IMPACT OF CLIMATE VARIABILITY ON AGRICULTURE IN NORTH KARNATAKA-AN ECONOMIC ANALYSIS

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BY

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CERTIFICATE

This is to certify that the thesis entitled "IMPACT OF CLIMATE VARIABILITY ON AGRICULTURE IN NORTH KARNATAKA - AN ECONOMIC ANALYSIS" submitted by LAXMI N. TIRLAPUR for the degree of DOCTOR OF PHILOSOPHY in AGRICULTURAL ECONOMICS to the College of Agriculture, University of Agricultural Sciences, Dharwad, is a record of bonafide research work carried out by her during the period of her study in this University, under my guidance and supervision and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

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LIST OF ABBREVIATIONS

Sl. No.	Acronyms	Full Forms
1.	AAS	Agromet Advisory Service
2.	BCR	Benefit Cost Ratio
3.	CRU	Climate Research Unit
4.	CV	Coefficient of Variation
5.	CO_2	Carbon Dioxide
6.	GDD	Growing Degree Days
7.	GHG	Green House Gases
8.	GIM	Global Investors Meet
9.	IGPR	Indo Gangetic Plain Region
10.	IMD	India Meteorological Department
11	IPCC	Intergovernment Panel on Climate Change
12	K EU	Kudoz Euro (Thousand Euro)
13	KSNDMC	Karnataka State National Disaster Monitoring Cell
14	NCA	National Commission on Agriculture
15	NDMA	National Disaster Management Authority
16	N_2O	Nitrous Oxide
17	RH	Relative Humidity
18	SD	Standard Deviation
19	SPI	Standardized Precipitation Index
20	SMR	Summer Monsoon Rainfall
21	Tg	Teragram

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1. INTRODUCTION

Indian economy is mainly agrarian, as agriculture is one of the main means of livelihood of almost 58 per cent of the population in the country. Agriculture sector alone representing 13.6 per cent of India's Gross National Product (GNP), plays a crucial role in the country's development and shall continue to occupy an important place in the national economy. It sustains the livelihood of nearly 70 per cent of the population, employs about 51 per cent of the work-force and nearly 10 per cent to export earnings.

Indian Agriculture and Climate Change

Climate and agriculture are inextricably linked. Climate change affects agriculture in a number of ways, including through changes in average temperatures, rainfall, climate extremes, changes in pests and diseases; changes in atmospheric carbon dioxide and ground-level ozone concentrations. Climate change is already affecting agriculture, with effects unevenly distributed across the world. Infuture will likely negatively affect crop production in low latitude countries, while effects in higher latitudes may be positive or negative. Climate change will probably increase the risk of food insecurity of the already vulnerable groups, or underdeveloped countries or people. It seems obvious that any significant change in climate on a global scale will impact local agriculture, and therefore affect the world's food supply. Considerable studies have been carried out to investigate how farming might be affected in the different regions. Many climatologists predict a significant global warning in the coming decades due to rising atmospheric carbon dioxide and other green house gases. Climate change will also have an economic impact on agriculture, including changes in farm profitability, prices, supply, demand and trade. The magnitude and geographical distribution of such climate induced changes may affect our ability to expand the food production, area as required to feed the burgeoning population. Agriculture is sensitive to short-term changes in weather and to seasonal, annual and longer-term variations in climate. In the long-term changes, agriculture is able to tolerate moderate variations from the climatic mean. Changes beyond these bands of tolerance may require shifts in crops and cultivars, new technologies and infrastructure or ultimately conversion to different land uses. The variations in the meteorological parameters are more of transitory in nature and have paramount influence on the agricultural systems.

The current climate change is linked mostly to greenhouse gas emissions resulting from human activities. These emissions of anthropogenic origin are by themselves responsible for more than 3/4 of the carbon dioxide (CO_2). The consumption of fossil fuels is by far the most incriminating factor. But we should not forget that changes in land use, including deforestation, occupy second place in term of responsibility for the worldwide increase in greenhouse gas emissions (17 % of global emissions). The rise in the concentration of green house gases was caused primarily by human and industrial activities. The increased agricultural activities and organic waste management are presumed to be contributing to the building up of both methane and nitrous oxide in the atmosphere. However, agriculture in general and Indian agriculture in particular is not contributing significantly to global climatic change. India's total contribution to global methane emission from all sources is only 18.5Tg per year. Agriculture (largely paddy fields and ruminant animal production) is a major source of CH_4 emission and contributes 68 % to it. Since India and China are the major paddy producing countries, an international opinion was made that Asia and in particular, India and China are contributing significantly to global warming and they should do something to prevent this phenomenon. Sinha *et al.* (2000) estimated that global annual methane emission from paddy cultivation is less than 13 Tg. The contribution of Indian paddies to global CH_4 budget was estimated to be only 4.2 Tg/year (Ziska *et al.,* 1997). The main reasons of low methane emissions from paddy fields in India are that the soils of major paddy growing areas have very low organic carbon and also not continuously flooded. Atmospheric concentration of N_2O is increasing at a rate of 0.22 ± 0.02 % per year. But despite its lower concentration and less rapid rise, N_2O is becoming an important GHG, because of its longer lifetime and greater global warming potential than that of CO_2 molecule (300 times more). About 5 % of total greenhouse effect can be ascribed to N_2O and it is also responsible for the destruction of stratospheric ozone. Estimates of total nitrous oxides from Indian agriculture are very low due to low soil fertility and lower amounts of fertilizers used in agriculture as compared to the western countries. In India, CO_2 fixation becomes more important, because we use almost 190 million hectare of land for farming. The estimated dry biomass production from agriculture in India is almost 800 million tonnes every year. This is equivalent to the fixation of 320 Tg of C or 1000 Tg of CO_2 per annum. IPCC (Intergovernment Panel on Climate Change) projections for climate change at global level by 2080 are global average surface warming (surface air temperature change) will be 1.1 - 6.4 °C, sea level will rise between 18 and 59 cm, oceans will become more acidic, hot extremes, heat waves and heavy precipitation events will continue to become more frequent, there will be more precipitation at higher latitudes and it is likely that there will be less precipitation in most subtropical land areas.

Impact of climate change

Global climate change is due to greenhouse gases. Some of the major contributors of greenhouse gases in our industrialized world include power plants (to generate electricity to operate our numerous electrical and electronic gadgets), industries, trade and commerce (to produce enough goods and services to satisfy our culture of consumerism), and our modes of transportation (*eg.* cars, planes, trains). The populations of the world's poorest countries are more vulnerable when faced with the effects of climate change even though they are less responsible for it. The developing countries are not able to either protect themselves against the impact of this phenomenon or adjust to it. Because of their location, their low incomes, the insufficiency of their resources and institutional capacities because they mostly count on climate dependent sectors like agriculture, populations of the poorest countries are the first victims of current and future climatic changes.

Impacts of climate change are generally adverse. Climate change will make monsoons less predictable and hence less dependable. As a result crop yield per hectare will be hit badly, causing food insecurity and loss of livelihood. Changes in climate around the globe are expected to trigger a steep fall in the production of cereals. It was estimated that a rise of 0.5 ^{0}C winter temperatures could cause a 0.45 tonnes per hectare fall in India's wheat production (Kalra *et al. 2003*).

Agriculture, in India, is strongly affected by two major hydro-meteorological disasters, namely drought and flood. Indian agriculture is heavily dependent on the monsoon as a source of water. Over 68-70 % of total sown area in India is vulnerable to drought. In some parts of India, the failure of the monsoons result in water shortages, resulting in below-average crop yields. This is particularly true of major drought-prone regions such as southern and eastern Maharashtra, northern Karnataka, Andhra Pradesh, Orissa, Gujarat, and Rajasthan. In the past, droughts have periodically led to major Indian famines. These include the Bengal famine of 1770, in which over five million died from starvation and famine-related illnesses, the 1876–1877 famine, in which over five million people died and the 1899 famine, in which over 4.5 million died. This has been posing an increasing threat to the agriculture and food security of the country, with increasing stress on rural livelihoods and resources such as land, soil, water and forests. To cope with this stress, farmers and land labourers in rural areas of India have started migrating seasonally, either temporarily or permanently, to urban areas in search of livelihoods.

As a result drought is considered as one of the biggest menace to agriculture among all weather related crises. Anonymous (2012) mentioned that the concept of drought varies from place to place depending upon normal climatic conditions, available water resources, agricultural practices and the various socio-economic activities of a region. The National Commission on Agriculture (NCA) in India defined three types of droughts, namely meteorological, agricultural and hydrological. Agricultural drought occurs when soil moisture and rainfall are inadequate during the growing season to support healthy crop growth to maturity and causes crop stress and wilting. Parmer *et al.,* 2005 reported that agricultural drought is probably the most important aspect of drought, but that problem is more specialized and complicated than some investigators seem to realize. The agricultural drought, that is the non availability of water for normal crop growth is more acute in arid, semi-arid and dry sub humid regions. These regions constitute nearly 77 per cent of the total land area in India and are consequently more prone to land degradation and frequent droughts. Past records indicate that in almost every year one part or other of the country has been subjected to drought, flood or cyclone.

The major drought years in India were 1877, 1899, 1918, 1972, 1987 and 2002. Over 68 per cent of India is vulnerable to drought. The 'chronically drought-prone area is around 33 per cent which receive less than 750 mm of rainfall, while 35 per cent classified as 'drought-prone' receive a rainfall of 750-1,125 mm. The drought-prone areas of the country are confined to peninsular and western India – primarily arid, semi-arid and sub-humid regions. An analysis of 100 years of rainfall data reveals that the frequency of 'below-normal rainfall' in arid, semi- arid and sub-humid regions is 54-57 %, while severe and rare droughts occurred once every eight to nine years in arid and semi-arid zones. In these zones, rare droughts of severe intensity occurred once in 32 years, with almost every third year being a drought year. The 2002 monsoon was one of the shortest in recorded history. No other drought in the past led to such a drop in food production as the 2002 drought. Food grain production dipped to 29 million tonnes from 183 million tonnes. Production of paddy fell drastically to 75.72 million tonnes (2002-03) as against 93.08 million tonnes during the previous year. Pulses fell to a level of 11.31 million tonnes. As far as commercial crops, production of oilseeds declined by 13.70 per cent during the 2002-03 *rabi* season. Cotton and sugarcane also recorded negative growths of 7.70 per cent and 7.20 per cent respectively. The impact of the drought of 2002-03 on hydroelectric power generation led to a decline of 13.90 per cent.The percentage reduction in power generation is the maximum when compared with the drought years of the recent past (Anonymous, 2008b).

Karnataka experienced a severe drought for three consecutive years (2001-02, 2002-03 and 2003-04) and 159 taluks/blocks were listed as drought affected. During these periods, the state received 23 per cent of less rainfall (Nagaratna & Sridhar, 2009). The agricultural production declined to 64 lakh tonnes against the target of 104.05 lakh tonnes and the availability of crop residues for livestock was substantially low (Anonymous 2003). The intense drought had put most of the farmers in the state to the precarious situation leading to the migration to the nearby towns and cities.

Another hydro-meteorological disaster is flood and hailstorm. There are about 175 flood gauzing and 10 IMD meteorological stations for flood forecasting in India. As per report of National Disaster Management Authority (NDMA 2012), in India about 49.81 Million hectare (15.20 % of total geographical area) is flood prone and on an average 10-12 Million hectare is affected every year causing a range of miseries. Heavy rains again during September in Andhra Pradesh, Karnataka and Kerala led to floods and thus the year 2009 was declared as the flood year in India. A huge crop loss was noticed in several states of the country due to floods in *kharif*, 2007. Heavy rains accompanied by hailstorm during March 2007 damaged wheat, sugarcane and oilseed crops in thousands of hectares in Punjab and Haryana. In Madhya Pradesh, entire pigeonpea crop in an area of 7,000 ha was damaged due to frost and extreme cold conditions. Hailstorm frequency has become serious problem all over India in the past decade damaging horticulture sector in several states particularly Maharashtra and southern Andhra Pradesh.

The complete avoidance of all farm losses due to weather factor is not possible but it can be minimized to some extent by making adjustments through timely and accurate information of weather forecast. Though studies on various facets of climate change like assessment, vulnerability, mitigation, adaptation strategies have been performed for more than a decade, it appeared for a while that farmers were not getting their due in terms of their preparedness – until the program on National Initiative (Innovation) on Climate Resilient Agriculture (NICRA) was envisaged. As part of this initiative, AICRP on Agrometeorology (AICRPAM) vigorously sensitized farmers on the need to achieve climate resilenvce by using; attest technologies as well as by adopting farming operations based on weather and weather forecasts. This pilot project, named AICRPAM-NICRA, was implemented at block level, which is in contrast to the district level agromet advisories under Gramin Krishi Mausam Sewa (GKMS) project (Venkatesh *et al.*, 2016). Forecast on various weather parameters are disseminate to farmers through email, collecting the ground truth on crop and soil status by mobile messages from Field Information Facilitators (FIF). FIFs and NGOs make multiple copies of the advisory and distribute to the farmers.

Weather forecast and weather based agro-met advisories help in increasing the economic benefit to the farmers by suggesting them the suitable management practices according to the weather conditions. Weather forecasting is to advise the farmers on the actual and expected weather and its impact on the various day-to-day farming operations *i.e.* sowing, weeding, time of pesticides spray, irrigation scheduling, fertilizer application *etc.* and overall crop management. Weather forecast helps to increase agriculture production, reduce losses, risks, reduce costs of inputs, improve quality of yield, increase efficiency in the use of water, labor and energy and reduce pollution with judicious use of agricultural chemicals. So that farmers can take immediate action. Keeping all this in view the present study was undertaken.

1.1 Importance of present study

Increased frequency and severity of extreme weather conditions resulting in an increased exposure of the farming sector to the greater vulnerability. As a result of hotter, drier summers will have a serious impact on soils and performance of crop. To address these constraints and to understand the weather parameter, would serve as the decision making supportive system for designing rational crop production and protection activities and contingent plans. With such action plan the risk and uncertainties due to the variation in climate could be well addressed to minimize the economic losses. Keeping in view the importance of climate variability and its impact on agriculture in mind the present study has been organized by designing the following specific objectives.

1.2 Objectives of the investigation

1. To assess the extent of rainfall and temperature variability and trends in the north-Karnataka.
2. To ascertain the impact of climate variability on crop yield in study area.
3. To analyze the economic benefits of weather based farming in improving farm productivity.
4. To analyze the impact of weather extremities on agriculture in study area.
5. To map the vulnerability of climate change for selected districts.

1.3 The hypotheses framed for the above-mentioned objectives are

1. Temperature and rainfall variability is more in the study area.
2. Climate variability has adverse effect on crop production.
3. Weather based farming has a positive economic impact on the farm productivity.
4. Agriculture activities are adversely affected by weather extremities.
5. Selected districts are having diverse spatial climate variations.

1.4 Limitations of the study

All possible efforts were made to collect time series meteorological data on rainfall and temperature parameters for all the districts of north Karnataka. Rainfall data was available for 31 years so analysis was done for this period. Data on temperature and relative humitity was available for 15 year so analysis was done only for that period.

Due to formation of new districts in north Katnataka analysis was done for the undivided districts of north Karnataka wherever required mainly during analysis of rainfall pattern. Analysis was not done for newly formed Yadgiri district due to non avalilability of time series data.

Since primary data on impact of hailstorm on agriculture was collected for the period 2014. Because of time lag response of the farmers was not good and misleading. Even though efforts were made to collect required data to arrive meaningfull conclusions.

1.5 Presentation of the study

The study is presented in six chapters. Chapter-I introduces the reader to the topic and presents the specific objectives of the study. Chapter II comprehensively presents a review of relevant research work done on the related topics. Chapter III outlines features of the study area, sampling design followed, collection of relevant data and analytical tools used in the study. Chapter IV is devoted to main findings of the study using tables, graphs *etc.* chapter V concentrates on discussion of results of the study. Chapter VI summarizes findings of the study and brings out policy implications that emerge from the findings of the study and last chapter deals with references of the related studies.

2. REVIEW OF LITERATURE

2.1 Trend in rainfall and temperature variability

Nityanand Singh and Sontakke (2002) conducted study on Paralleling the Southern Himalayan Province, the Indo-Gangetic Plains Region (IGPR) of India, in-order to document the instrumental-period fluctuations of important climatic parameters like rainfall (1829–1999), severe rainstorms (1880–1996) and temperature (1876–1997) exclusively for the IGPR.It was observed that, the summer monsoon rainfall over western IGPR showed increasing trend (170 mm/100-yr) from 1900. While over central IGPR it showed decreasing trend (5 mm/100-yr) from 1939 and over eastern IGPR decreasing trend (50 mm/100-yr) during 1900–1984 and insignificant increasing trend (480 mm/100-yr) during 1984–1999. Based on these it was inferred that, there has been a westward shift in rainfall activities over the IGPR. The annual surface air temperature of the IGPR showed rising trend (0.53 °C/100-yr) during 1875–1958 and decreasing trend (–0.93 °C/100-yr) during 1958–1997.

Shiyani *et al.* (2003) conducted a study on impact of drought on Saurashtra agriculture. For this study district wise rainfall data were obtained for the period from 1960 to 2000 and analysed using tabular analysis. Results of the study revealed that, average rainfall in the region varied from 517.8 mm in case of Jamnagar district to 922 mm in case of Junagadh district. Out of the 41 years data collected, rainfall was below the average for 25 years in case of Ameli and Jamnagar districts. Similarly it was 24 years for Junagadh, 23 years for Rajkot and 22 years for Bhavnagar districts. Temperature variability measured in terms of Coefficient of Variation (CV) showed that the existence of maximum variability in case of Junagadh district (63.95 %) followed by Junagadh (51.82 %), Amreli (47.51 %), Rajkot (44.96 %) and Bhavnagar (42.33 %). On account of irregularity and inadequacy of rainfall, none of the rivers of Saurashtra were observed to be perennial. Hence there was declined in yield of groundnut, cotton, sesamum, sorghum by 80 per cent, 7 per cent, 45 per cent, 58 per cent and 41 per cent, respectively.

Venkatesh *et al.* (2003) conducted a study on adaptations strategies for farmers in case of adverse impact of climate change on sorghum cultivation in north Karnataka. Monthly rainfall and temperature data for four districts namely Bellary, Vijayapura, Kalaburagi and Raichur were collected from India Meteorological Department (IMD) Pune. Rainfall and temperature trend in these district were calculated for three periods *viz.* for 1905-1926, 1927-1956 and 1957-1990. Results of the study revealed that, in Bellary district, September rainfall showed a decreasing tend. In Vijayapura positive trend of rainfall was noticed for both September and October months. Since, 1940 the low rainfall period of September synchronized with high rainfall period of October. A marked decrease of rainfall in September and increase in October were observed during the 20th century.

Parmar *et al.* (2005) conducted a study on climatic variability in Gujarat state. The parameters such as temperature and rainfall were studied using daily weather data recorded at Anand (1976-2002), Sagdividi (1987-2002) and Sardar Krushi Nagar (SK Nagar, 1983-2002). Results of the study revealed that moving averages of *kharif* showed a negative deviation in rainfall at SK Nagar (30.9 mm), Sagdividi (45.2 mm) and Anand (17.2 mm). Maximum temperature in *rabi* deviated negatively by 0.42 ^{0}C at SK Nagar followed by 0.22 ^{0}C at Anand. Minimum temperature showed positive departure at Sagdividi and SK Nagar.

Sivakumar *et al.* (2005) in their study of climate change in the Semi-Arid Tropics found that, warming trend in India was about 0.5 ^{0}C per 100 years. In Vietnam over the period (1895-1996) the mean warming trend was estimated at 0.32 ^{0}C. In Sri Lanka, during 1869-1993, conspicuous warming trend of 0.30 ^{0}C per 100 years was estimated. The study also showed an increase in extreme rainfall events over northwest India during the summer monsoon. In addition, there was a decline in the number of rainy days during the monsoon along east coastal stations. A long term decreasing trend in rainfall in Thailand was reported. However, there was no identifiable variability in number, frequency or intensity of tropical cyclones in northern Indian Ocean region over 100 years.

Panduranga *et al.* (2006) conducted a study on climate change and agriculture under the title, A case study of Tumkur district in Karnataka state. Results of the study revealed that, there is decrease in annual rainfall trend in the Karnataka state but increasing trend in Tumkur district. Karnataka state average annual rainfall for the past 50 years indicated a cycle of 16 years, wherein first 8 year show above normal trend followed by another 8 year of below normal with exception in 2 to 3 years.

Dash and Hunt (2007) conducted a study on variability of climate change in India. Results of the study revealed that, Indian mean annual temperature has increased by 0.5^{o}c in the period from 1901 to 2003. The warming trend has been associated with a rise in maximum temperature by 0.7 ^{o}C. Rise in minimum temperature varies significantly between the winter and post monsoon seasons. The countries minimum temperature has increased in the last 100 years but not as much as the maximum temperature. In the year an increase in minimum surface-temperature was about 0.75 ^{o}C during October to February and 0.3^{o}C in the other half of the year. After 1950 the minimum temperature during post-monsoon and winter months increased in the beginning five years (1950) and then onwards it was decreased till 1970; thereafter it was increased sharply by about 0.25 ^{o}C per decade.

Ruksana (2007) conducted a study on trend analysis of climate change at Satkhira, Bangladesh. Results of the study revealed that, there was a statistically non-significant increasing trend of annual maximum and minimum temperature and annual total rainfall through the period of 1950-2006. The trend analysis of seasonal rainfall for the period 1981-2006 revealed that, from the last two decades the seasonal normal rainfall pattern was altered. It was also noticed that, rainfall in pre-monsoon and winter season had a decreasing trend. Whereas it had an increasing trend during monsoon and post-monsoon seasons. During the study period the temperature variations had an observable negative effect on crop yield.

Deka and Nath (2008) conducted study on variability of climatic elements at Jorhat. Study was based on secondary data on monthly average of maximum and minimum temperature and total rainfall from agro-meteorology observatory of Assam Agricultural University for the period from 1970 to 2000. Results of the study revealed that, the monthly minimum temperature increased in all months of the years under observation with significant increase during June to September and in November. During the study period the pre-monsoon and monsoon rainfall decreased by 18.8 per cent and 3.30 per cent, respectively. In each of the years of study period monthly temperature range was reduced. While the seasonal minimum and average temperature increased the, seasonal maximum temperature decreased slightly during post-monsoon season of the years.

Krishnakumar *et al.* (2008) conducted a study on climate change at selected locations in Kerala. Study was based on secondary data. Time series analysis was carried out. Results of the study revealed that, rainfall and number of rainy days showed the declining trend during the southwest monsoon in Pilicode, Vellanikkara, Amabalavayal and Pampadumpara districts. At Vellanikkara district the significant declining trend in rainfall from 2000 to 2005 was observed with maximum of 22.0 mm rainfall. Amabalavayal and Pampadumpara districts recorded a rise in maximum temperature on annual basis at the rate of 0.006 ^{0}C/ year and 0.04 ^{0}C/ year, respectively. At Pampadumpara maximum temperature was increasing while minimum temperature had declined on the contrary. Due to pre-monsoon showers, cooler summer was observed at Vellanikkara district.

Krishnakumar and Prasad Rao (2008) conducted a study on trends and variability in northeast monsoon rainfall over Kerala. Study was based on secondary data. Time series analysis such as frequency distribution, moving averages, standard deviation and coefficient of variation were worked out for the period from 1871 to 1994. Results of the study revealed that, during October and November monthly rainfall over Kerala state showed an increasing trend. In the study period the overall annual rainfall recorded in Kerala state had increased by 20 per cent as against normal rainfall of 481.5 mm. During December rainfall was highly variable and undependable.

Chandrashekhar *et al.* (2009) conducted a study on crop production as influenced by rainfall in Haryana. Rainfall and crop production data were collected from different stations namely Hisar, Sirsa, Chandrashekhar, Karnal and Ambala. District wise (Sirsa, Hissar, Mohindergarh) crop production data of cereals, pulses, oilseeds, cotton, sugarcane and potato were collected from statistical abstract of Haryana for 30-41 crop seasons were used. Using the data the deviation from the previous seasons with respect to crop production and rainfall were calculated. Results of the study revealed that, in Sirsa district the impact of rainfall deviation on the cereals was highest with positive deviation of 115.50 per cent during 1978-79, whereas highest negative deviation (-51.4 %) was recorded during 1979-80 and the rainfall deviation during this period had ranged from 312.90 per cent to -64.7 per cent. In Hisar district the rainfall deviation ranged between 312.9 and -73 per cent whereas, in Mohindergarh district rainfall deviated between 222.1 and -66.9 per cent. In Ambala district rainfall deviated between 177.9 to -61 per cent during the study period. Rainfall deviation was highly correlated with pulses production in all stations except Ambala where best correlation was found with cereals production.

Parmer and Shrivastava (2009) conducted a study on variability of temperature in south Gujarat coast. For the data (1987 to 2009) of meteorological laboratory of Navasari agricultural university the moving average for 3, 5 and 10 year interval for minimum and maximum temperature was calculated. The data series depicted a decrease in maximum temperature and increase in minimum temperature. The 10 year moving average of minimum temperature was found to be closely following the trend line. The seasonal trend indicated that the minimum temperature during all the season had an increasing trend, with minimum deviation in trend line during winter season. However, the trend was found to be negative in the case of maximum temperature during different seasons. Trend analysis of extreme events showed the sharp rate of rise in minimum temperature (0.15 ^{0}C/ year) which could be affecting the physiology of crops grown in the region.

Prabhjyot-Kaur and Hundal (2009) conducted a study on production potential of cereal crops in relation to climate changes in Punjab. The trend line obtained using five yearly moving averages. Annual maximum temperature at Ludhiana revealed no changes in the past 38 years. But when an analysis was done on seasonal basis it was revealed that *kharif* season maximum temperature at Ludhiana has decreased from the normal at a rate of 0.01 ^{0}C/ year and in the *rabi* season maximum temperature at Ludhiana has increased from the normal at the rate of 0.02 ^{0}C/ year. In the annual, *kharif* and *rabi* season, minimum temperature at Ludhiana has increased from the normal at the rate of 0.06, 0.07 and 0.06 ^{0}C/year, respectively, over the past 38 years.

Rajegowda *et al.* (2009) conducted a study on impact of climate change on agriculture in Karnataka. Results of the study revealed that states mean annual rainfall was found to have decreasing trend along with its sixteen years cyclic periodicity. During the first half centurys (1901-1950) normal of 1,204 mm has been reduced to 1,140 mm during the second half of the century (1951 – 2000). Districts like Bengaluru, Kolar and Tumkur were gaining in their mean annual rainfall whereas Kodagu, Chikmagalur and Dakshina Kannada were losing in their mean annual rainfall.

Sigh *et al.* (2009) conducted study on climatic variability in Jhansi region of Uttar Pradesh. Secondary data on daily rainfall, maximum and minimum temperature data for the period from 1969 to 2003 was collected from agro-met observatory. The annual and *kharif* rainfall showed decreasing trend in recent decades from 1984-1993. Rainfall decrease at the rate of 0.8 and 1.1 mm per year in annual and *kharif* season, respectively during the past 35 years. Minimum temperature showed an increase of 0.05 and 0.13 ^{0}C per year during annual and *kharif* season.

Rao *et al.* (2010) conducted a study on temperature trends in different regions of India. Time series analysis of annual mean, maximum and minimum temperature revealed of 47 stations spread across different regions in India revealed the increasing trend in maximum temperature, lowest in 20 per cent of the stations in north zone and highest in 75 per cent of the stations in south zone. On the other hand, increase in minimum temperature is observed in 60 per cent of stations over all zones of India. Same trend is noticed in average temperature trend except in north zone where 45 per cent of stations have shown increasing trend.

Barna Maulick (2011) conducted a study on climate change and mitigation a shared responsibility in the context of India. The study revealed that, the decade of the 2000's was warmer than the 1990's which is warmer than the 1980. Main cause of this was due to carbon monoxide and dioxide emission from heavy industrial activity and motorized vehicles. India is the fifth largest greenhouse gas emitter and accounts for 5 per cent of the global emission. India's emission increases 65 per cent between 1990 and 2005. Agriculture suffers from the greater direct impact of climate change. Because of climate change agriculture is becoming more capital intensive which insisting the marginal and small farmers to take hard decision on selling their land which may lead to economic inequality.

Jagadish *et al.* (2012) conducted study on climate change which had affected the temperature and rainfall characteristics worldwide. In the present study, attempts were made to study temporal variation in monthly, seasonal and annual rainfall over the state during the period from 1871 to 2006. Long term changes in rainfall characteristics were determined by both parametric and non-parametric tests. The analysis revealed a long term insignificant decline trend of annual as well as monsoon rainfall, where as increasing trend in post-monsoon season over the state of Orissa. Rainfall during winter and summer seasons showed an increasing trend. Statistically monsoon rainfall can be considered as very dependable as the coefficient of variation observed to be 14.20 per cent. However, there is decreasing monthly rainfall trend in June, July and September, where as increasing trend in August. This trend is more predominant in last 10 year. Based on departure from mean, rainfall analysis also showed an increased number of dry years compared to wet years after 1950. This changing rainfall trend during monsoon months is major concern for the rain-fed agriculture. Moreover, this will affect hydro power generation and reservoir operation in the region.

Shashidahra and Reddy (2012) conducted a study on farmers perceptions and adaptation about changing climate and its variability in UKP area of Karnataka. Secondary data on temperature, rainfall, relative humidity *etc*, from 1990-2009 were used for the study to find out variability in crop yield. About 70.61 per cent of the rainfall occurred during monsoon whereas pre-monsoon (March-May) rainfall trend didn't show great variations. However, during last few years (2003 - 2006) there was a substantial decrease in the amount of rainfall received especially in monsoon. Further in 2009 heavy rainfall trend was noticed in the study area. The mean annual maximum temperature was highest in the year 2009 with temperature of 33.53 ^{0}C and mean annual minimum temperature was observed in the year 2007 with average minimum temperature of 17.88 ^{0}C. The linear trend line showed that mean annual maximum temperature had increased by 0.064 ^{0}C/ year and mean annual minimum temperature had increased by 0.01 ^{0}C/ year. Temperature was much higher in winter season compared to other seasons in Bheemarayangudi station.

Karthick *et al.* (2013) conducted a study on impact of climate change on agriculture – a case study in India. The study was mainly based on secondary data of weather parameter *viz.*, maximum temperature, minimum temperature, rainfall and area, production, productivity of crops for the period of 20 years (from 1990-91 to 2009-10). Due to the influence of weather events the coefficient of variation of area, production and productivity was more in case of sorghum, bajra, maize and groundnut. Results of the study revealed that, over the years there were not much fluctuations in minimum temperature. After 2000-01 there was a gradual increase in maximum temperature from 30 ^{0}C to 31 ^{0}C. After 2005-06, the maximum was 32 ^{0}C. As compared to the minimum and maximum temperature, much fluctuation was observed in rainfall over the period. It ranged from 663.6 mm to 1,304.1 mm.

Masato Kawanishi and Nobuo (2013) conducted a study on paddy farmer's response to climate and socio-economic impacts: a case study in north Sumatra, Indonesia. Average Monthly rainfall in Medan was collected from 1991 to 2010. Results of the study revealed that, average annual rainfall during the period was 1,994 mm with standard deviation (SD) of 459 mm. There are three years (1994, 1997 and 2002) when the annual rainfall was below 1,535 mm, which was the average minus one SD. There are also three years (2001, 2006 and 2007) when it was over 2,453 mm, which was the average plus one SD. Paddy production in 2000 and 2009 was around 3.5 million tonnes. Paddy productivity improved by more than 10 per cent from 4.1 thousand kg/ha in 2000 to 4.6 thousand kg/ha in 2009.

Anonymous (2013b) annual report documented the impact of minimum temperature on *kharif* paddy yields. Monthly minimum temperature data of Climate Research Unit (CRU), for the period 1971-2009, were used to detect trends at the district level for a total of 599 districts. The magnitude of rise in minimum temperature during *kharif* season was found to be 0.19 ℃ per 10 year for the country as whole. Minimum temperatures during the *kharif* season showed strong warming trend in southern states, Indo- Gangetic Plains (IGP), North-Eastern parts, majority of the Jammu & Kashmir, Gujarat and entire Himachal Pradesh. A strong warming trend was noticed over 52.70 per cent of geographical area and the degree of warming was about 0.24 ℃ per 10 year.

2.2 Impact of climate variability on crop yield

Hundal and Kaur (1996) examined the climate change impact on productivity of wheat, paddy, maize and groundnut crop in Punjab. If other climate variables like rainfall, relative humidity, wind speed were remained constant, temperature increase of 1 ^{0}C, 2 ^{0}C and 3 ^{0}C from present day condition, would reduce the grain yield of wheat by 8.1 per cent, 18.7 per cent and 25.7 per cent, paddy by 5.4 per cent, 7.4 per cent and 25.1 per cent, maize by 10.4 per cent, 14.6 per cent and 21.4 per cent and seed yield in groundnut by 8.7 per cent, 23.2 per cent and 36.2 per cent, respectively.

Ziska *et al.* (1997) studied the impact of climate change on the quality of different crops. Increase in temperature had significant effect on the quality of cotton, fruits, vegetables, tea, coffee, medicinal and aromatic plants. The nutritional quality of cereals and pulses also be moderately affected which, in turn, would improve hard consequences on nutritional security of several developing countries where cereals considered as primary items of the diet. These changes have let to the decline in the grain protein content of the cereals which as partly due to increasing CO_2 concentrations and temperatures.

Sahoo (1999) carried out simulation studies of maize for climate change under irrigated and rainfed conditions. Rise in temperature had decreased the yield under both the conditions. At CO_2 level of 350 ppm, grain yield decreased continuously with temperature rise till 4 ^{0}C. This was possibly due to reduction in days to 50 per cent silking and physiological maturity. At CO_2 level of 700 ppm, grain yield increased by about 9 per cent. The temperature rise effect in reduction of yield was noted in several maize cultivars. Effect of elevated carbon dioxide concentration on growth and yield of maize was established, but less pronounced when compared with crops, like wheat, bengalgram and mustard crops. The beneficial effect of 700 ppm CO_2 was nullified by an increase of only 0.6 ^{0}C in temperature. Further increase in temperature always resulted in lower yields.

Aggarwal *et al.* (2000) analyzed the historical trends in yields of paddy and wheat crops in the Indo-Gangetic plains using regional statistics, long term fertility experiments, other conventional field experiments and crop simulation models. The results illustrated that paddy yields during the last three decades showed a declining trend which could be partly attributed to gradual change in the weather conditions during the last two decades. Similar decline in paddy yields and their association with rising night temperatures had also been noticed in Phillipines.

Venkatesh *et al.* (2003) conducted a study adverse impact of climate change on sorghum cultivation in north Karnataka and adaptation strategies for farmers. Results of the study revealed that farmers used Gundudeni variety during 1940-70 because it was the best available cultivar having traits of drought resistance and yielding good quality of fodder and grain. Farmers shifted to the cultivation of M35-1, as they found it to be a high yielder having bold seeds and good fodder quality, in addition to being a drought resistant variety and fetching better market value. M35-1 had acceptability in Bellary district observed to the extent of 33 per cent, while in Vijayapura its acceptability was more and accounted to 96 per cent and in Raichur it was 80 per cent.

Mall *et al.* (2005) conducted a study on impact of climate change on Indian agriculture: A review. Results of the study revealed that, the inter-annual variations in Summer Monsoon Rainfall (SMR) and total food grain production anomalies were closely related. However, the magnitude of change in foodgrain production was smaller than the rainfall. During the years of deficit monsoon years (1966, 1972, 1974, 1979, 1982 and 1987) the foodgrain production declined, and during the years of excess or normal monsoon years (1970, 1975, 1978, 1983 and 1988) it was observed to be higher. The correlation between SMR and foodgrain production (0.71) was significant at the 1 % level. The SMR was responsible for 50 % of the variability in total foodgrain production anomalies. The SMR showed a high correlation (r = 0.80) with *kharif* foodgrain production and a moderate correlation (r = 0.41) with *rabi* foodgrain production anomalies. Among the individual crops correlation paddy (r = 0.66), wheat (r = 0.49) and bengalgram (r = 0.49) production had significant association with SMR.

Easterling *et al.* (2007) found through an analysis of modeling results that in mid to high latitude regions, a moderate local increase in temperature (1-3 ^{0}C), along with associated CO_2 increase and rainfall changes was likely to be beneficial for crop yields. As against this, in low-latitude regions, a temperature increase of 1-2 ^{0}C was likely to have a negative yield impacts for major cereals. It implied that food security of most developing countries including India, which happened to be in the low latitude regions, would likely to become vulnerable in the near future. At the same time, differential impacts of climate change on food production are likely to have consequences on international food prices and trade.

Wassmann and Dobermann (2007) reported that the agricultural production in south Asia could fall by 30 per cent by 2050 if no action would be taken to combat the effects of increasing temperatures and hydrologic disruption. It was also reported that since temperatures in south Asian continent were already reaching critical levels during the pre-monsoon seasons, this further increment would reduce effectively the yields of all crops including paddy.

Chandrashekhar *et al.* (2009) conducted a study on crop production as influenced by rainfall in Haryana. Rainfall and crop production data were collected from different stations. District wise crop production data of cereals, pulses, oilseeds, cotton, sugarcane and potato were collected from statistical abstract of Haryana for 30-41 crop seasons. Correlation between rainfall and crop production were calculated. Results of the study revealed that, Rainfall deviation was highly correlated with pulses production at Sirsa, Hisar, Mohindergarh and Karnal. In Ambala best correlation was found with cereals production. Pulse production was highly correlated with rainfall at Mohindergarh (0.75). At Mohindergarh (0.56) and Ambala (0.56) rainfall was highly correlated with food grain production.

Suchandan Bemal *et al.* (2009) conducted a study on seasonal climatic variability impact on paddy productivity in Haryana. For this study daily weather data (maximum and minimum temperature and rainfall) of *kharif* season (July to November) and productivity data for the past 15 years (1992-2006) of Karnal and Hisar were evaluated. Results of the study revealed that, maxmum (r=0.36), minimum (r=0.24) and mean temperature (r=0.36) were positively and rainfall (r= -0.79) was negatively correlated with paddy productivity at Karnal. While in Hisar, rainfall (r=0.35) was positively and maximum (r=-0.48), minimum (r=-0.28) and mean temperature (r=-0.51) were negatively correlated with paddy productivity.

Sushil kaul and Ghasi ram (2009) conducted a study on impact of global warming on production of sorghum in India. Data regarding temperature, rainfall, fertilizer, labour and other resources used in the production of sorghum were collected from Directorate of Economics and Statistics. The data were analysed by using multiple regression analysis. Results of the study revealed that, use of the fertilizer had negative impact on sorghum productivity, which was not correct on theoretical ground. However, the human labour variable has a positive and significant impact on sorghum productivity. The deviation from normal rainfall had negative impact on productivity. It was implied that, rainfall contributes significantly in raising productivity of sorghum crop. Mean maximum temperature during growing season of crop had a negative implication for the crop. While, minimum temperature effect on the crop productivity positively.

Basu (2010) conducted a study on impact of climate change on production of pulse in north India: A concern. It was documented from the study that, India is most vulnerable to climate change. Major impacts of climate change were on rainfed crops which accounts for nearly 60 per cent of cropland area. It was noticed that, during reproductive phase of the bengalgram the day temperature was maximum in the month of March 2008 was abruptly increased to 41^{o}C which was detrimental to pod setting and abortion. There was increased propensity in the occurrence of monsoon breaks over the subcontinent. Bengalgram crop often experiences abnormal high temperature and atmospheric drought during reproductive stage. As a result bengalgram variety released for north India BG-256 started showing significant reduction in grain yield.

Ajay and pritee (2013) conducted a study on impact of climate variability on agricultural productivity and food security in rural India. The study undertook state wise analysis based on secondary data for the duration from 1998 to 2009. Regression results of model proposed in this study shows that for most of the foodgrains and non foodgrains in quantity produced per unit of land and in terms of value of production, climate variation caused negative impact. The adverse impact of climate change on the value of agricultural production and foodgrains indicated food security threat to small and marginal farmers. The state wise food security index generated was also getting adversely affected due to climatic fluctuations.

Karthick *et al.* (2013) conducted a study on impact of climate change on agriculture – a case study in India. The present study was conducted in Tamil Nadu State of India. The study was based mainly on secondary data of weather parameter *viz.*, maximum temperature, minimum temperature, rainfall and area, production, productivity of crops for the period of 20 years (from 1990-91 to 2009-10). CV of area, production and productivity was more in sorghum, bajra, maize and groundnut may be influence of weather events. Hence, these four crops were selected for the present study. R^2 value revealed that 38 per cent and 24 per cent variation in productivity of groundnut and bajra, respectively were influenced by minimum temperature, maximum temperature and rainfall. Minimum temperature would negatively influence the productivity of sorghum, groundnut and bajra. The effect of minimum temperature on productivity of sorghum and bajra was not significant and the sign was expected one, and it also affects the productivity of groundnut negatively at 5 per cent level of significance which implies that one per cent increase in minimum temperature will reduce the productivity ground by 0.38 per cent. Rainfall affects the production of sorghum, maize and groundnut negatively.

Anonymous (2013b), in their annual report they have documented the trends in *kharif* paddy yields and minimum temperatures. Results of the study revealed that, rising trends in minimum temperature during *kharif* were found to have a negative impact on paddy yields in majority of the paddy growing districts of India. The magnitude of rise in minimum temperature during *kharif* season was found to be 0.19℃ per 10 year for the country as whole. Correlations worked out between monthly minimum temperatures and *kharif* paddy yields indicated that, 268 districts exhibited a negative impact of rising temperatures and 49 of them were statistically significant ($P = 0.05$). Minimum temperatures during August and September were exerting a negative impact on paddy yield in more number of districts (197) compared to June, July (<174 districts) or October months (105 districts). *Kharif* paddy yields declined at the rate of 859 kg/ha.

Sindhu and Kamal (2013) conducted a study on climate change and wheat yield in Punjab: The impact of temperature on wheat. Daily data on maximum and minimum temperature in Ludhiana district was collected for the year from 1975-2008. Growing Degree Days (GDD) was used to establish the relationship between rise in temperature and wheat yields. Results of the study revealed that, there was increasing trend in the monthly degree days during the wheat production period from October to March except in the month of October and December. The GDD were the highest in 1975 at 429 and the least during 1997 *i.e.* 186. Later wheat yield was regressed on monthly GDD and amount of fertilizer used. It was shown that, raising temperature had no adverse impact on the wheat yields. However temperature increase in December was favoring an increase in wheat yield.

Kavita (2014) conducted a study on impact of change in rainfall pattern on agriculture in Haveri district. Study was based on both primary and secondary data. Correlation, tabular analysis, compound growth rate were used for the study. Results of the study revealed that, year 1992 received a maximum rainfall (952.4 mm) and 2001 received lowest quantum of rainfall (300.5 mm) they proved to be the wettest and driest year respectively. Study also revealed that highest degree of positive correlation between the rainfall and paddy productivity (0.88) followed by rainfall and paddy production (0.80) compare to maize and groundnut.

Pratap *et al.* (2014) studied the impact of climate change on yield of major food crops in India. For this purpose secondary data regarding temperature and rainfall for the period from 1969 to 2005 was collected. Results of the study revealed that, increase in minimum temperature had a favorable effect on yield of most crops, but it was not sufficient to fully compensate the damages caused by the rise in maximum temperature. Maximum temperature had a negative and significant effect on yield of *kharif* as well as *rabi* crops. Rise in minimum temperature had a significant positive impact on yield of most crops. Whereas the rainfall had positive impact on most of *kharif* crop yields. Except rapeseed-mustard, other *rabi* crops yields were not significantly influenced by rainfall. On the other hand the pigeonpea, paddy, bengalgram and wheat were more vulnerable to the rise in temperature. The yields of coarse cereals were affected less while pulse crops were affected more.

2.3 Economic benefits of weather based farming in improving farm productivity

Parvinder Maini and Rathore (2011) assessed the economic impact of the Agro-meteorological Advisory Service (AAS) of India. Study was based on primary data collected from 40 AAS and 40 non-AAS farmers. Results of the study revealed that BCR was higher for the AAS farmers as compared to the non-AAS farmers. The variation in the BCR was seen to be least for the cereal crops grown in the northern belt of India (Ludhiana, Pantnagar, Hisar, *etc.*). It was also seen that, the AAS farmers were able to reduce the cost of cultivation by 2–5 per cent, except in the case of fruits where the cost of cultivation had increased.

Hanumanthappa *et al.* (2012) conducted study on Impact of weather based Agromet Advisory Services (AAS) in coastal zone of Karnataka. Results showed that, the average usability of maximum and minimum temperature, and cloud amount recorded were between 86.84 per cent and 88.64 per cent, 94.02 per cent and 97.70 per cent, and 74.59 and 75.88 per cent, respectively. This indicate that the predictability in terms of these parameters during four seasons of the year 2007-10 were more accurate when compared with observed intensities of these three parameters. The benefits gain by the farmers who had used AAS ranged from 7.12 to 56.71 per cent. Hence the medium range weather forecasts were more beneficial to the farming community of the region.

Venkatesh *et al.* (2012) studies results on farmer's perception on weather forecast outreach in Dharwad district of Karnataka indicated that, the synoptic maps and satellite cloude pictures were downloaded from various websites on real time basis and short range weather forecasts were generated and translate into vernacular script and later disseminated to the contact farmers daily at 11 am. The participated sixty farmers were interviewed from the five taluks of Dharwad district. Results of the study revealed that about 83 per cent of the respondents were used the weather forecast information for harvesting and 67.00 per cent were used for sowing of crops. Farmers adopted the SMS based field operations for multiple field activities (> 40 %) than for a single field activity.

Sarita brara (2012) conducted a study on Agromet Advisory Services (AAS) for the farmers. Documented that, AAS sms were brief note consisting of not more than 160 letters, providing information on weather forecast and other agricultural related issues to the farmers. The source material is prepared by 130 field units that were loated across the country. Impact of AAS revealed that, economic profit estimates was varying between ` 50,000 crore to ` 2,11,000 crore. AAS helped the farmers not only in increasing their production but also reducing their losses due to changing weather patterns and other problems.

Ananta *et al.* (2013) had analysed data on weather based Agroment Advisory Services (AAS) for enhancing the productivity and income of the farmers under changing climate scenario. The economic impact of AAS for wheat and carrot during *rabi* 2012-13 and for 2012 *kharif* paddy was analysed. For assessing the impact of AAS the users of AAS and non users of AAS were selected. The result showed that, the farmers who had followed the AAS were able to reduce the input cost and increased the net profit as compared to the non-AAS farmers growing wheat, carrot and paddy crops. The increase in the profit was due to the crop management done according to AAS bulletin information's. Thus, application of AAS based on weather forecast was observed to be useful tool for enhancing the production and income of the farmers.

