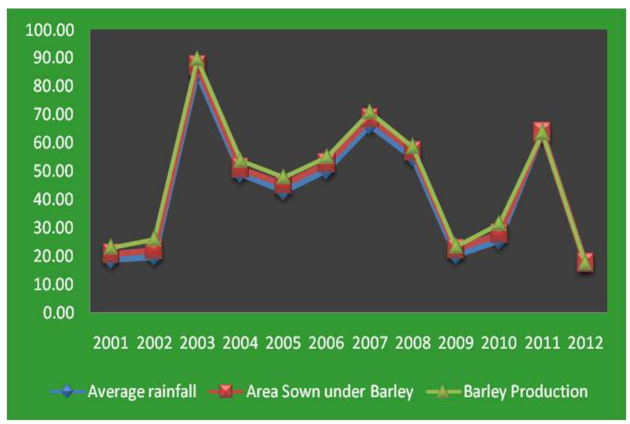
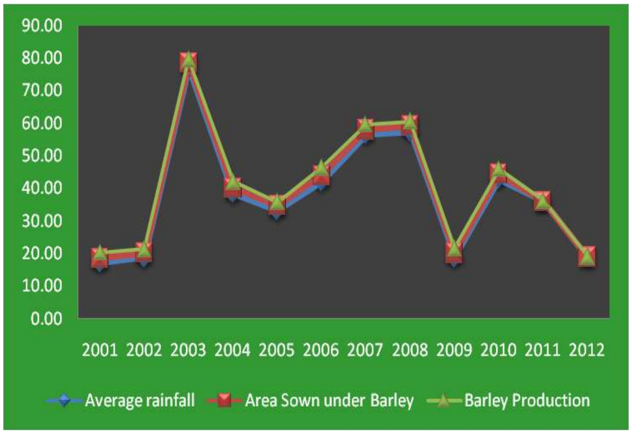
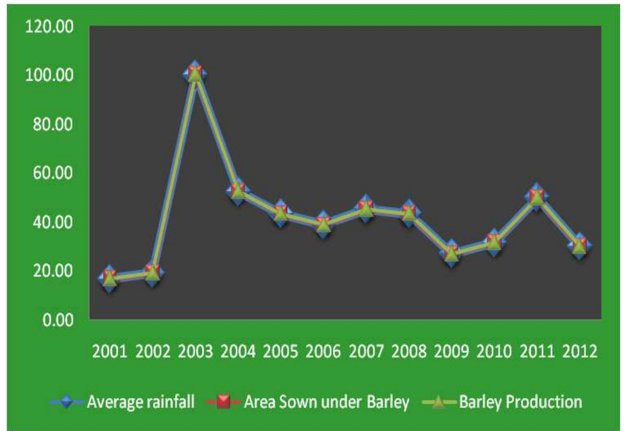