Anonymous (2013c) had documented the economic impact of AAS which revealed that, there was a significant increase in the farm productivity, resulting in increased availability of food and higher income generation. The services had helped the farmers not only in increasing their crops production levels but also helped in reducing their losses due to the changing weather patterns and other related problems. The AAS estimated 10-25 per cent of extra economic benefit obtained by the farmers. For this purpose the field study was carried out in 12 states and 1 Union territory. According to the report only 10 to 15 per cent of the farmers were benefitting from the AAS and about 24 per cent of farmers were aware on AAS. Further the AAS usage farmers economic profit estimates were vary between ` 50,000 Crore to ` 2,11,000. The margin of this economic return could also be increased by bringing greater percentage of proportion of farmers under this programme.

Manjappa and Yaledalli (2013) validated and assessed the economic impact of AAS issued based on medium range weather forecast for Uttara-Kannada district of Karnataka. The data revealed that, the forecasted and related advisories issued for day to day farm activities were found to be excellent in 30.6 cases, very good in 12.5 cases, good in 21.6 cases and satisfactory in 35.3 cases. Farmers appreciated weather based AAS and utilized the advise in scheduling of irrigation, application of chemical fertilizers and in deciding best time for taking control measures (spraying) against pest and diseases. The per cent gain in income from different crops by the AAS farmers over non AAS farmers was to the tune of 5.30 per cent to 25.0 per cent.

Anonymous (2013b) in their annual report analyses data to quantify the economic impact of AAS to the farmers. The AAS issued by the Udaipur center during the month of July containing the information on rainfall situation and sowing schedule of maize resulted in benefit ranging from ` 18,000 – ` 24,000 per hectare. Similarly in Vijayapura and sub-humid talukas of Belagavi district agro-met advisories were found useful. While in the semi-arid talukas, AAS with respect to pest and disease management were found useful. Advisory issues in Vijayapura and Belagavi are to taking up spraying after the forecasted five days of rainfall and on all the rainfall receiving five days it was advised to take up sowing across the slope to conserve the soil moisture.

Rajegowda (2013) studied the economic impact by assessing the AAS. For this data were collected from 120 AAS beneficiaries from two to three AAS receiving villages and in addition 40 farmers who were not aware of the AAS also selected. The impact study indicated that, 3-4 day AAS had minimized the loss of input used at various crop production stages namely, land preparation till the final produce reached the farmers home. As a result the AAS using farmers were largely benefited by reducing the post harvest losses and realized additional income of about ` 1,098 per acre in case of finger millet, ` 2,504 per acre in tur, ` 1,899 per acre in tomato and ` 4,535 per acre in field bean.

Rao and Bapuji Rao (2013) analysed role of AAS in climate risk management. The study revealed that, AAS, if properly designed and disseminated in time, enhances productivity on one hand and reduces the cost of production on the other. Hence the AAS forecast message on expected rainfall in next 3-4 days, helped in saving spray cost of ` 4,000 per acre. Similarly if rainfall was expected within 24 hours as per the forecast and to arrest further increase in the disease incidence immediate control measure the estimated losses to the extent of ` 60,000 could be saved.

Singh and Amod kumar (2013) conducted a study on economic use of medium range weather forecast at farmer`s field for wheat under Tarai & Bhabar agro-climatc zone of Uttranchal. Study was based on primary data collected from 25 AAS and 25 Non-AAS farmers for two subsequent *rabi* seasons *viz.* 2004-05 and 2005-06. It was concluded from the study that, AAS farmers were able to reduce the input expenditure cost because they were receiving the AAS-bulletins in real time which enables them to manipulate the agricultural practices according to the expected weather condition. Maximum benefit (50.00 % and 21.00 %) was reported in the reduction of irrigation cost followed by plant protection cost (30.00 % and 29.80 %), fertilizer cost (8.50 % and 1.90 %) and labour cost (4.90 % and 12.30 %) for *rabi* seasons. Seed cost and selling prices had very little variations under *rabi* season. The maximum benefit in case of irrigation cost reduction was reported by AAS utilizing farmers. The AAS farmers harvested 19.2 and 20.5 q of wheat per acre as compared to non-AAS farmers (17.9 and 18.7 q/acre) which was 7.26 and 9.62 per cent more than non-AAS farmers for both the *rabi* seasons.

Venkatesh *et al.* (2013) conducted a study on adoption of weather forecasts- A precursor towards adaptation to climate change. About 2500 farmers in Dharwad and Vijayapura districts receive forecast messages by 11 am. Feed back of the farmers was collected on how they utilized the received forecast SMS. The perception of sixty farmers of Dharwad district and forty farmers of Vijayapura district were interviewed. The utility was varied from hundred per cent in spraying in grape gardens to eight per cent for inter-cultivation activities in field crops. Thus by adopting the weather forecasts for important agricultural operations, the farmers were getting ready to face the adverse effects of climate change.

2.4 Impact of weather extremities on agriculture

Samra and Singh (2002) reported that extreme events such as droughts, floods, tropical cyclones, heavy precipitation and heat waves negatively impacted agricultural production and farmer’s livelihood. In view of this the recent drought of 2002 led to reduced area coverage to the extent of 15 million hectares *kharif* crops and resulted in the reduction of more than 10 per cent in food production. The projected increase in these events could result in greater instability in food production and threaten livelihood security of farmers. Increased production variability could perhaps be the most significant effect of global climate change on India.

Nagaraja (2003) studied the impact of drought on agriculture: challenges facing poor farmers of Karnataka, south India. Karnataka ranks second place next only to Rajasthan in India, in terms of total geographical area prone to drought. Among its 30 districts, 18 are drought prone. Karnataka state had experienced severe droughts for three consecutive years (2001-02, 2002-03 and 2003-04) and 159 taluks/blocks were listed as drought affected. During these periods, the state received 23 per cent of less rainfall. The agricultural production declined to 64 lakh tonnes as against the target of 104.05 lakh tonnes and the availability of crop residues for livestock was substantially low. The drought affected regions of Karnataka recorded lower crop yields and consequent increased poverty levels in the region. The repeated droughts have led to over exploitation of ground water besides increased in fire incidences in arid and semi-arid regions. The two districts of Karnataka (Raichur and Koppal) each belonging to severely affected categories and representing semi-arid climatic condition. The annual income of the households reduced to half in drought years. The reduction in the income was due to decline in the yield levels and labour usage.

Shiyani (2003) conducted a study on impact of drought on Saurashtra agriculture. Study was based on secondary data collected using pretested schedule by survey method for the drought year of 2000. Results were analysed using the tabular analysis. Results of the study revealed that, average yield of groundnut in Sourashtra region was 1737 kg/ha during normal year which had declined to 321 kg/ha during the drought year. Similarly cotton yield decline by 45 per cent, 77 per cent, sorghum by 58 per cent, sesamum by 45 per cent and bajra by 41 per cent of the normal year yield.

Hanish and Chandra sen (2004) conducted a study on drought effect on crop productivity and generation of income and employment in agriculture economy of Ballia district of Uttar Pradesh. Eight villages were selected randomly. A proportionate random sampling procedure was adopted to draw a sample of fifty farmers. Data was collected through survey method. It was revealed from the study that total area under crops during drought had decreased. The crop wise decline in acreage with respect to paddy, sugarcane, arhar and maize was amounted to 0.28 per cent, 12.95 per cent, 15.67 per cent and 9.33 per cent respectively.

Samra and Singh (2004) analyzed the impact of climate change on various crops in the Indo-Gangetic plains and found that, the temperatures were higher in these plains by 3-6 degrees centigrade, which is equivalent to almost 1 ^{0}C/ day over the whole crop season. As a result, wheat crop matured early (10-20 days) and the wheat production dropped by more than 4 million tonnes in the country. Losses were also very significant in other crops, such as mustard, pea, tomato, onion, garlic, and other vegetable and fruit crops.

Jat *et al.* (2005) conducted a study on drought over Rajasthan during the year 1987. Rainfall data from eight stations representing different agro-climatic zones for a period of 15 years (1981-1995) were used. At all the stations under study drought occurred in 7 out of 15 years. Jaipur experienced most four moderate drought years as compared to nil at Kota. Sriganganagar and Udaipur experienced three moderate drought years. Fatehpur, Pali and Banswara experienced two moderate drought years.

Rathore (2005) conducted a study on state level analysis of drought policies and impacts in Rajasthan, India. Results of the study revealed that in India *kharif* crops (rainy season) are relatively more affected by drought than *rabi* crops (winter season). Higher the intensity of drought, the lower the *kharif* crop production. Primary surveys have shown that losses of cows were much higher, compared to state level census data, as large numbers *i.e.*, 25 to 50 per cent of cows were abandoned due to starvation or put in charity centers, because of acute shortage of fodder and finances. The remaining cows became dry and weak. There was nobody to buy cows even for slaughter, as there is a ban on cow slaughter in Rajasthan. The severity of drought can be judged by the fact that even high price animals like buffaloes suffered and a few perished.

Ben Edwards *et al.* (2008) conducted study on social and economic impacts of drought on farm families and rural communities. Study was based on primary data. Results of the study revealed that, drought was associated with a higher likelihood of household member move out of the area since last 3 years. Rates of mobility out of an area were 2 per cent higher over a 3-year period in drought-affected areas than in below- or above-average rainfall areas. Farmers were worst affected in terms of annual household income. Farming households in drought affected areas were $4,267 worse off than farming households in below-average rainfall areas. People who were employed were also worse off (by $1,512) than their counterparts in below-average rainfall areas. Households in severely drought-affected and drought-affected areas, as defined by rainfall, had rates of financial hardship that were 4 to 5 percentage points higher than in below- or above-average rainfall areas.

Suchit and Singh (2008) conducted a study on analysis of drought intensity and frequency in two districts of north Bihar. Study was based on secondary data. Rainfall data for 52 years and 30 years for Pusa and Madhepura was collected for the period from 1974-2003. Results of the study revealed that 54 per cent of the years received rainfall less than mean at Pusa. Year 1992 was recorded as disastrous drought year. Severe drought was recorded during 1972 and 1994 which occurred once in 26 years. Largest drought occurred once in 13 years. At Madhepura, fifty per cent of the years received excess rainfall in the range of 8.6 per cent in year 1996 to 47 per cent in the year 1999 and rest 50 per cent of the years received deficit rainfall.

Nagaratna and Sridhar (2009) conducted research on consequences of 2003 drought in Karnataka. From the study it was observed that, during 2001, 2002 and 2003 Karnataka faced consecutive droughts. Study was based on primary data collected from 271 households belonging to Chamarajnagar, Gadag and Kalaburagi. Annual income of the household reduced to half in drought years. The reduction was more in case of crops (61.42 %) followed by livestock (30.00 %) and labour (20.00 %). There was significant difference was noticed for the average quantity of fodder purchased in normal (22.83 q) and drought (38.08 q) years. Per tone of fodder value was ` 2,199.00 in normal and ` 4,166.00 in drought years. Average distance traveled to purchase fodder was 4.25 km in normal and 44.07 km in drought years. Because of this 17.34 per cent of households resorted to distress selling of livestock.

Nicolaides *et al.* (2009) conducted a study on impact of hail storms on the agricultural economy of Cyprus (UK) and their characteristics. During the period from 1996 to 2005, 138 hail events have resulted in compensation by Agriculture Insurance Organization of Cyprus (AIO). Results of the study showed that, the maximum compensation was paid during study period 1997. Drought and high temperatures had high contribution to the formulation of the compensation paid for 1997. The minimum compensation paid was during 2004 (2199 K EU). The maximum compensation paid due to hail was during 2001 (3614.5 K EU) and the minimum in 1998 (464 K EU). The maximum total compensation was paid for grains (*i.e.* 29 348.9 K EU) and potatoes (*i.e.* 25 523.9 K EU). Compensation paid for citrus (*i.e.* 5826.5 K EU) and vines (*i.e.* 6498.2 K EU) were generally lesser as compared to deciduous, potatoes and grains.

Srinivas rao (2009) conducted a study on drought and its impact on growth. Drought caused a major economic crisis. The incidence of unemployment and under employment increases, especially in the rural areas. In India north region was more vulnerable to the *kharif* rainfall. Therefore paddy, pulses bajra, cotton, soybean and sugarcane were stand at risk. During the past 60 years there was a drought every few years and agrieconomy witnessed a negative growth. In Andhra Pradesh drought problem seems to be more serious than what was reported officially which was observed from sowing figures of paddy and groundnut in just 25-26 per cent of the normal area. Similarly sugarcane, maize, onion and tur were restricted to 51-57 per cent sown area while, cotton was slightly better off and extended to 76-100 per cent of sown area.

Sushil Pandey and Humnath Bhandari (2009) studied the drought coping mechanisms and poverty in India, China and Thailand. Three states form each countries were selected. From India, Chattisgarh, Jharkhand and Orissa were selected. From China and Thailand, Guangxi, Hubei, Zhejiang and Zone 1, Zone 2, Zone 3 were selected, respectively. Drought causes production losses of paddy and other major crops grown during and after the rainy season. The estimated average loss in paddy production during drought years for the three states of eastern India was 5.4 million tonnes. This was much higher than for north-eastern Thailand (less than 1 million tonnes) and southern China (about 1 million tonnes, but not statistically significant). The loss in paddy yield during drought years was estimated to be in the range of 25-40 per cent in Jharkhand and Orissa, but was almost 100 per cent in Chattisgarh, where there was almost complete crop failure during the 2002 drought.

Amrit (2010) conducted a study on climate change and agriculture need for mitigation and adoption. Results of the study revealed that, climate change effected heath, growth and productivity of crops, livestock, fish, forest and pasture in different ways. It also had impact on the incidence of pest and disease, biodiversity and ecosystems. Climate change impacts based on case studies in drought prone regions of Andhra-Pradesh and Maharashtra and flood prone districts in Orissa on the edge of climate tolerance limits highlights the possibility of declining yield levels of major dry land crops. In Andhra Pradesh sugarcane yield declined by 30 per cent and paddy production by 12 per cent in the flood prone coastal regions of Orissa.

Raji Reddy and Sreenivas (2010) conducted a study on drought management strategies in agriculture in Andhra Pradesh. Andhra Pradesh has historically was one of the drought affected states in India. Out of the 23 districts in Andhra Pradesh, four districts of Rayalaseema (Anantapur, Chittoor, Kadapa and Kurnool), four districts of Telangana (Ranga Reddy, Mahaboobnagar, Nalgonda and Medak) and one district of Coastal Andhra (Prakasam) are considered as drought prone districts. Rainfed crops like sorghum, maize, groundnut, greengram, blackgram and sunflower and one water-intensive crop like paddy crop generally affected owing to drought in these districts. The timely onset and well distribution of monsoon rain in the month of June and July decides the area coverage of rainfed crops. Any deviation in onset of monsoon rain results in significant change in area covered by different crops. During crop season drought would have significant influence on growth and development of crops which led to reduction in yield. Drought could be managed closely by monitoring seasonal conditions, suggesting contingent crops on near real time basis, adopting different farm level options like changing the sowing dates, adopting different crop varieties and supplemental irrigation using micro irrigation and advance weather information on occurrence of drought through extended range forecast/seasonal climate forecast and disseminating agro-met advisories issued based on medium range forecast for mid-season corrections.

Anil Gupta (2011) conducted a study on Drought disaster challenges and mitigation in India: strategic appraisal. Rainfall data for 200 years were collected and drought years were identified. Impacts of drought on crops were documented. Between 1801-1825, six drought years were observed they were 1801, 1804, 1806, 1812, 1819, 1825. Highest numbers of droughts were observed between 1975 and 2000. Total nine drought years were observed between this period. Some of these were very severe, posed a threat to the food security and caused human mortality all over the country.

Hamid and Mohamad (2011) conducted a study on impacts of drought on socio-economic conditions of paddy farmers in Guilan Province, north of Iran. Study was based on primary data. Total sample size was 270. In order to determine the scale of drought impacts, year 2008 (a year which paddy farmers had ensured water reservoir) compared with the year 2009 (a year which paddy farmers were caught by drought and water shortage). The results indicated that, drought caused decrease in white- paddy productivity by 312 kg per hectare. This problem also caused increase in costs, decrease in income, decrease in saved money, and increase in anxiety, mental problems *etc* on Guilan paddy farmers. Other findings indicated that, there was not statistically significant relationship between age and farming experience of paddy farmers with the amount of damage. However, there was statistically significant relationship between literacy, type of water resource and taking extension advises with amount of drought damage.

Pradhan *et al.* (2011) conducted a study on analysis of meteorological drought at New Delhi using Standardized Precipitation Index (SPI). Rainfall data from 1951-2009 was collected for four seasons (early, mid, late and whole *kharif*). Five years experienced moderate drought and three years experience with extremely drought during the early *kharif* season. During mid *kharif* season, seven years experienced moderate drought (1951, 1953, 1954, 1986, 1989, 1999, 2006), two years severe drought (1974, 1981) and one year experienced extreme drought. During whole *kharif* season three moderate, two extreme drought years were experienced.

Asha latha *et al.* (2012) conducted a study on impact of climate change on rainfed agriculture in India: a case study of Dharwad. The study results revealed that, the climatic variation such as occurrence of drought have high level of impact on the yield of rainfed crops. The farmers already act to the changes in the climatic changes both by adopting the technological coping mechanisms on the positive side and negatively through shifting to other professions. It was concluded that, the small and medium rainfed farmers were highly vulnerable to climate change and to a larger extent the small and medium rainfed farmers adopted coping mechanisms for climate change compared to large farmers. The study suggests that as the impact of climate change intensifying day by day it should be addressed through policy perspective at the earliest to avoid short term effect such as yield and income loss and long-term effects such as quitting agricultural profession by the Rainfed farmers.

Maximilian Auffhammer *et al.* (2012) research indicated that, monsoon rainfall became less frequent but more intense in India during the latter half of the Twentieth Century, thus increasing the risk of drought and flood damage to the country’s wet-season (*kharif*) paddy crop. Our statistical analysis of state-level Indian data confirms that, drought and extreme rainfall negatively affected paddy yield (harvest per hectare) in predominantly rainfed areas during 1966–2002, with drought having a much greater impact than extreme rainfall. Using Monte Carlo simulation, they found that yield would have been 1.7 per cent higher on average if monsoon characteristics, especially drought frequency, had not changed since 1960. Yield would have received an additional boost of nearly 4 per cent if two other meteorological changes (warmer nights and lower rainfall at the end of the growing season) had not occurred. In combination, these changes would have increased cumulative harvest during 1966–2002 by an amount equivalent to about a fifth of the increase caused by improvements in farming technology. Climate change evidently, already negatively affected India's hundreds of millions of paddy producers and consumers.

Arfaee (2013) conducted study on studying consequences of drought on economic condition of farmers in Iran (Ashtian). The study was based on primary data. Results showed that, economic effect of drought with respect to attitude of farmers was medium to high. Some important economic aspects of drought of this area included; decreasing motivation of investment on farming, decreasing purchase afford of farmers, increasing cost of required fertilizer and poison, decreasing additional income (income of crafts, husbandry…), decreasing income for performance of crops (agricultural and gardening), increasing cost of irrigation and supplying water, increasing debit of farmers, increasing unemployment for impossibility of planting, decreasing price of agricultural and gardening products due to decreasing their quality, increasing price of high quality lands. economic solutions in relation to balancing drought during recent years was poor and insurance of agricultural crops endangered for drought, extending refund of drought loan, non-reimbursable financial assistant, drought loan, banking loan for purchasing pump engine and machineries fall within first to fifth priorities

Rumi Aijaz (2013) conducted a study on monsoon variability and agricultural drought management in India. Results of the study revealed that, India experienced 24 major droughts and the severe drought years were 2009, 2002, 1987, 1972, 1918, 1899 and 1877. Insufficient and uneven rainfall leads to loss of certain crops. Some resistant varieties may sustain for 20 or 30 days, but some may not even for 10 days. In 2002, rainfall deficit was 19 per cent due to which 29 per cent of country's total area was affected, and there was a loss of 24 million tonnes of food grain. The 2009 drought was the third worst since 1901, when a rainfall deficit of 23 per cent was recorded and about 59 per cent of the area was affected. A State-level analysis reveals that in the drought-prone State of Andhra Pradesh, total decline in the yield of *kharif* food grains increased from 17 per cent in 2002-03 to 25 per cent in 2009-10. Many farmers were not able to sow the millets in Karnataka and in Gujarat due to less rainfall.

2.5 To map the vulnerability of climate change for selected districts

Moser (1998) studied vulnerability which was closely linked to asset ownership. He found that the more assets people had, the less vulnerable they were, and the greater the erosion of people's assets, the greater their insecurity.

Handmer *et al.* (1999) studied the coping mechanisms to environmental shock or hazard brought about by biophysical vulnerability. The factors like institutional stability and strength of public infrastructure were of crucial importance in determining the vulnerability to climate change. A well connected population with appropriate public infrastructure would be able to deal with it effectively and reduce the vulnerability. Such a society could be said to have low social vulnerability. If there is an absence of institutional capacity in terms of knowledge about the event and ability to deal with it, then such high vulnerability is likely to ensure that biophysical risk turns into an impact on the human population.

Adger (2001) stated that, it was only rural populations were vulnerable to climate change, if there was a high rate of urbanization caused by rural-urban migration, it was highly likely that the new migrants to the city would also be increasing their personal vulnerabilities by leaving behind the social networks and collective institutions that might have facilitated adaptation.

Heltberg *et al.* (2008) addressed human vulnerability to climate change and found that, climate events could result in irreversible losses to human and physical capital. In many parts of Africa and elsewhere, variability in rainfall and temperatures already caused variability in agricultural production and food security. The most vulnerable households were those with assets and livelihoods exposed and sensitive to climatic risks that had weak risk management capacity. Moreover, it was found that, people who depend on agriculture (especially rainfed), livestock, and fisheries would be at high risk compare to non agriculture households.

Deepa (2010) conducted a study on vulnerability assessment of climate change on the agricultural economy of Gujarat. Study was based on time series daily/ monthly/ annual meteorological data (temperature and rainfall) collected from different sources for selected stations of Gujarat which varied from 14 to 33 years. Results revealed that the vulnerability indices constructed for the selected districts revealed that the variables pertaining to agricultural vulnerability such as productivity of major crops, cropping intensity, irrigation intensity, net sown area, livestock population, forest area *etc* were the major contributors in the overall vulnerability to climate change during the different periods. Next to the agricultural indicators, the occupational indicators such as number of cultivators, agricultural labourers, industrial workers, marginal workers *etc* were found to be the second largest contributors towards overall vulnerability, as a result of which there is a need for livelihood security through income diversification.

3. METHODOLOGY

For finding a solution for any problem it needs a systematic investigation using appropriate method and procedures in order to arrive at a reliable, unbiased and practical conclusion. So this chapter includes general description of the study area, the data base and the analytical tools and techniques used. This chapter is arranged in the following sub headings

3.1 Description of the study area

3.2 Selection of the study area

3.2.1 Selection of crops

3.3 Nature and sources of data

3.3.1 Selection of secondary data

3.3.2 Selection of primary data

3.4 Analytical framework

3.4.1 Time series analysis

3.4.2 Tabular analysis

3.4.3 Multiple regression analysis

3.4.4 Index approach to study vulnerability

3.4.5 Run test

3.4.6 t-test (equal or unequal sample sizes, unequal variance)

3.4.7 Garrett Ranking

3.5 Terminologies used in the study

3.1 Description of the study area

Karnataka is the Western-most state of India located between 11°30' North and 18°30' North latitudes and 74° East and 78°30' East longitude. The geographical area of Karnataka is 190498 sq. km accounting for 5.81 per cent of the total area of the country. Total cultivable area in the state is 9.85 million ha which accounts for 51.4 per cent of total geographical area. Net irrigated area is 2.38 million ha constituting 24 per cent of the cultivated area.

The state receives normal annual rainfall of 1,248 mm mainly through south-west monsoon and north-east monsoon. The southwest monsoon accounts for almost 80 % of the rainfall that the state receives. Agumbe in the Western Ghats experiences the heaviest rainfall in the country next only to Cherrapunji. The districts of Vijayapura, Raichur, Bellary and southern half of Kalaburagi experience the lowest rainfall ranging from 500 mm to 600 mm while the west coastal region and Malenadu enjoy the highest rainfall. The state is divided into three meteorological sub divisions *viz.,* north interior Karnataka, south interior Karnataka and Coastal Karnataka. The Coastal Karnataka with an average annual rainfall of 3,456 mm is the rainiest regions in the state. Contrasting to this, the south interior Karnataka and north interior Karnataka receive only 1,286 mm and 731 mm of average annual rainfall, respectively.

The Karnataka state is being considered as one of the highest average elevations of Indian states situated at 1,500 feet. Day and night temperatures are more or less uniform over the state, except at the coastal region and high elevated plateau.

Table 3.1. District wise average area under different rain-fed crops (2010-11 to 2012-13) (in ha)

Crops	BAGALKOTE	BELAGAVI	BELLARY	BIDAR	VIJAYAPURA	DHARWAD	GADAG	KALABURAGI	HAVERI	KOPPAL	RAICHUR	UTTARA KANNADA	YADGIR
Paddy	0.00 (0.00)	60,964.67 (11.65)	0.00 (0.00)	2,820.33 (0.72)	0.00 (0.00)	23,257.33 (6.49)	157.33 (0.04)	913.33 (0.09)	16,472.67 (5.23)	27.33 (0.01)	1,090.00 (0.29)	62,003.00 (84.55)	24,158.67 (13.04)
Sorghum	95,417.33 (31.35)	1,39,546.33 (26.68)	32,845.67 (11.74)	76,632.33 (19.57)	1,60,144.33 (27.23)	41,020.33 (11.44)	57,025.67 (15.09)	2,36,962.00 (23.25)	33,298.67 (10.58)	44,935.33 (14.76)	89,948.67 (24.28)	8.00 (0.01)	31,698.33 (17.10)
Bajra	32,900.67 (10.81)	17,540.67 (3.35)	12,907.33 (4.61)	7,024.67 (1.79)	5,0971.33 (8.67)	0.00 (0.00)	2,220.33 (0.59)	23,869.67 (2.34)	2.67 (0.00)	61,461.00 (20.19)	44,217.33 (11.93)	0.00 (0.00)	11,483.00 (6.20)
maize	7,077.33 (2.33)	32,923.00 (6.29)	59,747.00 (21.36)	948.33 (0.24)	1,663.33 (0.28)	26,446.00 (7.38)	18,950.67 (5.02)	4,045.67 (0.40)	1,14,616.33 (36.40)	26,283.00 (8.64)	0.00 (0.00)	2,613.00 (3.56)	1,475.33 (0.80)
Ragi	0.00 (0.00)	1,165.33 (0.22)	3,996.00 (1.43)	0.00 (0.00)	0.00 (0.00)	35.33 (0.01)	7.33 (0.00)	0.00 (0.00)	549.33 (0.17)	0.00 (0.00)	0.00 (0.00)	628.67 (0.86)	2.67 (0.00)
Wheat	3,474.67 (1.14)	12,989.33 (2.48)	263.33 (0.09)	2,037.67 (0.52)	25,130.33 (4.27)	29,370.67 (8.19)	17,034.67 (4.51)	8,577.67 (0.84)	979.33 (0.31)	7,949.00 (2.61)	1,964.00 (0.53)	0.00 (0.00)	609.00 (0.33)
Total millets	35.00 (0.01)	2,086.33 (0.40)	3,380.33 (1.21)	65.33 (0.02)	0.00 (0.00)	911.67 (0.25)	240.33 (0.06)	69.33 (0.01)	3,023.33 (0.96)	3,038.67 (1.00)	21.00 (0.01)	0.00 (0.00)	69.00 (0.04)
Tur	7,826.33 (2.57)	4,818.00 (0.92)	9,516.00 (3.40)	71,912.67 (18.36)	1,31,953.67 (22.43)	3,029.33 (0.84)	2,823.67 (0.75)	3,61,717.00 (35.50)	2,737.33 (0.87)	11,455.33 (3.76)	39,298.00 (10.61)	23.00 (0.03)	48,354.67 (26.09)
Blackgram	51.33 (0.02)	3,345.33 (0.64)	72.33 (0.03)	39,676.67 (10.13)	132.00 (0.02)	2,010.00 (0.56)	62.33 (0.02)	40,675.33 (3.99)	618.33 (0.20)	235.33 (0.08)	55.33 (0.01)	2,100.33 (2.86)	851.00 (0.46)
Horsegram	1,877.00 (0.62)	4,422.00 (0.85)	5,304.00 (1.90)	0.00 (0.00)	8,294.00 (1.41)	1,900.67 (0.53)	2,143.67 (0.57)	1,080.00 (0.11)	4,053.00 (1.29)	7,809.33 (2.57)	962.33 (0.26)	305.33 (0.42)	297.33 (0.16)
Greengram	43,734.67 (14.37)	21,009.00 (4.02)	702.33 (0.25)	38,306.67 (9.78)	17,370.67 (2.95)	26,739.67 (7.46)	66,806.67 (17.68)	52,527.00 (5.15)	5,479.67 (1.74)	13,383.67 (4.40)	7,241.67 (1.95)	589.67 (0.80)	26,219.00 (14.15)
Field Bean	145.00 (0.05)	1,125.00 (0.22)	29.33 (0.01)	753.00 (0.19)	55.67 (0.01)	342.00 (0.10)	53.33 (0.01)	401.33 (0.04)	422.67 (0.13)	742.00 (0.24)	15.33 (0.00)	84.33 (0.11)	88.67 (0.05)
Cowpea	1,235.00 (0.41)	1,953.33 (0.37)	2,093.33 (0.75)	19.00 (0.00)	1,200.33 (0.20)	956.33 (0.27)	1,760.00 (0.47)	1,432.00 (0.14)	1,339.00 (0.43)	5,745.33 (1.89)	3,24.67 (0.09)	350.67 (0.48)	355.00 (0.19)

Contd……

Table 3.1 contd...

Crops	BAGALKOTE	BELAGAVI	BELLARY	BIDAR	VIJAYAPURA	DHARWAD	GADAG	KALABURAGI	HAVERI	KOPPAL	RAICHUR	UTTARA KANNADA	YADGIR
Other pulses	426.00 (0.14)	1,485.00 (0.28)	174.67 (0.06)	243.00 (0.06)	5,150.67 (0.88)	189.33 (0.05)	168.67 (0.04)	415.67 (0.04)	0.00 (0.00)	1,445.33 (0.47)	54.67 (0.01)	0.00 (0.00)	38.67 (0.02)
Bengal gram	65,185.67 (21.42)	56,932.00 (10.88)	24,759.00 (12.42)	72,288.33 (18.46)	84,177.67 (14.31)	49,847.00 (13.90)	64,261.67 (17.01)	1,98,216.33 (19.45)	1,328.00 (0.42)	35,821.00 (11.77)	89,579.33 (24.18)	4.67 (0.01)	12,313.33 (6.64)
Groundnut	3,278.67 (1.08)	33,295.33 (6.36)	56,168.00 (20.08)	338.67 (0.09)	25,274.00 (4.30)	35,288.67 (9.84)	51,047.33 (13.51)	3,366.67 (0.33)	16,755.33 (5.32)	17,643.33 (5.80)	6,229.67 (1.68)	2,532.00 (3.45)	3,134.33 (1.69)
Castor	6.67 (0.00)	214.33 (0.04)	177.33 (0.06)	0.00 (0.00)	10.33 (0.00)	0.00 (0.00)	45.67 (0.01)	101.33 (0.01)	13.33 (0.00)	717.33 (0.24)	1,048.00 (0.28)	0.00 (0.00)	17.00 (0.01)
Seasamum	2,256.33 (0.74)	554.33 (0.11)	1,842.33 (0.66)	4,853.67 (1.24)	960.33 (0.16)	341.33 (0.10)	1,024.67 (0.27)	11,227.33 (1.10)	254.67 (0.08)	4,818.00 (1.58)	5,293.67 (1.43)	25.33 (0.03)	216.67 (0.12)
Linseed	2,184.33 (0.72)	1,616.33 (0.31)	6.67 (0.00)	256.67 (0.07)	3,793.33 (0.64)	76.33 (0.02)	533.33 (0.14)	565.33 (0.06)	122.33 (0.04)	1,397.33 (0.46)	192.33 (0.05)	0.00 (0.00)	14.00 (0.01)
Soybean	3,415.33 (1.12)	84,439.67 (16.14)	0.00 (0.00)	54,002.67 (13.79)	1.33 (0.00)	30,020.33 (8.37)	1.33 (0.00)	1,033.33 (0.10)	7,964.67 (2.53)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	6.00 (0.00)
Niger	140.33 (0.05)	492.00 (0.09)	512.00 (0.18)	2,959.00 (0.76)	767.67 (0.13)	279.67 (0.08)	938.67 (0.25)	1,097.33 (0.11)	380.33 (0.12)	1,311.33 (0.43)	23.33 (0.01)	0.00 (0.00)	10.00 (0.01)
Rapeseed & mustard	4.00 (0.00)	481.00 (0.09)	12.67 (0.00)	35.33 (0.01)	0.00 (0.00)	11.67 (0.00)	94.33 (0.02)	17.67 (0.00)	13.67 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	10.67 (0.01)
Sunflower	30,161.67 (9.91)	10,353.67 (1.98)	31,899.33 (11.40)	4,982.00 (1.27)	62,897.33 (10.69)	3,279.33 (0.91)	33,992.00 (9.00)	54,810.33 (5.38)	2,047.00 (0.65)	41,265.33 (13.56)	65,368.67 (17.64)	0.00 (0.00)	6,514.33 (3.51)
Safflower	2,590.00 (0.85)	5,942.00 (1.14)	660.33 (0.24)	10,670.67 (2.72)	7,084.67 (1.20)	9,000.00 (2.51)	2,517.33 (0.67)	10,097.67 (0.99)	1,488.67 (0.47)	3,354.67 (1.10)	3,239.67 (0.87)	0.00 (0.00)	669.00 (0.36)
Cotton	914.00 (0.30)	23,431.67 (4.48)	22,692.00 (8.11)	850.67 (0.22)	1,178.67 (0.20)	7,422.5 (20.70)	53,960.67 (14.28)	5,800.00 (0.57)	1,00,896.00 (32.05)	13,523.33 (4.44)	14,342.67 (3.87)	2,064.67 (2.82)	16,729.67 (9.03)
Total	3,04,337.33	5,23,125.67	2,79,761.33	3,91,674.33	5,88,211.67	3,58,578.00	3,77,871.67	10,19,019.33	3,14,856.33	3,04,362.33	3,70,510.33	73,335.67	1,85,335.33

Note: Number in parenthesis indicate percentage to the total

Table 3.2. Major crops selected for each districts

Sl. No.	District	Crops Name	No. of crops
1	Bagalkote	Bajra, sorghum, greengram, bengalgram, sunflower,	5
2	Belagavi	Paddy, sorghum, maize, bengalgram, groundnut, soybean	6
3	Bellary	Sorghum, maize, bengalgram, groundnut, sunflower and cotton	6
4	Bidar	Sorghum, tur, blackgram, greengram, bengalgram, soybean	6
5	Vijayapura	Sorghum, bajra, tur, bengalgram, sunflower	5
6	Dharwad	Paddy, sorghum, maize, wheat, greengram, bengalgram, groundnut, soybean and cotton	9
7	Gadag	Sorghum, maize, greengram, bengalgram, groundnut, sunflower and cotton	7
8	Kalaburagi	Sorghum, tur, greengram, bengalgram, sunflower,	5
9	Haveri	Paddy, sorghum, maize, cotton	4
10	Raichur	Sorghum, bajra, tur, bengalgram, sunflower,	5
11	Uttara Kannada	Paddy	1

April and May are the hottest months in almost all the cities of Karnataka. The highest recorded temperature was 45.6 ^{0}C at Raichur on May 23, 1928. The lowest recorded temperature was 2.8 ^{0}C at Bidar on December 16, 1918. During April and May humidity is quite less in the atmosphere. The month of June is very unpleasant as the humidity rate increases marginally because of the soon approaching monsoon season. At this time, the average temperature is 34 ^{0}C with 75 per cent humidity. Towards the interior north cities of the state such as Vijayapura, Dharwad, Belagavi, Kalaburagi, Raichur have an average high temperature of 28 ^{0}C-34 ^{0}C and a temperature of 20 ^{0}C -22 ^{0}C. As per IMD in Karnataka state we marked four seasons in the year namely winter season from December to February, summer season from March to May, monsoon season from June to September and post-monsoon season from October to November. Karnataka has natural advantages that serve it well for diversified agricultural production with diversified climatic situations.

3.2 Selection of the study area

Study was carried out in the north-Karnataka. Because average annual rainfall of north Karnataka is 865 mm were as south Karnataka receives 1,500 mm of rainfall and this part of the state, since the beginning of new millennium is experiencing many weather extremities such as erratic rainfall, hailstorms, floods and droughts, extreme temperature and unseasonal rainfall compare to south Karnataka. These weather aberrant situations have become more frequent and influencing the agricultural production as well as livelihood aspects concerned to this part of the state. So Study was carried out in north-Karnataka purposively.

3.2.1 Selection of crops

To ascertain the impact of climate variability on crop yield of major dry land crops grown in each district, triennium average for area under different crops from 2010-11 to 2012-13 was calculated (Table 3.1). Dry land crops covering more than 5 per cent of the gross cropped area of that district were selected as major crops of that district. List of crops selected for each districts of north-Karnataka are presented in Table 3.2. Crops grown in a particular season and its respective seasonal weather parameters were used to know the impact of different seasonal weather parameters on yield of those selected crops grown in the identified districts to get results for drawing meaningful conclusions.

3.3 Nature and sources of data

Study was based on both primary and secondary data.

3.3.1 Selection of secondary data

Rainfall data for a period of about 31 years and monthly temperature data for 15 years, were collected and utilized in assessing the magnitude and extent of climate variability trend for the selected districts of north Karnataka.

For the purpose of assessing the impact of climate change on crop yield for the selected crops of north-Karnataka districts, 15 years data on actual rainfall, maximum temperature, minimum temperature, maximum relative humidity and minimum relative humidity were collected and analyzed.

Table 3.3. Indicators and their functional relationship with vulnerability to climate change

Sr. No	Components	Indicators	Functional relationship
1	Demographic (4)	Density of population (persons per sq. km)	↑
		Literacy rate (per cent)	↓
		Number of automobiles	↑
		Number of factories	↑
2	Climatic (4)	Variance of annual rainfall (mm^2)	↑
		Variance of Southwest monsoon (mm^2)	↑
		Variance of minimum temperature ($^o C^2$)	↑
		Variance of maximum temperature ($^o C^2$)	↑
3	Agricultural (12)	Total food grains (kg/ha)	↓
		Productivity of *kharif* groundnut (kg/ha)	↓
		Productivity of cotton (kg/ha)	↓
		Productivity of *kharif* paddy (kg/ha)	↓
		Productivity of *kharif* bajra (kg/ha)	↓
		Productivity of *kharif* maize (kg/ha)	↓
		Cropping intensity (per cent)	↓
		Irrigation intensity (per cent)	↓
		Forest area (per cent to geographic area)	↓
		Total food crops (per cent)	↓
		Net sown area (hectares)	↓
		Livestock population (number per hectare of gross cropped area)	↓
4	Occupational (6)	Total main workers (per hectare of net area sown)	↓
		Number of cultivators (per hectare of net area sown)	↓
		Agricultural labourers (per hectare of net sown area)	↓
		Industrial workers (per hectare of net sown area)	↓
		Marginal workers (per hectare of net sown area)	↓
		Non-workers (per hectare of net sown area)	↓

To assess the extent and magnitude of climate change, especially rainfall and temperature as well as to compute the vulnerability indices, the district was considered as most suitable unit to carry out disaggregated analysis within the state considering the availability of data. There is a growing consensus in the scientific community to address vulnerability issues related to climate change particularly at the district levels. This would enable to fine-tune the hot spot areas that need immediate intervention. Thus, the districts have been taken as the unit of analysis in the present study.

Several factors determine the district-wise vulnerability to climate change. These determinants can be broadly classified under three categories *viz*; Exposure, Sensitivity and Adaptation. However, it is not be possible to include all the sub-indicators under these three broad categories and so only those indicators relevant to north-Karnataka state were selected in the construction of vulnerability indices. Here, the important and maximum possible available indicators were selected for 1990's, 1995, 2000, 2005, 2010 and 2013 periods. Vulnerability to climate change is a comprehensive multidimensional process affected by large number of related indicators and hence it is necessary to measure the quantum of vulnerability by constructing a vulnerability index for the districts of north-Karnataka. Thus, it is well represented by composite indices. Composite indices are used as yardsticks to gauge the vulnerability of each district to climate change. For the purpose of computing vulnerability indices for the districts of north-Karnataka, the 26 indicators listed in Table 3.3 were selected and their functional relationship with climate change were identified as shown in the table.

All secondary data pertaining to rainfall, temperature and various socio-economic indicators were collected and compiled from different sources *viz*; Directorate of Economics and Statistics, Bangalore, Karnataka and one more book entitled as "Statistical analysis of hundred year's rainfall data of Karnataka" published by M. B.Rajeegowda, Head AICRP on Agro-meteorology project at UAS, Bangalore were used.

3.3.1.1 Brief description of the selected indicators and their functional relationship with vulnerability to climate change

The vulnerability indices suggested many important hypotheses relating the vulnerability of the districts to climate change with various key socio-economic, climatic and agricultural indicators.

The density of population of the district was found to influence its demographic vulnerability and consequently influence the overall vulnerability to climate change. It was hypothesized to be positively related to the vulnerability to climate change *i.e.*, with the increase in the number of persons per square kilometer, the vulnerability to climate change would increase due to its direct impact on global warming. This would be due to increased pollution and Green House Gas (GHG) emissions as a result of greater use of vehicles, enormous industrial carbon emissions, rapid use of non-renewable and other natural resources, greater use of non-biodegradable materials like polythene, growing human settlements and their activities leading to faster destruction of natural systems, deforestation, habitat destruction, extinctions, more exploitation of other living forms and non-living systems like rivers. For people there would be increase in illness and diseases, shortage of natural resources such as water, land, food, shortage of infrastructure namely medical facilities/medications *etc.* Moreover, any occurrence of extreme events *viz*, droughts, floods *etc* was likely to be more catastrophic for the people living in these districts (Patnaik and Narayanan, 2005).

The literacy rate, on the other hand, was hypothesized to have a negative functional relationship with demographic vulnerability and thereby, on the overall vulnerability to climate change. Literacy rate indicates the adaptability of the population to both adverse impacts caused by shocks and the opportunities created. It also implies the proportion of expenditure on education in total public expenditure which indicates investment in human capital. It was seen that a high value of this variable implied more literates in the region and so greater awareness to cope up with climate change impacts (Palanisami *et al.,* 2009).

Climatic vulnerability was assumed to be positively related to the indicators such as variances in annual rainfall and southwest monsoon as well as minimum and maximum temperature variances. This indicated that any increase in the variability of these climatic indicators would increase the vulnerability of the districts to climate change. Glantz and Wigley (1986) studied the worldwide climate change and showed that any change in climatic variables like temperature and precipitation could induce vulnerability of food production in a major way. For instance, the climatic abnormality during the 1970's caused relatively small fluctuations in the world cereal supplies.

Yield is more uncertain with unfamiliar technology. Quite often objective risks and uncertain due to weather fluctuations, susceptibility to pests, uncertainty regarding timely availability of critical inputs (Shiyani *et al.,* 1985). However, it could be seen that higher yields of crops led to higher incomes of the farmers and thereby increasing their risk bearing ability to various shocks. Increase in the livestock population per gross cropped area also resulted in an increase in farmer's incomes through various animal husbandry based activities, thereby its negative functional relationship towards vulnerability. Similarly, the percentage of total food crops and non-food crops, the cropping and irrigation intensities and the net sown area in the district, each of these comprising the agricultural indicators, were also hypothesized to have a negative influence on the vulnerability to climate change.

The forest area was assumed to have a negative functional relationship with climate change. Forest ecosystems capture and store carbon dioxide, making a major contribution to the mitigation of climate change. However, when forests are destroyed, over-harvested or burned, they can become a source of CO_2 emissions. Thus, an increase in the percentage forest covers would enable in reducing the vulnerability to climate change. Lastly, all the occupational indicators were hypothesized to have a negative functional relationship with respect to vulnerability to climate change as greater employment meant more secure incomes which would in turn increase the risk bearing capacities of the people.

3.3.2 Selection of primary data

Primary data was collected by following purposive sampling technique. The data required for the study from the respondents was gathered by following multi stage sampling methods. The procedure at profile and criteria's are as follows.

3.3.2.1 Sampling design

Multistage sampling procedure was adopted to select the samples.

3.3.2.1.1 Sampling design followed for selection of farmers using Agromet Advisory Service

To analyse the impact of ongoing Agro-met Advisory Services (AAS) (Both advisory and forecast) on farmers, primary data were collected from AAS beneficiary farmers of Belagavi district. From Belagavi districts Bailhongal, Raybag, Athani and Gokak taluks were selected.

Table 3.4. Selection of farmers using and not using Agromet Advisory Service (AAS)

District	Category	Taluks	Villages	Number of sample farmers
Belagavi	Beneficiaries	Bailhongal	Govinakoppa	9
			Chikkabellikatti	9
		Raybag	Harugeri	9
			Kandal	9
		Athani	Shegunshi	9
			Kuligudda	9
		Gokak	Arabhavi	6
			Total	**60**
	Non Beneficiaries	Bailhongal	Govinakoppa	5
			Chikkabellikatti	5
		Raybag	Harugeri	5
			Kandal	5
		Athani	Shegunshi	5
			Kuligudda	5
			Total	**30**

Table 3.5. District wise deviation in rainfall pattern in North-Karnataka during 2014-15

Sl. No.	Districts	Rainfall (mm)	% Deviation
1	Bagalkote	430.0	-26
2	**Belagavi**	**561.0**	**-37**
3	Bellary	635.0	-6
4	Bidar	585.0	-33
5	**Vijayapura**	**398.0**	**-38**
6	Dharwad	564.0	-29
7	Gadag	455.0	-31
8	Kalaburagi	551.0	-32
9	Haveri	604.0	-23
10	Koppal	512.0	-15
11	Raichur	462.0	-30
12	Uttara Kannada	2,106.0	-24

(Source: Karnataka State Natural Disaster Management Cell 2014-15)

From Bailhongal, Govinakoppa and Chikkabellikatti villages were selected. From Raybag, Harugeri and Kandal villages were selected. Shegunshi and Kuligudda villages were selected from Athani taluk. From all these villages nine beneficiaries were surveyed. From Gokak taluk Arabhavi village was selected, six beneficiaries were surveyed from Arabhavi village because of less number of beneficiaries presented in Arabhavi. On the other hand thirty non-AAS farmers equally from Bailhongal, Raybag and Athani were surveyed to compare the results AAS and non AAS farmers. Total sample size was 90 (Table 3.4).

3.3.2.1.2 Sampling design followed for selection of farmers affected by drought

In order to analyze the impact of drought in north Karnataka, Vijayapura and Belagavi were selected, since these two districts experienced higher negative deviation in rainfall during 2014-15 (Table 3.5). Agriculture area affected due to drought was more in Basavanabagewadi (32,795 ha) and Indi (58,212 ha) (Table 3.6) so these taluks were selected from Vijayapura district and Bailhongal and Hukkeri from Belagavi district.

Primary data were collected to study the impact of different weather parameters on the farm households the required information were collected in the form of primary data from 250 sample farmers.