Sirmaur



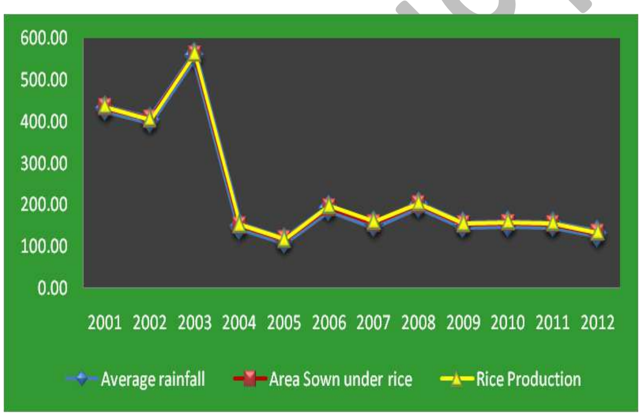
Solan



Una

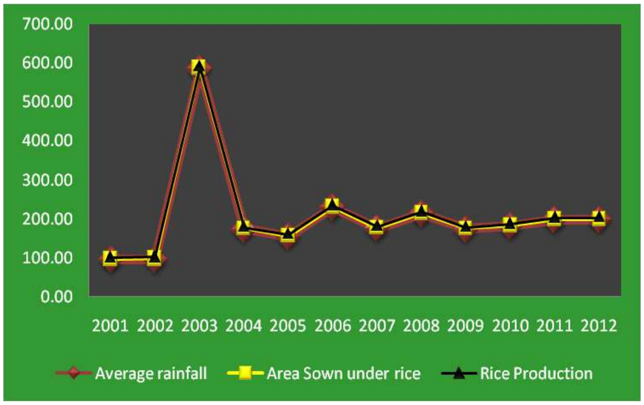
Correlation between barley production and rainfall was similar as that of wheat i.e. positive. The decrease or increase in production was influenced directly by the amount of rainfall an area received during the growing season of barley. The maximum production was recorded in the year 2002 in Bilaspur and 2003 in rest of the districts while minimum was observed during 2001 in Hamirpur, Kangra, Kullu, Mandi and Una, during 2004 in Kinnaur, during 2008 in Lahaul & Spiti, during 2009 in Bilaspur, Chamba and Shimla and during 2012 in Sirmour, Shimla and Solan districts. The variation in production might be due to the irregular and insufficient rainfall during the growing season.

Impact of rainfall on Rice:

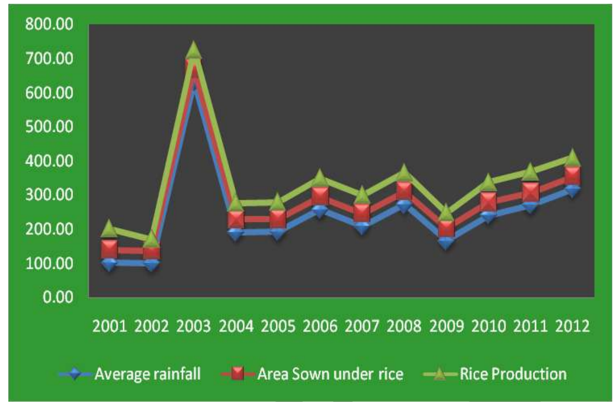


Bilaspur

Chamba



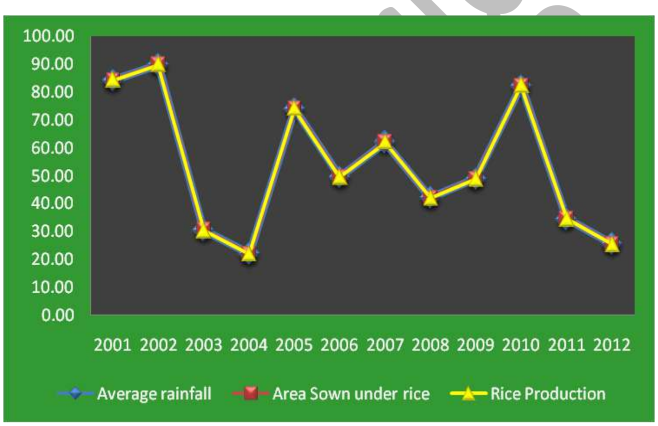
Hamirpur



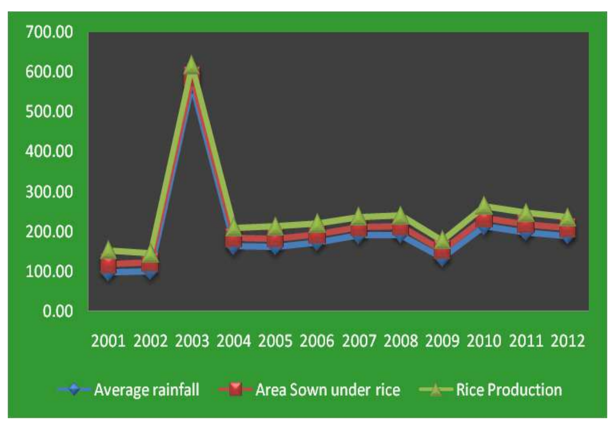
Kangra

Kinnaur

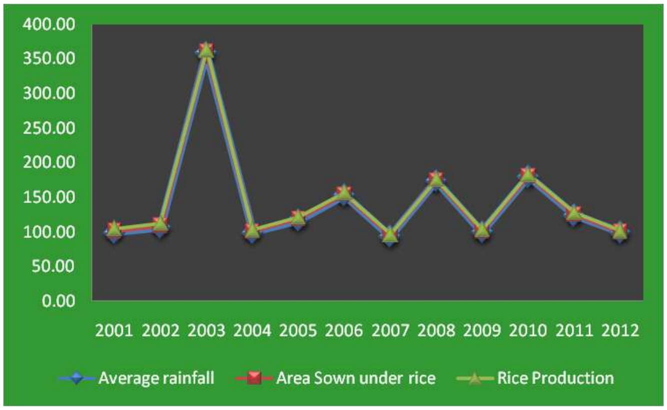
Kullu



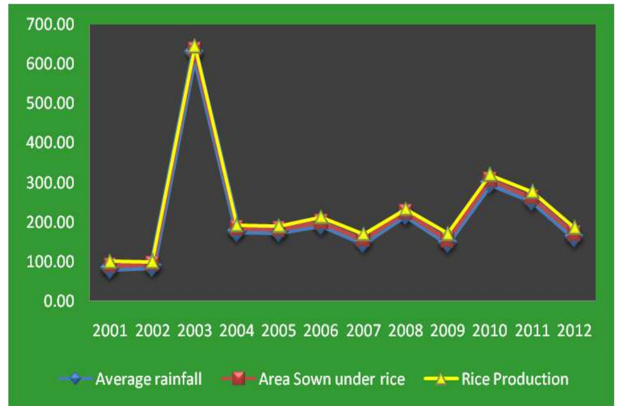
Lauhal & Spiti



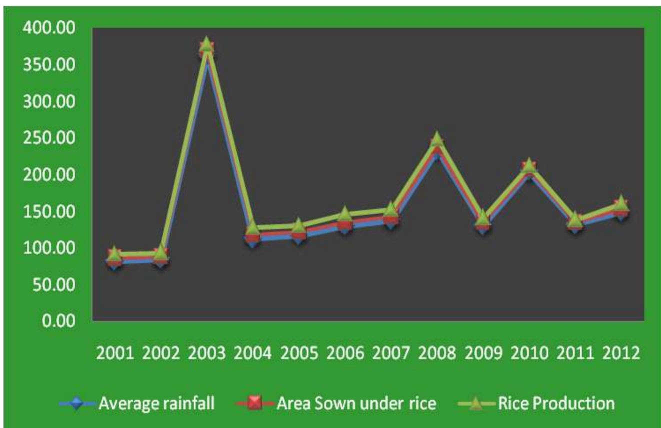
Mandi



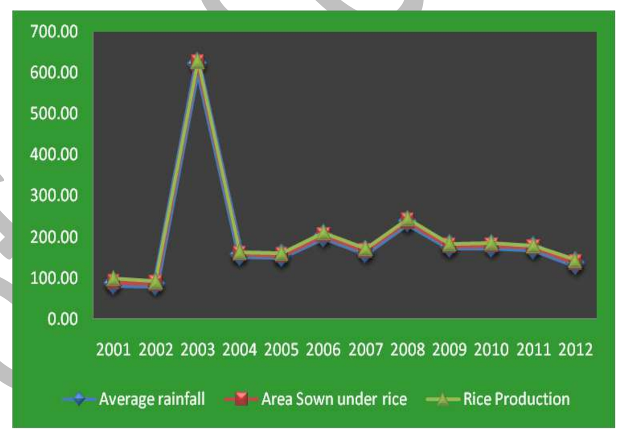
Shimla



Sirmour



Solan



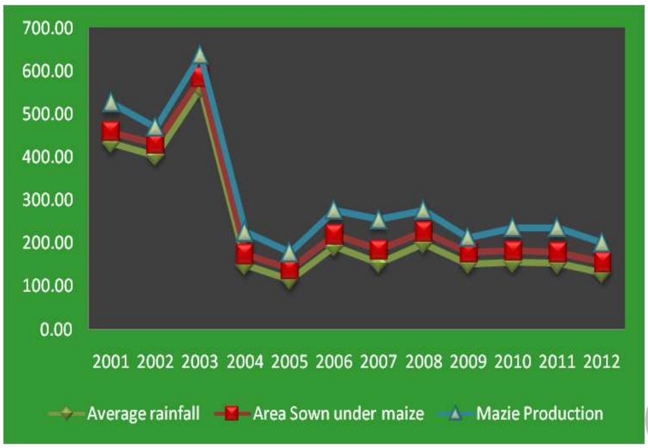
Una

Geographical distribution of rice growing areas in the world over regions of heavy rainfall in the relatively short period of the cropping season indicates that water supply is probably the chief limiting factor to the growth and production of rice. The pattern of frequency and depth of precipitation in different month of growing season would seem to have important physiological bearing of rice plants particularly relating to yield.