3.3.2.1.3 Sampling design followed for selection of farmers affected by hailstorm

With this procedure to know the hailstorms impact on agriculture, data were collected from farmers of Vijayapura districts. Because of heavy hailstorm was documented in Indi taluk of Vijayapura district during February and March 2014. From Indi taluk Ballolli and Indi hoblies were selected (Table 3.8). From each hobli two villages which were having more number of affected farmers was selected. Based on this Tadavalaga and Batagunki villages from Ballolli hobli and Hireroogi and Salotagi from Indi hobli were selected purposefully. 20 farmers from each village were surveyed. Total sample surveyed was 80 (Table 3.9).

3.4 Analytical tools and techniques used

Under this subhead of the methodology chapter for analyzing the data collected from different sources were subjected to analysis process by employing analytical tools to draw meaning full conclusions are presented under following sub titles.

3.4.1 Time series analysis

The temporal impact of the identified variables were studied by subjecting the time series data to the process of time series analysis. In view of this time series analysis was carried out to study the variations in monthly rainfall for the period of 31 years from 1983-84 to 2013-14. A time series is a complex mixture of four components namely, Trend (T), Seasonal (S), Cyclical (C) and Irregular (I) variations. These four types of movements are frequently found either separately or in combination in a time series. The relationship among these components is assumed to be additive or multiplicative, but the multiplicative model is the most commonly used method in economic analysis, which can be represented as.

Table 3.6. Taluk wise agriculture area affected due to drought in Vijayapura and Belagavi districts during 2014-15

Sl. No.	Districts	Agriculture area affected (ha)
1	**Belagavi**	
i	Athani	36,861
ii	Bailhongal	80,166
iii	Belgavi	32,657
iv	Chikkodi	43,418
v	Gokak	44,140
vi	Hukkeri	59,857
vii	Khanapur	31,750
viii	Ramdurga	19,381
ix	Raibag	22,270
x	Soundatti	54,136
2	**Vijayapura**	
i	Basavanabagewadi	32,795
ii	Vijayapura	30,728
iii	Indi	58,212
iv	Muddebihal	24,438
v	Sindagi	29,850

(Source: Karnataka State Natural Disaster Management Cell 2014-15)

Table 3.7. Selection of drought affected villages

	Districts	Taluks	Villages	No. of Samples
North Karnataka	Belagavi	Bailhongal	Bailhongal	20
		Hukkeri	Bagewadi	20
	Vijayapura	Basavanabagewadi	Managuli	20
		Indi	Chadchan	20
Total sample size				**80**

Table 3.8. Extent of hailstorm incidence in Indi taluk of Vijayapura district during 2014

Sl. No.	Hoblies	Number of villages affected	Number of farmers affected by hailstorm
1	Ballolli	17	2,523
2	Chadchan	30	1,765
3	Indi	11	2,448
4	Goshwavare	9	1,052

Table 3.9. Selection of hailstorm affected villages

Taluk	Hoblies	Villages
Indi	Ballolli (n=40)	Tadavalaga (n=20)
		Batagunki (n=20)
	Indi (n=40)	Hireroogi (n=20)
		Salotagi (n=20)

$$O_t = T \times C \times S \times I$$

Where,

O_t = Original observation at time 't'

T = Trend component

C = Cyclical element

S = Seasonal variations

I = Irregular fluctuations

3.4.1.1 Cyclical Component: Cyclical movements are fluctuations which differ from periodic movements. Cyclical movements have longer duration than a year and have periodically of several years as in business cycles.

The most commonly used method for estimating cyclical movement of time series is the residual method by eliminating the seasonal variation and trend. This is accomplished by dividing (Yt) by corresponding (S) for time 't' symbolically.

$$T.\,C.\,I. = \frac{T.\,C.\,S.\,I.}{S}$$

$$C.\,I. = \frac{T.\,C.\,I.}{T}$$

This trend cycle components are plotted against time for examining cyclical behaviour. If there is any existence of cycle, periodicity of cycle is noted. Again moving average of length equal to periodicity of cycle is computed for eliminating cyclical behaviour.

These moving averages are arranged cycle wise. These are adjusted for cyclical indices, as in the case of seasonal indices. Then trend cycle values (TC) are divided by adjusted components CI. The examination of both the graphs of trend cycle component as well as trend component will give a clear idea of the presence of cycle.

If there is similarity in these two graphs, it is an indication of non-existence of the cycle. However, the non-similarity in the two graphs is an indication of the presence of the cycle. If ultimately a cycle is reflected, then the cyclical effect is removed from T-C components. If no cycle is detected, then the trend cycle values are treated as pure trend values. The Friedman's two way analysis of variance was employed to know the significant difference among months within a cycle and also between cycles. A significant difference indicates the presence of changing cyclical behaviour and non-significant difference indicates the consistency of cyclical pattern.

3.4.1.2 Seasonal Component: The variation in a year is called as seasonal variation. To measure the seasonal variations in rainfall, seasonal indices were calculated employing twelve months ratio to moving average method.

The seasonal indices were calculated by adopting the following steps

1. Generate a series of 12 months moving totals

2. Generate a series of 12 months moving averages: A series of 12 months moving averages is generated by dividing 12 months moving totals by 12

3. Generate a series of centered 12 months moving averages. This step involves taking averages of pairs of two subsequent 12 months moving averages and entering between each pair. There are no corresponding moving averages for the first six and last six months.

4. Express each original value as a percentage of corresponding centered moving average. The percentage of moving average represents indices of seasonal and irregular components combined.

5. The next step involves removing the irregular component.

6. Arrange the percentages of moving averages in the form of monthly arrays.

7. Next, the average index for each month is calculated.

8. These averages are to be adjusted in such a way that their sum becomes 1200. This can be done by working out of correction factor and multiplying the average for each month by this correction factor. The correction factor (K) is worked out as follows.

$$K = \frac{1200}{S}$$

Where, K is correction factor and S is sum of average indices for 12 months, multiply K with the percentage of moving average for each month to obtain the seasonal indices.

3.4.1.3 Irregular Component: The random variations of the data comprise the deviations of the observed time series from the underlying pattern. With understanding the concepts of time series complex mixture of four components, their measurement and quantification methodology followed are presented below.

3.4.2 Tabular analysis

With regard to the rainfall aspect of the first objective, seasonal rainfall distributions for selected districts of north Karnataka were worked out. The time series daily rainfall data for 31 years were available for different periods for selected districts of Karnataka.

The mean annual rainfall (mm) and the rainfall deviations (per cent) from the mean (surplus/deficit) were computed for the selected districts of north-Karnataka. A study period of 31 years from 1983 to 2013 was taken into consideration. Based on the magnitude of these deviations, frequency distribution tables with classes corresponding to less than 10 per cent, 10 per cent to 20 per cent, 20 per cent to 30 per cent, 30 per cent to 40 per cent, 40 per cent to 50 per cent and finally 50 per cent rainfall deviations. The objective was to identify all those years in which the rainfall was surplus/deficit and the extent of surplus/ deficit rainfall in percentage. The frequencies of surplus/ deficit annual rainfall years during the period of study were also worked out for the selected districts.

For the temperature aspect of climate change, the season-wise average maximum and minimum temperatures were calculated for varying periods for the different districts of north-Karnataka according to the availability of meteorological data. The four meteorological seasons were considered in the present study are as follows:

Winter season (December-February),

Summer season (March-May)

Monsoon season (June-September)

Post-Monsoon season (October-November)

To analyse the impact of drought, flood and Agro-met Advisory Service (AAS) on farmer economy a tabular analysis was done by working out mean and percentage.

3.4.3 Multiple regression analysis

In order to study the impact of climate change on the productivity of the selected crops in various districts of north-Karnataka, an econometric model of crop production was attempted. For the purpose of our study, the list of crops grown in different districts is given in Table 3.2.

These crops were grown under rainfed conditions and any change in climate, particularly rainfall and temperature would affect the productivity of these crops significantly. For the purpose of our study multiple regression functions were used. The following multiple regression model was used to examine the cause and effect relationship between crop productivity and various explanatory variables mentioned below:

$$Y=f(X_1, X_2, X_3, X_4, X_5)$$

$$Y=a\, X^{b1}\, X_2^{\ b2}\, X_3^{\ b3}\, X4^{\ b4}\, X_5^{\ b5}\, e_u$$

In logarithmic form, it assumed a log-linear equation as under:

$$\text{Log } Y = \text{Log } a + b_1 \log x1 + b_2 \log x2 + b_3 \log x3 + b_4 \log x4 + b_5 \log x5 + u \log e.$$

Where,

Y= Crop yield on per hectare basis (kg/ha)

X_1= Actual rainfall during crop growing season (mm)

X_2=Mean maximum temperature during crop season (^{0}C)

X_3= Mean minimum temperature during crop season (^{0}C)

X_4= Mean maximum relative humidity during crop season (%)

$X_{5=}$ Mean minimum relative humidity during crop season (%)

The regression coefficients (bi) were tested for the significance using‘t’ test.

$$t = \frac{b_i}{\text{Standard error of bi}} \quad \text{..............} \ (3)$$

The co-efficient of multiple determination (R^2) was also worked out to test the goodness of fit of the model.

These weather parameters were affect the crop yield either directly or indirectly in any reasons. So these parameters were selected for analyzing the impact of weather on crop yield.

3.4.4 The index approach to study vulnerability

For each component of vulnerability, the collected data were arranged in the form of a rectangular matrix with rows representing districts and columns representing indicators. Let there be M regions/ districts and K indicators. Let Xij be the value of the indicator j corresponding to district i. The table with M rows and K columns is as shown below:

Districts	Indicators					
	1	2	--	J	--	K
1	X_{11}	X_{12}	--	X_{1j}		X_{1K}
2	X_{21}	--	--	--	--	--
--	--	--	--	--	--	--
I	X_{i1}	X_{i2}	--	X_{ij}		X_{ik}
--	--	--	--	--	--	--
M	X_{m1}	X_{m2}	--	X_{mj}	--	X_{mk}

3.4.4.1 Normalization of indicators using functional relationship

The indicators collected were in different units and scales. The methodology used in UNDP's Human Development Index (HDI) was followed to normalize them. That is, in order to obtain figures which were free from the units and also to standardize their values, first they were normalized so that they all lie between 0 and 1. Before doing this, the functional relationship between the indicators and vulnerability were identified. Two types of functional relationship were observed: vulnerability increases with increase (decrease) in the value of the indicator *i.e.*, positive and negative, respectively. The normalization in case of positive functional relationship was done using the formula:

$$[X_{ij}-Min\{X_{ij}\}]/[Max\{X_{ji}\}- Min\{X_{ij}\}]$$

Similarly, the formula used for normalization in case of negative functional relationship was given by:

$$[Max\{X_{ij}\}-X_{ij}]/[Max\{X_{ji}\}- Min\{X_{ij}\}]$$

3.4.4.2 Methodology for construction of vulnerability index

To measure the quantum of vulnerability, it is necessary to construct a vulnerability index for different districts of Karnataka. The commonly used three methods are listed below:

(A) Simple average method

(B) Patnaik and Narayanan's method

(C) Iyenger and Sudarshan's method

Further, these methods can be divided into two based on the weights assigned *viz.* (I) Methods with equal weights and (II) Methods with unequal weights. The detailed discussion of both these methods is given below:

(I) Methods with equal weights

(A) Simple average method: The method of simple averages is easy to calculate and simple to understand which is similar to the calculation of Human Development Index. In this method, first the values of the variables were standardized using the following formula.

$$(Actual\ X_i – Min\ X_i) / (Max\ X_i - Min\ X_i)$$

The value will lie between 0 and 1 and then the averages of these standardized scores were computed for the different districts of north-Karnatak. When equal weights were given, the simple averages of all the normalized scores were used to construct the vulnerability index (VI) by using the following formula:

$$VI=[\Sigma x_{ij} + y_{ij}]/K$$

Where,

Σx_{ij}= Sum of normalized scores for variables with positive functional relationship

$\Sigma\, y_{ij}$= Sum of normalized scores for variables with negative functional relationship

K = Total number of indicators

Finally, the vulnerability indices were used to rank the different districts in terms of vulnerability. A region with highest index is said to be the most vulnerable and it was given the rank 1, the region with next highest index was assigned rank 2 and so on.

(B) Patnaik and Narayanan's method: In this method, firstly the possible sources of vulnerability and for each source several indicators were identified. For example, the variables were grouped into four different sources such as (a) Demographic (b) Climatic (c) Agriculture and (d) Occupational. The list of all the indicators selected are listed in Table 3.9 Now for each variable, standardization was achieved by employing the following formula:

$$(\text{Actual } X_i - \text{Min } X_i) / (\text{Max } X_i - \text{Min } X_i)$$

Average Index (for each source of variability) was calculated by the formula:

$$AI = (I1 + I2 + \ldots\ldots + Ij) / J$$

Finally, the vulnerability index (VI) was computed by applying the formula:

$$VI = \{[\Sigma^{n}_{i=1} (\text{Average index})^{a}]^{1/a}\}/n$$

Where,

a=Number of main components

j= Number of indicators in each source of variability

N=Number of sources of variability's ($n=\alpha=4$)

(II) Methods with unequal weights: The method of simple averages and Patnaik and Narayanan's methods gave equal importance to all indicators which may not be necessarily correct. However, Iyenger and Sudarshan's method assigned weights according to the relative importance of different indicators.

(C) Iyengar and Sudarshan's method: Iyenger and Sudarshan (1982) developed a method to work-out a composite index from multivariate data and it was used to rank the districts in terms of their economic performance. This method is statistically sound and well suited for the development of composite index of vulnerability to climate change also. Hence, though vulnerability indices were constructed using all the three methods, the results of Sudarshan and Iyenger's method were retained for the present study. In all, based on the availability of data, 26 indicators were used in the construction of vulnerability indices for five different time periods *viz.*, 1991, 1996, 2001, 2005, 2010 and 2013 and for the 8 selected districts of the state. Out of the 26 indicators, 2 indicators are concerned with demographic vulnerability, 4 indicators are related to climatic vulnerability, 14 indicators deal with agricultural vulnerability and the rest 6 indicators represented the occupational vulnerability component.

A brief discussion about the methodology is given below.

It is assumed that there are M districts (M=8), K indicators (K=26) of vulnerability and x_{ij}, i= 1, 2,….M ; j=1, 2,….K are the normalized scores. The level or stage of development of j^{th} zone, is assumed to be a linear x_{ij} sum as

$$y\ 1=\Sigma w_j x_{ij}$$

Where, w's ($0<w<1$ and $\Sigma^k{}_{j=1}\ w_j=1$) are the weights. In Iyenger and Sudarshan's method the weights are assumed to vary inversely as the variance over the regions in the respective indicators of vulnerability. That is, the weight wj is determined by

$$Wj=c/\sqrt{varx_{ij}}$$

Where,

c is a normalizing constant such that

$$C=[\Sigma^k{}_{j=1}\ 1/\sqrt{varx_{ij}}]^{-1}$$

The choice of the weights in this manner would ensure that large variation in any one of the indicators would not unduly dominate the contribution of the rest of the indicators and distort inter-regional comparisons. The vulnerability index so computed lies between 0 and 1, with 1 indicating maximum vulnerability and 0 indicating no vulnerability at all. For classificatory purposes, a simple ranking of the regions based on the indices *viz.*,yi– would be enough. However, a meaningful characterization of the different stages of vulnerability, suitable fractile classification from an assumed probability distribution is needed. A probability distribution which was suitable for this purpose was the Beta distribution, which is generally skewed and takes values in the interval (0, 1). This distribution has the probability density given by:

$$F\ (z) = z^{a-1}\ (1-z)^{\ b-1} dx/\ B\ (a,b),\ 0<z<1 \text{ and } a,b>0$$

Where,

B (a,b) is the beta function defined by

$$B\ (a,b) = \int^1{}_0\ x^{a-1}\ (1-x)^{\ b-1}\ dx$$

The two parameters a and b of the distribution can be estimated by using the method by Iyenger and Sudarshan (1982).The beta distribution is skewed. Let (0, z1) (z_1, z_2) (z_2, z_2) (z_3, z_4) and (z_4,1) be the linear intervals such that each interval has the same probability weight of 20 per cent. These fractile intervals were used to characterize the various stages of vulnerability as shown below:

Less vulnerable	$0< \bar{y}_i< z_1$
Moderately vulnerable	$z_1< \bar{y}_i < z_2$
Vulnerable	$z_2< \bar{y}_i < z_3$
Highly vulnerable	$z_3< \bar{y}_i < z_4$
Very highly vulnerable	$z_4< \bar{y}_i < 1$

The parameters (a,b) in the assumed Beta distribution can be estimated by solving the following simultaneous equation.

$$(1-y^{-})a-y^{-}b=0$$

$$(y^{-}-m)a-m_2b=m_2-y^{-}$$

Where y^{-} is the overall mean of the district indices and m_2 is given by

$$m2 = S_{-y}^{2} + y^{-2}$$

where S_{-y}^{2} is the variance of the district indices. The cut off point z_1 to z_4 can be obtained from tables of incomplete Beta function or from table of F-distribution with degrees of freedom (2a, 2b), which are readily available.

If $F_{n1,n2;p}$ is the value of the F-statistic with n_1 and n_2 degrees of freedom corresponding to probability p, i.e,

$$Pr(F<\_F\ n_{1,}\ n_{2:}p)=P$$

then

$$Fn_{1,}\ n_2;\ p=\ n_2/\ n_1 * 1-z_p/\ z_p$$

Where z_p is the P^{th} fractile of the corresponding Beta distribution.

Here in our case z_p is given by

$$z_p=\ 1/(1+b/a\ Fn_{2,}\ n_1;\ p)$$

since $n_1=2a$, $n_2=2b$. Extensive tables are available for computing the fractile points on the F-distribution for selecting values of (n_2,n_1) and p. For values of F not readily available in the tables a two way interpolation is needed. A straightforward procedure would be as follows.

For values of p less than 0.5, let $Fn_{2k,}\ n_{2k}$ for a given point on the F- distribution. Taking k=1 and k=2, we wish to compute, say, $Fn_2,\ n_1$ for values of (n_2,n_1) where $n_{21}<n_2<n_{22}$ and $n_{11}<n_1<n_{12}$. It is easy to show that

$$Fn_2\ n_1=\ Fn_{21,}\ n_{11}+\ n_2-n_{21}/n_{22}-n_{21}*\ (Fn_{22},\ n_{11}-Fn_{21},n_{11})\ +\ n_1-n_{11}/n_{12}-n_{11}(Fn_{21},\ n_{12}-Fn_{21},\ n_{11})\ +\ (n_2-n_{21})(n_1-n_{11})\ /\ (n_{22}-n_{21})(n_{12}-n_{11})\ [F\ n_{21},\ n_{11}+Fn_{22}\ n_{12}-Fn_{21},\ n_{12}-F\ n_{22},\ n_{11}]$$

However, for p>0.5 the following result holds

$$Fn_1,n_2,p=\ 1/\ Fn_1,\ n_2,\ 1-p$$

3.4.5 Runs test

It is a non parametric method that is used in cases when parametric test is not in use. In this test, two different random samples from different population with different continuous cumulative distribution function is obtained. Running a test for randomness is carried out in a random model in which the observations vary around a constant mean. The observation in the random model in which the run test is carried out has a constant variance, and the observations are also probabilistically independent. The run in a run test is defined as the consecutive sequence of head and tail. This test checks whether or not the number of runs are the appropriate number of runs for a randomly generated series. The observations from the two independent samples are ranked in increasing order, and each value is coded as a 0 or 1, and the total number of runs is summed up and used as the test statistics. Small values do not support suggest different populations and large values suggest identical populations (the arrangements of the values should be random). Wald Wolfowitz run test is commonly used.

3.4.5.1 Formulation of hypothesis

Null Hypothesis: The order of the less than normal rainfall and more than normal rainfall is random.

Alternative Hypothesis: The order of the less than normal rainfall and more than normal rainfall is not random.

Let us consider that 'H' denotes the number of observations. The 'Ha' is considered to be the number that falls above the mean (rainfall above the normal), and 'Hb' is considered to be the number that falls below the mean (rainfall below the normal). The 'R' is considered to be the observed number of runs. After considering these symbols, then the probability of the observed number of runs is derived.

Formula of the mean and the variance of the observed number of the runs:

$E (R) = H + 2 Ha Hb / H$

$V (R) = 2 Ha Hb (2 Ha Hb – H) / H_2 (H – 1)$

The researcher should note that in the run test for the random type of model, if the number of observations is larger than twenty, then the distribution of the observed number of runs would approximately follow normal distribution. The value of the standard normal variate of the observed number of runs in the run test is given by the following:

$$Z = R – E (R) / Stdev (R)$$

where R is the observed number of runs, E(R), is the expected number of runs, and sR is the standard deviation of the number of runs. The values of E(R) and S(R) are computed as follows:

$$E(R)= [2n_1n_2/n_1+n_2]+1$$

$$S(R)= 2n_1n_2(2n_1n_2- n_1- n_2) / (n_1+n_2)^2(n_1+n_2-1)$$

with n1 and n2 denoting the number of positive and negative values in the series.

3.4.5.2 Testing for significance: The runs test rejects the null hypothesis if

$$|Z| > Z1\text{-}\alpha/2$$

For a large-sample runs test (where n1 > 10 and n2 > 10), the test statistic is compared to a standard normal table. That is, at the 5 % significance level, a test statistic with an absolute value greater than 1.96 indicates non-randomness. For a small-sample runs test, there are tables to determine critical values that depend on values of n_1 and n_2.

3.4.6 t-test (equal or unequal sample sizes, unequal variance)

This test, also known as Welch's t-test, is used only when the two population variances are not assumed to be equal (the two sample sizes may or may not be equal) and hence must be estimated separately. The t statistic to test whether the population means are different is calculated as

$$t = \frac{\bar{X}_1 - \bar{X}_2}{s_{X_1X_2} \cdot \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

where

$$s_{X_1X_2} = \sqrt{\frac{(n_1 - 1)s_{X_1}^2 + (n_2 - 1)s_{X_2}^2}{n_1 + n_2 - 2}}.$$

Note that the formulae above are generalizations of the case where both samples have equal sizes (substitute n for n1 and n2).

s_{X1X2} is an estimator of the common standard deviation of the two samples: it is defined in this way so that its square is an unbiased estimator of the common variance whether or not the population means are the same. In these formulae, n = number of participants, 1 = group one, 2 = group two. n – 1 is the number of degrees of freedom for either group, and the total sample size minus two (that is, n1 + n2 – 2) is the total number of degrees of freedom, which is used in significance testing.

If cal t> table t: Reject null hypothesis

3.4.7 Garrett ranking

Garrett's ranking technique was adopted for study the effective Agromet Advisory Service dissemination medias.

1. Electronic media (TV/Radio)
2. News paper/magazine
3. Agromet advisory bulletin
4. Forecast SMS

In the first stage: ranking given by 60 respondents for each media was analyzed.

In the second stage: Thus ranks assigned by the individual respondents were counted into percent position value by using the formula.

Per cent position = 100 (R_{ij} – 0.5)/N_j.

Where, R_{ij} stands for rank given for the i^{th} factor by the j^{th} individual.

N_j stands for number of factors ranked by j^{th} individual.

In stage three – For each per cent position scores were obtained with reference to Garrett's Ranking Conversion Table and each per cent position value was converted into scores by reference to Garret's Table given by Fisher 1995.

In the fourth stage – Summation of these scores for each factor was worked out for the number of respondents who ranked for each factor. Mean scores were calculated by dividing the total score by the number of respondents

In the last stage – Overall ranking was obtained by assigning ranks I, II, III , IV in the descending order of the mean score.

3.5 Terminologies used in the study

Climate: Climate is the statistics (usually, mean or variability) of weather, usually over a 30-year interval. It is measured by assessing the patterns of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other meteorological variables in a given region over long periods of time.

Weather: Weather is the set of meteorological conditions such as wind, rain, snow, sunshine, temperature, *etc.* at a particular time and place.

Climate change: Climate change is a change in the statistical distribution of weather patterns when that change lasts for an extended period of time (*i.e.*, decades to millions of years). Climate change may refer to a change in average weather conditions, or in the time variation of weather around longer-term average conditions.

Vulnerability: Vulnerability to climate change is the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change.

Drought: A drought is a period of below-average precipitation in a given region, resulting in prolonged shortages in its water supply.

Hailstorm: A hailstorm is a thunderstorm that produces hail.

Weather forecasting: Weather forecasting is a prediction of what the weather will be like in an hour, tomorrow, or next week.

Number of runs in run test: A run is defined as a series of consecutive positive (or negative) values. The number of increasing, or decreasing, values is the length of the run.

4. RESULTS

The results derived from the analysis of the data pertaining to various objectives of the study are presented in this chapter. The chapter is presented under the following broad heads:

4.1 Time series analysis of rainfall in north Karnataka

4.2 Rainfall deviations in districts of north Karnataka

4.3 Season-wise average maximum and minimum temperatures for the districts of north Karnataka

4.4 Influence of weather parameters on crop yield in selected districts of north Karnataka.

4.5 Economic benefits of weather based farming in improving farm productivity.

4.6 Impact of drought on agriculture in north Karnataka

4.7 Impact of hailstorm on agriculture in Vijayapura district

4.8 Vulnerability indices for the assessment of vulnerability of selected districts to climate change.

4.1 Time series analysis of rainfall in north Karnataka

4.1.1 Rainfall pattern in north Karnataka

Pattern of rainfall trend was computed and presented in Table 4.1. A rainfall fluctuation from 1983 to 2013 was analyzed. There was highest rainfall in the year 2007 with 866.7 mm rainfall followed by this highest rainfall was documented in 1983 (796.5 mm), 2010 (795.3 mm), 1988 (792.4 mm) and 1998 (790.0 mm). Lowest rainfall was seen during 2003 (505.2 mm) followed by 2002 (527.3 mm), 1985 (532.6 mm), 2001 (589.0 mm) and 1986 (605.6 mm).

4.1.2 Cyclical movement of rainfall in north Karnataka

In order to know the rainfall occurrence over the year cyclical variations in rainfall were analyzed (Table 4.1). In rainfall pattern, uneven cycles were observed. The number of cycles observed was nearly five. Each cycle repeats at an interval of six years.

4.1.3 Irregular variation of rainfall in north-Karnataka

An irregular variation of rainfall was presented in Table 4.1. Irregular variation was ranged from 0.56 to 0.51. Highest variation was observed during 1988 (0.56) and lowest during 1985 (0.51).

4.1.4 Seasonal variation in rainfall in north Karnataka

In order to ascertain the long term seasonal variation of rainfall pattern in India, seasonal indices of monthly rainfall was calculated and presented in Table 4.2. Figure reveals that rainfall showed a seasonal variation during April, May, June and July. Highest rainfall was observed during July with variation of 242.61 followed by August (234.51), June (221.18) and September (201.11). Seasonal index was 2.95, 2.32, 21.10, 27.17, 66.41, 140.74, 32.84 and 7.07 during January, February, March, April, May, October, November and December, respectively.

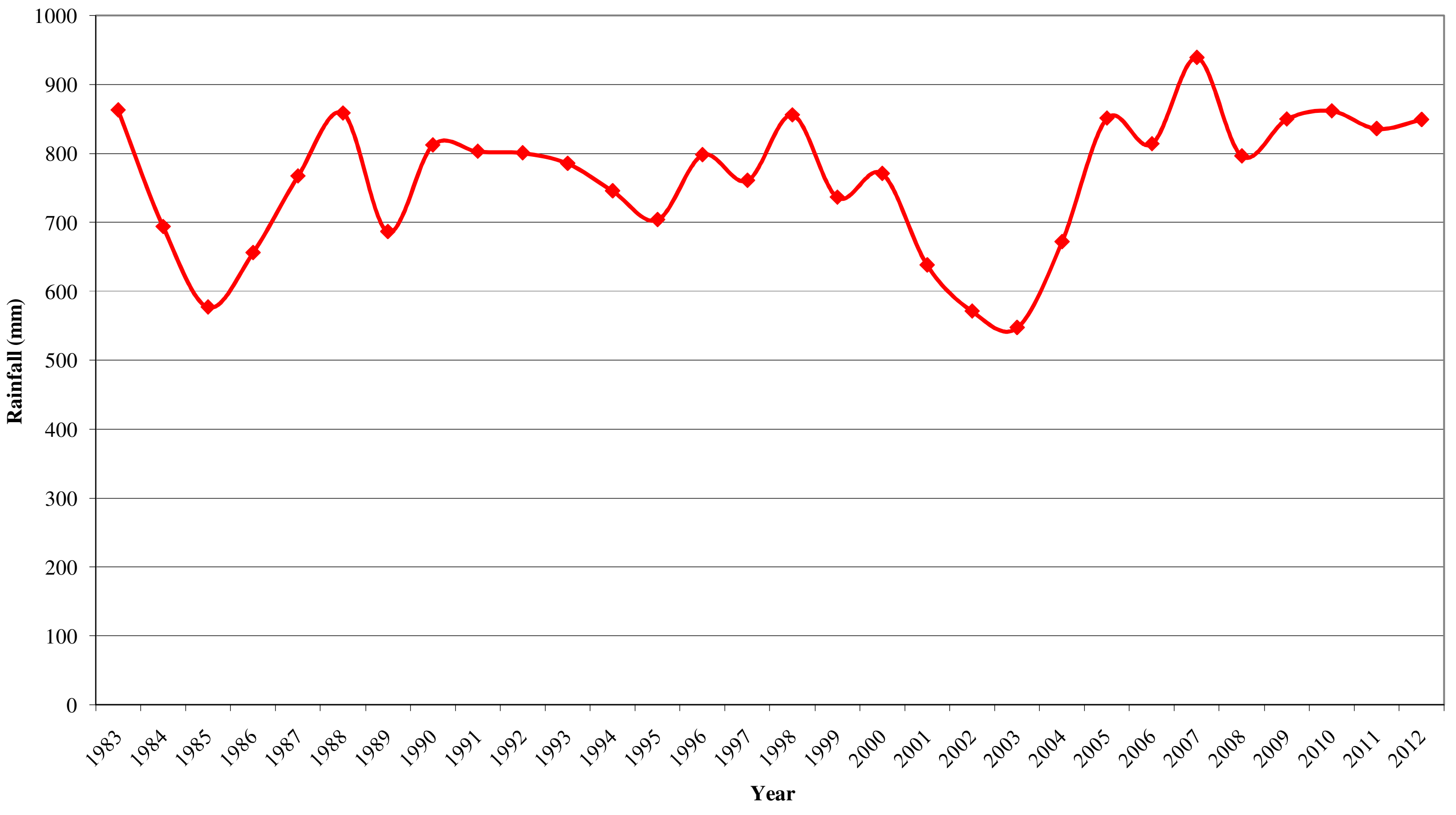

Fig. 1: Rainfall pattern in North Karnataka

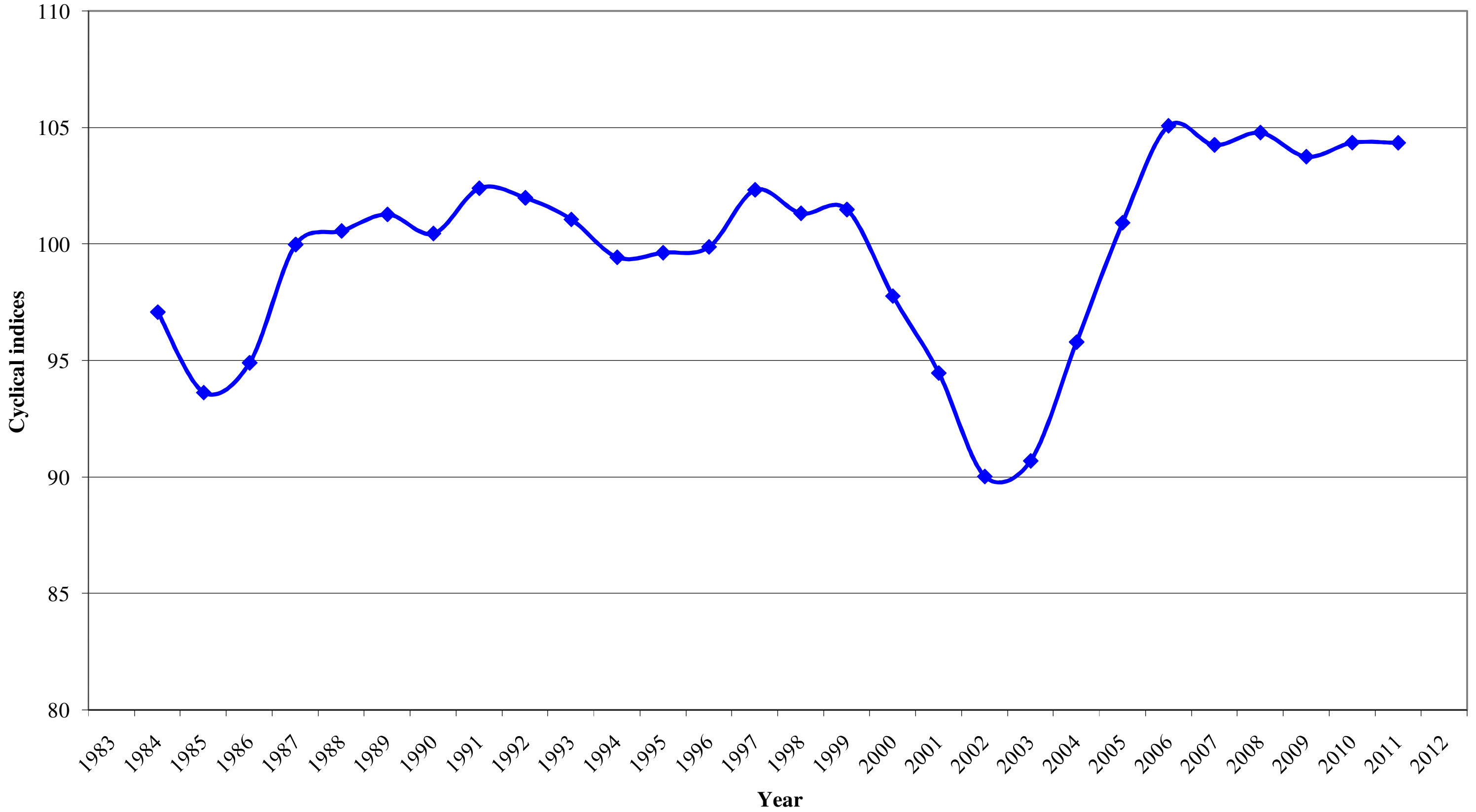

Fig. 2: Cyclical indices of rainfall in North Karnataka

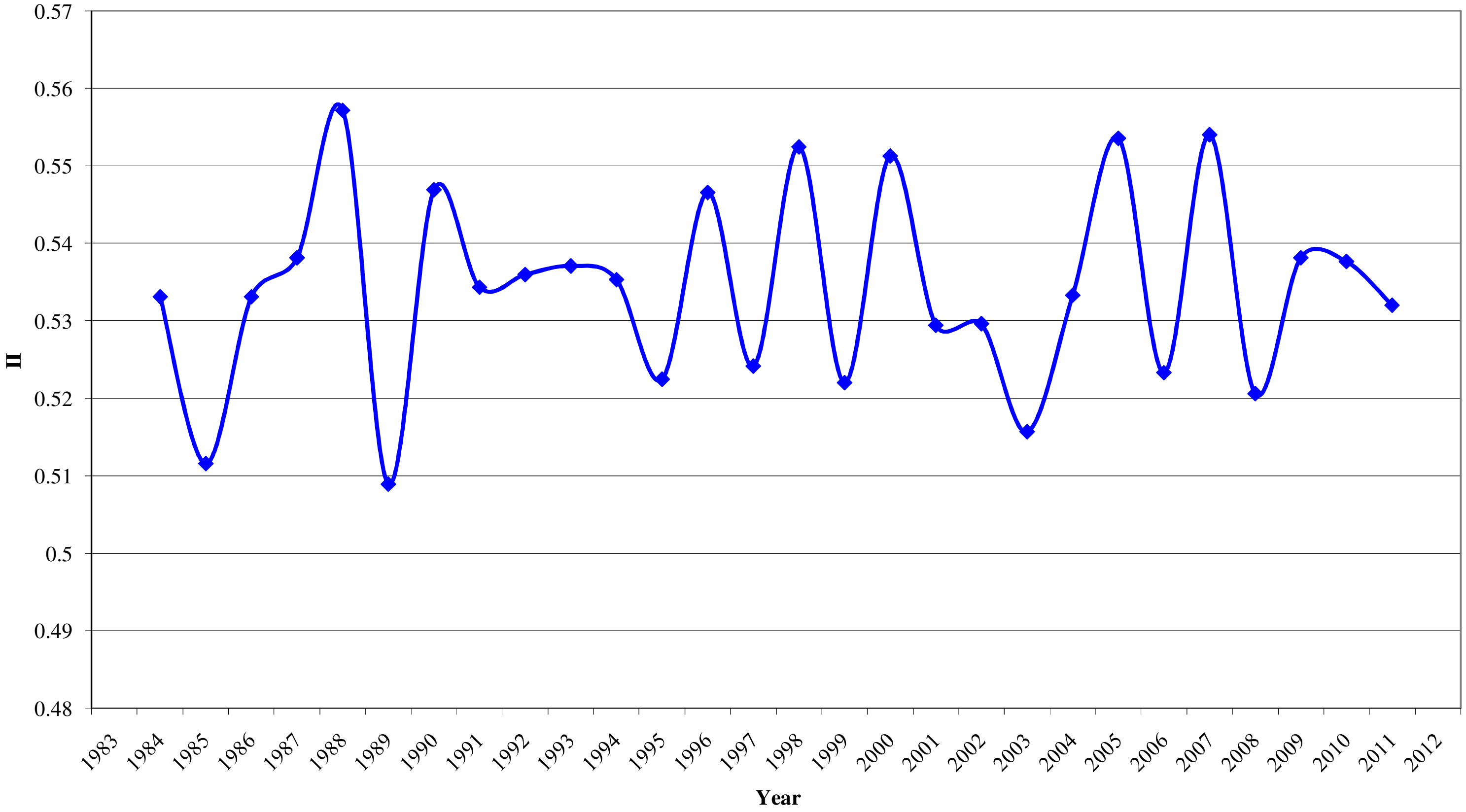

Fig. 3: Irregularities of rainfall in North Karnataka

Table 4.1. Trend and cyclical indices of rainfall in North Karnataka

Year	Average annual Rainfall (mm)	Irregular indices	Cyclical indices
1983	796.5	-	-
1984	640.4	0.5331	97.0824
1985	532.6	0.5116	93.6312
1986	605.6	0.5300	94.9072
1987	708.1	0.5382	99.9778
1988	792.4	0.5572	100.5651
1989	633.7	0.5089	101.2739
1990	749.6	0.5469	100.4516
1991	741.1	05343	102.3973
1992	739.1	0.5360	101.9840
1993	725.0	0.5371	101.0578
1994	688.3	0.5353	99.4320
1995	649.7	0.5225	99.6286
1996	736.6	0.5466	99.8810
1997	702.2	0.5242	102.3247
1998	790.0	0.5525	101.3167
1999	679.7	0.5220	101.4820
2000	711.5	0.5513	97.7692
2001	589.0	0.5294	94.4707
2002	527.3	0.5296	90.0290
2003	505.2	0.5157	90.6981
2004	620.1	0.5333	95.7975
2005	785.6	0.5536	100.9160
2006	751.3	0.5233	105.0725
2007	866.7	0.5540	104.2524
2008	735.0	0.5206	104.7811
2009	784.3	0.5382	103.7508
2010	795.3	0.5377	104.3504
2011	771.5	0.5320	104.3412
2012	783.7	0.5309	104.3200
2013	792.0	0.5432	105.2600

Table 4.2. Seasonal indices of rainfall in North Karnataka (1983-2013)

Months	Seasonal indices
January	2.9476
February	2.3224
March	21.0971
April	27.1683
May	66.4137
June	221.1781
July	242.6109
August	234.5089
September	201.1102
October	140.7368
November	32.8356
December	7.0705

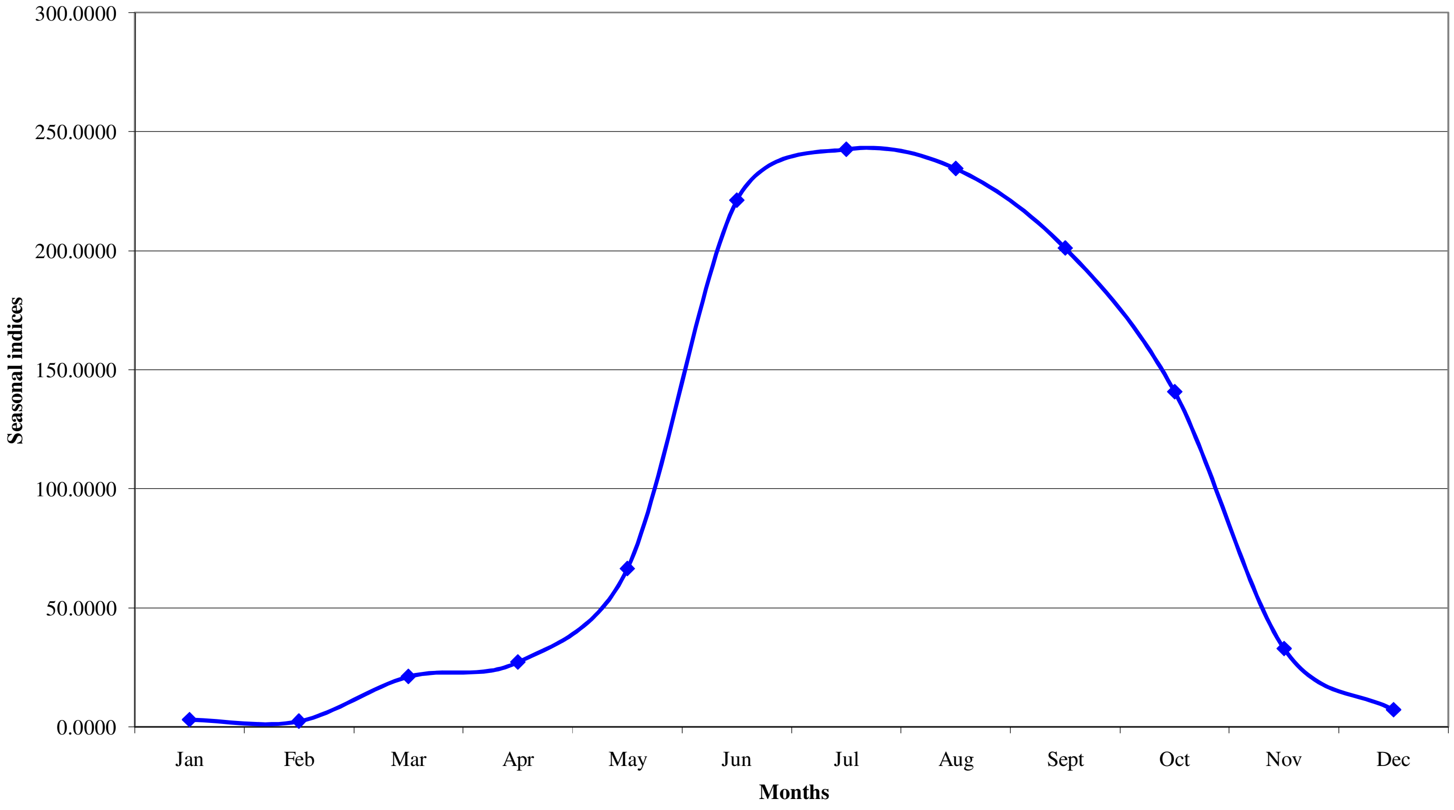

Fig. 4: Seasonal indices of rainfall in North Karnataka

Table 4.3. District wise rainfall pattern in North Karnataka

Sl.No.	Districts	Intercept (a)	Slope coefficient (b)	R^2
1	Belagavi	581.40	17.88**	0.4797
2	Vijayapura	610.29	-3.23	0.0504
3	Dharwad	670.43	1.00	0.0400
4	Uttara Kannada	2608.46	15.23	0.0190
5	Bellary	658.05	-5.55*	0.1200
6	Bidar	923.84	-4.62	0.0463
7	Kalaburagi	917.92	-11.09**	0.2358
8	Raichur	671.53	-4.34	0.0635

Note: **, * indicate significance at 1 % and 10 % respectively

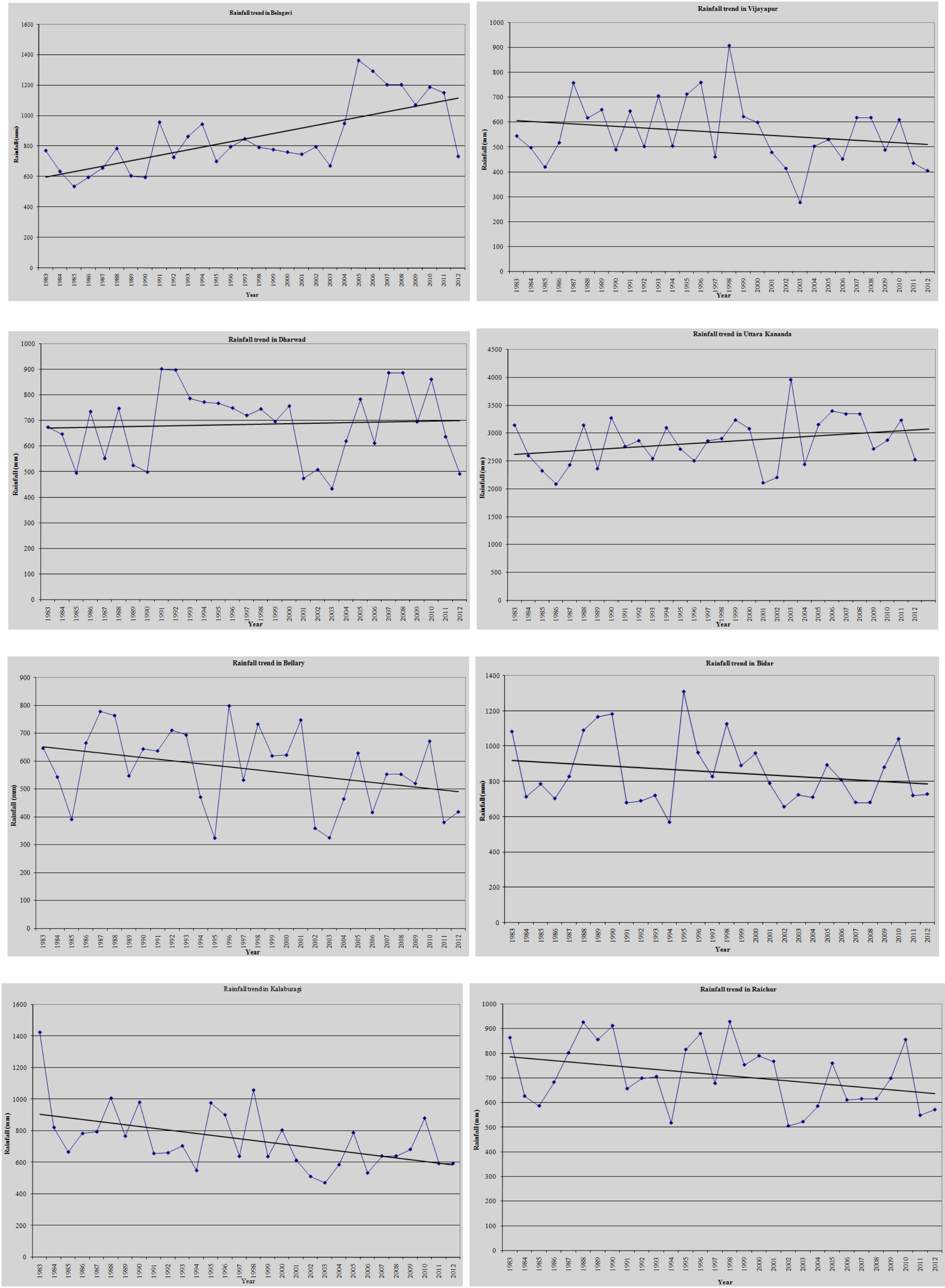

Fig. 5: Rain fall trend in districts of North Karnataka

4.1.5 Rainfall trend in different districts of north Karnataka

It was revealed that, in case of Bellary, Bidar, Vijayapura, Kalaburagi and Raichur rainfall showed decreasing trend whereas in case of Belagavi, Dharwad and Uttara Kannada districts rainfall showed increasing trend. Decreasing trend was observed in more number of districts and was more dominated compare to increasing trend in some of the districts (Table 4.3).

4.1.6 Compound annual growth rate of rainfall in the districts of north-Karnataka

It could be inferred from the Table 4.4 that, over the years there was too much fluctuation in rainfall in all the districts of north Karnataka. In districts like Bellary, Bidar, Vijayapura, Kalaburagi and Raichur, rainfall showed a decreasing trend with annual growth rate of -1.00, -0.47, -0.64, -1.36 and -0.81 per cent respectively. Among these districts declining trend was more in Kalaburagi (26.96) with more amount of variability followed by Raichur (25.12) and Bellary (24.67). The rainfall in Belagavi (2.04 %), Dharwad (0.11 %) and Uttar Kannada (0.53 %) showed an increasing trend over the period from 1983 to 2013. Among these districts, the variability was more in Kalaburagi district. By this we can conclude that the rainfall showed a decreasing trend with added fluctuations in most of the districts of north Karnataka.

4.2 Rainfall deviations in north-Karnataka

4.2.1 Percentage of deviation in actual rainfall from the normal for districts of north Karnataka

The actual annual rainfall (mm) and its deviations (per cent) from the normal (surplus/deficit) were computed for the districts of north-Karnataka for the period from 1983-84 to 2013-14and presented in the Table 4.5 and Table 4.6. The rainfall deviations were found to be both positive and negative. Based on the deviation, the classes corresponding to less than 10 per cent, 10 per cent to 20 per cent, 20 per cent to 30 per cent, 30 per cent to 40 per cent, 40 per cent to 50 per cent and 50 per cent and above for both positive and negative rainfall deviations were constructed.

Bidar district: The mean annual rainfall of 31 years for Bidar district was 852.1 mm. The relatively dry years during this period were 1984, 1986, 1991, 1992, 1994, 2002, 2003, 2004, 2007, 2008, 2011 and 2012 in which the negative deviations from the mean were noticed to be more than 20 per cent *i.e.*; accounting for 50 per cent of the total number of years. The driest year was 1994 with an average annual rainfall of only 567 mm resulting in a substantial negative deviation of -49.74 per cent, followed by the year 2007 and 2008 with a negative deviation of -31.03 and -30.29 per cent.

Dharwad district: The mean annual rainfall of 31 years for Dharwad district was 686.0 mm. The years of 1985, 1989, 1990, 2001, 2002, 2003 and 2012 were observed to be the relatively drier years, thereby accounting for 23.33 per cent of the total number of years under study wherein, the negative deviations from the mean were more than 30 per cent. The year 2001 was observed to be the driest year with an average annual rainfall of only 413 mm, resulting in the highest negative deviation of -86.92 per cent. It was followed by the year 2003 with a negative deviation of -80.37 per cent. The relatively wet years during the period were 1991 and 1992 with positive rainfall deviations of more than 20 per cent thus, accounting for 6.67 per cent of the total period under consideration.

Table 4.4. Compound annual growth rate of rainfall in the districts of North-Karnataka (1983-84 to 2013-14)

Sl. No.	Districts	Average annual rainfall (mm)	Growth rate (%)	CV (%)
1	Belagavi	858.5	2.04** (0.003)	26.47
2	Vijayapura	558.7	-0.64 (0.004)	23.30
3	Dharwad	686.0	0.11 (0.004)	20.27
4	Uttara Kannada	2,844.6	0.53 (0.003)	15.62
5	Bellary	571.9	-1.00 (0.005)	24.67
6	Bidar	852.1	-0.47 (0.004)	22.20
7	Kalaburagi	745.9	-1.36** (0.004)	26.96
8	Raichur	604.1	-0.81 (0.005)	25.12

Note- figures in the parentheses indicate standard error
** indicate significance at 5 per cent

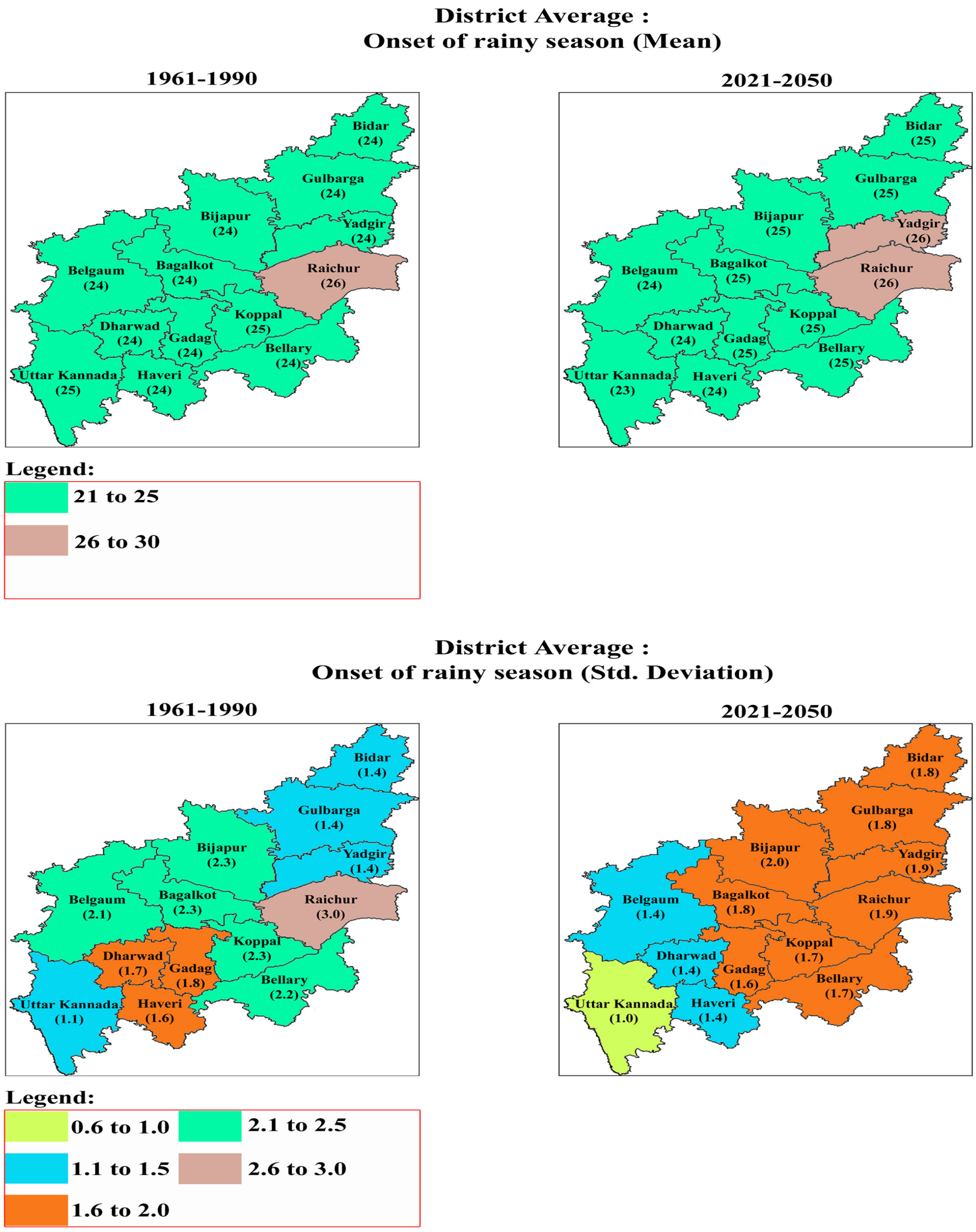

Fig. 6. District-wise mean and standard deviation of onset of rainy season in North Karnataka

Source : Annual Report, 2014, AICRP on Agrometeorology, Vijayapura

From Fig 6 it is noticed that except for Yadgir district not much deviation is expected in time of onset for the projected period when compared to the base. However, the inter-annual variations when presented in terms of standard deviation suggest that onset of monsoon is expected to be more risky in the drier regions of north Karnataka covering Bidar, Gulbarga, Bijapur, Bagalkot,Yadgir, Raichur, Koppal, and Bellary districts. There would not be much difference in Gadag district, while in the western districts of Belgaum, Dharwad, Haveri and uttara Kannada, the onset is expected to be more stable. The district-wise onset and end of rainy season from 1961-2010 in Northern Karnataka is given in Appendix I and II.

Table 4.5. Percentage of deviation in actual rainfall from the normal for districts of North Karnataka

Year	Dharwad	Gadag	Haveri	Vijayapura	Bagalkote	Belagavi	Raichur	Koppal	Uttara Kannada	Bellary	Kalaburagi	Bidar
1983	-2.39			-1.39		-1.58	19.16		12.18	11.12	50.75	16.08
1984	-6.67			-10.91		-23.61	-49.06		-6.35	-5.86	14.55	-27.53
1985	-39.28			-31.43		-46.29	-7.72		-18.78	-40.13	-5.40	-15.62
1986	6.06			-6.70		-31.55	1.09		-32.31	13.57	10.41	-29.24
1987	-26.61			27.10		-19.22	18.49		-13.64	20.14	11.62	-9.81
1988	4.14			7.93		-2.80	5.07		9.91	16.36	22.92	22.22
1989	-36.31			12.60		-33.33	-22.49		-19.82	-16.82	-1.30	27.30
1990	-43.40			-16.12		-35.57	6.84		13.49	0.78	20.88	28.28
1991	20.51			11.78		15.75	3.85		-2.57	-0.31	-18.26	-24.93
1992	20.16			-13.12		-10.99	15.63		1.19	10.13	-17.55	-22.93
1993	8.89			19.41		6.59	26.50		-11.31	7.93	-10.21	-17.80
1994	7.24			-12.67		14.90	-22.75		8.58	-35.67	-41.53	-49.74
1995	6.64			17.39		-15.26	21.49		-4.38	-97.22	20.55	35.09
1996	4.40			25.13		-1.25	33.00		-13.12	20.03	13.86	11.95
1997	-7.07	-3.73	17.61	-25.38	-1.63	4.83	-17.07	-32.41	1.05	-19.55	-21.60	-2.54
1998	-3.49	12.70	1.44	36.34	35.84	-1.89	32.57	23.83	2.48	13.23	26.63	24.71
1999	-10.76	-27.23	-2.59	7.22	4.42	-3.72	-0.16	10.76	12.50	-2.75	-21.98	4.72
2000	-6.34	12.32	11.20	4.78	5.23	-6.04	1.41	18.40	8.10	-2.25	3.48	11.68
2001	-86.92	-21.19	-48.23	-25.11	-13.08	-8.02	-3.61	-1.96	-34.23	14.97	-26.75	-7.49
2002	-36.40	-47.83	-37.41	-42.36	-32.55	-1.38	-62.21	-57.14	-28.40	-77.16	-52.05	-29.31
2003	-80.37	-76.37	-42.08	-83.49	-181.82	-24.26	-53.85	-77.13	-6.13	-87.69	-64.97	-23.24
2004	-23.72	-3.38	-16.56	-15.83	-33.99	12.20	-21.33	-13.92	-72.39	-31.47	-32.59	-25.67
2005	14.03	-5.88	14.04	-13.56	-23.33	38.87	4.91	-1.40	-33.25	3.02	1.52	0.11
2006	-8.43	-38.15	-10.41	-20.67	-60.09	35.52	-45.88	-76.60	-23.66	-46.63	-45.78	-10.27
2007	12.57	25.55	21.15	-4.71	0.58	30.76	8.01	19.53	-25.65	-10.31	-21.22	-31.03
2008	10.87	23.24	18.12	-14.49	14.87	30.18	2.97	18.70	13.80	-9.22	-30.89	-30.29
2009	-11.32	-4.82	-0.26	-33.62	-15.64	21.46	-32.66	-6.15	-6.10	-16.15	-22.84	-0.80
2010	9.85	9.34	23.03	-7.48	7.74	29.24	-0.15	21.84	-0.28	10.12	4.77	14.81
2011	-5.78	-58.94	-1.30	-77.53	-13.18	26.97	-82.68	-40.77	10.81	-58.95	-41.48	-23.23
2012	-49.62	-56.58	-42.18	-43.64	-56.99	-14.71	-46.31	-49.74	-14.20	-44.50	-41.75	-21.87
2013	-22.36	-35.62	-26.58	-45.63	-30.10	-15.02	-26.06	-22.38	-9.89	-32.02	-20.32	-16.35

Belagavi district: Belagavi district recorded an average annual rainfall of 858.5 mm during the period. The relatively dry years were 1984, 1985, 1986, 1989 and 1990 in which the negative deviations from the mean were noticed to be more than 20 per cent. The driest year was 1985 with an average annual rainfall of 536.4 mm resulting in a high negative deviation of -46.29 per cent, followed by the year 1990 with a deviation of -35.57 per cent (average annual rainfall 596 mm). On the contrary, the relatively wet years during the period were 2005, 2006, 2007 and 2008 in which the rainfall deviations from the mean were more than 30 per cent. The year 2005 was observed to be the wettest year with an average annual rainfall of 1,366 mm resulting in the highest positive deviation of 38.87 per cent.

Bellary district: Bellary district recorded 571.95 mm average rainfall during the period of study. The years observed to have more than 40 per cent negative rainfall deviations from the mean were 1985, 1995, 2002, 2003, 2006, 2011 and 2012 which accounted for 23.33 per cent of the total number of years. The driest year was 1995 with an average annual rainfall of only 324 mm resulting in a high negative deviation of -97.22 per cent, followed by the year 2003 with a deviation of -87.69 per cent. The relatively wet years were 1987 and 1996 in which the rainfall deviations from the mean were more than 20 per cent. The year 1987 with an average annual rainfall of 778.5 mm resulted in the highest positive deviation of + 20.14 per cent, hence being reported as the wettest year. It was followed by the year 1996 with a deviation of + 20.03 per cent (mean annual rainfall 799 mm).

Vijayapura district: The mean annual rainfall of 31 years for Vijayapura district was 552.0 mm. The relatively dry years during this period were 2003 and 2011 in which the negative rainfall deviations of more than 50 per cent were observed. The year 2003 happened to be the driest year during the entire period of study with an average annual rainfall of 315 mm as a result of which, a negative deviation of -83.49 per cent was observed. It was followed by the year 2011 with a deviation of -77.53 per cent. Conversely, the relatively wet years during the period were 1987, 1996 and 1998 in which the rainfall deviations from the mean were more than 20 per cent which accounted for 10 per cent of the total number of years.

Raichur district: The mean annual rainfall of 31 years for Raichur district was 604.2 mm. The relatively dry years during this period were 2002, 2003 and 2011 in which the negative deviations from the mean rainfall were noticed to be more than 50 per cent. The driest year was 2011 with an average annual rainfall of only 358 mm resulting in a high negative deviation of -82.68 per cent, followed by the year 2002 with a deviation of -62.21 per cent (average annual rainfall 389 mm). On the other hand, the relatively wet years during the period were 1996 and 1998 in which the rainfall deviations from the mean were more than 30 per cent. The year 1996 with an average annual rainfall of 894 mm was the wettest year. It was followed by the year 1998 with a positive deviation of + 32.57 per cent.

Kalaburagi district: The mean annual rainfall for Kalaburagi district during the period was 745.9 mm. The relatively dry years with more than 50 per cent negative deviations from the mean rainfall were 2002 and 2003. The driest year was 2003 with an average annual rainfall of only 471 mm resulting in a high negative deviation of -64.97 per cent. It was followed by the year 2002 with a deviation of -52.05 per cent (average annual rainfall 511 mm). The relatively wet years during the period were 1983 in which the positive deviations from the average rainfall were more than 50 per cent. The year

1983 was the wettest year with an average annual rainfall of 1,425.0 mm resulting in the highest positive deviation of + 50.75 per cent moreover, it can be seen from the Table 4.6 that the number of years with negative rainfall deviations was much more as compared to the years with positive rainfall deviations.

Frequency of rainfall deviation in the district of north-Karnataka was shown in Table 4.6. Deviation in the actual rainfall from normal was categorized into positive and negative deviations. If the actual rainfall is 50 per cent more than the normal rainfall were categorized as positive deviations and less than 50 per cent are categorized as negative deviations. In case of Dharwad, Belagavi, Bellary and Kalaburagi districts, 61.29 per cent of the study period were experienced positive deviation and 38.71 per cent of the study period experienced negative deviations. In case of Vijayapura (67.74 %) and Uttara Kannada (67.74 %) districts negative deviation in rainfall that is droughts were more compare to positive deviations. Haveri experienced nearly equal number of positive and negative deviations in rainfall. Vijayapur and Uttara Kannada experienced highest number of negative deviations in rainfall compared to posive deviations.

Probability of occurrence of positive and negative deviations from normal rainfall using runs test is presented in Table 4.7. Probability of occurrence of positive and negative deviations in rainfall was found to be more in case of Raichur (0.50) district followed by Haveri (0.44). In Dharwad, Belagavi, Bellary and Kalaburagi districts probability of occurrence of positive and negative deviations in rainfall was 40 per cent. Number of runs is the series of consecutive positive (or negative) values. Numbers of runs were found to be more in case of Bellary followed by Kalaburagi, Uttara Kannada and Raichur. It was revealed from Z test that probability of occurrence of positive and negative deviations in rainfall are random in all the districts of north Karnataka are random so null hypothesis was accepted.

4.2.2 Driest and wettest years of north Karnataka during the period from 1983 to 2013

Driest and wettest years during the study period from 1983-2013 is presented in the Table 4.8. Belagavi experienced driest year during 1985 and wettest year during 2005. Rainfall during driest year was 536 mm where as in wettest year it was 1,366 mm. In Bagalkote district wettest year was 1998 with rainfall of 876 mm and driest year 2003 documented rainfall of 242 mm. Bagalkote district experienced severe dry year among the different districts of north-Karnataka. Vijayapura experienced rainfall of 315 mm and 908 mm during driest year (2003) and wettest year (1998), respectively. In Dharwad district 2001 was the driest year with rainfall of 413 mm and 1991 was the wettest year with rainfall of 902 mm. Gadag experienced highest rainfall during 2007 and 2008 and least during 2003. Maximum rainfall documented during 2007 and 2008 was 822 mm and minimum rainfall documented during 2003 was 347 mm. Haveri district experienced the rainfall of 508 mm during driest year 2001 and 1,016 mm during wettest year 2010.

Table 4.6. Distribution of years according to deviation in rainfall (1983-2013)

% deviation		Dharwad	Gadag	Haveri	Vijayapura	Bagalkote	Belagavi	Raichur	Koppal	Uttara Kannada	Bellary	Kalaburagi	Bidar
+ ve	50 % and above											1983 (1)	
	50 %-40 %												
	40 % - 30 %				1998 (1)	1998 (1)	2005, 2006, 2007, 2008 (4)	1996, 1998 (2)	1996 (1)				1995 (1)
	30 % - 20 %	1991, 1992, (2)	1991, 1992, 2007, 2008 (4)	1991, 1992, 2004, 2010 (4)	1987, 1996 (2)	1987, 1996 (2)	2009, 2010, 2011 (3)	1993, 1995 (2)	1993, 1995, 1998, 2010 (4)		1987, 1996 (2)	1988, 1990, 1998 (3)	1988, 1989, 1990, 1998 (4)
	20 %- 10 %	2005, 2007, 2008 (3)	1998, 2000 (2)	1997, 2000, 2005, 2008 (4)	1989, 1991, 1993, 1995 (4)	1989, 1991, 1993, 1995, 2008 (5)	1991, 1994, 2004 (3)	1983, 1987, 1992 (3)	1983, 1987, 1992, 1999, 2000, 2004, 2007, 2008 (8)	1983, 1999, 2008, 2011 (4)	1983, 1986, 1988, 1992, 1998, 2001, 2010 (7)	1984, 1986, 1987, 1995, 1996 (5)	1983, 1996, 2000, 2010 (4)
	<10 %	1986, 1988, 1993, 1994, 1995, 1996, 2010 (7)	1986, 1988, 1993, 1994, 1995, 1996, 2010 (7)	1986, 1988, 1993, 1994, 1995, 1996, 1998 (7)	1988, 1999, 2000 (3)	1988, 1999, 2000, 2007, 2010 (5)	1993, 1997 (2)	1986, 1988, 1990, 1991, 2000, 2001, 2005, 2007, 2008 (9)	1986, 1988, 1990, 1991 (4)	1988, 1992, 1994, 1997, 1998, 2000 (6)	1990, 1993, 2005 (3)	2000, 2005, 2010 (3)	1999, 2005 (2)
Sum		12	13	15	10	13	12	16	17	10	12	12	11
%		38.71	41.94	48.39	32.26	41.94	38.71	51.61	54.84	32.26	38.71	38.71	35.48

Contd.....

Table 4.6 contd......

% deviation		Dharwad	Gadag	Haveri	Vijayapura	Bagalkote	Belagavi	Raichur	Koppal	Uttara Kannada	Bellary	Kalaburagi	Bidar
-ve	<10 %	1983, 1984, 1997, 1998, 2000, 2006, 2011 (7)	1983, 1984, 1997, 2004, 2005, 2009 (6)	1983, 1984, 1999, 2009, 2010 (5)	1983, 1986, 2007, 2010 (4)	1983, 1986, 1997 (3)	1983, 1988, 1996, 1998, 1999, 2000. 2001, 2002 (8)	1985, 1999, 2010 (3)	1985, 2001, 2005, 2009 (4)	1984, 1991, 1995, 2003, 2009, 2010, 2013 (7)	1984, 1991, 1999, 2000, 2008 (5)	1985, 1989 (2)	1987, 1997, 2001, 2009 (4)
	20 %- 10 %	1999, 2009 (2)		2004, 2006 (2)	1984, 1990, 1992, 1994, 2004, 2005, 2008 (7)	1984, 1990, 1992, 1994, 2001, 2009, 2011 (7)	1987, 1992, 1995, 2012, 2013 (5)	1997 (1)	1997 (1)	1985, 1987, 1989, 1990, 1993, 1996, 2012 (7)	1989, 1997, 2007, 2009 (4)	1991, 1992, 1993 (3)	1985, 1993, 2006, 2013 (4)
	30 % - 20 %	1987, 2004, 2013 (3)	1987, 1999, 2001 (3)	1987, 2013 (2)	1997, 2001, 2006 (3)	2005 (1)	1984, 2003 (2)	1989, 1994, 2004, 2009, 2013 (5)	1989, 1994, 2013 (3)	2002, 2006, 2007 (3)		1997, 1999, 2001, 2007, 2009, 2013 (6)	1984, 1986, 1991, 1992, 2002, 2003, 2004, 2011, 2012 (9)
	40 % - 30 %	1985, 1989, 2002 (3)	1985, 1989, 2006, 2013 (4)	1985, 1989, 2002 (3)	1985, 2009 (2)	1985, 2002, 2004, 2013 (4)	1986, 1989, 1990 (3)			1986, 2001, 2005 (3)	1994, 2004, 2013 (3)	2004, 2008(2)	2007, 2008 (2)
	50 %- 40 %	1990, 2012 (2)	1990, 2002 (2)	1990, 2001, 2003, 2012 (4)	2002, 2012, 2013 (3)		1985 (1)	1989, 2006, 2012 (3)	1984, 2011, 2012 (3)		1985, 2006, 2012 (3)	1994, 2006, 2011, 2012 (4)	1994 (1)
	50 % and above	2001, 2003 (2)	2003, 2011, 2012 (3)		2003, 2011 (2)	2003, 2006, 2012 (3)		2002, 2003, 2011 (3)	2002, 2003, 2006 (3)	2004 (1)	1995, 2002, 2003, 2011 (4)	2002, 2003 (2)	
Sum		19	18	16	21	18	19	15	14	21	19	19	20
%		61.29	58.06	51.61	67.74	58.06	61.29	48.39	45.16	67.74	61.29	61.29	64.52

Note: Figure in the parenthesis indicate frequencies

Table 4.7. Probability of occurrence of more than and less than normal rainfall using runs test

Districts	Probability (Test value)	Number of runs	Significance	Cal Z	Acceptance of hypothesis
Dharwad	0.40	13.00	0.46	-0.74	H_0
Gadag	0.31	9.00	0.70	0.38	H_0
Haveri	0.44	10.00	0.74	0.33	H_0
Vijayapura	0.33	11.00	0.23	-1.19	H_0
Bagalkote	0.38	7.00	0.58	-0.56	H_0
Belagavi	0.40	9.00	0.02	-2.29	H_0
Raichur	0.50	16.00	1.00	0.00	H_0
Koppal	0.38	7.00	0.58	-0.56	H_0
Uttara Kannada	0.37	16.00	0.82	0.23	H_0
Bellary	0.40	18.00	0.42	0.81	H_0
Kalaburagi	0.40	16.00	0.97	0.04	H_0
Bidar	0.37	12.00	0.33	-0.98	H_0

Note: H_0= Occurrence of positive and negative deviations in rainfall are random
H_1= Occurrence of positive and negative deviations in rainfall are not random

Table 4.8. Driest and wettest years during the period 1983-2013 in North Karnataka

Sl. No.	District	Driest year	Rainfall (mm)	Wettest year	Rainfall (mm)	Range
1	Belagavi	1985	536.4	2005	1,366.0	829.60
2	Bagalkote	2003	242.0	1998	876.0	634.00
3	Vijayapura	2003	315.0	1998	908.0	593.00
4	Dharwad	2001	413.0	1991	902.0	489.00
5	Gadag	2003	347.0	2007 and 2008	822.0	475.00
6	Haveri	2001	508.0	2010	1,016.0	508.00
7	Uttara Kannada	1986	2,089.1	2003	3,965.0	1875.90
8	Bellary	1995	324.0	1996	799.0	475.00
9	Bidar	1994	567.0	1995	1,308.0	741.00
10	Kalaburagi	2003	471.0	1983	1,425.9	954.90
11	Raichur	2011	358.0	1998	921.0	563.00
12	Koppal	2003	328.0	1998	751.0	423.00

Table 4.9. Range of positive and negative (> 50 per cent) deviation in rainfall values (mm) for selected districts of North-Karnataka

Sl. No.	District	Average rainfall > 50 % positive deviation (mm)	Average rainfall > 50 % negative deviation (mm)	Range (mm)
1	Belagavi	1,088.1	705.4	382.7
2	Bagalkote	677.0	459.7	217.3
3	Vijayapura	698.9	478.6	220.3
4	Dharwad	818.2	611.5	206.6
5	Gadag	747.8	486.5	261.2
6	Haveri	904.0	638.8	265.1
7	Uttara Kannada	3,063.1	2677.4	385.7
8	Bellary	701.6	472.7	228.8
9	Bidar	1,062.8	730.1	332.7
10	Kalaburagi	935.8	619.2	316.5
11	Raichur	715.3	493.0	222.2
12	Koppal	659.0	479.3	179.7

Uttara Kannada district experienced highest rainfall of 3,965 mm during 2003 and lowest rainfall of 2,089.1 mm during 1986. Uttara Kannada district receives highest rainfall among different districts of north-Karnataka. Bellary district were experienced rainfall of 324 mm and 799 mm during 1995 and 1996, respectively. These years are the driest and wettest years of Bellary district. Bidar district experienced highest rainfall of 1,308 mm during 1995 and least rainfall of 567 mm during 1994. Kalaburagi and Raichur districts experienced least rainfall of 471 mm and 358 mm during 2003 and 2011, respectively. Wettest years of Kalaburagi and Raichur districts are 1983 and 1998 with rainfall of 1,425 mm and 921 mm respectively. Koppal district experienced highest rainfall of 751 mm during 1998 and lowest rainfall of 328 mm during 2003. So 2003 and 1998 were said to be the driest and wettest years of Koppal district.

4.2.3 Range of positive and negative (> 50 per cent) deviation values (mm) for selected districts of north-Karnataka

Table 4.9 shows that the maximum deviation in the magnitude of average rainfall between the driest and wettest years was observed in Uttara Kannada district *i.e.*; 385.7 mm. Followed by Belagavi (382.7 mm), Bidar (332.7 mm). It can be seen from Table 4.9 that, in Dharwad district witnessed the minimum deviation in the quantum of average rainfall between the driest and wettest years *i.e.* 206.6 mm. The deviation in the magnitude of average rainfall between the driest and wettest years was observed to be the 217.3 mm in Bagalkote district. The district Vijayapura witnessed the deviation in the magnitude of average rainfall between the driest and wettest years *i.e.*; 220.3 mm. Koppal district witnessed the deviation in the magnitude of average rainfall between the driest and wettest years *i.e.*; 179.7 mm.

4.3 Season-wise average maximum and minimum temperatures for the districts of north Karnataka

Season-wise average maximum and minimum temperatures (degrees centigrade) for the districts of north Karnataka as presented in Table 4.10. In Belagavi district average maximum temperature was documented during summer season *i.e.* 36.93 ^{0}C and average minimum temperature was observed during winter season *i.e.* 15.75 ^{0}C. Highest average maximum temperature of 36.59 ^{0}C was observed in Bagalkote district during summer season and lowest average minimum temperature of 16.31 ^{0}C was documented during winter season. In Vijayapura and Dharwad districts, average maximum temperature was observed during summer that is 37.80 ^{0}C and 35.67 ^{0}C, respectively. Average minimum temperature was least during winter in both the districts. Gadag district experienced average maximum temperature of 37.33^{0}C during summer followed by winter (30.93 ^{0}C), monsoon (30.33 ^{0}C) and post monsoon (30.19 ^{0}C) seasons. And average minimum temperature was observed during winter (15.56 ^{0}C) followed by post monsoon (19.11 ^{0}C), monsoon (21.36 ^{0}C) and summer (22.36 ^{0}C) season. In Haveri district average maximum and minimum temperature was observed during summer (35.67 ^{0}C) and winter (17.84 ^{0}C), respectively.

Table 4.10. Season-wise average maximum and minimum temperatures (degrees centigrade) for the districts of North Karnataka (1999-2000 to 2013-14)

Sl. No.	Districts	Winter		Summer		Monsoon		Post-monsoon	
		Dec- Feb		March-May		June-Sept		Oct-Nov	
		Avg Max Temp.	Avg Min Temp.	Avg Max Temp.	Avg Min Temp.	Avg Max Temp.	Avg Min Temp.	Avg Max Temp.	Avg Min Temp.
1	Belagavi	31.96	15.75	36.93	21.29	29.97	21.22	31.48	19.33
2	Bagalkote	30.79	16.31	36.59	21.69	30.22	21.23	30.29	19.20
3	Vijayapura	32.62	17.36	37.80	23.44	31.57	22.24	30.81	18.06
4	Dharwad	30.48	14.88	35.67	20.63	28.04	20.68	29.70	17.99
5	Gadag	30.93	15.56	37.33	22.36	30.33	21.36	30.19	19.11
6	Haveri	31.78	17.84	35.67	22.41	28.17	21.93	30.12	20.71
7	Uttara Kannada	31.35	17.83	33.57	22.69	27.97	22.58	30.28	20.40
8	Bellary	31.79	18.78	35.80	22.91	30.50	21.83	30.17	19.71
9	Bidar	31.29	16.08	38.82	23.38	31.17	22.45	30.45	19.02
10	Kalaburagi	31.88	16.69	39.93	24.12	31.45	23.02	31.05	21.28
11	Raichur	31.95	17.72	38.47	24.28	32.74	23.56	31.58	20.69
12	Koppal	30.82	16.07	36.79	21.98	30.24	20.86	30.10	18.84

Uttara Kannada district experienced average maximum temperature during summer (33.57 ^{0}C) followed by winter (31.35 ^{0}C), post monsoon season (30.28 ^{0}C) and monsoon (27.97 ^{0}C) season. Least average minimum temperature was observed during winter followed by post monsoon season, monsoon season and summer seasons in Uttara Kannada district. In Bellary and Bidar districts average maximum during winter was 31.79 ^{0}C and 31.29 ^{0}C, respectively on the contrary average minimum temperature during winter was 18.78 ^{0}C and 16.08 ^{0}C in Bellary and Bidar districts respectively. Summer average maximum temperature was 35.80 ^{0}C and 38.82 ^{0}C in Bellary and Bidar districts, respectively. Kalaburagi had experienced highest maximum average temperature of 39.93 ^{0}C during summer compared to other districts in north- Karnataka and it was experienced average minimum temperature of 16.69 ^{0}C during winter season. Koppal district experienced highest average temperature during summer *i.e.* 36.79 ^{0}C. Among the districts of north –Karnataka, minimum average temperature was least in Gadag (15.56 ^{0}C) followed by Belagavi (15.75 ^{0}C), Koppal (16.07 ^{0}C), Bidar (16.08 ^{0}C), Bagalkote (16.31 ^{0}C), Kalaburagi (16.69 ^{0}C) and Vijayapura (17.36 ^{0}C).

During summer season almost all the districts of north-Karnataka experience average minimum temperature in the range between 20.63 ^{0}C to 24.28 ^{0}C. And average maximum temperature was maximum in Raichur district (32.74 ^{0}C) followed by Vijayapura (31.57 ^{0}C), Kalaburagi (31.45 ^{0}C), Bidar (31.17 ^{0}C), Bellary (30.50 ^{0}C) and Gadag (30.33 ^{0}C) during monsoon season. During post monsoon season average minimum temperature range was more compare to monsoon season. It ranges between 17.99 ^{0}C to 21.28 ^{0}C.

4.4 Influence of weather parameters on major crop yield in selected districts of north-Karnataka

In order to study the impact of climate change on the productivity of the selected crops in various districts of north Karnataka, multiple regression function was finally retained as it gave the best fit according the statistical criteria of high coefficient of multiple determination (R^2) and low standard error.

The district-wise results of multiple regression analysis for the selected crops are presented in Table 4.11 to 4.21. A perusal of Table 4.11 indicated that 55.38 per cent of the variation in the Paddy yield around its mean was explained by the selected explanatory variables in case of Belagavi district. About 80.02 per cent of variation in sorghum yield was explained by the selected variables. Out of these variables, actual rainfall had a positive and significant effect on the yield at five per cent level of significance. Yield of sorghum crop increased by 0.55 per cent with every one per cent increase in the rainfall. Contrary to this, deviation from the maximum relative humidity had a negative coefficient (-20.09) implying a negative and significant impact on the productivity of sorghum. In bengalgram and soybean crops, maximum relative humidity was significantly and negatively contributing to the yield of these crops. Variation in the yield levels of bengalgram and soybean was explained by the selected variables to the extent of 54.05 per cent and 57.49 per cent, respectively in Belagavi district.

Table 4.11. Influence of seasonal weather parameters on major crop yield in Belagavi district (1999-2000 to 2013-14)

Variables	Paddy	Sorghum	Maize	Bengalgram	Groundnut	Soybean
Intercept	64.05	121.37	34.17	140.09	95.05	38.66
Actual rainfall	0.26 (0.36)	0.55** (0.22)	0.28 (0.25)	0.33 (0.36)	0.13 (0.21)	0.28 (0.20)
Maximum temperature	-12.28 (8.95)	-11.00 (5.46)	-6.84 (6.21)	-14.63 (9.05)	-17.34 (10.87)	-5.55 (5.04)
Minimum temperature	3.04 (10.89)	1.97 (6.64)	5.41 (7.56)	3.19 (11.01)	-3.49 (3.25)	9.33 (6.14)
Maximum relative humidity	-6.23 (9.52)	-20.09** (5.80)	-4.83 (6.60)	-23.30** (9.62)	-3.97 (2.95)	-11.62* (5.36)
Minimum relative humidity	0.43 (3.41)	0.38 (2.08)	-0.07 (2.37)	1.45 (3.45)	0.14 (0.96)	1.80 (1.92)
R^2	**0.55**	**0.80**	**0.54**	**0.54**	**0.37**	**0.57**
F	**1.98**	**6.41**	**1.90**	**1.88**	**0.95**	**2.16**

Note: Figure in the parentheses indicate standard error
*,** indicates significance at 5 % and 1 % respectively

Table 4.12. Influence of seasonal weather parameters on major crop yield in Bagalkote district (1999-2000 to 2013-14)

Variables	Bajra	Sorghum	Greengram	Bengalgram	Sunflower
Intercept	-39.12	39.75	0.85	75.38	45.18
Actual rainfall	0.66* (0.22)	1.98** (0.37)	1.04 (0.65)	1.14* (0.26)	0.83* (0.28)
Maximum temperature	1.69 (2.57)	4.01 (1.32)	1.31 (7.60)	-0.77 (3.07)	-1.05 (3.33)
Minimum temperature	1.90 (1.69)	-4.89 (2.85)	2.80 (5.02)	-3.03 (2.03)	0.30 (2.20)
Maximum relative humidity	4.20* (1.82)	-4.45 (3.07)	-4.30 (5.41)	-7.50* (2.18)	-5.57 (2.37)
Minimum relative humidity	3.08 (2.16)	-5.73 (3.69)	0.90 (6.49)	-7.45* (2.69)	-4.10* (2.85)
R^2	**0.69**	**0.86**	**0.31**	**0.84**	**0.66**
F	**3.56**	**10.23**	**0.73**	**8.51**	**3.09**

Note: Figure in the parentheses indicate standard error
*,** indicates significance at 10 % and 5 % respectively

Bajra, maize, greengram, bengalgram and sunflower crop was selected for Bagalkote district considering their major area in the region. It was found that 68.98 per cent of the variation in bajra yield was explained by the selected explanatory variables, out of which, actual rainfall and maximum relative humidity had a highly significant and positive impact on the yield (Table 4.12) at 5 per cent level of significance. The variables pertaining to actual rainfall during the crop growth period had significant impact on the sorghum productivity. The results showed that one per cent increase in the actual rainfall led to 1.98 per cent increase in the sorghum yield. The negative impact of maximum relative humidity could be probably attributed low productivity in case of sunflower because increase in maximum relative humidity by one per cent would decrease the sunflower yield by 4.10 per cent. Maximum relative humidity and minimum relative humidity were contributing negatively and significantly to the yield of bengalgram in Bagalkote district. All variables together contribute 84.17 per cent variation in the yield of bengalgram.

The estimated coefficients of multiple regression function for sorghum in Vijayapura is presented in Table 4.13 the output elasticities of maximum relative humidity (-10.76) and minimum relative humidity (5.02) were indicated that the production of sorghum was significantly influenced by these variables. The output elasticities of actual rainfall (0.44), maximum temperature (0.11) and minimum temperature (2.65) were non-significant and had positive relationship. The coefficient of multiple determination (R^2) for sorghum production (0.57) indicated that the variables included in the function have explained 57.94 per cent of the variation in the production of sorghum. The estimated coefficients of multiple regression function for bajra is indicated that output elasticities of actual rainfall (-0.11), maximum relative humidity (-3.47) and minimum temperature (-2.04) have indicated that the production of bajra was negatively influenced by these variables. The output elasticities of maximum temperature (2.18) and minimum relative humidity (2.16) were non-significant, had positive relationship. The coefficient of multiple determination (R^2) for bajra production (0.51) indicated that the variables included in the function have explained 50.82 per cent of the variation in the production of bajra. Coefficient of determination for bengalgram and tur was 35.42 per cent and 28.63 per cent, respectively. It indicates that these variables together contribute to the variation in productivity of bengalgram and tur. The estimated coefficients of multiple regression function for sunflower is presented in Table 4.13. The output elasticity of minimum temperature (13.07) and minimum relative humidity (5.02) has indicated that the production of sunflower was significantly influenced by this variable. The output elasticities of actual rainfall (0.31), maximum temperature (2.69) were non-significant and had positive relationship. Maximum relative humidity (-10.86) were non-significant and had negative relationship. The coefficient of multiple determination (R^2) for sunflower production (0.66) indicated that the variables included in the function have explained 66.02 per cent of the variation in the production of sunflower.

In Dharwad district coefficient of determination for paddy, sorghum, maize, greengram, groundnut, soybean, wheat, bengalgram and cotton was 81.50 per cent, 82.04 per cent, 79.57 per cent, 61.36 per cent, 90.40 per cent, 49.76 per cent, 67.80 per cent, 60.77 per cent and 72.65 per cent, respectively. The estimated coefficients of multiple regression function for paddy is presented in

Table 4.14. Actual rainfall was significantly contributing to the productivity of paddy (3.19), sorghum (1.92), maize (1.66), greengram (1.94), and groundnut (1.97). Maximum temperature was negatively contributing to the productivity of paddy (-0.46), sorghum (-14.13), maize (-15.52), greengram (-21.43), groundnut (-34.82), and soybean (-11.66). Minimum temperature was positive and significantly contributing to the yield of sorghum, paddy, greengram, groundnut, soybean, wheat, bengalgram and cotton, but negatively to the productivity of maize (-28.98). The output elasticities of maximum temperature (-34.82), minimum temperature (39.53), maximum relative humidity (-7.31) and minimum relative humidity (-31.13) have indicated that the production of groundnut was significantly influenced by these variables. Minimum relative humidity (-7.95) in case of soybean, maximum relative humidity (13.79) in case of wheat, bengalgram (14.54) and cotton (9.40) were significantly contributing to their respective yield levels.

The estimated coefficients of multiple regression function for sorghum in Gadag is presented in Table 4.15, the output elasticity of actual rainfall (1.37), maximum temperature (-3.80), minimum temperature (2.75), maximum relative humidity (-1.59) and minimum relative humidity (-2.82) indicated that the production of sorghum was influenced by these variables. The coefficient of multiple determination (R^2) for sorghum production (0.79) indicated that the variables included in the function have explained 79.08 per cent of the variation in the production of sorghum. Actual rainfall was significantly contributing to the productivity of maize (0.53), greengram (1.44), bengalgram (0.90), groundnut (1.16), sunflower (0.61) and cotton (1.33). In case of maize production, output elasticity's of maximum temperature (-5.46) and maximum relative humidity (-5.63) were non-significant, had negative relationship with yield of maize but minimum temperature was positively contributing. Minimum temperature (-6.88) was significant and negatively contributing to the yield of groundnut. In case of sunflower, maximum relative humidity (-8.98) was influencing yield level negatively and minimum relative humidity (4.64) was influencing positively.

The estimated coefficients of multiple regression function for Paddy in Haveri district is presented in Table 4.16. The output elasticities of actual rainfall (3.18) have indicated that the production of Paddy was significantly influenced by this variable. The output elasticities of maximum temperature (-23.02), maximum relative humidity (-4.77) and minimum relative humidity (-7.61) were non-significant, had negative relationship, where as minimum temperature (10.99) has non-significant and positive relation with Paddy yield. The coefficient of multiple determination (R^2) for Paddy production (0.75) indicated that the variables included in the function have explained 75.35 per cent of the variation in the production of Paddy. The coefficient of multiple determination (R^2) for sorghum, maize and cotton was 75.68 per cent, 53.69 per cent and 66.00 per cent, respectively. Among the different variables under consideration, actual rainfall was contributing significantly to the production of sorghum (1.27) and cotton (1.00) in positive manner.

The estimated coefficients of multiple regression function for Paddy in Uttara Kannada district is presented in Table 4.17. The output elasticities of actual rainfall (0.86), maximum temperature (3.88) and minimum relative humidity (3.98) indicated that the production of Paddy was significantly influenced by these variables. The output elasticities of minimum temperature (4.53) and maximum relative humidity (1.36) were non-significant and had positive relationship. The coefficient of multiple determination (R^2) for Paddy production (0.89) indicated that the variables included in the function have explained 89.24 per cent of the variation in the production of Paddy.