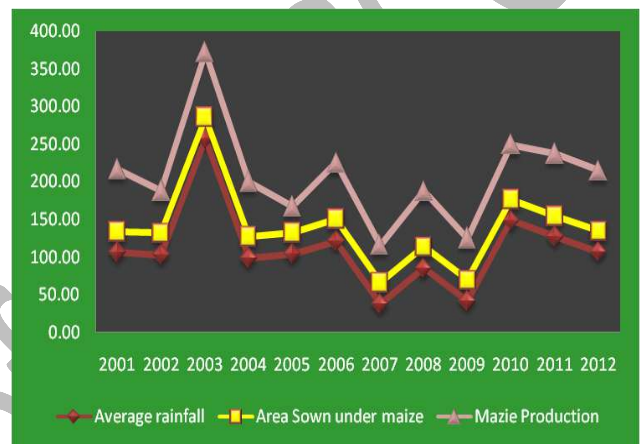
The rice production and area sown under rice is positively correlated with the amount of rainfall received during the growing season of rice. The maximum production was recorded during 2003 in Bilaspur, Chamba, Hamirpur, Kinnaur, Kullu, Mandi, Shimla, Sirmour, Solan and Una while in Lahaul & Spiti the maximum production was recorded during the year 2002. The minimum production was observed in during 2005 in Bilaspur. In Chamba minimum production was recorded in

2007 and 2009. In Hamirpur minimum production was recorded in the year 2001 and 2002. In Kangra, Sirmour, Mandi, Solan and Una minimum production was observed during the year 2002. In Kinnaur minimum production was recorded in 2004 and 2012. In Lahaul & Spiti minimum production was observed in 2004 and in Shimla during the year 2012. Decrease in production and area sown was might be due to low rainfall or untimely irregular rainfall during the growing season of rice.

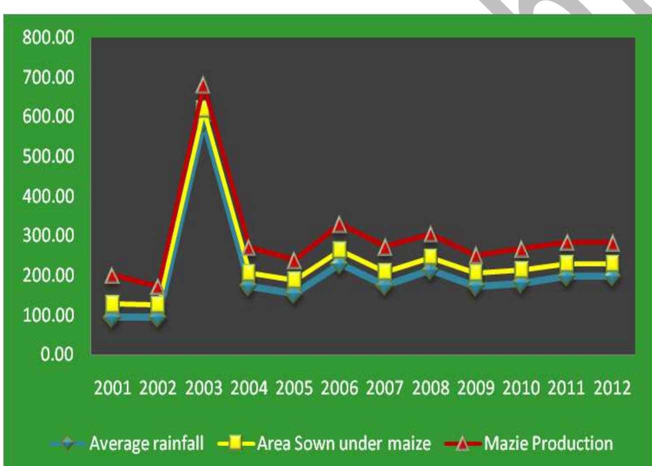
Impact of rainfall on Maize:



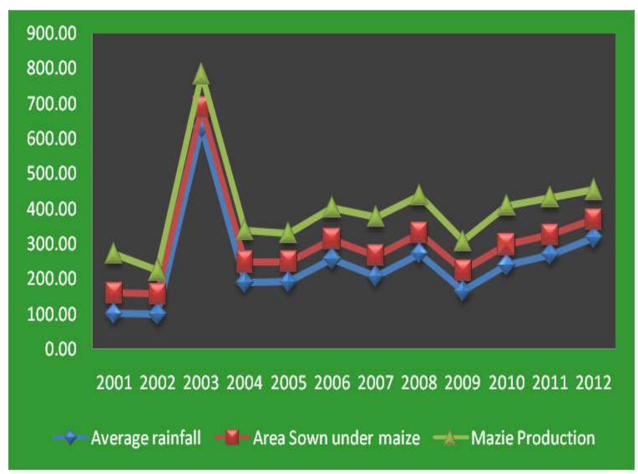
Bilaspur



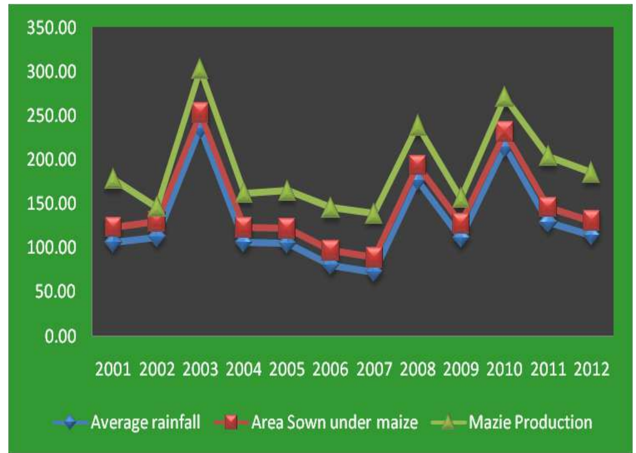
Chamba



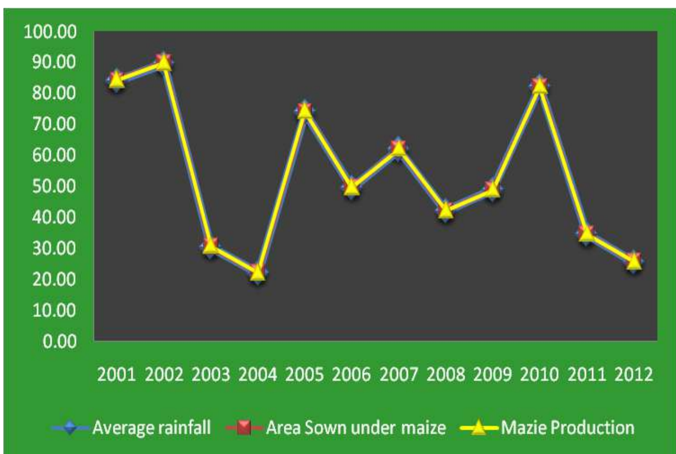
Hamirpur

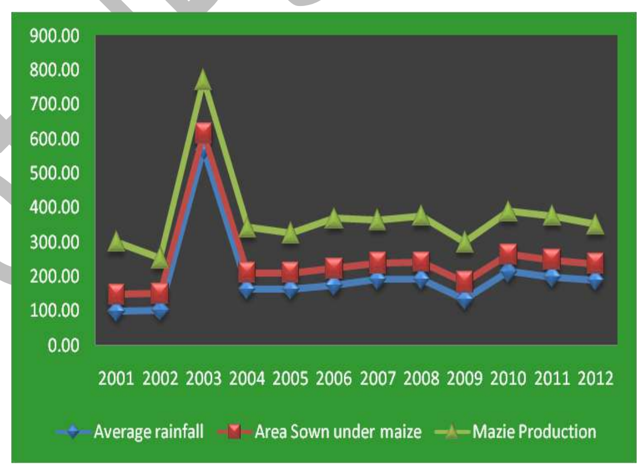


Kangra

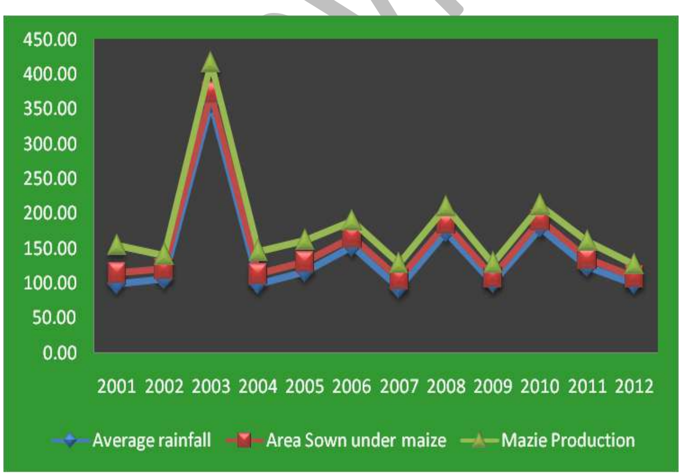


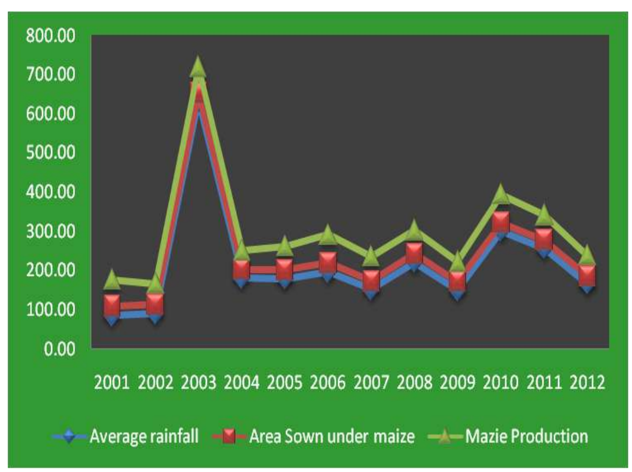
Kinnaur **Kullu**



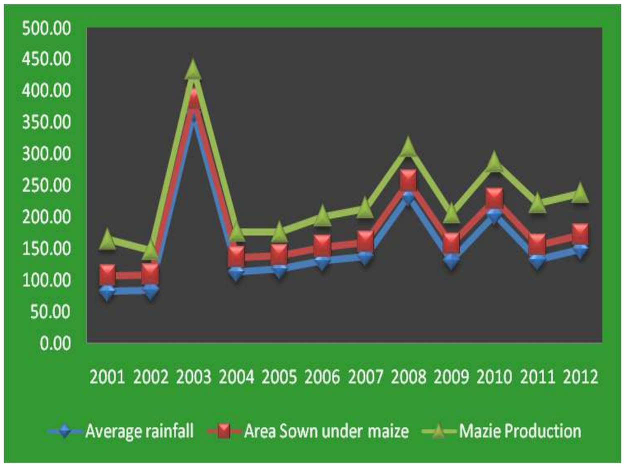


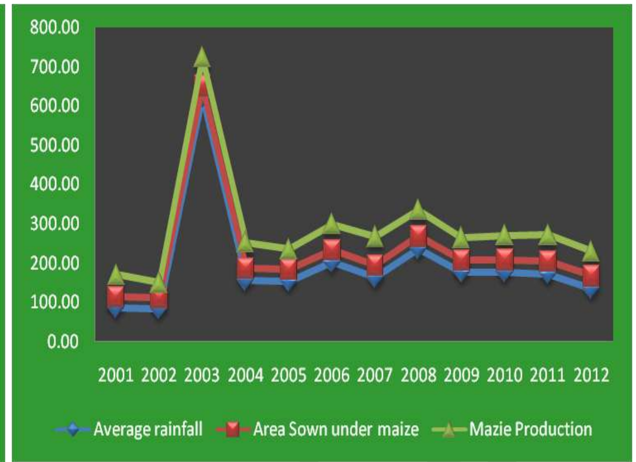
Lauhal & Spiti **Mandi**





Shimla **Sirmaur**





Solan **Una**

Maize performs best in well well-drained, well aerated, deep, warm loamy and silt loamy soils containing adequate organic matter and well supplied with available nutrients (Purseglore, 1992). The reason for this is deduced from the observation made by Ojo, et al. (2001) that the patterns of mean rain days generally follow the same pattern with mean rainfall amounts and that greater percentages of the rain days will be during the rainy season. Therefore, the concentration of rain days during rainy season is having a great influence on maize yield annually such that the higher and less evenly distributed the number of rain days the lower the maize yield. Maize requires a well-distributed, considerable amount of rainfall over an appropriate numbers of days during its growing season for optimum yield.

The rainfall directly influenced the production as well as area sown under maize which showed positive correlation between them. When there was sufficient rainfall during the growing season of maize the production was high however during less rainfall, irregular and untimely rainfall there was decrease in production and area under the crop. The maximum production of maize was recorded during the year 2003 in Bilaspur, Chamba, Hamirpur, Kinnaur, Kangra, Kullu, Mandi, Shimla, Sirmour, Solan and Una while in Lahaul & Spiti during the year 2002. The minimum production was recorded during 2005 in Bilaspur, 2007 and 2009 in Chamba and Shimla, 2004 in Kinnaur and Lahaul & Spiti and during the year 2002 in rest of the districts.