Table 4.13. Influence of seasonal weather parameters on major crop yield in Vijayapura district (1999-2000 to 2013-14)

Variables	Sorghum	Bajra	Bengalgram	Tur	Sunflower
Intercept	21.39	11.17	112.40	55.35	-19.60
Actual rainfall	0.44 (0.39)	-0.11 (0.16)	0.16 (0.32)	-0.24 (0.53)	0.31 (0.47)
Maximum temperature	0.11 (5.07)	2.18 (8.01)	-26.23 (16.16)	0.11 (6.79)	2.69 (6.12)
Minimum temperature	2.65 (5.38)	-2.04 (1.77)	0.97 (3.58)	-8.99 (7.21)	13.07* (6.49)
Maximum relative humidity	-10.76* (4.92)	-3.47 (3.12)	-1.24 (6.29)	-6.25 (6.59)	-10.86 (5.94)
Minimum relative humidity	5.02** (2.20)	2.16 (1.78)	-3.60 (3.60)	1.64 (2.95)	5.02* (2.66)
R^2	**0.58**	**0.51**	**0.35**	**0.28**	**0.66**
F	**2.20**	**1.65**	**0.87**	**0.64**	**3.11**

Note: Figure in the parentheses indicate standard error
*, ** indicates significance at 5 % and 1 % respectively

Table 4.14. Influence of seasonal weather parameters on major crop yield in Dharwad district (1999-2000 to 2013-14)

Variables	Paddy	Sorghum	Maize	Green gram	Groundn ut	Soybean	Wheat	Bengal gram	Cotton
Intercept	-43.54	20.30	27.51	100.81	80.04	48.95	-169.76	-198.91	-61.92
Actual rainfall	3.19** (0.89)	1.92** (0.48)	1.66** (0.41)	1.94** (0.75)	1.97*** (0.38)	-0.42 (0.34)	0.34 (0.40))	0.414 (0.48)	0.52 (0.53)
Maximum temperature	-0.46 (17.74)	-14.13 (9.58)	-15.52 (8.35)	-21.43 (15.00)	-34.82** (7.57)	-11.66 (6.80)	24.72 (16.37)	30.01 (19.56)	0.38 (10.68)
Minimum temperature	8.88 (17.86)	23.95** (9.65)	-28.98** (8.41)	19.77 (15.10)	39.53*** (7.63))	9.85 (6.85)	19.33 (10.87)	23.07 (12.99)	7.04 (10.76)
Maximum relative humidity	-2.17 (8.22)	-4.19 (4.44)	-6.36 (3.87)	-10.55 (6.95)	-7.31* (3.51)	0.75 (3.15)	13.79** (3.88)	14.54** (4.63)	9.40* (4.95)
Minimum relative humidity	3.58 (10.71)	-7.21 (5.78)	-8.72 (5.04)	-11.21 (9.06)	-31.13** (4.57)	-7.95* (4.10)	-5.94 (4.35)	-6.67 (5.19)	-0.23 (6.45)
R^2	**0.81**	**0.82**	**0.79**	**0.61**	**0.90**	**0.49**	**0.67**	**0.60**	**0.72**
F	**7.05**	**7.31**	**6.23**	**2.54**	**15.14**	**1.58**	**3.37**	**2.47**	**4.25**

Note: Figure in the parentheses indicate standard error
*, **, *** indicates significance at 10 %, 5 % and 1 % respectively

Table 4.15. Influence of seasonal weather parameters on major crop yield in Gadag district (1999-2000 to 2013-14)

Variables	Sorghum	Maize	Greengram	Bengalgram	Groundnut	Sunflower	Cotton
Intercept	21.64	32.51	20.21	13.14	20.87	24.97	13.06
Actual rainfall	1.37*** (0.25)	0.53** (0.18)	1.44** (0.51)	0.90** (0.30)	1.16*** (0.19)	0.61*** (0.12)	1.33** (0.31)
Maximum temperature	-3.80 (3.46)	-5.46** (2.41)	-10.07 (6.85)	-3.22 (4.04)	0.77 (2.65)	-2.13 (1.72)	1.46 (4.18)
Minimum temperature	2.75 (3.38)	1.21** (2.35)	-0.43 (6.69)	4.92 (3.92)	-6.88** (2.59)	1.19 (1.68)	-0.92 (4.08)
Maximum relative humidity	-1.59 (4.28)	-5.63* (2.96)	5.20 (8.42)	-8.02 (4.97)	1.88 (3.27)	-8.98** (2.12)	0.79 (5.14)
Minimum relative humidity	-2.82 (3.36)	2.65 (2.34)	-2.45 (6.66)	4.24 (3.95)	-2.72 (2.58)	4.64** (1.67)	-5.08 (4.06)
R^2	**0.79**	**0.73**	**0.64**	**0.63**	**0.85**	**0.85**	**0.71**
F	**6.05**	**4.45**	**2.87**	**2.74**	**9.04**	**9.30**	**3.89**

Note: Figure in the parentheses indicate standard error
*, **, *** indicates significance at 10 %, 5 % and 1 % respectively

Sorghum, maize, bengalgram, groundnut, sunflower and cotton crop were selected for Bellary district considering its significance in the region. It was found that 80.11 per cent of the variation in yield of sorghum was explained by the selected explanatory variables, out of which, actual rainfall (0.95) had a highly significant and positive impact on the yield (Table 4.18). Moreover, maximum temperature (-1.47), minimum temperature (-2.80), maximum relative humidity (-6.54) were had a negative and non-significant impact on the yield of sorghum. The variables pertaining to actual rainfall (0.72) and maximum relative humidity (12.89) during the crop growth period had significant impact on the maize productivity. The results showed that one per cent increase in the actual rainfall leads to 0.72 per cent increase in the yield but a one per cent increase in the maximum relative humidity led to a 12.89 per cent increase in the yield of maize. The negative impact of minimum temperature (-2.04) on maize crop yield was observed. All the variables together contribute 55.02 per cent variation in the yield of bengalgram. Among the variables, actual rainfall (1.42) was significantly contributing to the bengalgram yield. It indicates that one per cent increase in the actual rainfall led to 1.42 per cent increase in the yield of bengalgram. In case of groundnut crop minimum temperature (-10.70) and minimum relative humidity (-13.38) were significantly and negatively contributing to the yield level. About 67.71 per cent of the variation in groundnut crop was explained by these variables. In case of sunflower (0.43) and cotton (0.48) crops, actual rainfall was significantly contributing to the yield. All the variables together explain 48.86 per cent and 86.50 per cent variation in the yield of sunflower and cotton crops respectively.

In case of Bidar district sorghum, blackgram, greengram, bengalgram, tur and soybean were selected as major crops of this district (Table 4.19). About 36.51 per cent of variation in sorghum yield, 38.98 per cent of variation in blackgram yield, 18.83 per cent of variation in greengram yield, 35.97 per cent variation in bengalgram yield, 43.49 per cent of variation in tur and 35.97 per cent of variation in soybean yield was explained by these variables under study. In case of soybean, minimum relative humidity was significantly contributing to the yield at negative rate. In case of Kalaburagi district (Table 4.20), variations in the yield of sorghum, greengram, bengalgram, tur and sunflower was explained by the variables under study to the extent of 84.60 per cent, 49.56 per cent, 33.90 per cent, 27.18 per cent and 40.48 per cent, respectively. In case of sorghum crop, maximum temperature (3.45) and maximum relative humidity (5.99) were significantly contributing to the yield.

In Raichur district (Table 4.21), total variation in the yield of sorghum was explained by the variables under study to the extent of 81.56 per cent. It indicates that one per cent variation in actual rainfall will increase the sorghum yield by 1.06 per cent. One per cent increase in maximum and minimum relative humidity will increase the yield of sorghum by 5.59 per cent and 7.38 per cent, respectively. In case of bajra, actual rainfall (0.90) was significantly contributing to the yield. One per cent increase in actual rainfall leads to 0.90 per cent increase in yield of bajra. In case of bengalgram, actual rainfall (0.48) was significantly contributing to the yield. Minimum relative humidity (-3.24) was negative and significantly contributing to the yield of bengalgram. In case of sunflower, actual rainfall (0.35), maximum temperature (21.90) and maximum relative humidity (7.98) were significantly and positively contributing to the yield. Minimum temperature (-20.12) and minimum relative humidity (-13.41) were contributing to the yield of sunflower negatively.

Table 4.16. Influence of seasonal weather parameters on major crop yield in Haveri district (1999-2000 to 2013-14)

Variables	Paddy	Sorghum	Maize	Cotton
Intercept	84.33	-56.74	27.44	40.53
Actual rainfall	3.18* (0.75)	1.27* (0.29)	1.17 (0.66)	1.00* (0.47)
Maximum temperature	-23.02 (14.96)	9.48 (10.56)	-6.22 (13.03)	-6.39 (9.36)
Minimum temperature	10.99 (17.00)	-4.62 (14.02)	15.79 (14.81)	4.76 (10.64)
Maximum relative humidity	-4.77 (9.77)	3.97 (5.60)	-12.11 (8.51)	-9.71 (6.11)
Minimum relative humidity	-7.61 (5.70)	4.74 (7.42)	-0.15 (4.96)	2.06 (3.57)
R^2	**0.75**	**0.75**	**0.53**	**0.66**
F	**4.89**	**4.98**	**1.85**	**3.11**

Note: Figure in the parentheses indicate standard error
* indicates significance at 5 %

Table 4.17. Influence of seasonal weather parameters on major crop yield in Uttara Kannada district (1999-2000 to 2013-14)

Variables	Paddy
Intercept	-49.97
Actual rainfall	0.86** (0.16)
Maximum temperature	3.88* (1.84)
Minimum temperature	4.53 (3.40)
Maximum relative humidity	1.36 (3.67)
Minimum relative humidity	3.98* (2.05)
R^2	**0.89**
F	**13.27**

Note: Figure in the parentheses indicate standard error
*, ** indicates significance at 10 % and 1 % respectively

Table 4.18. Influence of seasonal weather parameters on major crop yield in Bellary district (1999-2000 to 2013-14)

Variables	Sorghum	Maize	Bengalgram	Groundnut	Sunflower	Cotton
Intercept	41.84	39.04	-54.88	105.51	-7.53	-66.06
Actual rainfall	0.95*** (0.18)	0.72** (0.23)	1.42** (0.49)	0.67 (0.46)	0.43* (0.20)	0.48** (0.22)
Maximum temperature	-1.47 (2.12)	2.15 (3.11)	8.31 (6.80)	-1.73 (5.46)	442 (2.41)	5.29** (2.33)
Minimum temperature	-2.80 (1.64)	-2.04 (2.41)	-6.66 (4.00)	-10.70** (4.23)	-1.07 (1.87)	1.94 (1.30)
Maximum relative humidity	-6.54 (3.87)	12.89** (5.68)	7.02 (5.45)	-1.83 (9.96)	-2.97 (4.40)	6.34 (3.56)
Minimum relative humidity	0.38 (2.38)	4.58 (3.50)	3.75 (3.99)	-13.38** (6.13)	2.81 (2.71)	4.69* (2.43)
R^2	**0.80**	**0.58**	**0.55**	**0.68**	**0.49**	**0.86**
F	**6.44**	**2.23**	**1.96**	**3.36**	**1.53**	**10.29**

Note: Figure in the parentheses indicate standard error
*, **, *** indicates significance at 10 %, 5 % and 1 % respectively

Table 4.19. Influence of seasonal weather parameters on major crop yield in Bidar district (1999-2000 to 2013-14)

Variables	Sorghum	Blackgram	Greengram	Bengalgram	Tur	Soybean
Intercept	18.76	-4.51	-20.86	-15.41	37.91	54.76
Actual rainfall	0.12 (0.40)	-0.53 (0.53)	-3.94 (0.74)	-0.34 (0.31)	0.46 (0.59)	-0.009 (0.86)
Maximum temperature	-1.51 (3.48)	11.36 (14.36)	15.24 (19.91)	3.01 (2.73)	-4.94 (5.08)	-8.11 (7.44)
Minimum temperature	-2.27 (3.37)	-7.32 (8.12)	-8.33 (11.25)	4.70 (2.64)	-6.65 (4.92)	-6.18 (7.20)
Maximum relative humidity	4.32 (2.87)	3.33 (6.60)	4.82 (9.15)	-1.69 (2.25)	6.05 (4.20)	11.09 (6.14)
Minimum relative humidity	-4.56 (2.91)	-5.00 (6.16)	-5.26 (8.54)	1.53 (2.28)	-5.49 (4.25)	-11.75* (6.21)
R^2	**0.36**	**0.39**	**0.19**	**0.35**	**0.43**	**0.36**
F	**0.92**	**1.02**	**0.37**	**0.89**	**1.23**	**0.89**

Note: Figure in the parentheses indicate standard error
* indicates significance at 5 % respectively

Table 4.20. Influence of seasonal weather parameters on major crop yield in Kalaburagi district (1999-2000 to 2013-14)

Variables	Sorghum	Greengram	Bengalgram	Tur	Sunflower
Intercept	-31.53	-32.56	0.20	20.82	2.67
Actual rainfall	0.12 (0.13)	0.87 (0.84)	0.27 (0.40)	0.22 (0.37)	0.19 (0.30)
Maximum temperature	3.45* (1.56)	10.02 (11.13)	2.05 (4.81)	0.04 (4.92)	2.70 (4.03)
Minimum temperature	1.34 (1.18)	-3.13 (10.43)	-0.01 (3.66)	-5.67 (4.61)	-0.39 (3.77)
Maximum relative humidity	5.99** (2.26)	12.42 (13.85)	0.94 (6.97)	1.59 (6.12)	0.70 (5.01)
Minimum relative humidity	-1.04 (0.94)	-11.08 (8.00)	-1.72 (2.91)	-1.25 (3.53)	-2.18 (2.89)
R^2	**0.85**	**0.49**	**0.34**	**0.27**	**0.40**
F	**8.79**	**1.57**	**0.82**	**0.59**	**1.09**

Note: Figure in the parentheses indicate standard error
*, ** indicates significance at 5 % and 1 % respectively

Table 4.21. Influence of seasonal weather parameters on major crop yield in Raichur district (1999-2000 to 2013-14)

Variables	Sorghum	Bajra	Bengalgram	Tur	Sunflower
Intercept	-72.86	58.50	10.91	67.23	11.50
Actual rainfall	1.06** (0.28)	0.90* (0.43)	0.48* (0.24)	0.05 (0.39)	0.35** (0.11)
Maximum temperature	3.60 (5.17)	7.62 (9.92)	0.57 (4.40)	-10.62 (10.62)	21.90*** (2.65)
Minimum temperature	2.05 (3.90)	-20.01** (8.80)	-0.19 (3.32)	-8.46 (8.18)	-20.12*** (2.32)
Maximum relative humidity	5.59** (2.29)	-1.25 (4.43)	0.95 (1.94)	-1.23 (6.39)	7.98*** (1.18)
Minimum relative humidity	7.38* (1.75)	-3.76 (5.16)	-3.24* (1.49)	1.25 (2.19)	-13.41*** (1.37)
R^2	**0.81**	**0.69**	**0.58**	**0.28**	**0.94**
F	**7.08**	**3.58**	**2.29**	**0.61**	**26.70**

Note: Figure in the parentheses indicate standard error
*, **, *** indicates significance at 10 %, 5 % and 1 % respectively

4.5 Economic benefits of weather based farming in improving farm productivity

Farmer's perception about Agro-met Advisory Service and its impact on farm income is presented under following sub headings.

4.5.1 Season-wise usability of rainfall forecasts in study area

In order to analyse the impact of Agro-met Advisory Service (AAS), 60 beneficiary farmers were surveyed and results of the analysis were presented in Table 4.22. Out of total beneficiaries 88.33 per cent of them were using the forecast service throughout the year. About 70 per cent of them were using the service during winter season followed by pre-monsoon season (65.00 %), monsoon season (26.66 %) and post monsoon season (15.00 %). Very few farmers using the AAS during post monsoon season.

4.5.2 Operation wise usability of AAS by the beneficiary farmers

Operation wise usability of AAS is presented in Table 4.23. Majority of the farmers were using the AAS during spaying operation (78.33 %). About 73.33 per cent of the respondents were using the AAS for harvesting and drying operations followed by irrigation (66.67 %), sowing (43.33 %) and fertilizer application (13.33 %). Farmers were rarely using AAS for seed treatment (1.67 %), seedling stage (3.33 %) and during weeding operations (6.67 %). None of the sample farmers used the AAS during land preparation operation. Only single farmer used this information for seed treatment purpose.

4.5.3 Input utilization pattern by AAS beneficiaries and Non-AAS farmers

Per acre input utilization by AAS and non-AAS farmers is presented in Table 4.25. In case of maize crop AAS beneficiaries were able to reduce the cost of cultivation by 8 per cent (Table 4.24). Among the different costs incurred in cultivation of maize, cost on insecticides (` 193.00) and human labour (` 3,297.00) was less in AAS beneficiaries compare to non-AAS farmers. Seed cost incurred by AAS beneficiaries was ` 735.68 compare to non-AAS farmers (` 794.54). Cost difference in cultivation of wheat by AAS (` 7,577.00) beneficiaries and non-AAS (` 7,734.00) farmers was 3.54 per cent. Among the different input, cost incurred on fertilizer (` 1,170.73), human labour (` 3,158.98) and machine labour (` 2,015.21) was less in case of AAS beneficiaries compare to non-AAS farmers by 2.33 per cent, 2.25 per cent and 1.97 per cent respectively.

Cost incurred on sorghum crop was ` 7,206.00 by the AAS beneficiaries and ` 7,500.00 by non AAS farmers. The difference in cost between them was 4.09 per cent. Among the different inputs, cost incurred on manure was less in case of AAS beneficiaries (` 250.00) compare to non-AAS farmers (` 270.00). About 6.21 per cent cost reduction was observed in case of animal labour by AAS beneficiaries (` 821.00) compare to non AAS farmers (` 872.00). In case of greengram crop 8.79 per cent reduction in cost of cultivation was observed in AAS-beneficiaries (` 6,669.00).

Table 4.22. Season-wise usability of forecast in Belagavi district

(n=60)

Season	No. of farmers	Percentage
Pre-monsoon	39	65.00
Monsoon	16	26.66
Post-Monsoon	9	15.00
Winter	42	70.00
Whole year	53	88.33

Table 4.23. Operation wise usability of Agromet Advisory Service (AAS) by the beneficiary farmers

(n=60)

Sl. No.	Purpose	No. of farmers	Percentage
1	Land Preparation	0	0.00
2	Seed treatment	1	1.67
3	Sowing	26	43.33
4	Seedling stage	2	3.33
5	Weeding	4	6.67
6	Fertilizer application	8	13.33
7	Spraying of PPC	47	78.33
8	Irrigation	40	66.67
9	Harvesting	44	73.33
10	Drying of produce	44	73.33

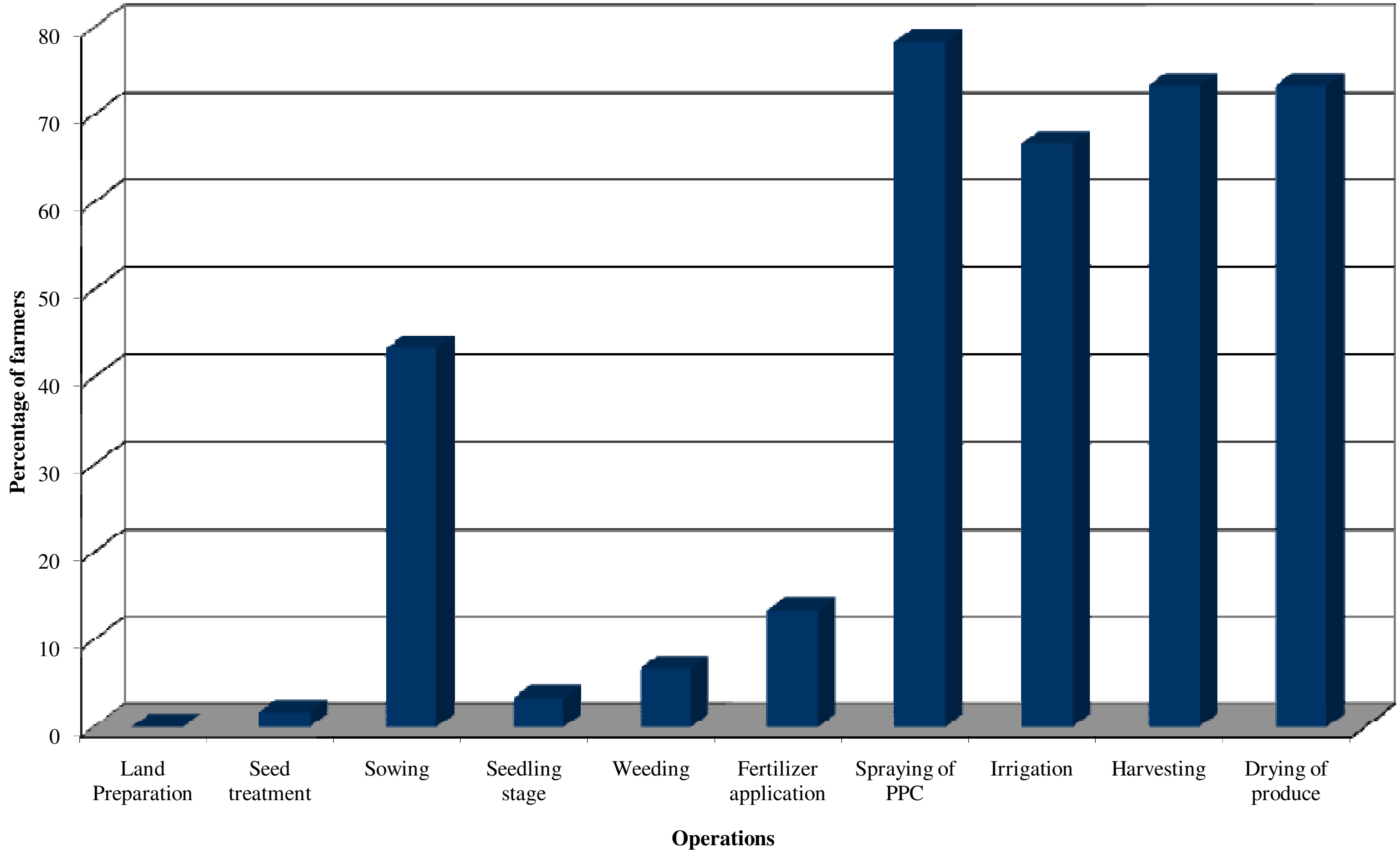

Fig. 7: Operation wise usability of Agromet Advisory Service (AAS) by the beneficiary farmers

Table 4.24. Difference in cost of production observed between AAS and non AAS farmers

Crops	AAS	Non-AAS	% difference
Maize	8,667.00	9,360.00	**-8.00**
Wheat	7,577.00	7,734.00	**-2.07**
Sorghum	7,206.00	7,500.00	**-4.09**
Greengram	6,669.00	7,250.00	**-8.79**
Bengalgram	7,426.00	9,200.00	**-23.88**
Soybean	7,757.00	9,650.00	**-24.41**
Groundnut	10,694.00	12,100.00	**-13.14**
Sunflower	5,044.00	5,750.00	**-13.99**
Safflower	5,236.00	5,600.00	**-6.96**
Cotton	12,444.00	15,200.00	**-22.14**
Sugarcane	20,500.00	22,000.00	**-7.32**

*AAS-Agromet Advisory Service
Sample size: AAS=60 and Non AAS=30

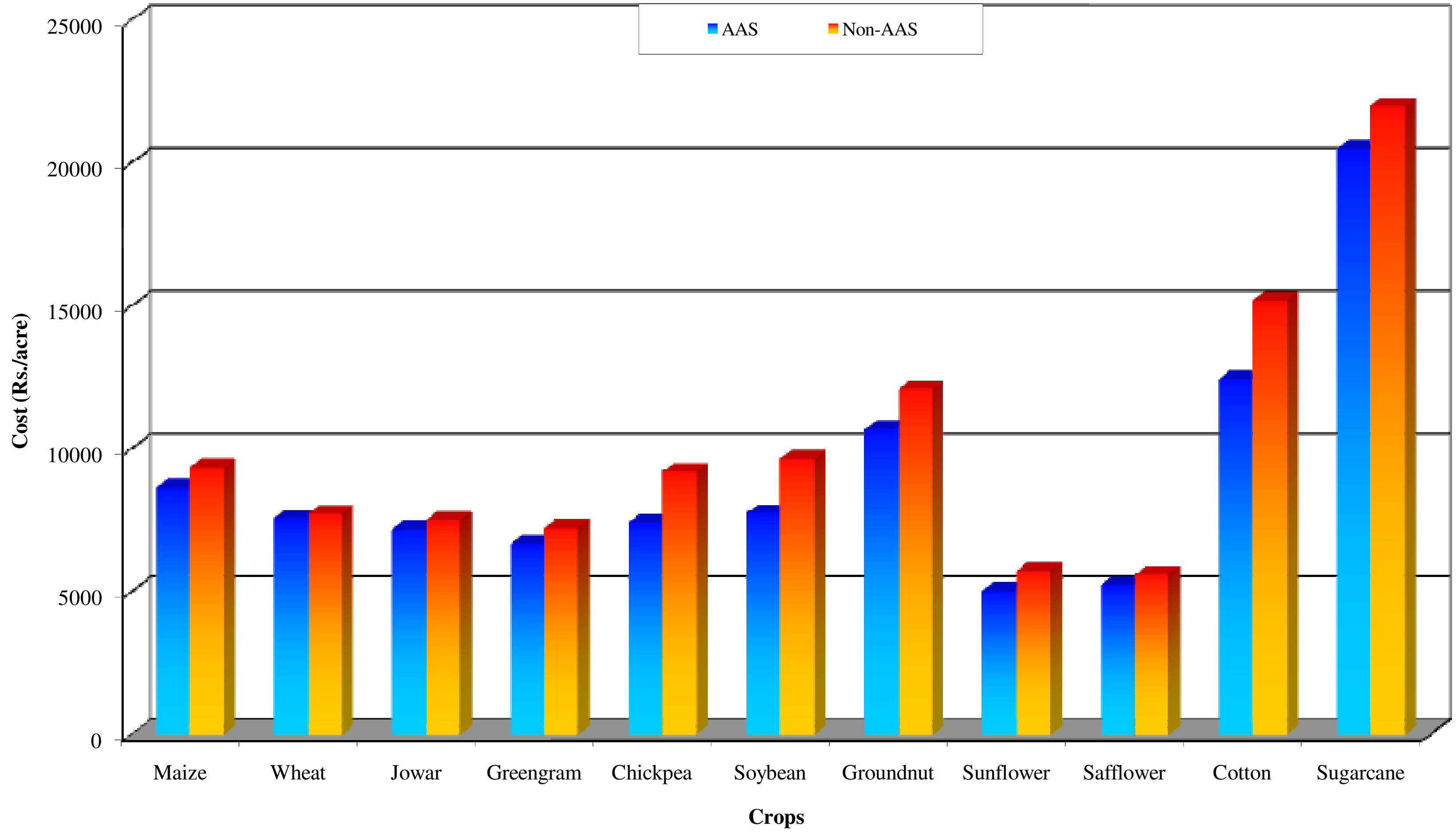

Fig. 8: Difference in cost of production observed between AAS and non AAS farmers

Table 4.25. Input utilization pattern by AAS beneficiaries and Non-AAS farmers (Rs/acre) (n=90)

	Category	Maize	Wheat	Sorghum	Greengram	Bengalgram	Soybean	Groundnut	Sunflower	Safflower	Cotton	Sugarcane
Seed	AAS	735.68	826.78	269.37	593.32	1,625.00	1,559.42	3,001.34	635.36	417.66	2,121.24	579.53
	Non-AAS	794.54	840.00	280.38	644.97	1,989.00	1,600.00	3,400.00	744.00	446.72	2,491.00	633.00
	% difference	**-8.00**	**-1.60**	**-4.09**	**-8.70**	**-22.40**	**-2.60**	**-13.28**	**-17.10**	**-6.86**	**-17.43**	**-9.23**
Fertilizer	AAS	1,739.82	1,170.73	800.00	355.19	750.00	624.45	1,686.73	755.19	594.00	1,434.19	3,543.70
	Non-AAS	1,850.00	1,198.00	823.00	386.11	929.11	778.00	1,928.00	871.00	635.33	1,751.76	3,885.00
	% difference	**-6.33**	**-2.33**	**-2.88**	**-8.70**	**-23.88**	**-24.59**	**-14.30**	**-15.33**	**-6.90**	**-22.14**	**-9.63**
Manure	AAS	275.00	0.00	250.00	209.00	220.00	286.77	155.00	147.00	0.00	225.53	631.30
	Non-AAS	297.00	0.00	270.00	227.19	272.54	356.76	195.00	165.00	0.00	275.47	677.49
	% difference	**-8.00**	**0.00**	**-8.00**	**-8.70**	**-23.47**	**-24.41**	**-25.81**	**-12.24**	**0.00**	**-22.14**	**-7.32**
Insecticide	AAS	193.00	122.55	0.00	250.00	655.00	1,022.00	283.00	138.00	64.00	404.92	251.00
	Non-AAS	225.00	124.00	0.00	462.00	995.00	1,885.00	392.00	207.00	94.00	745.00	345.00
	% difference	**-16.58**	**-1.19**	**0.00**	**-84.80**	**-51.91**	**-84.44**	**-38.52**	**-50.00**	**-46.88**	**-83.99**	**-37.45**
Human Labour	AAS	3,297.00	3,158.98	3,918.00	3,562.00	2,532.00	2,707.78	3,800.00	1,786.00	2,895.00	5,848.65	1,3445.00
	Non-AAS	3,678.00	3,230.00	4,074.00	3,900.00	2,977.00	3,389.00	4,264.00	1,936.00	3,070.00	6,973.00	1,4295.00
	% difference	**-11.56**	**-2.25**	**-3.98**	**-9.49**	**-17.58**	**-25.16**	**-12.21**	**-8.40**	**-6.04**	**-19.22**	**-6.32**
Animal Labour	AAS	737.00	282.67	821.00	880.23	665.41	356.34	1,127.44	629.39	922.02	1,031.45	799.65
	Non-AAS	785.00	287.00	872.00	739.00	824.32	392.00	1,186.00	727.00	986.17	1,280.00	865.00
	% difference	**-6.51**	**-1.53**	**-6.21**	**16.04**	**-23.33**	**-10.01**	**-5.19**	**-15.51**	**-6.96**	**-24.10**	**-8.17**
Machine Labour	AAS	1,689.00	2,015.21	1,148.00	819.41	979.02	1,200.00	640.36	953.00	343.41	1,378.46	1,249.97
	Non-AAS	1,730.00	2,055.00	1,181.00	890.73	1,212.83	1,249.00	735.00	1,100.00	367.30	1,683.69	1,300.00
	% difference	**-2.43**	**-1.97**	**-2.87**	**-8.70**	**-23.18**	**-4.08**	**-14.78**	**-15.42**	**-6.69**	**-22.14**	**-4.00**

Note: *AAS-Agromet Advisory Service
Sample size: AAS=60 and Non AAS=30

Cost incurred in cultivation of greengram by non AAS farmers was ` 7,250.00. Among the different variable costs, cost on insecticides was very less in case of AAS beneficiaries (` 250.00) compare to non AAS farmers (` 462.00). Followed by these beneficiary farmers were able to reduce cost on seed, fertilizers, manure and machine labour by 8.70 per cent. About 9.49 per cent of human labour cost was also reduced in cultivation of greengram by AAS beneficiary farmers. About 23.88 per cent reduction in cost of cultivation of bengalgram was observed in case of AAS beneficiaries. Among the different variable costs, cost on insecticides was ` 655.00 in AAS beneficiaries were as in case of non-AAS farmers it was ` 995.00. Reduction in cost incurred on seed, fertilizer, manure, animal labour and machine labour was 22.40 per cent, 23.88 per cent, 23.47 per cent, 23.33 per cent and 23.18 per cent respectively by AAS beneficiaries.

In case of soybean crop cost of cultivation was ` 7,757.00 in case of AAS beneficiaries and ` 9,650.00 in case of non AAS farmers. Among the different variables costs, more cost difference among AAS and non AAS farmers was observed in case of insecticide (-84.44 %) followed by human labour (-25.16 %) and manure (-24.41 %). Least cost difference was observed in case of seed (-2.60 %) followed by machine labour (-4.08 %) and animal labour (-10.01 %). More cost difference in cultivation of groundnut was observed in case of insecticides (-38.52 %). AAS beneficiaries were able to incur ` 283.00 on insecticides whereas non AAS farmers were spent ` 392.00. Cost incurred in cultivation of groundnut was ` 10,694.00 by AAS beneficiaries and ` 12,100.00 by non AAS farmers. Groundnut cost of cultivation differences was observed to be 13.14 per cent. AAS beneficiaries were able to reduce the cultivation cost by 13.14 per cent than non AAS farmers. Cost incurred on manure (` 155.00) and machine labour (` 640.36) by AAS beneficiaries was less compare to non AAS farmers by 25.81 per cent and 14.78 per cent respectively.

AAS beneficiary farmers growing sunflower were able to incur cost of ` 5,044.00 whereas non AAS farmers incurred ` 5,750.00. Cost incurred on insecticides was ` 138.00 by AAS beneficiaries but AAS farmers (` 207.00) were able to incur 50 per cent more cost. More cost difference in cultivation of sunflower between AAS beneficiaries and non AAS farmers was observed in case of seed (17.10 %), animal labour (15.51 %), machine labour (15.42 %) and fertilizer (15.33 %). Cost difference in cultivation of safflower by AAS (` 5,236.00) beneficiaries and non AAS (` 5,600.00) farmers was 7 per cent. Least cost difference in cultivation of safflower was observed in case of human labour (6.04 %) followed by machine labour (6.69 %), seed (6.86 %), fertilizer (6.90 %) and animal labour (6.96 %). Cost of cultivation of cotton was ` 12,444.00 in case of AAS beneficiaries and ` 15,200.00 in non AAS farmers. About 83.99 per cent insecticide cost reduction was observed in case of AAS beneficiaries (` 404.92) compare to non AAS (` 745.00) farmers. Cost difference among AAS and non AAS famers was observed in case of seed (17.43 %) and human labour (19.22 %). In case of sugarcane crop AAS beneficiaries were incurred ` 20,500.00 whereas non AAS farmers spent 7.32 per cent more cost i.e ` 22,000.00. Insecticide cost was more in case of non AAS (` 345.00) farmers compare to AAS farmers (` 251.00).

4.5.4 Impact of AAS on cost and returns of selected crops

Cost incurred in cultivation of maize crop by AAS farmers was ` 8,667.67 whereas non AAS farmers incurred ` 9,360.00 Yield obtained by both the farmers was nearly same, but gross return obtained by the AAS (` 16,988.52) farmers was more compared to non AAS (` 16,064.00) farmers. Because of this BCR was more in case of AAS (1.96) farmers. BCR obtained by AAS and non AAS was 1.64 and 1.46 respectively in case of wheat. Cost involved in cultivation of wheat was ` 7,577.00 in case of AAS farmers whereas in non AAS farmers it was ` 7,734.00, more difference was found in case of gross returns (8.00 %) (Table 4.26). Cost incurred in cultivation of sorghum was ` 7,500.00 in case of non AAS farmers whereas in case of AAS beneficiaries it was ` 7,205.50. Yield difference was 12.57 per cent in case of sorghum among AAS and non AAS farmers. A gross return was more in case of AAS (` 14,295.00) beneficiaries compare to non AAS (12,787.50) farmers. Cost of cultivation and gross returns involved in cultivation of greengram was ` 6,669.44 and ` 16,162.22, respectively in case of AAS beneficiaries and ` 7,250.00 and ` 14,232.40 in case of non AAS farmers. The BCR was observed to be 2.42 and 1.96 in case of AAS and non AAS farmers respectively. AAS beneficiaries were incurred ` 7,426.47 in cultivation of bengalgram were as non AAS farmers spent ` 9,200.00. AAS farmers were able to get 1.13 per cent of less return compare to non AAS farmers. Net return obtained by AAS (` 8683.38) farmers was more compare to non AAS (` 6,552.32) farmers.

In case of soybean cultivation AAS farmers was incurred ` 7,756.82 but non AAS farmers incurred ` 9,650.00. Yield difference among AAS and non AAS farmers was 8.10 per cent in cultivation of soybean. BCR obtained by AAS (2.24) farmers was more compare to non AAS (1.70) farmers. AAS beneficiaries got 29.46 per cent more returns compare to non AAS farmers in case of soybean cultivation. In case of groundnut crop AAS (` 14,326.39) beneficiaries got 20.92 per cent more net returns compare to non AAS (` 11,330.00) farmers. Yield difference among the farmers was (6.36 %) was less compare to cost incurred in cultivation (13.14 %) of groundnut. BCR in cultivation of groundnut was 2.34 in case of AAS and 1.94 in case of non AAS farmers. Cost of cultivation of sunflower was ` 5,044.44 in case of AAS farmers were as it was ` 5,750.00 in case of non AAS farmers. Yield difference was 3.84 per cent between AAS and non AAS farmers. Net returns obtained by AAS (` 4,738.89) farmers was more compare to non AAS (` 3,637.49) farmers.

In case of safflower, cost incurred by AAS farmers was ` 5,235.71 whereas non AAS (` 5,600.00) farmers incurred 6.96 per cent more. Yield difference was 3.45 per cent between AAS and non AAS farmers. But returns obtained from safflower was more in case of non AAS (` 2,365.00) farmers compare to AAS (` 2,357.14) beneficiaries. BCR obtained by cultivating cotton crop was 2.26 in case of AAS beneficiaries were as in case of non AAS farmers it was 1.74. Cost incurred in cultivation of cotton was ` 12,444.44 by AAS beneficiaries and ` 15,200.00 by non AAS farmers. AAS farmers were able to get 28.44 per cent more net returns compare to non AAS farmers. AAS farmers cultivating sugarcane were able to get ` 41,883.33 but non AAS farmers got ` 37,757.50 net retuns. Yield difference was 3.01 between AAS and non AAS farmers. Cost involved in sugarcane cultivation was ` 20,500.00 in case of AAS farmers were as in case of non AAS farmers it was ` 22,000.00.

Table 4.26. Impact of Agromet Advisory Service (AAS) on cost and returns of major crops (Rs/acre) (n=90)

Crop		**Maize**	**Wheat**	**Sorghum**	**Greengram**	**Bengal gram**	**Soybean**	**Groundnut**	**Sunflower**	**Safflower**	**Cotton**	**Sugarcane**
Yield	AAS	13.70	4.12	6.86	2.80	4.02	5.39	7.06	4.06	4.14	7.24	30.06
	Non-AAS	13.10	3.89	6.00	2.38	3.89	4.95	6.60	3.90	4.00	6.85	29.15
	% Change	**4.41**	**5.65**	**12.57**	**15.08**	**3.25**	**8.10**	**6.46**	**3.84**	**3.45**	**5.44**	**3.01**
Rs/q	AAS	1,240.74	2,976.92	2,080.00	5,761.11	4,004.12	3,234.09	3,552.78	2,400.00	2,357.14	3,883.33	2,077.78
	Non-AAS	1,226.25	2,900.00	2,131.25	5,980.00	4,049.44	3,319.23	3,550.00	2,458.33	2,365.00	3,858.33	2,050.00
	% Change	**1.17**	**2.58**	**-2.46**	**-3.80**	**-1.13**	**-2.63**	**0.08**	**-2.43**	**-0.33**	**0.64**	**1.34**
Gross return	AAS	16,988.52	12,261.54	14,295.00	16,162.22	16,109.85	17,368.18	25,020.83	9,783.33	9,757.14	28,136.67	62,383.33
	Non-AAS	16,063.88	11,281.00	12,787.50	14,232.40	15,752.32	16,430.19	23,430.00	9,587.49	9,460.00	26,429.56	59,757.50
	% Change	**5.44**	**8.00**	**10.55**	**11.94**	**2.22**	**5.40**	**6.36**	**2.00**	**3.05**	**6.07**	**4.21**
Net return	AAS	8,321.85	4,684.54	7,089.50	9,492.78	8,683.38	9,611.36	14,326.39	4,738.89	4,521.43	15,692.22	41,883.33
	Non-AAS	6,703.88	3,523.00	5,287.50	6,982.40	6,552.32	6,780.19	11,330.00	3,637.49	3,860.00	11,229.56	37,757.50
	% Change	**19.44**	**24.79**	**25.42**	**26.45**	**24.54**	**29.46**	**20.92**	**23.24**	**14.63**	**28.44**	**9.85**
BCR	AAS	1.96	1.64	1.98	2.42	2.17	2.24	2.34	1.94	1.86	2.26	3.04
	Non-AAS	1.72	1.46	1.71	1.96	1.71	1.70	1.94	1.61	1.69	1.74	2.72

Note: *AAS- Agromet Advisory service
Sample size: AAS=60 and Non AAS=30

4.5.5 AAS technology dissemination pattern

As part of NICRA project AICRPAM was implemented Agromet Advisory Service to the farmers. AAS bulletin was provided to farmers from 2010. This technology dissemination process. During 2011, four members utilized agro-met advisory service. Number of farmers using agro-met advisory service increased over the year. During 2012, farmers getting AAS increased to six members similarly it was adopted by 14 members during 2013. During 2014 and 2015, 29 and seven members used agro-met advisory service respectively. Number of farmers using AAS was showed increasing trend over the year.

4.5.6 Ratings of agro-met advisory information by the farmers

Rating of AAS by the beneficiary farmers is presented in Table 4.27. Agromet Advisory Service (AAS) given to the farmers was excellent according to 21 per cent of the framers. Twenty eight per cent of the farmers rated AAS as very good source of information and 11 per cent of them rated as good source of information.

4.5.7 Suggestions for improvement in Agromet Advisory Service (AAS)

In order to overcome the drawbacks of AAS suggestions from farmers were asked. Results of the farmer’s feedback were presented in Table 4.28. About 58.33 per cent of the farmers stated that there is no need to increase the coverage of AAS but 41.67 per cent of the farmers were said that AAS coverage has to be increased means AAS bulletin must be provided to still more number of farmers. Usually Agro-met-Advisory bulletin was provided to the farmers twice in a week. But 28.33 per cent of the farmers suggested to increase its frequency and 71.67 per cent of the farmers said that there is no need to increase the frequency of AAS. Lead time is time between availability of forecast & taking action. If lead time is more farmers make use of this time to plan according to forecasts. So 76.67 per cent of the farmers suggested increasing the lead time of AAS. Agro-met advisory bulletin contain weather forecast for three days. About 85 per cent of the farmers suggested that forecast contained in agro-met advisory bulletin must be increased.

4.5.8 Rank of effective information dissemination media

Ranks given by the AAS beneficiaries for different information dissemination media is presented in Table 4.29. Farmers are getting weathers forecasts by different ways such as TV, News paper, Radio, Agro-met Advisory bulletin and mobile SMS. Ranks given by the farmers for different information dissemination media is presented in Table 4.29. Among different sources, 66.93 per cent of the farmers said that forecast information provided through mobile SMS was more accurate, specific and timely available. Followed by mobile SMS, agro-met advisory bulletin was ranked second (59.55 %) by the beneficiary farmers. Information given in news paper and TV/Radio were ranked third and fourth, respectively.

Table 4.27. Ratings of agro-met advisory information by the farmers of Belagavi district

(n=60)

Rating	Number of farmers
Excellent	21 (35.00)
Very good	28 (46.66)
Good	11 (18.33)
Satisfactory	0 (0.00)
Irrelevent	0 (0.00)

Note: Figures in parentheses indicate percentage to the total sample farmers

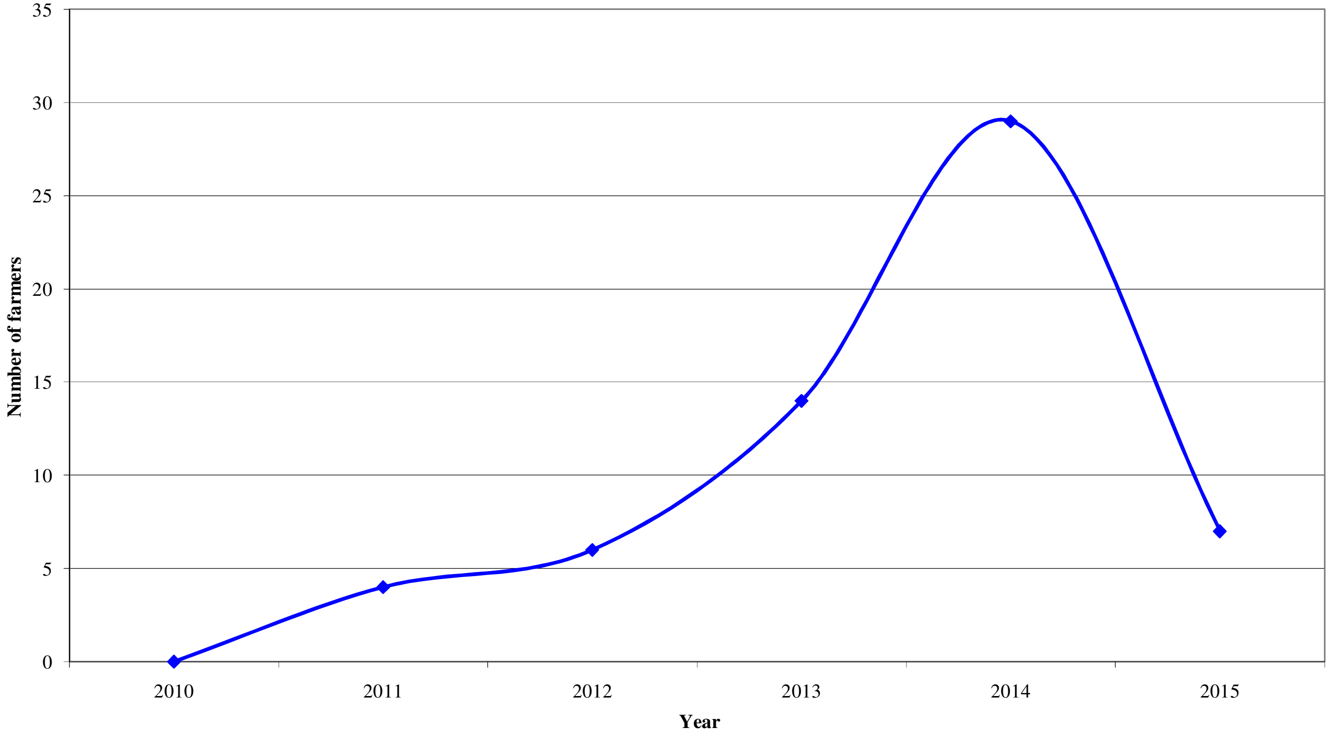

Fig. 9: AAS technology dissimination pattern

4.6 Impact of drought on agriculture in north Karnataka

Impacts of drought on crop yield and farmer's perception about drought and various administrative drought mitigating measures were documented and presented under following subheadings.

4.6.1 Socio-economic characters of sample farmers in drought affected area

Socio economic characters of farmers are presented in Table 4.30. Average age of the sample farmers was 44.89 years. Out of the total farmers surveyed, 38.75 per cent of them were had primary education followed by high school (35.00 %), college and above (16.25 %) and illiterate (10.00 %). Average family size was six. Out of them 50 per cent were male, 33.32 per cent were female and 16.68 per cent were children. Majority of the families was nuclear (83.75 per cent) and 16.25 per cent of them were having joint family. Average land holding of the farmers was 12.23 acre. About 37.50 per cent of the farmers was semi medium, followed by large (25.00 %), small (18.75 %), medium (16.25 %) and marginal (2.50 %). In each family on an average two members were involved in agriculture. About 87.50 per cent of them were having agriculture as main source of income and 46.25 per cent of them were depend on alternative source of income along with agriculture.

4.6.2 Farmer's perception of drought impacts in north Karnataka

Farmer's perception about drought in north-Karnataka is presented in Table 4.31. Among the total farmers surveyed in Belagavi and Vijayapura 68 of them opinioned that drought leads to drying of water resources. Drought leads to crop failure and increases the food prices as said by 76 and 66 sample farmers. About 13.75 per cent and 51.25 per cent of the sample farmers were said that drought leads to loss of livestock and decline in livestock prices.

In Vijayapura majority of the farmers opinioned that drought leads to crop failure (60.00 %), drying of water resources (56.67 %), increases the food prices (50.00 %), decrease in livestock prices (30.00 %) and makes surrounding dryer (20.00 %). In Belagavi district, 66.67 per cent of the farmers opinioned that drought leads to crop failure and it leads to increase in prices of food grains (60.00 %). Other impacts of drought in Belagavi district as opinioned by farmers are drying of water resource (56.67 %), prices of livestock were declined (38.33 %) and surrounding was dries (21.67 %).

4.6.3 Impact of drought on socio-economic characters of farmers

Various Likert type responses related to socio- economic impacts of drought perceived by farmers are fixed and farmer's opinion about them was documented and is presented in Table 4.32. About 97.50 per cent of the respondents have answered that drought cause's very high reduction in household income and it causes unemployment (86.25 %). About 37.50 per cent and 18.75 per cent of the respondents opinioned that population migration and conflicts for water in the society was very high due to drought. Nearly 54 % of respondents reported that due to drought there was medium (67.50 %) to less 31.25 %) reduction in their expenses on festival celebrations. About 60% of respondents reported high (40.00 %) to medium (60.00 %) food scarcity during the drought years as compared to the normal years and 26.25 per cent of respondents said that drought highly threatened their household food security. Approximately 71.25 per cent and 21.25 per cent of respondents agreed that they have medium to less food grain choices for their daily consumption.

Table 4.28. Suggestions for improvement in AAS (n=60)

Suggestions	Increase	Decrease	Not change
Coverage should	25 (41.67)	0 (0.00)	35 (58.33)
Frequency should	17 (28.33)	0 (0.00)	43 (71.67)
Lead time should	46 (76.67)	0 (0.00)	14 (23.33)
Length of forecast should	51 (85.00)	0 (0.00)	9 (15.00)

Note: Figure in the parentheses indicate percentage to the total

Table 4.29. Effective AAS information dissemination medias (n=60)

Sl. No.	Media	Score	Percentage	Rank
1	Electronic(TV/Radio)	1908	31.80	IV
2	New paper/magazine	2383	39.72	III
3	Agromet Advisory bulletin	3573	59.55	II
4	Forecast SMS	4016	66.93	I

Table 4.30. Socio-economic characters of sample farmers in drought affected area (n=80)

Sl. No.	Particulars	Average (in no.)	Percentage
1	Age (years)	44.89	
2	Education		
	Illiterate	8	10.00
	Primary	31	38.75
	High school	28	35.00
	college and above	13	16.25
			100.00
3	Family size	6	
	Male	3	50.00
	Female	2	33.32
	Children's	1	16.68
			100.00
4	Family type		
	Nuclear	67	83.75
	Joint	13	16.25
			100.00
5	Average land holding (acres)	12.23	
	Marginal	2 (2.20)	2.50
	Small	15 (3.82)	18.75
	Semi medium	30 (8.86)	37.50
	Medium	13 (13.70)	16.25
	Large	20 (32.58)	25.00
			100.00
6	No of family members involved in agriculture	2	
7	Agriculture as main source of income	70	87.5
8	Number of farmers depend on alternative sources of income	37	46.25

Note: Figures in parentheses indicate average land holding in acres

Table 4.31. Farmer's perception of drought impacts in North Karnataka

Drought impacts	Vijayapura (n=40)		Belagavi (n=40)		Total (n=80)	
	No. of farmers	%	No. of farmers	%	No. of farmers	%
Drying of water sources	34	56.67	34	56.67	68	85.00
Makes surrounding dryer	12	20.00	13	21.67	25	31.25
Famine	0	0.00	0	0.00	0	0.00
Crop failures	36	60.00	40	66.67	76	95.00
Loss of livestock	9	15.00	2	3.33	11	13.75
Poor health of humans/ malnutrition	1	1.67	0	0.00	1	1.25
Poor health of livestock	0	000	0	0.00	0	0.00
Increase in food prices	30	50.00	36	60.00	66	82.50
Decline in livestock prices	18	30.00	23	38.33	41	51.25

These economic impacts resulted into social, health and psychological impacts on farming livelihoods. It involved impacts such as inequities in the distribution of water or conflicts between water users, population migration and poor health. Table 4.32 shows that about 18.75 %, 37.50 % and 5.00 % respondents rated these impacts to high to a very high extent respectively. About 73.75 per cent, 71.25 per cent, 67.50 per cent, 63.75 per cent, 60.00 per cent and 48.75 per cent of the respondents answered that drought threatened household food security, caused no choice in food preferences, reduced in spending on festivals, affected schooling of children, caused food scarcity and affected on health to a medium extent.

4.6.4 Environmental impacts of drought in north Karnataka

Perception of farmers about impact of drought on environment is presented in Table 4.33. Drought had very high impact on some of the parameters such as declining in ground water level (85.00 %), created water scarcity (71.25 %), average temperature was increased (18.75 %) and degraded pasture (6.25 %). About 18.75 per cent and 57.50 per cent of the respondents said that drought had high and medium impact on forest degradation, respectively. Deterioration in water quality (55.00 %) was high due to drought as answered by respondents. Drought had medium impact on wild life and fish habitat (68.75 %) in the study area.

4.6.5 Drought preparedness measures adopted by farmers in north Karnataka

A drought preparedness measure adopted by farmers in north Karnataka is presented in Table 4.34. Majority of the farmers said in order to overcome the drought they search for alternative source of income (71.25 %) and store the crops for future consumption (70.00 %). Other alternative preparative measures adopted by farmers to overcome the negative impacts of drought are storing of crop residue for livestock (57.50 %), growing less water consuming crops (45.00 %), selling of some livestock’s (33.75 %) and migrated for alternative source of employment (11.25 %).

4.6.6 Impact of drought on crop yield

Impact of drought on crop yield is presented in Table 4.35. Average yield of the major crops during normal and drought years in Belagavi and Vijayapura districts are presented. During normal year farmers were able to get 4.39 q, 3.16 q, 3.18 q, 8.28 q, 4.89 q, 3 q, 3.89 q, 10 q, 9.85 q, 4.55 q and 4.62 q of sorghum, wheat, bajra, maize, tur, greengram, bengalgram, groundnut, cotton, sunflower and safflower, respectively in case of Vijayapura district. But during drought years yield levels of the crops was less. About 74.28 per cent less yield was obtained in case of bajra followed by 61.34 per cent reduction in tur yield. In case of Belagavi district, farmers were able to get 53.26 per cent reduction in sorghum yield. Farmers were able to get 15.52 q and 12.11 q of maize during normal and drought years in Belagavi district, respectively. The difference in yield level was 78.03 per cent in case of maize. Yield difference during drought and normal years in case of bengalgram was 70.57 per cent. During normal years farmers were able to get 3.98 q of bengalgram were as during drought years they got 2.81q. About 91.23 per cent reduction in yield level was observed in case of sugarcane. In case of groundnut and safflower farmers were able to get 73.21 per cent and 82.52 per cent less yield compare to normal years. Greengram yield during normal years was 3.36 q but due to drought farmers were able to get 69.42 per cent less yield. Similarly in case of wheat farmers were able to get 63.11 per cent less yield due to drought.

Table 4.32. Impact of drought on socio-economic characters of farmers

(n=80)

Impacts	Very high	High	Medium	Less	Very less
Drought threatened household food security	0 (0.00)	21 (26.25)	59 (73.75)	0 (0.00)	0 (0.00)
Drought has caused food scarcity	0 (0.00)	32 (40.00)	48 (60.00)	0 (0.00)	0 (0.00)
Drought caused no choice in food preferences	1 (1.25)	5 (6.25)	57 (71.25)	17 (21.25)	0 (0.00)
Drought caused malnutrition	0 (0.00)	3 (3.75)	31 (38.75)	46 (57.50)	0 (0.00)
Drought affected on health	4 (5.00)	0 (0.00)	39 (48.75)	37 (46.25)	0 (0.00)
Drought caused unemployment	69 (86.25)	9 (11.25)	2 (2.50)	0 (0.00)	0 (0.00)
Drought caused reduction in household income	78 (97.50)	2 (2.50)	0 (0.00)	0 (0.00)	0 (0.00)
Drought caused reduction in spending on festivals	0 (0.00)	1 (1.25)	54 (67.50)	25 (31.25)	0 (0.00)
Drought caused population migration	30 (37.50)	47 (58.75)	3 (3.75)	0 (0.00)	0 (0.00)
Drought affected schooling of children	0 (0.00)	4 (5.00)	51 (63.75)	25 (31.25)	0 (0.00)
Drought caused hopefulness and sense of loss	0 (0.00)	27 (33.75)	17 (21.25)	36 (45.00)	0 (0.00)
Drought caused conflict for water in society	15 (18.75)	49 (61.25)	16 (20.00)	0 (0.00)	0 (0.00)
Drought caused farmers suicide	0 (0.00)	4 (5.00)	28 (35.00)	48 (60.00)	0 (0.00)

Note: Figures in parentheses indicate percentage to the total

Table 4.33. Environmental impacts of drought in North Karnataka

(n=80)

Sl. No.	Environmental impacts	Very high	High	Medium	Less	Very less
1	Increase in average temp	15 (18.75)	45 (56.25)	20 (25.00)	0 (0.00)	0 (0.00)
2	Forest degradation	0 (0.00)	15 (18.75)	46 (57.50)	19 (23.75)	0 (0.00)
3	Pasture degradation	5 (6.25)	36 (45.00)	38 (47.50)	1 (1.25)	0 (0.00)
4	Water scarcity	57 (71.25)	23 (28.75)	0 (0.00)	0 (0.00)	0 (0.00)
5	Decline in ground water level	68 (85.00)	12 (15.00)	0 (0.00)	0 (0.00)	0 (0.00)
6	Deterioration in water quality	2 (2.50)	44 (55.00)	30 (37.50)	4 (5.00)	0 (0.00)
7	Damage to wild life and fish habitat	0 (0.00)	19 (23.75)	55 (68.75)	6 (7.50)	0 (0.00)

Note: Figures in parentheses indicate percentages to the total

4.6.7 Impact of drought on area sown and cost of sowing

Impacts of drought on area sown and cost of sowing is presented in Table 4.36. Average land holding in Vijayapura was 11.13 acres whereas; in case of Belagavi it was 13.32 acre. Average land holding in north Karnataka was 12.23 acre. During normal year farmers were able to cultivate 11.03 acre and 11.25 acre in Vijayapura and Belagavi respectively. But due to drought farmers were able to sow only 9.38 acre and 8.13 acre of area. Farmers were not able to sow 14.95 and 27.67 per cent of area in Vijayapura and Belagavi district, respectively due to drought.

Average cost of sowing was ` 4,250.00 and ` 3,437.00 in case of Vijayapura and Belagavi district, respectively. Due to drought farmers were carried out double sowing. About 31.66 per cent and 20 per cent of the respondents were able to carry double sowing in Vijayapura and Belagavi district. Cost of double sowing was ` 1,468.75 and ` 1,300.00 in case of Vijayapura and Belagavi district, respectively. Average cost of double sowing due to drought in north Karnataka was ` 1,384.37.

4.6.8 Impact of drought on livestock population

Drought impact on livestock is presented in Table 4.37. Due to drought 50 per cent of the bullock population was retained during drought year were as 50 per cent of the bullocks were sold by the farmers. During normal year average number of bullocks retained by the farmers was two but due to drought, in Vijayapura farmers retained the bullocks but in Belagavi farmers sold their bullocks. Average number of cows per household was one in Vijayapura and Belagavi districts during normal years but due to drought farmers sold all the cows. Average number of buffalo and goat during normal year in Vijayapura district was one and two respectively. Where as in case of Belagavi district average number of buffalo and goat was two and zero, respectively. Due to drought farmers sold goat in Vijayapura and buffalo in Belagavi. Farmers retained buffalo in Vijayapura even during drought situation.

4.6.9 Impact of drought on farm income

Variation in farm income due to drought is presented in Table 4.38. In case of Vijayapura during normal year farmers were able get income of ` 27,421.05 during normal year but due to drought income were reduced to the extent of 58.54 per cent. In case of Belagavi district farmers were getting income of ` 48,650.00 per acre and ` 30,450.00 during normal and drought year, respectively. Percentage reduction in income was 62.59. Per acre average reduction in income due to drought was 61.13 per cent in case of north-Karnataka.

Due to drought farmers were able to get more income from livestock. Average income from livestock during normal year was ` 3,397.22 whereas during drought year it was ` 4,000.00. Farmers were able to get 17.74 per cent more income from livestock farming during drought year in Vijayapura. In case of Belagavi district, farmers obtained income of ` 3,966.67 and ` 4,120.83 during normal and drought years respectively. Farmers were able to get 3.89 per cent more income from livestock during drought situation.

Table 4.34. Drought preparedness measures adopted by farmers in North Karnataka

(n=80)

Sl. No.	Preparedness activities	No. of farmers	Percentage
1	Do nothing	6	7.50
2	Store crop harvest	56	70.00
3	Store fodder for livestock	46	57.50
4	Save money	0	0.00
5	Migration for employment	9	11.25
6	Sell some livestock	27	33.75
7	Seek alternative source of income	57	71.25
8	Selecting less water consuming crops	36	45.00
9	Early sowing	0	0.00

Table 4.35. Impact of drought on crop yield (n=80)

(in quintals/acre)

Crops	Vijayapura (n=40)			Belagavi (n=40)		
	Normal year	Drought year	% change	Normal year	Drought year	% change
Sorghum	4.39	2.57	58.62*	6.57	3.50	53.26*
Wheat	3.16	1.70	53.68*	4.06	2.56	63.11*
Bajra	3.18	2.36	74.28*	-	-	-
Maize	8.28	2.85	34.48*	15.52	12.11	78.03*
Tur	4.89	3.00	61.34*	-	-	-
Greengram	3.00	1.75	58.33*	3.36	2.33	69.42*
Bengalgram	3.89	2.09	53.53*	3.98	2.81	70.57*
Soybean	-	-	-	4.19	2.95	70.45*
Groundnut	10.00	4.71	47.14*	10.50	7.68	73.21*
Cotton	9.85	3.00	30.43*	5.62	3.96	70.55*
Sunflower	4.55	1.78	39.02*	-	-	-
Safflower	4.63	2.31	50.00*	3.95	3.26	82.52*
Sugarcane (tones)	-	-	-	39.72	36.24	91.23*

Note: H_0: There was no difference in yield during normal and drought situation
H_1: There exist difference in yield during normal and drought situation
*Difference in yield due to drought was significant at 5 per cent as revealed by t teat so alternative hypothesis was accepted

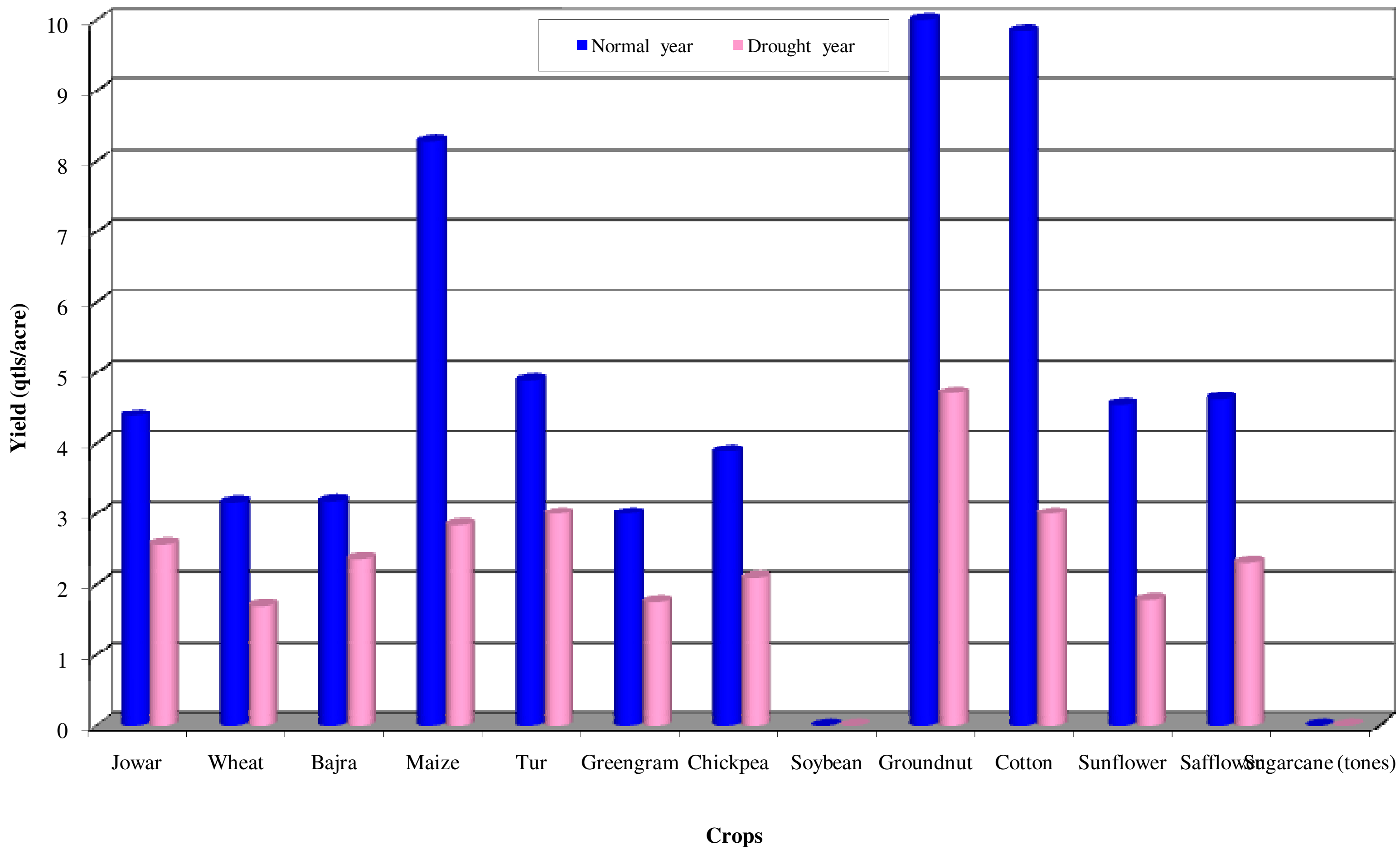

Fig. 10: Difference in yield due to drought in Vijayapur

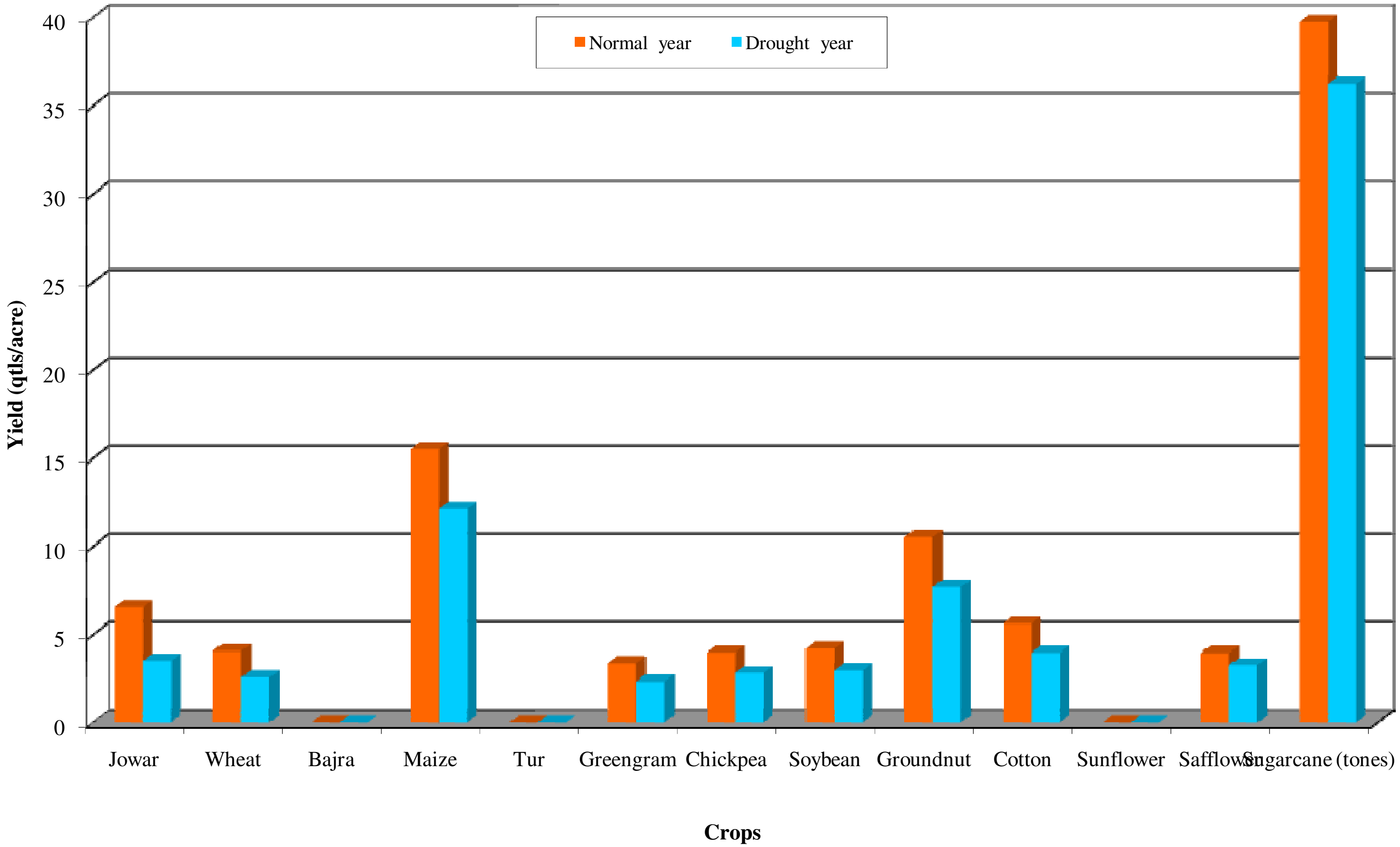

Fig. 11: Difference in yield due to drought in Belagavi

Table 4.36. Impact of drought on area sown and cost of sowing (n=80)

Area		Vijayapura	Belagavi	Average
Land holding(acre)		11.13	13.32	12.23
Area sown during normal year (acre)		11.03	11.25	11.15
Area sown during drought year (acre)		9.38	8.13	8.76
% Change in area sown		14.95	27.67	21.36
Average cost of sowing (in Rs/acre)		4250	3437	3843
No. of farmers underrating double sowing	Yes	19 (31.66)	12 (20.00)	15.5 (25.83)
	No	21 (35.00)	28 (46.66)	24.5 (40.83)
Cost of double sowing (in Rs/acre)		1,468.75	1,300.00	1,384.37

Note: Figures in parentheses indicate percentages

Table 4.37. Impact of drought on livestock population (in No.)

(n=80)

Sl. No.	Livestocks	Year	Vijayapura	Belagavi	Total
1	Bullock	Normal	2	2	4
		Drought	2	0	2
		% change	**100**	**0**	**50**
2	Cows	Normal	1	1	2
		Drought	0	0	0
		% change	**100**	**100**	**100**
3	Buffalos	Normal	1	2	3
		Drought	1	1	2
		% change	**100**	**50**	**67**
4	Goat	Normal	2	0	2
		Drought	1	0	1
		% change	**50**	**0**	**50**

Table 4.38. Impact of drought on farm income (in Rs.)

(n=80)

Sl. No.	Items	Area	Normal	Drought	% change
1	Agriculture income (Rs./ acre/year)	Vijayapura	27,421.05	16,052.63	-58.54*
		Belagavi	48,650.00	30,450.00	-62.59*
		Average	76,071.05	46,502.63	-61.13*
2	Average income from livestock per month	Vijayapura	3,397.22	4,000.00	+17.74**
		Belagavi	3,966.67	4,120.83	+3.89**
		Average	7,363.89	8,120.83	+10.28**

Note: H_0: There was no difference in farm income during normal and drought situation
H_1: There exist difference in farm income during normal and drought situation
*indicate significant difference in yield was observed during normal and drought year as revealed by z test so alternative hypothesis was accepted

H_0: There was no difference in income from livestock during normal and drought year
H_0: There exist difference in income from livestock during normal and drought year
** indicate that there was no any significant difference in income from livestock during normal and drought year so null hypothesis was accepted

4.6.10 Impact of administrative measures taken in drought affected area.

4.6.10.1 Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) for drought situation and farmers responses to it in north Karnataka

The government has undertaken various relief measures, which included provision of employment, supply of drinking water and distribution of fodder in cattle camps. In addition to this, the government has also provided agricultural loans with low interest rates, crop insurance schemes, and waived electricity bills depending on intensity of drought. These relief measures were undertaken to overcome the burden of drought on farmers.

As an administrative measure MGNREGA employment act was implemented to mitigate drought. Farmer's response to MGNREGA is presented in Table 4.39. About 83.75 per cent of the farmers were known about MGNREGA but 16.25 per cent were not known about MGNREGA. Out of the 67 farmers knowing about MGNREGA only 47.76 per cent of the farmers were asked for job in MGNREGA. Remaining 52.24 per cent constitute the farmers who knew about MGNREGA but not asked for job in it. Out of 32 farmers asked for job in MGNREGA, 28.13 per cent opinioned that, they were got sufficient job and 71.88 per cent said that they dint got sufficient job. Average wage for men and women in MGNREGA was ` 195.93 and ` 145.93 in case of Vijayapura but in Belagavi it was ` 204.41 and ` 156.76 respectively. Average wage for men and women was ` 200.17 and ` 151.34 in north Karnataka, respectively.

Satisfaction from MGNREGA was very less as answered by 5 per cent and 3.75 per cent of the farmers from Vijayapura and Belagavi district respectively. About 53.75 per cent of the respondent opinioned that they were less satisfied from MGNREGA programme in north Karnataka. Satisfaction level about MGNREGA was medium for 28.75 per cent of the respondents in north Karnataka. In case of Vijayapura and Belagavi district 3.75 per cent and 5 per cent of the respondents respectively opinioned that they are highly satisfied with MGNREGA programme.

4.6.10.2 Farmers opinion about crop insurance programme under drought situation in north-Karnataka

Crop insurance programme was implemented in those areas which were affected by drought. Impact of this programme and farmers perception about this programme is presented in Table 4.40. Out of the total farmers surveyed, about 71.25 per cent of the respondents were got crop insurance and 28.75 per cent were did not get crop insurance. Compensation amount was not sufficient as opinioned by 61.40 per cent and 26.32 per cent of farmers from Vijayapura and Belagavi district, respectively. But 12.28 per cent of the farmers were satisfied with insurance amount that they get. Average amount of insurance was ` 2,826.32 and ` 3,347.37 in case of Vijayapura and Belagavi district, respectively. Level of satisfaction derived from crop insurance was less (60.00 %) to very less (28.75 %) in case of north-Karnataka. Majority of the farmers from Vijayapura answered that insurance give was less (28.75 %) to very less (16.25 %) and they were not satisfied with it. Whereas in case of Belagavi district 31.25 per cent and 12.50 per cent of the farmers answered that their satisfaction level was less and very less respectively.

Table 4.39. Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) for drought situation and farmers responses to it in North Karnataka

(n=80)

Particulars	Opinion	Vijayapura	Belagavi	Total
Information	Yes	34 (42.50)	33 (41.25)	67 (83.75)
	No	6 (7.50)	7 (8.75)	13 (16.25)
				80(100.00)
Do you ask for job	Yes	15 (22.39)	17 (25.37)	32 (47.76)
	NO	19 (28.36)	16 (23.88)	35 (52.24)
				67(100.00)
Got sufficient job?	Yes	6 (18.75)	3 (9.38)	9 (28.13)
	NO	9 (28.13)	14 (43.75)	23 (71.88)
				32 (100.00)
Average wage (Rs/man day)	Men	195.93	204.41	200.17
	Women	145.93	156.76	151.34
Satisfaction level	Very high	0 (0.00)	0 (0.00)	0 (0.00)
	High	3 (3.75)	4 (5.00)	7 (8.75)
	Medium	10 (12.50)	13 (16.25)	23 (28.75)
	less	23 (28.75)	20 (25.00)	43 (53.75)
	Very less	4 (5.00)	3 (3.75)	7 (8.75)
				80 (100.00)

Note: Figures in parentheses indicate percentages

Table 4.40. Farmers opinion about crop insurance programme under drought situation in North-Karnataka

(n=80)

Particulars	Opinion	Vijayapura	Belagavi	Total
Do you got crop insurance	Yes	38 (47.50)	19 (23.75)	57 (71.25)
	No	2 (2.50)	21 (26.25)	23 (28.75)
				80 (100.00)
Did you got sufficient compensation	Yes	3 (5.26)	4 (7.02)	7 (12.28)
	NO	35 (61.40)	15 (26.32)	50 (87.71)
				57 (100.00)
How much was the compensation (Rs/ ha)		2,826.32	3,347.37	3,086.84
Level of satisfaction	Very high	0 (0.00)	0 (0.00)	0 (0.00)
	High	0 (0.00)	0 (0.00)	0 (0.00)
	Medium	4 (5.00)	5 (6.25)	9 (11.25)
	Less	23 (28.75)	25 (31.25)	48 (60.00)
	Very less	13 (16.25)	10 (12.50)	23 (28.75)

Note: Figures in parentheses indicate percentages

Table 4.41. Farmer's opinion about administrative drought mitigating measures

Drought mitigating measures	Satisfaction level	Belagavi (n=40)	%	Vijayapura (n=40)	%
Water supply tankers	Very high	0	0.00	0	0.00
	High	0	0.00	0	0.00
	Medium	2	5.00	0	0.00
	less	16	40.00	19	47.50
	Very less	22	55.00	21	52.50
Cattle camps	Very high	0	0.00	0	0.00
	High	0	0.00	0	0.00
	Medium	8	20.00	9	22.50
	less	13	32.50	14	35.00
	Very less	19	47.50	17	42.50

4.6.10.3 Farmer's opinion about cattle camps and water supply tankers

To overcome the negative impacts of drought, administrative measure were taken by the government such as supply of water through tankers and conducting of cattle camps. Farmer's opinion about such measures is presented in Table 4.41. Majority of the farmers from Belagavi opinioned that they were very less (55.00 %) satisfied with water supply tankers. In case of Vijayapura 52.50 per cent of the farmers were very less satisfied with water supply tankers followed by 47.50 per cent were less satisfied. In case of cattle camps, 47.50 per cent and 42.50 per cent of the farmers from Belagavi and Vijayapura were less satisfied. Satisfaction level was less for 32.50 per cent and 35.00 per cent of the farmers from Belagavi and Vijayapura district respectively.

4.6.11 Coping mechanisms adopted by the farmers to mitigate the impact of drought

Coping mechanism adopted by the farmers to mitigate drought is presented in Table 4.42. As a part of technical coping mechanism to overcome drought farmers were growing drought resistance varieties (80.00 %) followed by this they were practicing seed treatment (80.00 %), changing the cropping pattern (77.50 %) and soil organic matter enrichment using vermicompost (16.25 %). To overcome drought situation farmers use to borrow money from others (81.25 %) and they use to sell land and livestock's (55.00 %) these were some of the socio economic coping measured adopted by farmers. Shifting to other profession (62.50 %) and crop insurance (16.25 %) were the other socio economic measures adopted by farmers in study area.

4.7 Impact of hailstorm on agriculture in Vijayapura district

4.7.1 Impact of hailstorm on crop yield and returns

Heavy hailstorm was occurred during February and March 2014 in Indi taluk of Vijayapura district. Due to this heavy crop yield loss was occurred. It impacts on yield and returns of crop are presented in Table 4.43. A major crop observed in field during hailstorm incidence was Grape, Pomegranate, Banana, Lime, Onion, Tomato, Other vegetables, groundnut and maize. About 171.20 acre of grape, 106.40 acre of pomegranate, 51.20 acre of banana, 168 acre of lime, 108 acre of onion, 44.80 acre of tomato, 85.60 acres of other vegetables, 20.80 acre of groundnut and 8.80 acre of maize area was affected due hailstorm. Average cropped area affected was 9.56 acres. Normal yield obtained per acre of grape, pomegranate, banana, lime, onion, tomato, other vegetables, groundnut and maize are 6.88 tonnes, 4.45 tonnes 15.38 tonnes, 9.72 tons, 8.10 tonnes, 15.79 tonnes, 7.69 tonnes, 0.28 tonnes and 1.82 tonnes respectively. Due to hailstorm 5.18 tonnes of Grape, 3.95 tonnes of pomagranate, 14.13 tonnes of banana, 7.65 tonnes of lime, 6.23 tonnes of onion, 13.20 tonnes of tomato, 0.18 tonnes of groundnut, 0.63 tonnes of maize, 6.07 tonnes of other vegetables like ridgegourd, cucumber, brinjol and others were damaged. Average yield loss per farmer was due to hailstorm was 63.86 tonnes in that lime (16.07 tonnes) accounts for major loss followed by grape (11.09 tonnes), banana (9.04 tonnes), onion (8.41 tonnes), tomato (7.39 tonnes), other vegetables (6.49 tonnes), pomegranate (5.25 tonnes), maize (0.07 tonnes) and groundnut (0.05 tonnes).

Table 4.42. Coping mechanisms adopted by the farmers to mitigate the impact of drought (in no.) (n=80)

Coping mechanisms		Vijayapura (n=40)	Belagavi (n=40)	Total (n=80)
Technical coping mechanisms	Change cropping pattern	29	33	62 (77.50)
	Mixed farming	0	0	0 (0.00)
	Cultivating trees	0	0	0 (0.00)
	Soil organic matter enrichment	4	9	13 (16.25)
	Drought resistant crops	35	29	64 (80.00)
	Seed treatment	30	34	64 (80.00)
Socioeconomic coping mechanisms	Reduce consumption expenditure	0	0	0 (0.00)
	Shifting to other profession	27	23	50 (62.50)
	Borrowing	35	30	65 (81.25)
	Crop insurance	10	3	13 (16.25)
	Selling land and livestock	22	22	44 (55.00)

Note: Figures in parentheses indicate percentages

Table 4.43. Impact of hailstorm on crop yield and returns in Vijayapura district

(n=80)

Sl. No	Crops	Total cropped area affected in acre (n=80)	Average cropped area affected in acre	Normal yield /acre (tonnes)	Yield loss/acre (tonnes)	Total yield loss due to hailstorm (tonnes)	Average yield loss due to hailstorm (tonnes)/ha	Approximate Price (Rs/tone)	Total loss in lakhs	Average loss in Lakh/ha
1	Grapes	171.20	2.14	6.88	5.18	886.82	11.09	25,000.00	221.70	2.77
2	Pomegranate	106.40	1.33	4.45	3.95	420.28	5.25	78,000.00	327.82	4.10
3	Banana	51.20	0.64	15.38	14.13	723.46	9.04	11,000.00	79.58	0.99
4	Lime	168.00	2.10	9.72	7.65	1,285.20	16.07	13,000.00	167.08	2.09
5	Onion	108.00	1.35	8.10	6.23	672.84	8.41	10,000.00	67.28	0.84
6	Tomato	44.80	0.56	15.79	13.20	591.36	7.39	3,500.00	20.70	0.26
7	Other vegetables	85.60	1.07	7.69	6.07	519.59	6.49	4,500.00	23.38	0.29
8	Groundnut	20.80	0.26	0.28	0.18	3.74	0.05	60,000.00	2.25	0.03
9	Maize	8.80	0.11	1.82	0.63	5.54	0.07	13,000.00	0.72	0.01
		764.80	**9.56**			**5,108.83**	**63.86**		**910.51**	**11.38**

Table 4.44. Post harvest loss due to hailstorm in Vijayapura

(n=80)

Sl. No.	Crop	Average yield loss (q)	Rs/q	Average economic loss (Rs.)	Government support (Rs/q)	Average government support (Rs.)
1	Sorghum	3.00	2,100	6,300.00	1,800	5,400.00
2	Maize	10.00	1,400	14,000.00	1,310	13,100.00
3	Wheat	1.95	1,550	3,022.50	1,350	2,632.50
4	Bengal gram	2.10	4,800	10,080.00	3,150	6,615.00
5	Cotton	2.95	4,939	14,570.10	3,500	10,325.00
6	Safflower	2.16	3,565	7,700.40	2,200	4,752.00

Table 4.45. Average compensation received by farmers due to hailstorm in Vijayapura (in Rs/acre)

(n=80)

Sl. No.	Villages	Perennial input subsidy	Annual input subsidy	Total input subsidy
1	Tadavalaga	20,400	0	20,400
2	Banagunki	11,800	8,160	19,960
3	Hireroogi	28,000	0	28,000
4	Salotagi	22,520	1,500	24,020
5	Bijapur	20,680	2,415	23,095

Average loss due to hailstorm was observed to be ` 11.38 lakhs/ha. In that pomegranate accounted to be highest followed by grape (` 2.77 lakhs/ha), lime (` 2.09 lakhs/ha), banana (` 0.99 lakhs/ha), onion (` 0.84 lakhs/ha), tomato (` 0.26 lakhs/ha), groundnut (` 0.03 lakhs/ha) and maize (` 0.01 lakhs/ha).

4.7.2 Post harvest loss due to hailstorm in Vijayapura

Post harvest loss due to hailstorm is presented in Table 4.44. Crops which were harvested but unprocessed were exist in farmer field are sorghum, maize, wheat, bengalgram, cotton and safflower. Average yield loss was observed to be more in maize (10 q) followed by sorghum (3 q), cotton (2.95 q), safflower (2.16 q) and wheat (1.95 q). Average economic loss was ` 6,300.00 in case of sorghum, ` 14,000.00 in case of maize, ` 3,022.50 in case of wheat, ` 10,080 in case of bengalgram, ` 14,570.10 in case of cotton and ` 7,700.40 in case of safflower. Average government assistance was ` 5,400.00, ` 13,100.00, ` 2,632.50, ` 6,615.00, ` 10,325.00 and ` 4,752.00 in case of sorghum, maize, wheat, bengalgram, cotton and safflower, respectively.

4.7.3 Average compensation received by the farmers due to hailstorm

In Vijayapura district due to hailstorm heavy crop loss was occurred. Average compensation received by the farmers was presented in Table 4.45. About ` 20,680.00 perennial input subsidy, ` 2,415.00 annual input subsidy and ` 23,095.00 total input subsidy was given to the farmers due to hailstorm. Highest total input subsidy was given in case of Hireroogi (` 28,000.00) followed by Salotagi (` 24,020.00), Tadavalaga (` 20,400.00) and Banagunki (` 19,960.00).

4.8 Vulnerability indices for the assessment of vulnerability of selected districts to climate change

In this section, the results of vulnerability indices for the selected districts of north Karnataka, for the five different periods *viz.*, 1990-91, 1995-96, 2000-01, 2005-06, 2010-11 and 2013-14 are presented.

Vulnerability is often reflected in the condition of the economic system as well as the socio-economic characteristics of the population living in the system. It is hypothesized to be a function of its exposure (to the external stressor causing vulnerability), sensitivity of the entity's outcome to the external stressor, and its adaptive capacity in overcoming the adverse impact of the stressor on its outcome. The vulnerability index, measured tried to capture a more comprehensive scale of vulnerability. This was done by including many indicators that served as proxies to look at different aspects of vulnerability. In other words, it was assumed that vulnerability could arise out of variety of factors. However, more specifically, four major sources of vulnerability were taken into consideration. These included the demographic factors, climatic factors, agricultural factors and occupational factors.

Table 4.46. Component-wise contributions to the overall vulnerability to climate change (%)

Year	Districts	Belagavi	Vijayapura	Dharwad	Uttara Kannada	Bellary	Bidar	Kalaburagi	Raichur
1990-91	Demographic and economic	27.28	12.98	27.50	43.05	16.05	12.83	32.11	40.61
	Climatic	4.65	4.78	12.33	56.95	2.49	11.90	21.21	21.48
	Agriculture	65.88	55.12	36.63	0.00	43.53	44.71	46.29	30.14
	Occupational	2.19	27.13	23.54	0.00	37.93	30.56	0.39	7.77
		100.00	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
1995-96	Demographic and economic	34.20	14.06	33.02	42.33	18.3	14.05	38.04	43.00
	Climatic	4.17	4.76	12.54	47.04	1.14	10.95	24.28	20.59
	Agriculture	59.57	60.75	38.02	10.63	53.75	43.62	37.68	33.62
	Occupational	2.05	20.44	16.42	0.00	26.81	31.38	0.00	2.79
		100.00	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
2000-01	Demographic and economic	35.56	20.41	36.17	42.12	23.55	14.44	30.71	44.45
	Climatic	4.60	5.75	12.65	45.07	0.09	11.29	16.68	20.43
	Agriculture	57.95	44.48	21.53	12.81	44.78	43.95	52.62	29.39
	Occupational	1.88	29.36	29.64	0.00	31.59	30.32	0.00	5.74
		100.00	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
2005-06	Demographic and economic	37.18	17.82	29.29	36.80	24.03	14.18	29.91	45.43
	Climatic	4.08	4.19	11.60	40.05	3.08	11.01	17.36	21.45
	Agriculture	58.74	51.53	34.76	23.15	46.10	47.21	52.74	33.11
	Occupational	0.00	26.46	24.35	0.00	26.78	27.60	0.00	0.00
		100.00	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
2010-11	Demographic and economic	43.23	26.06	41.23	40.03	31.61	16.24	45.95	47.39
	Climatic	5.10	12.10	10.93	39.33	0.79	9.25	22.06	23.55
	Agriculture	51.67	60.17	32.62	20.64	55.59	44.65	30.50	29.06
	Occupational	0.00	1.67	15.22	0.00	12.01	29.87	1.48	0.00
		100.00	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
2012-13	Demographic and economic	51.53	40.21	40.87	54.14	42.85	28.18	53.81	53.74
	Climatic	6.75	9.37	9.14	27.66	0.99	12.93	17.80	16.43
	Agriculture	41.73	49.32	31.52	18.20	47.30	30.91	26.49	29.83
	Occupational	0.00	1.10	18.47	0.00	8.86	27.98	1.91	0.00
		100.00	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Table 4.47. Component–wise and overall vulnerability indices for the year 1990-91

Districts	Demographic and economic	Rank	Climatic	Rank	Agriculture	Rank	Occupational	Rank	Total	Rank
Belagavi	0.0939	5	0.0160	7	0.2268	3	0.0075	6	0.3443	5
Vijayapura	0.0542	8	0.0200	6	0.2303	2	0.1134	3	0.4179	2
Dharwad	0.1115	2	0.0500	5	0.1486	6	0.0955	4	0.4056	3
Uttara Kannada	0.1063	3	0.1407	1	0.0000	8	0.0000	8	0.2470	8
Bellary	0.0586	7	0.0091	8	0.1590	4	0.1385	2	0.3652	4
Bidar	0.0793	6	0.0736	2	0.2765	1	0.1890	1	0.6184	1
Kalaburagi	0.1053	4	0.0696	3	0.1519	5	0.0013	7	0.3281	6
Raichur	0.1263	1	0.0668	4	0.0937	7	0.0242	5	0.3109	7

It may be seen from Table 4.47 that out of the 8 districts, Bidar ranked first and the district of Vijayapura ranked second in the overall vulnerability to climate change therefore indices was found to be highest during 1990-91. This implies that the district of Bidar was the most vulnerable during 1990-91 periods. The agricultural and occupational sector played a significant role in ranking Bidar district at the first position by contributing to the tune 44.71 per cent, followed by occupational (30.56 %), demographic (12.83 %), and climatic factors (11.90 %). The districts namely Vijayapura and Dharwad ranked second and third, respectively with respect to the overall vulnerability to climate change. Agricultural (36.63 %) and demographic (27.50 %) sector were contributing to the vulnerability to climate change in Dharwad district where as in Vijayapura district, agriculture (55.12 %) and occupational (27.13 %) factors were alone contributing more that 75 per cent of vulnerability to climate change during 1990-91 (Table 4.47).

During 1995-96, the Bidar (0.6440) district ranked first in the overall vulnerability to climate change among all the districts followed by Bellary (0.5221), Vijayapura (0.4622) and Dharwad (0.4109). In Bidar district again agriculture (43.62 %) sector followed by occupational (31.38 %) factors were contributing to vulnerability due to climate change (Table 4.46). In case of Bellary district same factors were responsible for climate change as in 1990-91. The per cent share from agriculture and occupational factors was more compared to other factors responsible for vulnerability to climate change. Kalaburagi district (0.2890) was least vulnerable to climate change replacing Uttara Kannada (0.3115) district as before (Table 4.48).

Again Bidar retained its position as highly vulnerable district during 2000-01 (Table 4.49). Bidar was followed by Bellary (0.4056), Belagavi (0.3892) and Vijayapura (0.3860). Least vulnerable districts documented during 2000-01 are Uttara Kannada (0.2987), followed by Raichur (0.3128) and Dharwad (0.3613). Factors namely agriculture (43.95 %) and occupational factors (30.32 %) were contributing to the vulnerability to climate change in Bidar district as before, whereas in case of Belagavi district, agriculture (57.95 %) and demographic factors (35.56 %) were highly responsible for vulnerability. Factors responsible for least vulnerable to climate change in Uttara Kannada district are demographic (42.12 %) and climatic (45.07 %) parameters. Vulnerability indices during 2000-01 were varied between 0.2987 and 0.5904. Majority of the districts were fall under vulnerable category.

In 2005-06, the district of Bidar ranked first in the overall vulnerability to climate change amongst all the selected districts of north-Karnataka followed by, Dharwad, Vijayapura and Bellary district. It can be seen from the table that these three districts were therefore classified as vulnerable districts (Table 4.50). Agricultural and occupational indicators were the major factors contributing to the highest vulnerability of Bidar district with 47.21 per cent and 27.60 per cent contribution, respectively. The second rank of Dharwad district could be attributed mainly to the agricultural (34.76 %) and demographic (29.29 %) indicators. The district Raichur was the least vulnerable, followed by Uttara Kannada district and Kalaburagi district, respectively. Agricultural and demographic indicators played a predominant role for the ranking of Kalaburagi district at the last position. The values of vulnerability indices varied from 0.3038 (Raichur) to 0.6266 (Bidar) in 2005-06.