The graphs show dramatic variations in all district in crop yield and cultivatable areas both with significant downward trend. The production has been on steady decline due to erratic rainfall variability and the area planted to maize has also been reduced to adapt to the anticipated drought period. The risk associated with climate variability of crop production in general depends mainly on the growth stage of the crop when the weather aberration occurs. The fluctuation in production of these major crops in Himachal Pradesh might be due to many factors but rainfall is the main factor that is affecting these crops to the maximum. The uncertainty about weather conditions is one of the key risk factors associated with crop production. The variation in rainfall is due to change in climate. Climate change influences the precipitation in many ways viz. change in rainfall pattern, frequency and intensity of rainfall etc. While there is general agreement that average temperatures will gradually increase, the distribution, frequency and intensity of changes in precipitation regimes are much more uncertain. From regional-level agronomic studies, large losses in wheat, rice and maize, among other crops, are projected for the 2050s. Crop production decreases and increases vary widely depending upon scenario assumptions of CO_2 fertilization effects, with low-income calorie importers suffering greater relative losses regardless. During various studies on climate change it is reported that depending on the climate scenario and assumptions of CO_2 effectiveness, all regions of the world may experience significant decreases or increases in crop yields. The scientific evidence on rainfall variability with its momentous impacts on crop yield is now stronger than ever. It is even more so on grains that serve as staple food in most parts of the world. The facts to note here are that; the severity of impacts of climate variability and change on crop yield in relation to activities of rainfall vary from region to region and from year to year as some stations are observing increase in yield, others witness reduction, depending on crop type/variety. Climate variability has been and continues to be, the principal source of fluctuations in global food production in countries of the developing world. The report by World Meteorological Organization (WMO) revealed that the overall global warming is expected to add in one way or another to the difficulties of food production and scarcity. The report also stated that reduced availability of water resources would pose one of the greatest problems to agriculture and food production, especially in the developing countries.

Mitigation:

The options available for HP are mitigation measures to reduce the pace and magnitude of the changes in anthropogenic climate change activities or adaptation measures to reduce the adverse impacts on human-well being as a result of the climate change occurrences – enough mitigation to avoid the unmanageable, enough adaptation to manage the unavoidable. The possible mitigation agricultural strategies required to be implemented are to reduce GHG emissions, enhance carbon sinks and proper understanding of the effects of climate change helps scientists to guide farmers to make crop management decisions such as selection of crops, cultivars, sowing dates and irrigation scheduling to minimize the risks.

- Switching to crop that can withstand higher temperature.
- Decrease emission of green house gases.
- Development of arid land crops and pest management as well as capacity building of extension workers and NGO's to support better vulnerability reducing practices.
- Programme to minimize the adverse effects of drought on production of crops and livestocks and on productivity of land, water and human resources, so as to ultimately lead to drought proofing of affected areas.
- Aim to promote overall economic development and improve the socioeconomic development condition of resource poor and disadvantaged section inhibiting the programme areas.
- Improve methods to conserve soil and water. Non conventional methods for utilization of water, including inter-basin transfers, artificial recharge of groundwater and desalination of brackish or sea water, as well as traditional water conservation practices like rainwater harvesting, including roof top rainwater harvesting should be practiced to increase utilizable water resources.
- Development of drought and pest resistant crop varieties.
- There should be stakeholder consultations, training workshops and demonstration exercises for farming communities for agro-climatic information sharing and dissemination.
- Financial support to enable farmers to invest in and adopt relevant technologies to overcome climate related stresses.

- Supplying customized information can boost farm productivity and farm incomes.
- Use of genetic engineering to convert C-3 crops to the more carbon responsive C-4 crops to achieve greater photosynthetic efficiency for obtaining increase productivity at higher levels of carbon dioxide in atmosphere.
- Development of crops with better water and nitrogen use efficiency which may result in reduced emissions of GHG's or greater tolerance to drought or salinity.

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