Table 4.48. Component–wise and overall vulnerability indices for the year 1995-96

Districts	Demographic and economic	Rank	Climatic	Rank	Agriculture	Rank	Occupational	Rank	Total	Rank
Belagavi	0.1385	2	0.0169	7	0.2412	4	0.0083	6	0.4049	5
Vijayapura	0.0650	8	0.0220	6	0.2808	2	0.0945	3	0.4622	3
Dharwad	0.1357	3	0.0515	5	0.1562	5	0.0675	4	0.4109	4
Uttara Kannada	0.1319	4	0.1465	1	0.0331	8	0.0000	7	0.3115	7
Bellary	0.0956	6	0.0059	8	0.2806	3	0.1400	2	0.5221	2
Bidar	0.0905	7	0.0705	2	0.2809	1	0.2021	1	0.6440	1
Kalaburagi	0.1100	5	0.0702	3	0.1089	7	0.0000	7	0.2890	8
Raichur	0.1448	1	0.0694	4	0.1132	6	0.0094	5	0.3368	6

Table 4.49. Component–wise and overall vulnerability indices for the year 2000-01

Districts	Demographic and economic	Rank	Climatic	Rank	Agriculture	Rank	Occupational	Rank	Total	Rank
Belagavi	0.1384	2	0.0179	7	0.2255	2	0.0073	6	0.3892	3
Vijayapura	0.0788	8	0.0222	6	0.1717	5	0.1133	3	0.3860	4
Dharwad	0.1307	3	0.0457	5	0.0778	7	0.1071	4	0.3613	6
Uttara Kannada	0.1258	4	0.1346	1	0.0382	8	0.0000	7	0.2987	8
Bellary	0.0955	6	0.0004	8	0.1816	4	0.1281	2	0.4056	2
Bidar	0.0853	7	0.0666	2	0.2595	1	0.1790	1	0.5904	1
Kalaburagi	0.1177	5	0.0639	3	0.2017	3	0.0000	7	0.3832	5
Raichur	0.1391	1	0.0639	4	0.0919	6	0.0179	5	0.3128	7

Table 4.50. Component–wise and overall vulnerability indices for the year 2005-06

Districts	Demographic and economic	Rank	Climatic	Rank	Agriculture	Rank	Occupational	Rank	Total	Rank
Belagavi	0.1431	1	0.0157	7	0.2261	2	0.0000	5	0.3849	5
Vijayapura	0.0767	8	0.0180	6	0.2219	3	0.1139	2	0.4306	3
Dharwad	0.1281	3	0.0507	5	0.1520	6	0.1065	3	0.4372	2
Uttara Kannada	0.1233	4	0.1342	1	0.0776	8	0.0000	5	0.3351	7
Bellary	0.0944	6	0.0121	8	0.1811	5	0.1052	4	0.3927	4
Bidar	0.0889	7	0.0690	2	0.2958	1	0.1729	1	0.6266	1
Kalaburagi	0.1128	5	0.0655	3	0.1990	4	0.0000	5	0.3773	6
Raichur	0.1380	2	0.0652	4	0.1006	7	0.0000	5	0.3038	8

Table 4.51. Component–wise and overall vulnerability indices for the year 2010-11

Districts	Demographic and economic	Rank	Climatic	Rank	Agriculture	Rank	Occupational	Rank	Total	Rank
Belagavi	0.1520	1	0.0179	7	0.1816	3	0.0000	6	0.3515	4
Vijayapura	0.0780	8	0.0362	6	0.1800	4	0.0050	4	0.2992	6
Dharwad	0.1515	2	0.0402	5	0.1198	5	0.0559	2	0.3674	2
Uttara Kannada	0.1278	4	0.1255	1	0.0659	8	0.0000	6	0.3192	5
Bellary	0.1126	6	0.0028	8	0.1981	2	0.0428	3	0.3563	3
Bidar	0.0928	7	0.0529	4	0.2553	1	0.1708	1	0.5719	1
Kalaburagi	0.1312	3	0.0630	3	0.0871	6	0.0042	5	0.2856	7
Raichur	0.1278	4	0.0635	2	0.0783	7	0.0000	6	0.2696	8

Table 4.52. Component–wise and overall vulnerability indices for the year 2013-14

Districts	Demographic and economic	Ranks	Climatic	Ranks	Agriculture	Ranks	Occupational	Ranks	Total	Ranks
Belagavi	0.1489	1	0.0195	7	0.1206	2	0.0000	6	0.2890	3
Vijayapura	0.0904	8	0.0211	6	0.1109	3	0.0025	5	0.2249	8
Dharwad	0.1299	3	0.0291	5	0.1002	5	0.0587	2	0.3178	2
Uttara Kannada	0.1254	5	0.0641	1	0.0422	8	0.0000	6	0.2317	7
Bellary	0.1116	6	0.0026	8	0.1231	1	0.0231	3	0.2603	4
Bidar	0.0965	7	0.0443	2	0.1058	4	0.0958	1	0.3423	1
Kalaburagi	0.1275	4	0.0422	4	0.0628	7	0.0045	4	0.2370	6
Raichur	0.1392	2	0.0425	3	0.0773	6	0.0000	6	0.2590	5

Table 4.53. Beta distribution of Vulnerability indices

Year	Less vulnerable	Moderately vulnerable	Vulnerable	Highly vulnerable	Very highly vulnerable
1990	0.292	0.355	0.416	0.491	1.000
1995	0.324	0.394	0.459	0.538	1.000
2000	0.320	0.370	0.417	0.475	1.000
2005	0.331	0.388	0.440	0.504	1.000
2010	0.279	0.332	0.382	0.445	1.000
2013	0.237	0.261	0.283	0.310	1.000

Table 4.54. Classification of districts under different degrees of vulnerability for the subsequent year

Year	Less vulnerable	Moderately vulnerable	Vulnerable	Highly vulnerable	Very highly vulnerable
1990	Uttara Kannada	Belagavi, Kalaburagi, Raichur	Bellary, Dharwad	Vijayapura	Bidar
1995	Uttara Kannada, Kalaburagi	Raichur	Belagavi, Dharwad	Bellary, Vijayapura	Bidar
2000	Uttara Kannada, Raichur	Dharwad	Belagavi, Bellary, Vijayapura, Kalaburagi	--	Bidar
2005	Raichur	Belagavi, Kalaburagi Uttara Kannada,	Bellary, Vijayapura, Dharwad	--	Bidar
2010	Raichur	Vijayapura, Kalaburagi, Uttara Kannada,	Belagavi, Bellary, Dharwad	--	Bidar
2013	Vijayapura, Kalaburagi, Uttara Kannada	Bellary, Raichur	--	Belagavi	Bidar, Dharwad

Component–wise and overall vulnerability indices during 2010-11 was presented in the Table 4.51. Vulnerability indices were varied between 0.2696 and 0.5719. Among the districts of north-Karnataka, again Bidar (0.5719) retained first place in vulnerability to climate change followed by Dharwad (0.3674), Bellary (0.3563) and Belagavi (0.3515). Raichur (0.2696), Kalaburagi (0.2856) and Vijayapura (0.2992) were less vulnerable to climate change. In case of highly vulnerable district like Bidar, agricultural (44.65 %) and occupational (29.87 %) factors were responsible for its vulnerability whereas in case of less vulnerable district like Raichur, demographic (47.39 %) and agricultural (29.06 %) factors were more contributing to the vulnerability to climate change.

In the year 2013-14, Bidar (0.3423) district continued to maintain its first position thereby being the most vulnerable district to climate change. Dharwad (0.3178) and Belagavi (0.2890) districts occupied second and third positions, respectively which could be attributed to the greater contribution of agricultural and demographic indicators responsible for vulnerability to climate change. Similarly, Vijayapura (0.2249) district ranked the last during this period thus, making it the least vulnerable district overtaking Uttara Kannada (0.2317) as before. In case of Vijayapura, agriculture (49.32 %) and demographic (40.21 %) factors were more responsible to make district as less vulnerable to climate change. During 2013-14, vulnerability indices were varied between 0.2249 to 0.3423.

Classification of districts under different degrees of vulnerability for the subsequent year is presented in Table 4.53 and 4.54. Using vulnerability indices by following beta distribution districts were categorized into less vulnerable, moderately vulnerable, vulnerable, highly vulnerable and very highly vulnerable. During 1990-91, Z_i values were as follows 0.2919, 0.3552, 0.4155, 0.4909 and 1. Uttara Kannada district was having vulnerability index of 0.2470 so it was classified as less vulnerable to climate change. Similarly Zi values for 1995-96 are 0.3243, 0.3943, 0.4591, 0.5376 and 1. Uttara Kannada (0.3115) and Bidar (0.6439) were less vulnerable and very highly vulnerable to climate change since. Zi values during 2000-01 are 0.3196, 0.3705, 0.4174, 0.4750 and 1. Uttara Kannada and Bidar itself were at the extremes of vulnerability gauge. For 2013-14, beta distribution for the Zi values was worked out and Zi values obtained are 0.237, 0.261, 0.283, 0.310 and 1. Using this Zi values each districts were categorized under different degree of vulnerability. Since Vijayapura, Kalaburagi and Uttara Kannada were having vulnerability index of 0.2249, 0.2370 and 0.2317 respectively so they were classified as less vulnerable districts. Bidar and Dharwad were having index of about 0.3423 and 0.3178 respectively which was more than 0.310 so they were classified as very highly vulnerable districts to climate change during 2013.

5. DISCUSSION

The findings of the study which are presented in the previous chapter are discussed in detail in this chapter. The main focus here is to throw a light on some of the causes responsible for the major trends observed in the findings. Keeping the objectives of the study in view the results are discussed under the following heads.

5.1 Time series analysis of rainfall in north Karnataka

5.2 Rainfall deviations in districts of north-Karnataka

5.3 Season-wise average maximum and minimum temperatures for the districts of north-Karnataka

5.4 Influence of weather parameters on crop yield in selected districts of north-Karnataka.

5.5 Economic benefits of weather based farming in improving farm productivity.

5.6 Impact of drought on agriculture in north Karnataka

5.7 Impact of hailstorm on agriculture in Vijayapura district

5.8 Vulnerability indices for the assessment of vulnerability of selected districts to climate change.

5.1 Time series analysis of rainfall in north-Karnataka

The analyzed results information concern to the rainfall in north-Karnataka is discussed under the following sub head.

5.1.1 Rainfall pattern in north-Karnataka

Pattern of rainfall trend was computed. Rainfall in north Karnataka was showing slight increasing trend but with, lot of variations from the year 1983-84 to 2013-14 (Table 4.1). It does not mean that, north-Karnataka had experienced more number of wet years. Some of the regions in north Karnataka namely Bagalkote, Vijayapura and Koppal did experience the drought years while in some places of north Karnataka, the rainfall was more than the normal (Uttara Kannada). Hence on an average the rainfall had showed an increasing trend in north Karnataka. Further, under the circumstance the rainfall in north Karnataka also indicated the cyclical movement (Between wet and dry years) with irregular cycles. From the study it was inferred that each cyclical movement was repeated after an interval of 6 to 7 year.

The seasonal indices of monthly rainfall (1983-84 to 2013-14) were indicated that, there was no rainfall during January and February months (Table 4.2). Thus, the rainfall in the study area started to recover from March and goes on increasing, the highest rainfall was observed during the month of July and later on it showed decreasing pattern. Thus for this type of rainfall pattern, the June month southwest monsoon winds were considered to be the significant in bringing 80.00 per cent of rainfall in many parts of the Karnataka state. In the later winter season (January to February), in the hot summer season (March and May) and in the post monsoon season remaining 20.00 per cent of the annual rainfall was received (KSDMA). Thus, in the region the irregular rainfall variation was observed. The highest variation was observed in 1988 (0.56) while, the lowest was during 1985 (0.51). These results were in line with results published in Anon. 2013. This type of variation in the rainfall in the north-Karnataka as well in India as a whole could be attributed to the irregular performance of monsoon in India which was greatly influenced by the deforestation would brought down precipitation and increased the temperature which led to drying of perennial water bodies like rivers and lakes. But to compensate there was no sufficient rainfall in areas where it was getting dryer. Hence, it had resulted in to drought in one area and flood in another.

Rainfall trend in all the districts of Undivided north-Karnataka was presented in Fig. 5. Over the period of years an increasing trend in rainfall was observed in case of Belagavi, Dharwad and Uttara Kannada districts. The reason for observing such rainfall trend in these districts could be attributed towards their existence in Transitional and the Hilly zones with greater amount of forest coverage. Similar trend was also observed in the study conducted by Kavita 2014. Whereas in case of Vijayapura, Bellary, Bidar, Kalaburagi and Raichur districts durig the period rainfall showed decreasing trend. These districts come under dry zone which receives least amount of rainfall as compared with Coastal, Hilly and Transitional zones of Karnataka. The less amount of rainfall in these districts could be due to lesser forest coverage (less than 2.00 per cent of total land) and existence of increased temperature condition in the regions.

5.1.2 Growth trend in rainfall in the districts of north-Karnataka

It could be inferred from the Table-4.3 that, over the years (1983-84 to 2013-14) there was too much fluctuation in rainfall in all the districts of north Karnataka. Further among the districts of north-karnataka, the rainfall showed decreasing trend particularly in Eastern districts namely Bellary, Bidar, Vijayapura, Kalaburagi and Raichur. It was observed that, the human activities are the primary driver for this kind of trend by adding CO_2 from fossil fuel combustion, cement manufacture and deforestation have disturbed the balance, adding CO_2 to the atmosphere faster than it can be taken up by the land biosphere and the oceans. On average over the last 50 years, about 25 per cent of total CO_2 emission was absorbed by the ovean making sea water more acidic and 30 per cent was taken up on land, largely by increased plant growth stimulated by rising atmospheric CO_2, increased nutrient availability, and responses to warming and rainfall changes. This declining trend in rainfall had varied impact on water resources indicating a need for greater emphasis to be laid on the water use efficiency, water harvesting, ground water recharge and incorporating climate change concern in designing and management of irrigation reservoirs (Jagadish *et al.,* 2012). The rainfall in Belagavi (2.04 %), Dharwad (0.11 %) and Uttara Kannada (0.53 %) showed an increasing trend in rainfall over the period (1983 to 2013). Among these north Karnataka districts, the variability in rainfall was more observed in Kalaburagi district. By this we can conclude that, the rainfall showed a decreasing trend with added fluctuations in most north eastern districts of north Karnataka. Hence, under the circumstance this rainfall parameter greatly affects the crop production and ultimately the food security in the state and livelihood security of the farmer of north-eastern districts of the state in particular. In view of this with the changing situation suitable intervention need to be provided to conserve water with efficient water use practices (Naveen Singh *et al.,*2014) coupled with change in cropping pattern with dry land agricultural practices for realizing sustainability in the food grain production.

5.2 Rainfall deviations in north-Karnataka

The effects of the rainfall deviation in the north Karnataka are illustrated in the following sub titles.

5.2.1 Percentage of deviation in actual rainfall from the normal for districts of north Karnataka

The actual annual rainfall (mm) and its deviations (per cent) from the normal (surplus/deficit) were computed for the districts of north-Karnataka for 31 years (1983-84 to 2013-14) and presented in the Table-4.5, Table-4.6 and Table-4.7. In case of Bidar district mean annual rainfall of 31 years was 852.1 mm. The relatively dry years during this period were 1984, 1986, 1991, 1992, 1994, 2002, 2003, 2004, 2007, 2008, 2011 and 2012 in which the negative deviations from the mean were noticed to the tune of more than 20 per cent. These observations were confirmed with results published in The Hindu on 8th August 2015 by anonymous. Out of the total period under study, 64.52 per cent of the years were experienced drought and only 35.48 per cent of the years were experienced positive deviation. Looking to the gravity of drought situation and to provide livelihood security to the residents of the district an alternative activity on industrial base for garments production was strengthened. Further, the Bidar administration had also work up the measures to mitigate the drought situation in the district by supplying water through tankers to the villages, where most of the water resources had dried up.

The years of 1985, 1989, 1990, 2001, 2002, 2003 and 2012 were observed to be relatively drier years in Dharwad district. These results were in line with results published in GIM 2012 (Anonymous 2012). Though this district comes under Transitional zone with the changed climate parameters the normal monsoon was affected. Because of scanty rainfall in Dharwad district the farm activities were affected. In the above said relatively drier years farmers had borrowed money and bought seeds and fertilizer expecting good rainfall. On the contrary due to the drought situation farmers of the district could not attend the sowing operation and extend their agricultural production activities with no crop production. As a result they were pushed in to difficult position.

Belagavi district recorded an average annual rainfall of 858.5 mm during the period. In this district relatively dry years were less (1985, 1986, 1989 and 1990) as compare to Bidar and Dharwad districts and the negative deviations from the mean were noticed to be more than 20 per cent in these years. On the contrary, for the observed relatively wet years were 2005, 2006, 2007 and 2008 in which the rainfall deviations from the mean were more than 30 per cent. These results agree with the results published in The Hindu 18th July 2008 (Anon. 2008). Since Belagavi district partially comes under Hilly and Transitional zones and part of the district as well fall under dry zone. Thus, some of the taluks namely Athani and Ramadurga declared drought affected areas since these taluks fall under Dry zone and experienced erratic and insufficient rainfall. As a result during 2003 these two taluks had experience the threat of drought and situation had forced the concerned authorities to supply water through tankers and to establish fodder bank cater the needs of the fodder requirement of livestock mentained by the farmers. On the other hand gravity of this problem was relatively observed less in the other parts of the Belagavi district where in the taluks had experience more than normal rainfall especially in the year 2008.

Bellary district recorded 571.9 mm average rainfall during the period of study. For this district, the driest year was 1995 with an average annual rainfall of only 324.0 mm. Over the period the highest negative deviation in districts rainfall was observed during the years 1995, 2002, 2003 and 2011. The year 1987 with an average annual rainfall of 778.5 mm resulted in the highest positive deviation (+ 20.14 per cent). Hence this year was reported as the wettest year in contrast the year 2011. Hence with the deficient and dry spell for more than 25 days drought in six out of seven talukas of Bellary district (excluding the irrigation tracts) were declared hit talukas during negative deviation in rainfall period. Consequently the impact of the drought had affected crops grown on 1.33 lakh hectares which were weathered and farmers had lost the crop yields to the tune of 50.00 per cent (Anon. 2009).

The mean annual rainfall of 31 years for Vijayapura district was 552.0 mm. The relatively dry years during this period were 2002, 2003, 2009, 2011and 2012. These results were in line with results published by Pradeepkumar Kadkol 2009. Due to the reoccurrence of these subsequent droughts more than 70 villages in the district did face acute shortage of drinking water. Looking to the ill effects of subsequent drought years to support the 2009 farming activities the district administrative supplies 2,500 tonnes of seeds and 8,000 tonnes of chemical fertilizer to farmers through 18 centers. With this effort farmers did complete sowing on 1.95 lakh hectares as against the target area of 3.9 lakh hectares. The set target could not be achieved due to the prevelance of 2009 drought. In comparison with district drought years, 1987, 1996 and 1998 were relatively considered as wet years in which the rainfall deviation from the mean was more than 20 per cent. However, during these years farmers were relaxed to some extent due to good harvests and able to recover some of the debts increased during drought year.

The mean annual rainfall of 31 years for Raichur district was 604.2 mm. The relatively dry years during this period were 2002, 2003, 2006, 2011 and 2012. On the other hand for the district the relatively wet years during the period were 1996 and 1998 in which the rainfall deviations from the mean were more than 30 per cent. From the facts and figure it was observed that, there were nearly equal numbers of positive and negative deviations. However, negative maximum deviation(more than -30 % deviations) were observed to be more compared to positive deviations. Such deviation pattern was due to the uneven distribution of rainfall as well as the consequent delay in the arrival of the southwest monsoon. As a result the critical stage of crops was badly affected and resulted in a decline in crop yield. Such influences were observed with major crops like paddy and sorghum which lead to decline in their respective yield levels under the years 2002 and 2003. Further, the crops such as bajra, maize yields was decreased in the year 2006 (Surthi and Mahammed Aslam, 2015). This clearly suggest for the selection of appropriate crop which can sustain the ill effects of climate change.

The mean annual rainfall for Kalaburagi district during the period was 745.9 mm. The relatively dry years with more than 50 per cent negative deviations from the mean rainfall were observed during the year 2002 and 2003. These two years were considered to be the severe drought years in the Kalaburagi district. These results were in line with result published in The Hindu news paper on 2003.As a result all seven taluks in Kalaburagi district were declared as drought-hit talukas. In these talukas rainfall deficit ranged from minimum of 65 per cent to maximum of 85 per cent in some of these taluks. Hence, this district experienced more number of negative deviation as compare to positive deviations. In view of this district with the subsequent negative rainfall deviations the district farmers were not able to under take the sowing which amounted to 60 per cent of the total agriculture area. On the contrary the year 1983 was observed as wettest year with an average annual rainfall of 1,425.9 mm. These both dry and wet years have grately affected the crop production activities in dry years (2002 and 2003) and brought standstill all agricultural activity. Looking to these climate changes the regular crop production was largely affected which in turn influenced the value chain of pulses in the district.

From these facts it was concluded that, incase of Vijayapura, Uttara Kannada, Bidar, Dharwad, Belagavi, Kalaburagi, Bellary, Bagalkote and Gadag districts negative deviation in Rainfall was more compare to positive deviations. With recurring deviation farmers of these districts had lost the confidence and interest in carrying out agriculture operations and inturn migrating to nearby cities towards seeking alternative sources of employment. On the other hand in case of Uttara Kannada district negative deviations in rainfall was more as compared to positive deviations. But distributions of negative deviations were near to the mean values. It was because of the reason that, Uttara Kannada district is one of the biggest districts with 8.28 hectares is forest land. Therefore during the study period it received steady rainfall over the year. Hence, farmers were depending more on agriculture and allied activities.

Results of the Run test revealed that the occurances of positive and negative deviations in rainfall are random in all the districts of north-Karnataka. The probability of occurance of more than normal rainfall and less than normal rainfall was ranging from 50 to 31 per cent. Numbers of runs are more in case of Bellary it indicates the variation from normal rainfall.

5.2.2 Driest and wettest years of north Karnataka during the period from 1983 to 2012

Driest and wettest years during the study period were documented in Table-4.8. Year 2003 was the driest year in case of Bagalkote, Vijayapura, Gadag, Kalaburagi and Koppala where as for Dharwad and Haveri, 2001 was the driest year. In case of Belagavi and Uttara Kannada districts, 1985 and 1986 were the driest years. Thus, the driest years influence in these district under respective years lead to decline in yield of different crops and livestock production. As a result farm employment declined which associated with decreased income of farmers which were the most immediate economic impacts of dryest year. On the contrary wettest year was 1998 in case of Bagalokot, Vijayapura, Raichur and Koppal. While 1996 and 1995 were the wettest years in case of Bellary and Bidar respectively.Under these years of good monsoons, farmers in the respective districts were tend to under take the production of high-income crops like paddy, cotton, soybean, pulses, maize, chilli and wheat from low-income crops like coarse cereals cultivation were limited to the marginal lands for taking the advantages of goodmonsoon. On the account of this, and greater amount of particular crop area coverage, over production of such crops lead to glut in the market prices of such crops which had further mounted the pressure on farmers due to non availability of storage facilities especially for storing the food grains. Hence, the management of dry and wet year bottle neck need to be understood by farmers as well line departments for their effective management in general.

But in north Karnataka droughts becoming more common compare to wet years. The northern regions of Karnataka comes under arid and semi arid regions, so more number of worst droughts the state has seen in the last 30 years, even some of the rain rich parts of the state have been declared drought-hit, as said by Srinivas Reddy, Director of Karnataka State National Disaster Monitoring Cell (KSNDMC). The perpetual aberrations observed with climate rythem in the north Karnataka in search of supplement a situation has be created among the farming community to shift from agricultural activities to non agricultural activities. Hence rural youth every day move out of their native villages to adjoining peri urban area in search of employment.

5.2.3 Range of positive and negative (> 50 per cent) deviation in rainfall values (mm) for selected districts of north-Karnataka

Range of positive and negative deviation in rainfall values are presented in Table-4.9. Highest average positive deviated rainfall was observed in case of Uttara Kannada which falls under Coastal Zone. Geographically this district has proximity to the Coastal Zone which receives rain from southwest monsoon and is distributed between June and September. Hence under the Uttara Kannada district the average positive deviation in rain was more observed followed by this, Belagavi, Haveri and Dharwad districts which fall under Northern Transition Zone. In similarity with Hilly zone during study period this zone received the rain from southwest. Immediately after receeds of south monsoon this zone also received northeast monsoons and distributed from May to November. However rainfall received in these districts was less as compared to Coastal Zone. Further, Bidar and part of Kalaburagi districts fall under North Eastern Transitional Zone. In this predominantly *kharif* crops growing zone, most of its rain received during June to September. This zone receives relatively less rainfall as compared to Northern Transitional Zone.

Based on the above said information it could be concluded that, the range between negative and positive deviations in rainfall was more in case of Uttara Kannada followed by Belagavi, Bidar, parts of Kalaburagi and Haveri. This was because of more extremities observed with respect to the associated climatic parameters related to Costal, Northern Transitional and North Eastern Transitional Zones. In contrary to this the least range was observed in case of Koppal followed by Dharwad, Bagalkote, Vijayapura and Raichur districts where in no such negative and positive deviation in rainfall were observed.

5.3 Season-wise average maximum and minimum temperatures (degrees centigrade) for the districts of north Karnataka

Discussion about season-wise average maximum and minimum temperatures (degrees centigrade) for the districts of north Karnataka are presented in Table-4.10. Average maximum temperature recorded during the period 1999-2000 to 2013-14 was more in case of Belagavi followed by Raichur, Kalaburagi, Gadag, Koppal and Bagalkote and least temperature was observed in Dharwad district. Under the well marked reasons the maximum summer temperature was observed in case of Kalaburagi followed by Bidar, Raichur and Vijayapura. The reason for maximum summer temperature in these three districts could be attributed to their existance in Northern Dry Zone where in the amount of rainfall received was least. Main reason for receiving least amount of rainfall could be attributed to the existence of negative correlation between temperature and rainfall. Hence, these three districts in the state experience more temperature and less rainfall. Further, the average maximum temperature during post monsoon was more in case of Raichur followed by part of Belagavi, Kalaburagi, Vijayapura and Bidar. In contrast to this average maximum temperature was least during post monsoon in case of Dharwad followed by Haveri, Bellary and Gadag.

5.4 Influence of weather parameters on major crop yield in selected districts of north-Karnataka

Impact of climate change on the productivity of the selected crops in various districts of north Karnataka were analysed using multiple regression function presented in Table 4.11 to 4.21 are discussed below.

In case of Belagavi district, the variations in the paddy (55.88 per cent), sorghum (80.02 per cent), maize (54.29 per cent), bengalgram (54.05 per cent), groundnut (37.20 per cent) and soybean (57.49 per cent) yields were explained by the variables such as actual rainfall, maximum temperature, minimum temperature, maximum relative humidity and minimum relative humidity. These observations were in line with results obtained by Chandrashekhar *et al.,* 2009. The positive impact of normal rainfall could be probably attributed to the good rainfall which supports the crop growth and critical stages of grain and pod filling in paddy, maize, sorghum, bengalgram, groundnut and soybean crops. In relative to this the yield levels of these crops were in tune of desired levels. On the other hand mean maximum temperature had affected the performance of maize crop during the study period and which was observed in the decline in maize crop yiield. These results were agreed with the results obtained by Deepa Hiremath (2010). Since, maize crop dose perform better under the humid climate and deviation in the mean maximum temperature would affect maize crop yield badly.

In case of Bagalkote it was found that, the variation in bajra yield (68.98 %) was explained by the selected explanatory variables, out of which, actual rainfall and maximum relative humidity had highly significant and positive impact on the yield. Thus bajra being the dryland crop if little water is available than it threws still well and give good retuns (Ajay Kumar and Pritee Sharma 2013).

In the district in case of sorghum, the variables pertaining to actual rainfall received during the crop growth stage had significant impact on the sorghum productivity. This result was in aggrement with the result obtained from Karthick *et al.,* (2013). Fom this it could be inferred that sorghum requires moderate rainfall (30 to 65 cm) and can be successfully grown as dry land crop. Further excessive moisture (above 100 cm) and prolonged droughts situation does harm the performance of the sorghum crop in the district. The average rainfall in the Bagalkote is approximately 318 mm annually. Thus it observed to be very much suitable for growing of sorghum

Other parameters of climate mentioned below significantly influence the yield of bengalgram in Bagalkote district. bengalgram, it grown well under *rabi* season good moisture with ideal temperature (24 ^{0}C to 30 ^{0}C) and desired relative humidity existed in Bagalkote district had significant impact on yield of bengalgram. In the district the negative impact of maximum and minimum relative humidity had greatly attributed for low productivity of sunflower. From these observations it could be said that in Bagalkote district under rainfall condition in relation to the climate sorghum and bengalgram cultivation is safe.

Climatic parameters influencing the performance of different crops under rainfed condition in Vijayapura indicated that, production of sorghum during the study period

The estimated coefficients of multiple regression function for bajra was significantly influenced by maximum (10.76) and minimum relative humidity (5.02). Output elasticities of actual rainfall (-0.11), maximum relative humidity (-3.47) and minimum temperature (-2.04) have indicated that the production of bajra was negatively influenced by these variables. Since bajra crop comes up well in warm weather and dry climate. If rainfall and relative humidity are more bajra seed does not germinate and grow well. Poor emergence and seedling growth may result if planted before soil temperatures reach 23 ^{0}C. It is more tolerant to higher temperatures rather than minimum temperature and rainfall. In this situation sorghum perform well with lesser average rainfall (35.0 to 85.0 mm). Thus the prevailing relative humidity and lesser quantity of average annual rainfall of Vijayapura district observed to be ideal for the cultivation of sorghum. The output elasticity of minimum temperature (13.07) and minimum relative humidity (5.02) had indicated that the production of sunflower was significantly and positively influenced by this variable. Thus sunflower thrives well in climates ranging from arid under irrigation to temperate under rainfed conditions with these climate parameters for the better performance minimum temperature and relative humidity were positively influenced in realizing better yield of sunflower.

From the above information for Vijayapura situation and prevailing climate parameters under rainfed condition cultivation of sorghum, bajra and sunflower would respond positively and resulting better yield with maximum risk.

In Dharwad district the coefficient of determination of climatic parameters for the crops like paddy, sorghum, maize, greengram, groundnut, soybean, wheat, bengalgram and cotton were observed to be more than 50 per cent and confirm on their contribution towards better performance of these crops. Further in Dharwad district actual rainfall had significant impact on Paddy yield, for which the monthly rainfall received during crop cultivation period was observed to be ideal. Hence Paddy had performed better during the study period. The weather parameters such as minimum temperature and actual rainfall were significantly influencing the sorghum yield in Dharwad district. Sorghum is best adapted to areas having an average annual rainfall of 45 to 65 cm so it threw well if actual rainfall of that region lies in this range. Similarly in case of maize, actual rainfall and minimum temperature were significantly influencing maize yield. maize is one of the most widely cultivated crop and grown in both tropical and warm temperate latitude. Water is more important for maize crop. In areas of lesser rainfall, the crop is irrigated. Long dry spells are harmful to maize and affect the yield levels. Groundnut and greengram were influenced by actual rainfall significantly at positive rate. Warm and moist conditions are very favorable for groundnut crop. Adequate and well distributed rainfall during the growing season, especially during flowering, pegging and pod formation stages, is essential for maximum yield and quality of groundnut. Therefore actual rainfall was significantly contributing to yield levels. Wheat, bengalgram and cotton were significantly influenced by maximum relative humidity. Wheat is crop of cool environment. So it was influenced by relative humidity.

The estimated coefficients of multiple regression function for sorghum, maize, greengram, bengalgram, groundnut, sunflower and cotton in Gadag is presented in Table 4.15. Rainfall was significantly contributed to the yield of these crops. Water is an important climatic factor. Through precipitation mainly rainfall, liquid water is made available to plants as surface water, soil moisture, or groundwater. Water affects or determines plant growth and development. Its availability, or scarcity, can mean a successful harvest, or diminution in yield, or total failure. Plants utilize most of the water absorbed from the soil for transpiration (95.00 %), but a small portion of the water absorbed is used during photosynthesis for producing the carbohydrates necessary for plant growth (5.00 %). Therefore rainfall had significant impact on crop yield. Minimum temperature was significant and negatively contributing to the yield of groundnut. Climatic conditions such as temperature and rainfall significantly influence the groundnut production. Warm and moist conditions are very favorable than cool and wet climate in case of groundnut. Temperature is a major environmental factor that determines the rate of crop development. Optimum mean daily temperature to grow is 30℃. If temperature exceeds it inhibit the growth of groundnut. Maximum and minimum temperature was significantly contributed to maize yield. Since maize usually grows well under temperatures varying from 21℃ to 27℃ excess or low temperature hinder the growth of this crop. In case of sunflower maximum and minimum relative humidity were significantly contributed to yield. Sunflowers thrive in warmer weather and climates. Sunflowers are full sun plants that only thrive in environments in which they are provided six or more hours of direct sunshine per day. Mean minimum, relative humidity occurs in the early afternoon. Low relative humidity in the afternoon is due to expansion of air and thus increases the total water vapour capacity it allow the sunlight and helps to get direct sunshine to crop.

The estimated coefficients of multiple regression function for Paddy in Haveri district is presented in Table 4.16. In case of Haveri district rainfall was significantly contributed to the yield of paddy, sorghum and cotton. These results were in line with results obtained by Kavita 2014. Since rainfall being the main source of water it helps in the process of photosynthesis by which plants prepare their food and help to improve the productivity of them. Therefore yield of these crops were highly influenced by rainfall in that region. The estimated coefficients of multiple regression function for Paddy in Uttara Kannada district is presented in Table 4.17. The output elasticities of actual rainfall (0.86), maximum temperature (3.88) and minimum relative humidity (3.98) were indicated that the production of Paddy was significantly influenced by these variables. These results were in line with results obtained from Suchandan Bemal *et al.,* 2009. Relative Humidity (RH) directly influences the water relations of plant and indirectly affects leaf growth, photosynthesis, pollination, occurrence of diseases and finally economic yield so minimum relative humidity helps to get good yield in case of Paddy. Paddy being a tropical and sub-tropical plant requires a fairly high temperature which influence on yield of Paddy directly.

Variation in yield of sorghum was explained by the selected explanatory variables, out of which, actual rainfall had a highly significant and positive impact on the yield in Bellary district (Table 4.18). Sorghum is best adapted to areas having an average annual rainfall between 45 to 65 cm. Sorghum can respond to good moisture supplies so it threw well if rainfall is good. So rainfall had positive impact on sorghum yield. Rainfall and maximum relative humidity were significantly contributed to the yield of maize. Maize crop is grown in climates ranging from temperate to tropic during the period when mean daily temperatures are above 15℃ and below 45℃. Crop tolerates hot and dry atmospheric conditions so long as sufficient water is available to the plant. So rainfall has significant impact on maize yield. Negative and significant impact of minimum temperature and minimum relative humidity on groundnut was observed. These results were in line with results obtained from (Vasanth Kumar *et al.,* 2015). Rainfall, maximum temperature and minimum relative humidity were had positive and significant impact on cotton yield in Bellary. Cotton is a warm season (tropical) crop. It can be profitably grown in regions with rainfall of 850.0-1,100.0 mm, but economic yields cannot be realized in the region with a rainfall less than 500.0 mm.

About 36.51 per cent of variation in sorghum yield, 38.98 per cent of variation in blackgram yield, 18.83 per cent of variation in greengram yield, 35.97 per cent variation in bengalgram yield, 43.49 per cent of variation in tur and 35.97 per cent of variation in soybean yield was explained by these variables under study in case of Bidar district (Table 4.19). In Kalaburagi district (Table 4.20), variations in the yield of sorghum, greengram, bengalgram, tur and sunflower was explained by the variables under study to the extent of 84.60 per cent, 49.56 per cent, 33.90 per cent, 27.18 per cent and 40.48 per cent, respectively. In case of sorghum crop, maximum temperature and minimum relative humidity were significantly contributing to the yield in Kalaburagi district (Sushil kaul and Ghasi ram 2009). Since sorghum crop requires rainfall of 40 cm. Economic yield was more if rainfall is good.

In Raichur district actual rainfall (0.35), maximum temperature (21.90) and maximum relative humidity (7.98) were significantly and positively contributing to the sunflower yield. Sunflower is mainly grown under rainfed conditions on a wide range of soils. Under erratic and low rainfall, a rather deep soil with good water holding capacity is required to get economic yield. Therefore rainfall had positive impact on sunflower growth and development. Minimum temperature (-20.12) and minimum relative humidity (-13.41) were contributing to the yield of sunflower negatively. Rainfall was significantly contributing to the yield of sorghum, bajra and bengalgram. These results were in line with results obtained from Pratap *et al.,* 2014. Water requirement of the crop depends on transpiration rate. A plant with greater total leaf area will transpire more water compared to one having less. In case of bajra and sorghum because of more leaf area transpiration is more and mean while they need rainfall to get good yield.

5.5 Economic benefits of weather based farming in improving farm productivity

Agro-meteorological service is an innovative step to contribute to weather forecast along with advisory on crop/livestock management strategies and operations dedicated to enhancing crop production by providing real time crop and location specific Agro-met Advisory Services (AAS) with outreach to village level. Economic importance and farmers opinion about AAS is presented under following sub headings.

5.5.1 Season-wise usability of rainfall forecasts in study area

Impact of Agro-met Advisory Service (AAS) was presented in Table 4.22. Out of total beneficiaries 88.33 per cent of them were using the agromet forecast and advisory service throughout the year because farmers were growing crops in all seasons in study area. Followed by this 65 per cent of farmers were using AAS during pre-monsoon season. Results obtained from Manjappa and Yeledalli in year 2013 was in line with these results. During pre-monsoon season there was no guarantee about rains which is most important for carrying agricultural operations. Therefore farmers were using AAS and forecasts to plan their agricultural operations according to the meteorological conditions. If forecast was such that, there will be no rains, than they would not carry out agriculture operations which helps to reduce the unnecessary cost incurred by the farmers. About 26.66 per cent and 15 per cent of the farmers were using forecast during monsoon and post monsoon season only. Since some of the farmers were rainfed, they carry out agriculture only during monsoon and post monsoon seasons. They left their land fallow during summer and not using AAS during such condition.

5.5.2 Operation wise usability of AAS by the beneficiary farmers

Operation wise usability of AAS is presented in Table 4.23. Majority of the farmers were using the AAS during spraying operation (78.33 %). If the forecast is that there will be rainfall in next two days. Looking to that farmer can carry spraying early or else they can spray after two days. This helped farmers to reduce the cost of chemical and labour involved in that operation. About 73 per cent of the respondents were using the AAS for harvesting and drying operations. After incurring so much of cost and efforts farmers get good produce. If it rains, while drying the produce than it leads to loss of produce. Farmer's may not get good price for their produce due to loss of quality. To prevent such loss farmers were using the forecast during the drying process. In order to reduce the loss of water, seed and fertilizers farmers were using advisory service during irrigation (66.67 %), sowing (43.33 %) and fertilizer application (13.33 %). If farmers carried sowing than if it not rained properly, it may leads to poor germination and reduction in the yield. Similarly if farmers applied fertilizers thinking that it is cloudy it will rain. If farmers guess goes wrong than fertilizers effect will not be observed instead it may give heating effect to plants and plants may get burn.

5.5.3 Input utilization pattern by AAS beneficiaries and Non-AAS farmers

Results of per acre input utilization by AAS and non-AAS farmers presented in Table 4.25 are discussed here. Among the different costs incurred in cultivation of maize, cost on insecticides (` 193.00) and human labour (` 3,297.00) was less in AAS beneficiaries compare to non-AAS farmers (Table 4.24). In case of maize farmers were using the AAS mainly for spraying purpose. AAS farmers using forecast were able to carry out spraying based on forecast. This leads to reduction in unnecessary cost incurred on chemical and labour used in spraying. Cost difference in cultivation of wheat and sorghum by AAS beneficiaries and non-AAS farmers was 2 per cent and 4 per cent, respectively. These results were in line with results obtained by Rathore *et al.,* 2004. Farmers were using AAS mainly during spaying purpose since farmers were not carrying spraying in case of wheat and sorghum cultivation cost difference was observed between AAS and non-AAS farmers was least. Among the different input, cost incurred on fertilizer (` 1,170.73), human labour (` 3,158.98) and machine labour (` 2,015.21) was less in case of AAS beneficiaries compare to non-AAS farmers growing wheat. Farmers were using AAS during fertilizer application in case of wheat so cost difference was observed to be more in case of fertilizer compare to other operations.

About 24 per cent reduction in cost of cultivation of bengalgram was observed in case of AAS beneficiaries. In case of soybean crop cost of cultivation was less in case of AAS beneficiaries compare to non AAS farmers. Cost of cultivation of cotton was less (` 12,444.00) in case of AAS beneficiaries compare to (` 15,200.00) non AAS farmers. These results were in line with results obtained by Parvinder and Rathore 2011. In soybean, bengalgram and cotton crops cost difference between AAS and non AAS was 24.41 per cent, 23.88 per cent and 22.14 per cent. This difference was mainly due to insecticide cost. Bengalgram crops are susceptible to pest attack namely helicoverpa. Cotton is susceptible to a wide range of insect pests. Among the most destructive are the cotton bollworm, plant bugs, stink bugs, aphids, thrips and spider mites. Soybeans have as many insect pests associated with them such as beetles, foliage feeders and caterpillars. Therefore all these crops require more amounts of insecticides application. Insecticides were applied two to three times so farmers were using forecast to plan spraying operation. This help to reduce the insecticides cost and labour involved in carrying the spraying operation.

Least cost difference in bengalgram, wheat and sorghum was observed in case of seed. Because these are the *rabi* crops which were grown on residual moisture. Either AAS or non AAS farmers were following sowing without expecting any rain and without seeing the advisory. Therefore seed cost difference was same in case of these crops (Ananta Vashisth *et al.,* 2013). In case of sunflower and safflower cost difference was 13.99 per cent and 6.96 per cent, respectively. Among different costs between AAS and non AAS farmers, human labour cost was least and insecticides cost was more (Rathore and Parvinder 2008). It was mainly because of caterpillar and pod borer. In majority of the crops cost difference between AAS and non AAS was seen in case of insecticides. This was because of the reason that, farmers were using forecast to plan the spraying operations. In case if it was forecasted as there is rainfall than farmers carry spraying before or else after the forecast period. Otherwise chemical get washed away and pest were not controlled. This would help them to reduce the cost of spray and labour involved in spraying. Therefore spraying cost difference was more in case of bengalgram, greengram, cotton, soybean, sunflower and safflower since those crops which need more amount of sprays.

5.5.4 Impact of AAS on cost and returns of selected crops

Difference in cost and returns among AAS and non AAS farmers is presented in Table 4.26 are discussed here. Cost difference was observed to be more in case of soybean followed by bengalgram, cotton and groundnut. Because of using AAS farmers were able to plan their agricultural operations preferably spraying, draying of produce, harvesting and weeding. Because of planned spraying they were able to control pests and able to get good quality produce. Along with that farmers were able to get reduce the wastage of cost incurred on inputs. This was reflected in returns form. Even though the difference in returns obtained by AAS and non AAS farmers was marginal but cost reduction was observed to be more due to use of AAS. In case of sorghum, geengram, sunflower and safflower non AAS farmers were able to get more returns compare to AAS beneficiaries. This was because of the reason that they had used good quality seed, frequent irrigations and good management practices. But cost incurred by non AAS farmers in cultivation of these crops was observed to be surpassing difference existed in returns. Therefore Benefit Cost Ratio (BCR) was observed to be more in case of AAS farmers.

In case of maize and wheat cost difference was observed to be 8 per cent and 3.54 per cent, respectively between AAS and non AAS farmers. Results obtained by Singh and Amod Kumar 2013 are in line with these results. AAS farmers were able to incur less cost compare to non AAS farmers. From above table it was known that cost difference between AAS and non AAS farmers was mainly due to spraying. Farmers opinioned that maize requires maximum of one spray only in case of severe pest attach and wheat need not require any spraying in the study area. So farmers were not following spraying in case of these crops. Therefore cost difference in this crop between AAS and non AAS farmers was less (Rao and Bapuji 2013). Kushwha et al. (2010) reported that in Tarai and Bhabar agro climatic zone of Uttarkhand, the AAS farmers have harvested 3.5 to 6.1 % more yield of wheat and 5.5 to 9.8 % more yield of paddy than non AAS farmers during four *rabi* seasons of 2004-08.Farmers were rarely using AAS in case of sugarcane. Therefore its cost difference was observed to be less between AAS and non AAS farmers.

5.5.5 AAS technology dissemination pattern

AAS bulletin was provided to farmers since 2010. Number of farmers using AAS was showed increasing trend over the year. This was mainly because of usefulness of this technology in this changing climatic situation. It was because of horizontal dissemination of technology among the farm innovators. It is known that a technology disseminate only if farmers were getting benefits out of it either in the farm of increase in income or in the form of reduction in cost. Since, this technology disseminated to more number of farmers over the years it indicate that it is very economic to adopt.

5.5.6 Ratings of agro-met advisory information by the farmers

Rating of AAS by the beneficiary farmers is presented in Table 4.27. AAS was excellent according to 21 per cent of the framers. Twenty eight per cent of the farmers rated AAS as very good source of information and 11 per cent of them rated as good source of information. Farmers appreciated weather based agro advisory service since it gives accurate information so farmers utilized the advise in scheduling agricultural operation. These results were in line with results obtained for Manjappa and Yeledalli 2013.

5.5.7 Suggestions for improvement in Agromet Advisory Service (AAS)

In order to overcome the drawbacks of AAS suggestions from farmers were documented and presented in Table 4.28. About 58.33 per cent of the farmers stated that there is no need to increase the coverage of AAS but 41.67 per cent of the farmers were said that AAS coverage has to be increased. Since AAS was given only to 15 to 20 farmers in each village. So this service must be made available to still more number of farmers. So that everyone can get benefit out of it. According to 58.33 per cent of the farmers, if one get AAS than he will share it with interested farmers. So there is no need to give this service to each and every farmers in the village. About 28.33 per cent of the farmers suggested to increase its frequency and 71.67 per cent of the farmers said that there is no need to increase the frequency of AAS. AAS was given twice a week. This was convenient for them.

No need to increase its frequency. Lead time is time between availability of forecast & taking action. If lead time is more farmers make use of this time to plan according to forecasts. So 76.67 per cent of the farmers suggested increasing the lead time of AAS.

5.5.8 Effective AAS information dissemination media

Ranks given by the farmers for different information dissemination media is presented in Table 4.29. Farmers said that forecast information provided through mobile SMS was more accurate, specific and timely available. Since farmers were keeping mobile with them all the time it was helping them to see the message immediately and take the actions as required. Forecast information was available on TV also. But they were not able to watch TV programmes because of power problem and inconvenience. Most of the farmers were not buying news papers because of illiteracy even though it is economical. So forecast printed in news papers or magazines were ranked third by the farmers.

5.6 Impact of drought on agriculture in north Karnataka

Drought is considered as one of the biggest menace to agriculture among all weather related crises. Agricultural drought occurs when soil moisture and rainfall are inadequate during the growing season to support healthy crop growth to maturity and causes crop stress and wilting. Some of such impacts of drought on agriculture are discussed under following sub headings.

5.6.1 Socio-economic characters of sample farmers in drought affected area

Socio economic characters of farmers are presented in Table 4.30. Average age of the sample farmers was 44.89 years. Majority of the farmers were having primary education followed by high school. Education level had a important implication on technology adoption and its usage. Successful adoption of modem technology is a function of various factors such as knowledge, skill, finance and other factors. Hence educational qualification is a key factor in the process of production. Farmers in study area are educated and they can seek alternative source of income during drought situation. Another socio-economic indicator deciding agriculture production and technology usage was education and size of land holding. Majority of the families in the study area were nuclear (83.75 %) followed by joint family (16.25 %). Farm size was significantly related with adoption of farm innovations. Majority of the farmers in the study area was semi medium (2 to 4 ha). It was advocated critical minimum size for the successful adoption of improved practices. It was reported by that medium to large farmers encouraged the use of improved practices. Small farmers are showing interest in using modern inputs. According to them if adequate working capital is made availat.31e to these farms, they have the potential for increasing the production by using modem inputs. Majority of the farmers were having agriculture (87.50 %) as main source of income and nearly half (46.25 %) of them were depend on alternative source of income along with agriculture. It was indicated that if the farmers were having alternative sources of income it help them to overcome the risks from drought, flood, hailstorm *etc* to some extent.

5.6.2 Farmer's perception of drought impacts in north Karnataka

Among the total farmers surveyed in Belagavi and Vijayapura districts, majority of them opinioned that drought leads to drying of water resources followed by crop failure, increase in food prices and loss of livestock. These results were in line with results obtained from Abul Hasnat *et al.,*

2014. Drought produces a complex web of impacts that spans many sectors of the economy and reaches well beyond the area experiencing physical drought. This complexity exists because water is integral to society's ability to produce goods and provide services. The most immediate consequence of drought is a fall in crop production, due to inadequate and poorly distributed rainfall. Farmers are faced with harvests that are too small to feed their families and fulfill their other commitments. Livestock sales act as a buffer in times of hardship, farmers disinvesting in these assets to buy food (Rishikesh B. D.,2015).

5.6.3 Impact of drought on socio-economic characters of farmers

Impact of drought on socio-economic characters of farmers is presented in Table 4.32. Drought had very high impact on employment and income level. Drought leads to population migration and conflict for water in the society. Because of this many people were flee a drought-stricken area in search of a new home with a better supply of water, enough food, and without the disease and conflict that were present in the place they are leaving (Abul Hasnat *et al.,* 2014). Medium impacts of droughts are threatening of household food security, food scarcity, no choice in food preferences, and reduction in spending on festivals and affected schooling of children. These results were in line with results obtained from Parmeshwar *et al.,* 2014. They were discussed that drought impacts are commonly referred to as direct and indirect. Many economic impacts occur in agriculture and related sectors are the direct impacts of drought. This is because of the reliance of these sectors on surface and groundwater supplies. In addition to losses in yields in both crop and livestock production, income loss is another indicator used in assessing the impacts of drought. Reduced income for farmers has a ripple effect. Due to drought prices for food, energy, and other products increase as supplies are reduced. In some cases, local shortages of certain goods result in importing these goods from outside the drought-stricken region.

5.6.4 Environmental impacts of drought in north Karnataka

Drought had very high impact on some of the parameters such as declining in ground water level, created water scarcity, increased average temperature and degraded pasture. Drought had medium impact on wild life and fish habitat (68.75 %) in the study area. In addition to the economy, drought also affects the environment and society. Wildlife habitat, for example, may be degraded through the loss of wetlands, lakes, and vegetation. However, many species eventually recover from this temporary aberration. The degradation of landscape quality, including increased soil erosion, may lead to a more permanent loss of biological productivity.

5.6.5 Drought preparedness measures adopted by farmers in north Karnataka

Majority of the farmers said that in order to overcome the drought they search for alternative source of income and store the crops for future consumption. These preparedness measures adopted by farmers are due to the reason that, due to drought farmers were not able to take up all agricultural activities it leads to partial or complete crop failure. So they seek for alternative sources of income. Other alternative preparative measures adopted by farmers to overcome the negative impacts of drought are storing of crop residue for livestock, growing less water consuming crops, selling of some assets like livestock’s and migrated for alternative source of employment. The livestock has a major role to play in subsistence rural agricultural economy. The livestock unfortunately, is dismally low in their productive capacities owing to several reasons. More than 70 per cent of feed requirement of livestock is met by crop residues. Reduction in agricultural production during drought affects the livestock due to decreased availability of crop residues, in turn affecting the livelihood of farmers (Rathore 2005; Sushil Pandey and Bhandari 2006; Glordano and Villholth 2007; Herani *et al.,* 2008). These results were same as results discusses in Natural Disaster Management Guidelines 2010. Considering the increase in frequency of droughts in different parts of the country, it is necessary that there is need to shift in public policy from drought relief to drought preparedness and mitigation measures. Most of these measures are related to integrated soil, water and forest management and form part of soil conservation, watershed development and forestry programmes. Drought proofing measures are taken before the crop is planted and drought management measures are taken during the crop growing period including in-situ conservation, reduction in plant population, supplemental irrigation *etc.*

5.6.6 Impact of drought on crop yield

The drought need not be a lengthier one even a dry spell during the critical growth period can cause significant damage to crop and harm local economy. Production loss which is often used as a measure of the cost of drought is only a part of the overall economic cost. The effect of drought on major crop yield in north Karnataka is presented in Table 4.35. In Vijayapura district reduction in yield levels was observed to be more in case of bajra, tur, sorghum, greengram, wheat, bengalgram, safflower, groundnut, sunflower, maize and cotton. Similarly in Belagavi district reduction in yield of sugarcane was more (91.23 %) followed by safflower, maize, bengalgram, soybean, cotton, greengram, wheat and sorghum. It is evident from table that if there was moderate deviation in precipitation there will be high reduction in the yield of Rainfed crops (Asha latha *et al.,* 2012). Agricultural losses impact the income and purchasing power of farmers converting small and medium farmers into agricultural labourers resulting in an increase in unemployment. Consequently, farmers and farm workers tend to migrate to urban areas in search of employment opportunities (Brij Mohan Singh *et al.,* 2014).

5.6.7 Impact of drought on area sown and cost of sowing

During normal year farmers were able to cultivate 11.03 acre and 11.25 acre in Vijayapura and Belagavi respectively. But due to drought farmers were not able to carry out agriculture in whole cultivable area. It was because of the reason that agricultural drought is characterized by deficiency in water availability including soil moisture for specific agricultural operations (Nagaratna and Sridhar 2009). Due to drought about 31.66 per cent and 20 per cent of the respondents were able to carry double sowing in Vijayapura and Belagavi district, respectively. Due to double sowing farmers was incurred extra cost. This additional cost was able to reduce the net returns and quality of the produce due to delay in sowing (Nagaraja 2003).

5.6.8 Impact of drought on livestock population

Due to drought 50 per cent of the bullock population was retained and remaining was sold out by the sample farmers in the study area. Farmers were sold all the cows during drought. This was due to the reason that, cows were more sensitive than bullocks which would not tolerate fodder and water shortage. These results were in line with results obtained by Herani et. al 2008. He reported that losses of cows were much higher as most of them were either abandoned due to starvation or put in charity centers, because of acute shortage of fodder and finances. During drought farmers were sold 50 per cent and 67 per cent of Buffalos and goats. These results were in line with results obtained from Nagaratna and Sridhar 2009. Herani *et al.,* in 2008 reported that the important component of agricultural sector is livestock and is an insurance against harvest failures and a source of easily cashable investment capital.

5.6.9 Impact of drought on farm income

In case of Vijayapura during normal year farmers were able get good income (` 27,421.05) but due to drought income was reduced to the extent of 58.54 per cent. In Belagavi reduction in income due to drought was 62.59 per cent. These results were in line with results obtained from Nagaratna and Sridhar 2009. Sweeth (2001) reported that income of household reduced to a quarter of average monthly income due to crop losses, livestock mortality and reduced employment opportunities. Glordand and Villholth (2007) reported that there was an overall drop in income to 33 per cent of its previous levels by the end of the 4 year subsequent drought. Pandey and Bhandari (2006) reported that in Chhattisgarh, Jharkhand, and Orissa, almost 13 million people who sit perilously just above the poverty line fall back below it due to drought induced income loss. The total farm household income was drop by 40 to 80 per cent in drought years relative to normal years.

Farmers were able to get 17.74 per cent and 3.89 per cent more income from livestock farming during drought year in Vijayapura and Belagavi district, respectively. It was because of the reason that, due to reduction in feed availability, selling of livestock, mortality and forced culling livestock population was reduced and prices of livestock products was increased. It leads to increase in income from livestock's (Bidinger *et al.,* 1991).

5.6.10 Impact of administrative measures taken in drought affected area.

Besides household level adaptation measures, administrative strategies play a very crucial role in adapting to drought. Impacts of such administrative measures were discussed under following sub headings.

5.6.10.1 Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) for drought situation and farmers responses to it in north Karnataka

Besides household level adaptation measures, administrative strategies play a very crucial role in adapting to drought. As part of administrative measure MGNREGA was implemented. Out of total farmers surveyed 83.75 per cent of them were knowing about MGNREGA. Under this scheme, drought proofing activities such as water conservation, increase in water harvesting potential of ponds and reservoirs in terms of manual excavation and construction of tanks, check dams, percolation tanks, underground dykes, ponds, rain water harvesting structures *etc.* are undertaken in drought prone areas. Along with these activities, it was also includes activities such as watershed development, tree plantation, labor intensive fencing, nursery raising, canal development, renovation of traditional water bodies and other related activities were carried out. Out of the 67 farmers knowing about MGNREGA only 47.76 per cent of the farmers were asked for job in it. But 28.13 per cent opinioned that, they got sufficient job and 71.88 per cent said that they did not got sufficient job. This opinion differs among households depending on number of family members, employment condition and living standard. Average wage for men and women in MGNREGA was ` 195.93 and ` 145.93 in case of Vijayapura but in Belagavi it was ` 204.41 and ` 156.76 respectively. This wage rates was very less compare to other alternative sources of employment. About 53.75 per cent of the respondent opinioned that they were less satisfied from MGNREGA programme. About 53.75 per cent of the respondent opinioned that they were less satisfied from MGNREGA programme. These results were in line with results obtained by Parmeshwar Udmale *et al.,* during 2014. He discussed that problems such as lack of desired and timely employment, low and untimely payment of wages, corruption, fake jobs and lack of proper MGNREGA implementation guideline were reported by the respondents are the major reasons for low level of satisfaction derived by the farmers.

5.6.10.2 Farmers opinion about crop insurance programme under drought situation in north-Karnataka

Farmer's perception about crop insurance and impact of this programme is discussed here. Out of the total farmers surveyed, 71.25 per cent of them were not received crop insurance and only 28.75 per cent were got crop insurance. Majority of them opinioned that compensation amount was not sufficient. Satisfaction derived from the crop insurance was very less as opinioned by the sample farmers, because this insurance amount was very less. Farmers cannot fulfill their basic needs with this compensation amount.

5.6.10.3 Farmer's opinion about cattle camps and water supply tankers

It was revealed from the survey that, government services like cattle camps and water supply tankers were not working well in the study area. During drought majority of the farmers were not going to keep the livestock's instead they sell them. Some of the farmers who kept livestock during drought where depend on other alternative sources of fodder such as borrowing from others and feeding less than usual quantity (Nagaratna Biradar and Sridhar 2009).

Prolonged drought always results in increased dependency on ground water resources. Excessive exploitation of ground water resources results in depletion of ground water level and drying of bore wells. These kinds of problems are observed very frequently in the DPA, which threatens the household drinking water supply. However, water is made available to villages through private and government tankers depending on intensity of drought and villagers need. But water supplied through this method was not sufficient for farm families.

5.6.11 Coping mechanisms adopted by the farmers to mitigate the impact of drought

Karnataka stands on second place after Rajasthan, in terms of total geographical area prone to drought. Nearly 90 % of the population in this semi-arid region is dependent on agriculture for their livelihood. Due to consequence drought had put most of the farmers in the state to the precarious situation leading many coping mechanism (Nagaraja 2003). As a part of technical coping mechanism to overcome drought, farmers were growing drought resistance varieties followed by this they were practicing seed treatment, changing the cropping pattern and soil organic matter enrichment using vermicompost. Farmers were felt that these coping mechanisms are financially feasible for them to adopt. Socioeconomic coping mechanisms adopted by the farmers are borrowing money from others to meet their livelihood, and shifting to the other alternative profession which helps to meet basic needs. Above all this if they were not able to meet their basic needs than they sell their land and livestock.

5.7 Impact of hailstorm on agriculture in Vijayapura district

North Karnataka has experienced heavy rainfall at many places and hailstorms also since 26th February 2014 till 11th March 2012. The timing of the thunderstorm-hailstorm activity in early summer has resulted in very heavy crop losses, because un-harvested or harvested-but-unprocessed *rabi* crops. Such impact of hailstorm on crops and income of the farmers were presented under following subheadings.

5.7.1 Impact of hailstorm on crop yield and returns

Analysis of the spatial distribution of monthly hailstorm events showed that, most of the hailstorm events in India are confined to January-May (Rao *et al.,* 2014). Similar heavy hailstorm was occurred during February and March 2014 in Indi taluk of Vijayapura district. It was summer season when hailstorm was occurred, so major crops observed in field during that period are horticulture crops namely grape, pomegranate, banana, lime, onion, tomato, other vegetables and few summer field crops like groundnut and maize were there. Grape, pomegranate, banana, lime, onion and tomato was under highest area during hailstorm incidence. Average cropped area affected was 9.56 acres. Due to hailstorm 5.18 tonnes of grape, 3.95 tonnes of pomegranate, 14.13 tonnes of banana, 7.65 tonnes of lime, 6.23 tonnes of onion and 13.20 tonnes of tomato was lost by the farmers. Due to hails with gales has uprooted entire trees, broke open the twigs, branches and made lesions on the bark of the trunk of perennial orchard at several locations. Vines were uprooted with their staking badly damaged. Fruit bunches mostly got detached and those intact with the vines were spoiled. Hail events coincided with the harvesting time of grapes and there was hardly any garden that got escape in the hill hit area. The losses occurred due to multiplicity of factors – rainfall, hail, high-speed winds and increase in relative humidity. Hail impact and dropping damage could be noticed distinctly on the fruits, and it has led to their poor marketability. Farmers realized very low prices because of both quality loss as well as a sudden glut in the local markets (Rao *et. al* 2014). Average loss due to hailstorm was observed to be ` 11.38 lakhs. These results were in line with results published in NICRA Annual Report 2013-14. The timing of the thunderstorm-hailstorm activity in early summer has resulted in very heavy crop losses, because un-harvested or harvested-but-unprocessed *rabi* crops namely bengalgram, wheat and safflower were still in the field, and horticulture crops like grape, pomegranate, papaya, lemon *etc* were ready for harvest and post harvest operations like raisin making was under process.

5.7.2 Post harvest loss due to hailstorm in Vijayapura

Post harvest loss due to hailstorm is presented in Table 4.44. Average economic loss in case of harvested but unprocessed crops was more in case of sorghum followed by maize, wheat, bengalgram, cotton and safflower. Physical impact of hail stones has turned the fields yellow and grain discolored. Average government assistance was ` 5,400.00, ` 13,100.00, ` 2,632.50, ` 6,615.00, ` 10,325.00 and ` 4,752.00 in case of sorghum, maize, wheat, bengalgram, cotton and safflower, respectively.

5.7.3 Average compensation received by the farmers due to hailstorm

About ` 20,680.00 perennial input subsidy, ` 2,415.00 annual input subsidy and ` 23,095.00 total input subsidy was given to the farmers due to hailstorm (Table 4.45). Farmers were not fully satisfied with this compensation amount because of perennial crop loss incurred by the farmers. Farmers have to wait for more years to get the returns from perennial crops.

5.8 Vulnerability indices for the assessment of vulnerability of selected districts to climate change

In this section, the results of vulnerability indices for the selected districts of north Karnataka, for the five different periods *viz.*, 1990-91, 1995-96, 2000-01, 2005-06, 2010-11 and 2013-14 are discussed. It may be seen from Table-4.47 that out of the 8 districts, Bidar ranked first and the district of Vijayapura ranked last in the overall vulnerability to climate change during 1990-91. The agriculture and occupational sector played a significant role in ranking Bidar district at the first position. Thus to reduce the climate change impact or to adapt with it, the first and foremost is livelihood security through income diversification. There is need to reduce the dependence solely on agriculture, by encouraging other non-farm sources of income, must be considered. The districts namely Vijayapura and Dharwad ranked second and third, respectively with respect to the overall vulnerability to climate change.

During 1995-96, the Bidar district ranked first in the overall vulnerability to climate change among all the districts followed by Bellary, Vijayapura and Dharwad. The per cent share from agriculture and occupational factors was more compare to other factors responsible for vulnerability to climate change.

Again Bidar retained its position as highly vulnerable district during 2000-01. Bidar was followed by Bellary, Belagavi and Vijayapura. Least vulnerable districts documented during 2000-01 are Uttara Kannada, followed by Raichur and Dharwad. Factors namely agriculture and occupational factors were contributing to the vulnerability to climate change in Bidar district. Factors responsible for least vulnerable to climate change in Uttara Kannada district are demographic and climatic parameters.

In 2005-06, the district of Bidar ranked first in the overall vulnerability to climate change amongst all the selected districts of north-Karnataka followed by, Dharwad, Vijayapura and Bellary district. Agricultural and occupational indicators were the major factors contributing to the highest vulnerability of Bidar district. The district Raichur was the least vulnerable, followed by Uttara Kannada district and Kalaburagi district, respectively. Agricultural and demographic indicators played a predominant role for the ranking of Kalaburagi district at the last position.

During 2010-11 Bidar retained first place in vulnerability to climate change followed by Dharwad, Bellary and Belagavi. In case of highly vulnerable district like Bidar, agricultural and occupational factors were responsible for its vulnerability whereas in case of less vulnerable district like Raichur, demographic and agricultural factors were more contributing to the vulnerability to climate change.

In the year 2013-14, Bidar district continued to maintain its first position thereby being the most vulnerable district to climate change. Vijayapura district ranked the last during 2013-14 thus, making it the least vulnerable district overtaking Uttara Kannada (0.2317) as before. In case of Vijayapura, agriculture (49.32 %) and demographic (40.21 %) factors were more responsible to make district as less vulnerable to climate change. These results were in line with results obtained by Deepa 2010.

The results showed that the ranks and relative magnitudes of the vulnerability indices varied across the various districts over three decades. Agriculture sector was found to have the greatest bearing towards the overall vulnerability of different districts to climate change. Thus, there is a need to shift focus towards investment in adaptation research capacity: particularly, in the development of climate proof crops (drought resistant and heat varieties). An improvement in the agronomic practices of different crops such as revising planting dates, plant densities and crop sequences can help cope with the delayed rainy seasons, longer dry spells and earlier plant maturity. Also, technologies for minimizing soil disturbance such as reduced tillage, conservation agriculture and crop rotation must be adopted. New strategies must be built around green agricultural technologies, such as adaptive plant breeding, pest forecasting and rainwater harvesting and fertilizer microdosing (Modi, 2009) must be followed.

6. SUMMARY AND POLICY IMPLICATIONS

This chapter summarises the findings of the investigation and suggests appropriate policies on causes of climate change and

6.1 Introduction

Climate and Agriculture are inextricably linked. Climate change affects agriculture in a number of ways, including through changes in average temperatures, rainfall, climate extremes, changes in pests and diseases; changes in atmospheric carbon dioxide and ground-level ozone concentrations; changes in the nutritional quality of some foods; and changes in sea level. It seems obvious that any significant change in climate on a global scale will impact local agriculture, and therefore affect the world's food supply. It leads to food insecurity and loss of livelihood. Agriculture is sensitive to short-term changes in weather and to seasonal, annual and longer-term variations in climate. For the long-term changes, agriculture is able to tolerate moderate variations in the climatic mean. Changes beyond these bands of tolerance may require shifts in cultivars and crops, new technologies and infrastructure or ultimately conversion to different land uses. The variations in the meteorological parameters are more of transitory in nature and have paramount influence on the agricultural systems.

Agriculture, in India, is strongly affected by two major hydro-meteorological disasters, namely drought and flood. As a result drought is considered as one of the biggest menace to agriculture among all weather related crisis. Rathore (2005) mentioned that the concept of drought varies from place to place depending upon normal climatic conditions, available water resources, agricultural practices and the various socio-economic activities of a region. The 2002 monsoon was one of the shortest in recorded history. No other drought in the past led to such a drop in food production as the 2002 drought. Another hydro-meteorological disaster is flood and hailstorm. Hailstorm frequency has become serious problem all over India in the past decade damaging horticulture sector in several states particularly Maharashtra and southern Andhra Pradesh. The complete avoidance of all farm losses due to weather factor is not possible but it can be minimized to some extent by making adjustments through timely and accurate information of weather forecast. The National Centre for Medium Range Weather Forecasting (NCMRWF) under the Ministry of Earth Sciences (MoES), Government of India in collaboration with India Meteorological Department (IMD), Indian Council of Agricultural Research and State Agricultural Universities had been providing Agro-meteorological Advisory Services (AAS) at the scale of agro climatic zone to the farming community based on location-specific Medium-Range Weather Forecast (MRWF). As a part of this scheme IMD collect medium range forecast on various weather parameters and disseminate to farmers, collecting the ground truth on crop and soil status by mobile messages from Field Information Facilitators (FIF). Weather forecast and weather based agromet advisories help in increasing the economic benefit to the farmers by suggesting them the suitable management practices according to the weather conditions. So that farmers can take immediate action. Keeping all this in view the present study was undertaken.

6.2 Objectives

1. To assess the extent of rainfall and temperature variability and trends in the north-Karnataka.
2. To ascertain the impact of climate variability on crop yield in study area.
3. To analyze the economic benefits of weather based farming in improving farm productivity.
4. To analyze the impact of weather extremities on agriculture in study area.
5. To map the vulnerability of climate change for selected districts.

6.3 Methodology

6.3.1 Sampling frame and sources of data

Study was based on both primary and secondary data. Secondary data on monthly temperature and rainfall data for a period of about 30 years and 14 years respectively, were collected from Directorate of Economics and Statistics, Bangalore and book published by M. B.Rajeegowda, Head AICRP on Agro-meteorology project at UAS, Bangalore entitled as "Statistical analysis of hundred year's rainfall data of Karnataka" were used. The data pertaining to various socio-economic indicators and meteorological data were collected and compiled from different sources viz; Directorate of Economics and Statistics, Bangalore, Karnataka state published a book "Karnataka at a glance"

To analyse the impact of ongoing Agro-met Advisory Services (AAS) (Both advisory and forecast) to farmers, primary data were collected from AAS beneficiary farmers of Belagavi district. From Belgum districts Bailhongal, Raybag, Athani and Gokak taluks were selected. From each taluk fifteen AAS beneficiary farmers were selected. On the other hand thirty non-AAS farmers were surveyed equally from Bailhongal, Raybag, Athani to compare the results with AAS farmers. Total sample size was 90.

To know the hailstorms impact on agriculture, data were collected from farmers of Vijayapura districts. Because of heavy hailstorm was documented in Indi taluk of Vijayapura district during February and March 2014. From Indi taluk, Ballolli and Indi hoblies were selected. From each hobli two villages which were having more number of affected farmers was selected. Based on this Tadavalaga and Batagunki villages from Ballolli hobli and Hireroogi and Salotagi from Indi hobli were selected purposefully. Twenty farmers from each village were surveyed. Total sample surveyed was 80.

In order to analyze the impact of drought in north Karnataka, Vijayapura and Belagavi were selected, since these two districts experienced higher negative deviation in rainfall during 2014-15. Agriculture area affected due to drought was more in Basavanabagewadi (32,795 ha) and Indi (58,212 ha) so these taluks were selected from Vijayapura district and Bailhongal and Hukkeri from Belagavi district.

6.3.2 Analytical tools used

Keeping in view the objectives of the study, the following analytical techniques were employed.

The temporal impact of the identified variables was studied by subjecting the time series data to the process of time series analysis. With regard to the rainfall aspect, seasonal rainfall distributions for selected districts of north Karnataka and for the temperature aspect of climate change such as season-wise average maximum and minimum temperatures were calculated using tabular analysis. To know the rainfall deviations from the normal and to test for its significance, Run test was carried out. In order to analyse the impact of Agroment Advisory service, drought impacts and hailstorm impact on farmers was analysed using tabular analysis and t test was carried out to know the significant difference in yield. In order to study the impact of climate change on the productivity of the selected crops in various districts of north-Karnataka, multiple regression function was carried out. Index approach for multivariate data was used to study vulnerability of different districts to climate change.

6.4 Findings of the study

6.4.1 Time series analysis of rainfall in north-Karnataka

Pattern of rainfall trend was computed in Table 1. A rainfall fluctuation from 1983 to 2013 was analyzed. There was highest rainfall in the year 2007 with 866.6 mm and lowest rainfall was seen during 2003 (505.2 mm). Cyclical variations in rainfall indicated that each cycle between wet and dry years were repeating at an interval of six years. Seasonal indices revealed that, rainfall showed a seasonal variation during April, May, June and July. Highest rainfall was observed during July with variation of 242.61. Highest variation was observed during 1988 (0.56) and lowest during 1985 (0.51).

In case of Bellary, Bidar, Vijayapura, Kalaburagi and Raichur rainfall showed decreasing trend where as incase of Belagavi, Dharwad and Uttara Kannda districts rainfall showed increasing trend.

6.4.2 Rainfall deviations in north-Karnataka

The mean annual rainfall of 31 years for Bidar district was 852.1 mm. The driest year was 1994 with an average annual rainfall of only 567 mm resulting in a substantial negative deviation of -49.74 per cent. The year 2001 was observed to be the driest year with an average annual rainfall of only 413 mm, resulting in the highest negative deviation of -86.92 per cent in Dharwad district. In Belagavi district driest year was 1985 with an average annual rainfall of 536.4 mm resulting in a high negative deviation of -46.29 per cent. On the contrary, the relatively wet years during the period were 2005, 2006, 2007 and 2008 in which the rainfall deviations from the mean were more than 30 per cent.

In Bellary district driest year was 1995 with an average annual rainfall of only 324 mm and wet years were 1987 and 1996 in which the rainfall deviations from the mean was more than 20 per cent. The mean annual rainfall of 31 years for Vijayapura district was 552.0 mm. The year 2003 happened to be the driest year during the entire period of study with an average annual rainfall of 315 mm as a result of which, a negative deviation of -83.49 per cent was observed. Conversely, the relatively wet years during the period were 1987, 1996 and 1998 in which the rainfall deviations from the mean were more than 20 per cent. In Raichur district driest year was 2011 with an average annual rainfall of only 358 mm resulting in a high negative deviation of -82.68 per cent and On the other hand, the relatively wet years during the period were 1996 and 1998 in which the rainfall deviations from the mean were more than 30 per cent. The relatively dry years with more than 50 per cent negative deviations from the mean rainfall was 2002 and 2003 in Kalaburagi district. The year 1983 was the wettest year with an average annual rainfall of 1425.9 mm resulting in the highest positive deviation of + 50.75 per cent. The probability of occurance of positive and negative deviations in rainfall from normal rainfall was found to be random from run test.

Maximum deviation in the magnitude of average rainfall between the driest and wettest years was observed in Uttara Kannada district *i.e.*; 385.7 mm. Followed by Belagavi (382.7 mm), Bidar (332.7 mm). Dharwad district witnessed the minimum deviation in the quantum of average rainfall between the driest and wettest years *i.e.* 206.6 mm.

6.4.3 Season-wise average maximum and minimum temperatures for the districts of north Karnataka

Season-wise average maximum and minimum temperatures for the districts of north Karnataka as presented in Table 4.10. Highest average maximum temperature of 32.62 ^{0}C was observed in Vijayapura district during winter season. In Bellary highest average minimum temperature (18.78 ^{0}C) was observed. During summer highest average maximum temperature was observed in Kalaburagi and highest minimum temperature was observed in Raichur. Highest maximum temperature during monsoon and post monsoon season was observed in Raichur. Among the districts of north –Karnataka, minimum average temperature was least in Belagavi (15.75 ^{0}C) followed by Gadag (15.56 ^{0}C), Koppal (16.07 ^{0}C), Bidar (16.08 ^{0}C), Bagalkote (16.31 ^{0}C), Kalaburagi (16.69 ^{0}C) and Vijayapura (17.36 ^{0}C).

6.4.4 Influence of weather parameters on major crop yield in selected districts of north-Karnataka

The district-wise results of multiple regression analysis for the selected crops are presented in Table No. 4.11 to 4.21. About 80.02 per cent of variation in sorghum yield was explained by the selected variables. Out of these variables, actual rainfall had a positive and significant effect on the yield at five per cent level. Variation in the yield levels of bengalgram and soybean was explained by the selected variables to the extent of 54.05 per cent and 57.49 per cent, respectively in Belagavi district. In Bagalkote district it was found that 68.98 per cent of the variation in bajra yield was explained by the selected explanatory variables. The negative impact of maximum relative humidity could be probably attributed low productivity in case of sunflower. Maximum relative humidity and minimum relative humidity were contributing significantly to the yield of bengalgram in Bagalkote district. The estimated coefficients of multiple regression function for sorghum in Vijayapura is presented in Table 4.13. The coefficient of multiple determination (R^2) for sorghum production (0.57) indicated that the variables included in the function have explained 57.94 per cent of the variation in the production of sorghum. The output elasticity of actual rainfall (0.31), maximum temperature (2.69) was non-significant and had positive relationship with sunflower yield.

Actual rainfall was significantly contributing to the productivity of paddy (3.19), sorghum (1.92), maize (1.66), greengram (1.94), and groundnut (1.97) in Dharwad district. Minimum temperature was positive and significantly contributing to the yield of sorghum but negatively to the productivity of maize (-28.98). The output elasticity of maximum temperature (-34.82), minimum temperature (39.53), maximum relative humidity (7.31) and minimum relative humidity (-31.13) have indicated that the production of groundnut was significantly influenced by these variables. In case of Gadag district actual rainfall was significantly contributing to the productivity of maize (0.53), greengram (1.44), bengalgram (0.90), groundnut (1.16), sunflower (0.61) and cotton (1.33). Minimum temperature was significant and negatively contributing to the yield of groundnut. The estimated coefficients of multiple regression function for paddy in Haveri district is presented in Table 4.16. The coefficient of multiple determination (R^2) for sorghum, maize and cotton was 75.68 per cent, 53.69 per cent and 66.00 per cent, respectively. Among the different variables under consideration, actual rainfall was contributing significantly to the production of sorghum (1.27) and cotton (1.00) in positive manner. In Uttara Kannada district output elasticity of actual rainfall (0.86), maximum temperature (3.88) and minimum relative humidity (3.98) were indicated that the production of paddy was significantly influenced by these variables.

The variables pertaining to actual rainfall and maximum relative humidity during the crop growth period had significant impact on the maize productivity. Minimum temperature was negatively contributed to the yield of maize. Among the variables, actual rainfall was significantly contributing to the bengalgram, sorghum, maize, sunflower and cotton yield. Variation in soybean yield was explained by these variables under study to the extent of 35.97 per cent in Bidar district. In Kalaburagi district, maximum temperature and minimum relative humidity were significantly contributing to the yield of sorghum. In case of sunflower, actual rainfall (0.35), maximum temperature (21.90) and maximum relative humidity (7.98) were significantly and positively contributing to the yield in case of Raichur district.

6.4.5 Economic benefits of weather based farming in improving farm productivity

Majority of the farmers were using the AAS throughout the year. Farmers were using the AAS during spaying operation (78.33 %). About 73 per cent of the respondents were using the AAS for harvesting and drying operations followed by irrigation (66.67 %), sowing (43.33 %) and fertilizer application (13.33 %). Cost of cultivation between AAS and non AAS was more in case of bengalgram followed by soybean, cotton, sunflower and groundnut. Among the different operations cost difference between AAS and non AAS farmers was observed in case of insecticide application followed by in bengalgram. Cost incurred in cultivation of greengram by non AAS farmers was ` 7,250.00. Among the different variable costs, cost on insecticides was very less in case of AAS beneficiaries (` 250.00) compare to non AAS farmers (` 462.00). In case of soybean crop cost of cultivation was ` 7,757.00 in case of AAS beneficiaries and ` 9,650.00 in case of non AAS farmers. Groundnut cost of cultivation differences was observed to be 13 per cent. AAS beneficiaries were able to reduce the cultivation cost by 13 per cent than non AAS farmers. About 83.99 per cent cost reduction was observed in case of AAS beneficiaries (` 404.92) compare to non AAS (` 745.00) farmers in case of cotton. Insecticide cost was more in case of non AAS (` 345.00) farmers compare to AAS farmers (` 251.00).

Difference in net returns obtained by AAS and non AAS farmers was observed to be more in case of soybean (29.46 %) followed by cotton (28.44 %), wheat (26.49 %), greengram (26.45 %), sorghum (25.42 %), bengalgram (24.54 %), sunflower (23.24 %), groundnut (20.92 %), maize (19.44 %) and safflower (14.63 %).

In order to overcome the drawbacks of AAS suggestions from farmers were asked. About 58.33 per cent of the farmers stated that there is no need to increase the coverage of AAS but 41.67 per cent of the farmers were said that AAS coverage has to be increased. But 28.33 per cent of the farmers suggested to increase its frequency and 71.67 per cent of the farmers said that there is no need to increase the frequency of AAS. Majority of the farmers revealed that there is no need to increase the lead time and length of forecast.

Farmers are getting weathers forecasts by different ways such as TV, News paper, Radio, Agro-met Advisory bulletin and mobile SMS. Among different sources, 66.93 per cent of the farmers said that forecast information provided through mobile SMS was more accurate, specific and timely available.

6.4.6 Impact of drought on agriculture in north Karnataka

Socio economic characters of farmers are presented in Table 4.30. Average age of the sample farmers was 44.89 years. Average family size was six. Majority of the families was nuclear (83.75 per cent). Average land holding of the farmers was 12.23 acre. About 37.50 per cent of the farmers was semi medium, followed by large (25.00 %), small (18.75 %), medium (16.25 %) and marginal (2.50 %). Farmers were perceived that drought leads to crop failure followed by drying of water resources, increase in food prices, and decline in livestock prices. Drought had very high environmental impact on some of the parameters such as declining in ground water level (85 %), created water scarcity (71.25 %), average temperature was increased (18.75 %) and degraded pasture (6.25 %).

A drought preparedness measure adopted by farmers in north Karnataka is presented in Table 4.34. Majority of the farmers said in order to overcome the drought they search for alternative source of income (71.25 %), store the crops for future consumption (70.00 %), storing of crop residue for livestock (57.50 %), growing less water consuming crops (45.00 %), selling of some livestock's (33.75 %) and migrated for alternative source of employment (11.25 %).

Due to drought farmers were able to get 74.28 per cent less yield in case of bajra followed by 61.34 per cent reduction in tur yield. Crops namely bajra, tur, sorghum and greengram were worst affected due to drought in case of Vijayapura. Whereas in case of Belagavi district crops such as sugarcane, safflower, bengalgram and cotton were affected to a greater extent due to drought. Due to drought farmers were carried double sowing and cost of double sowing was observed to be ` 1,384.37. During normal year farmers were able to cultivate 11.03 acre and 11.25 acre in Vijayapura and Belagavi respectively. But due to drought farmers were able to sow only 9.38 acre and 8.13 acre of area. Due to drought farmers were carried double sowing and cost of double sowing was observed to be ` 1,384.37. Percentage reduction in income was 62.59. Per acre average reduction in income due to drought was 61.13 per cent in case of north-Karnataka. Farmers were able to get 3.89 per cent more income from livestock during drought situation.

Due to drought 50 per cent of the bullock population was retained during drought year were as 50 per cent of the bullocks were sold by the farmers. Average number of cows per household was one in Vijayapura and Belagavi districts during normal years but due to drought farmers sold all the cows. Due to drought farmers sold goat in Vijayapura and buffalo in Belagavi. Farmers retained buffalo in Vijayapura even during drought situation.

As an administrative measure MGNREGA employment act was implemented to mitigate drought. Majority of the farmers knew about MGNREGA in study area. Average wage for men and women in MGNREGA was ` 200.17 and ` 151.34 in north Karnataka, respectively. About 53.75 per cent of the respondent opinioned that they were less satisfied from MGNREGA programme.

Out of the total farmers surveyed, about 71.25 per cent of the respondents were got crop insurance and 28.75 per cent were dint get crop insurance. Compensation amount was not sufficient as opinioned by 61.40 per cent and 26.32 per cent of farmers from Vijayapura and Belagavi district, respectively. Level of satisfaction derived from crop insurance was less (60.00 %) to very less (28.75 %) in case of north-Karnataka.

To overcome the negative impacts of drought, administrative measure were taken by the government such as supply of water through tankers and conducting of cattle camps. In case of cattle camps, 47.50 per cent and 42.50 per cent of the farmers from Belagavi and Vijayapura were less satisfied. Satisfaction level was less for 32.50 per cent and 35.00 per cent of the farmers from Belagavi and Vijayapura district respectively.

As a part of technical coping mechanism to overcome drought farmers were growing drought resistance varieties (80.00 %) followed by this they were practicing seed treatment (80.00 %), changing the cropping pattern (77.50 %) and soil organic matter enrichment using vermicompost (16.25 %). To overcome drought situation farmers use to borrow money from others (81.25 %) and they use to sell land and livestock's (55.00 %) these were some of the socio economic coping measured adopted by farmers.

6.4.7 Impact of hailstorm on agriculture in Vijayapura district

About 171.20 acre of Grape, 106.40 acre of Pomegranate, 51.20 acre of Banana, 168 acre of Lime, 108 acre of onion, 44.80 acre of Tomato, 85.60 acres of other vegetables, 20.80 acre of groundnut and 8.80 acre of maize area was affected due hailstorm. Average cropped area affected was 9.56 acres. Due to hailstorm 5.18 tonnes of grape, 3.95 tonnes of pomagranate, 14.13 tonnes of banana, 7.65 tonnes of lime, 6.23 tonnes of onion, 13.20 tonnes of tomato, 0.18 tonnes of groundnut, 0.63 tonnes of maize, 6.07 tonnes of other vegetables like ridgegourd, cucumber, brinjol and others were damaged. Average loss due to hailstorm was observed to be ` 11.38 lakhs.

Post harvest loss due to hailstorm is presented in Table 4.44. Average yield loss was observed to be more in maize (10 q) followed by sorghum (3 q), cotton (2.95 q), safflower (2.16 q) and wheat (1.95 q). Average government assistance was ` 5,400, ` 13,100.00, ` 2,632.50, ` 6,615.00, ` 10,325.00 and ` 4,752.00 in case of sorghum, maize, wheat, bengalgram, cotton and safflower, respectively. About ` 20,680.00 perennial input subsidy, ` 2,415.00 annual input subsidy and ` 23,095.00 total input subsidy was given to the farmers due to hailstorm.

6.4.8 Vulnerability indices for the assessment of vulnerability of selected districts to climate change

Bidar ranked first and the district of Vijayapura ranked last in the overall vulnerability to climate change during 1990-91. The agricultural and occupational sector played a significant role in ranking Bidar district at the first position. Again Bidar retained its position as highly vulnerable district during 2000-01. Bidar was followed by Bellary (0.4056), Belagavi (0.3892) and Vijayapura (0.3860). Least vulnerable districts documented during 2000-01 are Uttara Kannada (0.2987), followed by Raichur (0.3128) and Dharwad (0.3613). Factors namely agriculture (43.95 %) and occupational factors (30.32 %) were contributing to the vulnerability to climate change in Bidar district as before. In the year 2013-14, Bidar district continued to maintain its first position thereby being the most vulnerable district to climate change. Vijayapura district ranked the last during 2013-14 thus, making it the least vulnerable district overtaking Uttara Kannada as before. In case of Vijayapura, agriculture (49.32 %) and demographic (40.21 %) factors were more responsible to make district as less vulnerable to climate change.

Conclusions

Based on the findings of the study the following policies were suggested to reduce the adverse impacts of climate change on agriculture.

1. In the study area rainfall was showing decreasing trend (in Vijayapura, Bellary, Bidar, Kalaburagi and Raichur) and temperature was showing increasing trend. This was mainly due to human activities which lead to emission of green house gasses resulting in increase of earth temperature. For reduction of emissions of GHGs there is a need to switch over from fossil fuel based power generation to alternative sources of renewable energy like solar, wind, nuclear *etc*. Along with this programmes related to climate change mitigation and adaptation such as National Solar Mission, National Mission for Enhanced Energy Efficiency in Industry, National Water Mission and National Mission for Green India *etc* must be implemented and evaluated strictly.
2. Agriculture is highly depending on climate. Most of the crops respond very quickly to the climate change. During scarce rainfall situation yield of the crops were affected negatively. There is a need to manage the water requirement of the crops by insitue water harvesting technologies like farm pond and compartmental bunding. Initiatives must be taken to popularize these practices among the farmers. Motivate the farmers to use organic fertilizers and pesticides so that soil moisture content will be maintained. This can be done through supply of organic products to the farmers at subsidized rate through government departments during required time and motivating the farmers to produce the organic products at in situ.
3. Drought was found to be very severe in most of the districts of north Karnataka. The only way to mitigate this is through adequate planning and providing relief measures by coordinating at the micro level. Conservation of water through introduction and implementation of water harvesting practices at the community level and in situ water harvesting practices.

4. The most immediate consequence of drought is a fall in crop production due to inadequate and poorly distributed rainfall. Due to this farmers are faced with harvests that are too small to feed their families and livestock as opinioned by 73.75 per cent of the farmers. Therefore livestock sales act as a buffer in times of hardship. About 33.75 per cent of the farmers are disinvesting in these assets to buy food. Since there is a need to maintain livestock population in order to carry the farm operations and as alternative source of income to the farming families especially to the small and medium farm families. Working of cattle camps regularly during drought situations has to be monitered. This may lead to supply of required quantity of fodder and vaccination to the livestock which may lead to maintenance of livestock population.
5. MGNREGA aims at enhancing livelihood security by providing at least one hundred days of guaranteed wage employment in a financial year to every rural household. Original objectives of MGNREGA have yet to be achieved on a large scale and its true potential as an instrument of rural transformation is yet to be fully realized in north Karnataka as opinioned by 88.75 per cent of farmers. Delay in payments to workers and other malpractices can be reduced by Direct Benefit Transper (DBT) and making the scheme truly demand-based.
6. Level of satisfaction from water supply through the tanks was very less amongst 55 per cent respondents because water-supplying tankers did not have a fixed schedule. Water supply was irregular (once in two days to once in two weeks), both quantity and quality of water was insufficient and inequity in water distribution among households. To avoid conflicts among households community suggested to supply water through existing elevated public water supply tanks and distributing through pipes for fixed duration to all households as a possible solution to the aforementioned problem.
7. Crop insurance given to the farmers was very less (Rs. 3086.85 per acre). The claim is calculated on the basis of crop cutting experiments carried out by agricultural departments of respective states. This insurance amount paid cannot compensate the crop loss fully. So there is a need to fix insurance amount based on average yield levels of the crops in that region. Insurance amount paid must cover at least 50 per cent of the value of crop loss.
8. Agromet Advisory Service helps the farmers to save significant losses of farm inputs like seeds, water, pesticides and fertilizers to reap better harvest and made their farming more profitable by using AAS in case of crops like soybean (29.46 %), cotton (28.44 %), greengram (26.45 %) *etc*. Due to financial and technical drawbacks AAS implementation was stopped since 2015 February. Therefore cooperative efforts are needed to continue the implementation of AAS. Developing mechanism for context specific and need based forecasting and agro-met advisory system including local language for better understanding is necessary.
9. Agriculture production indicators were found to have the greatest bearing towards the overall vulnerability of different districts to climate change followed by occupational indicators. Thus, there is a need to shift focus towards investment in adaptation research particularly, in the development of climate proof crops (drought resistant and heat varieties).

10. Due to changing climate and increasing frequency of adverse climatic conditions most of the farmers are selling their lands and shifting to the other alternative sources of employment. In order to retain the farmers in their occupation a fixed source of income need to be provided.

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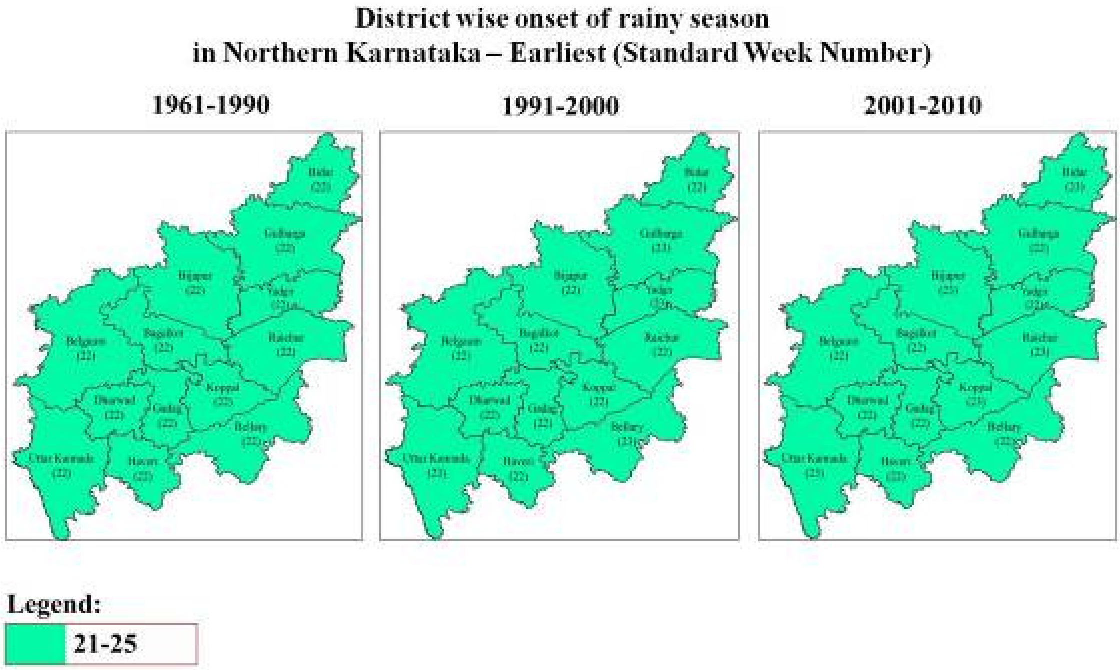
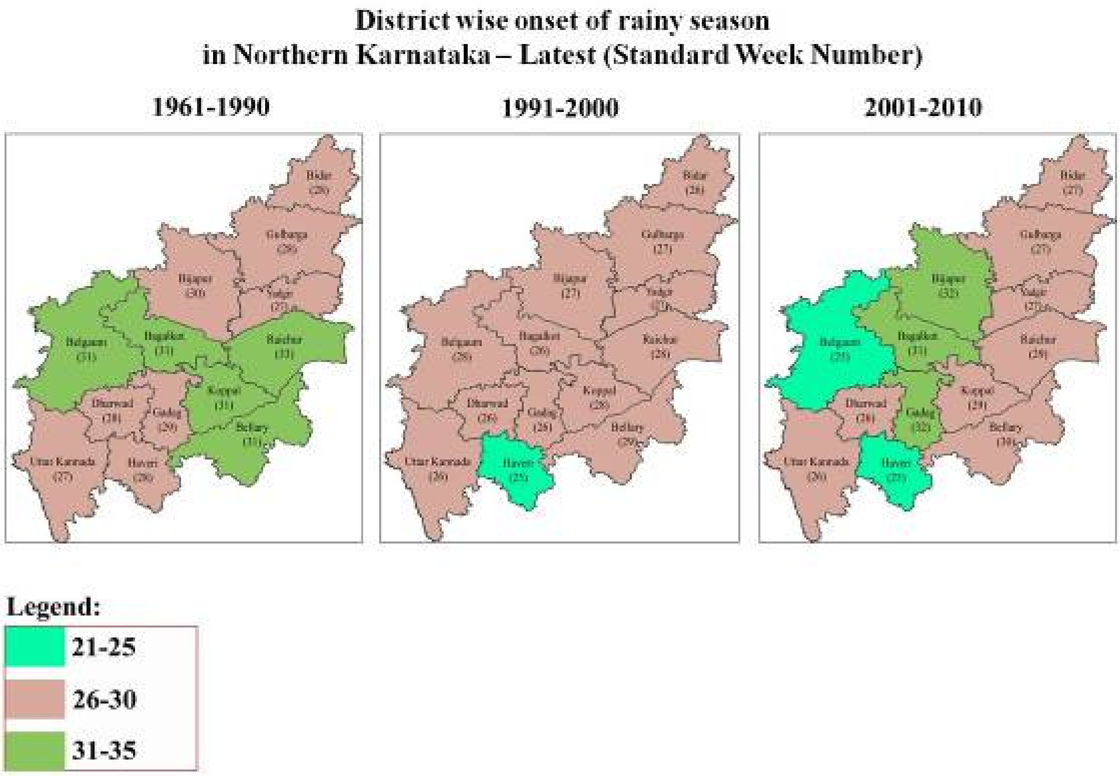
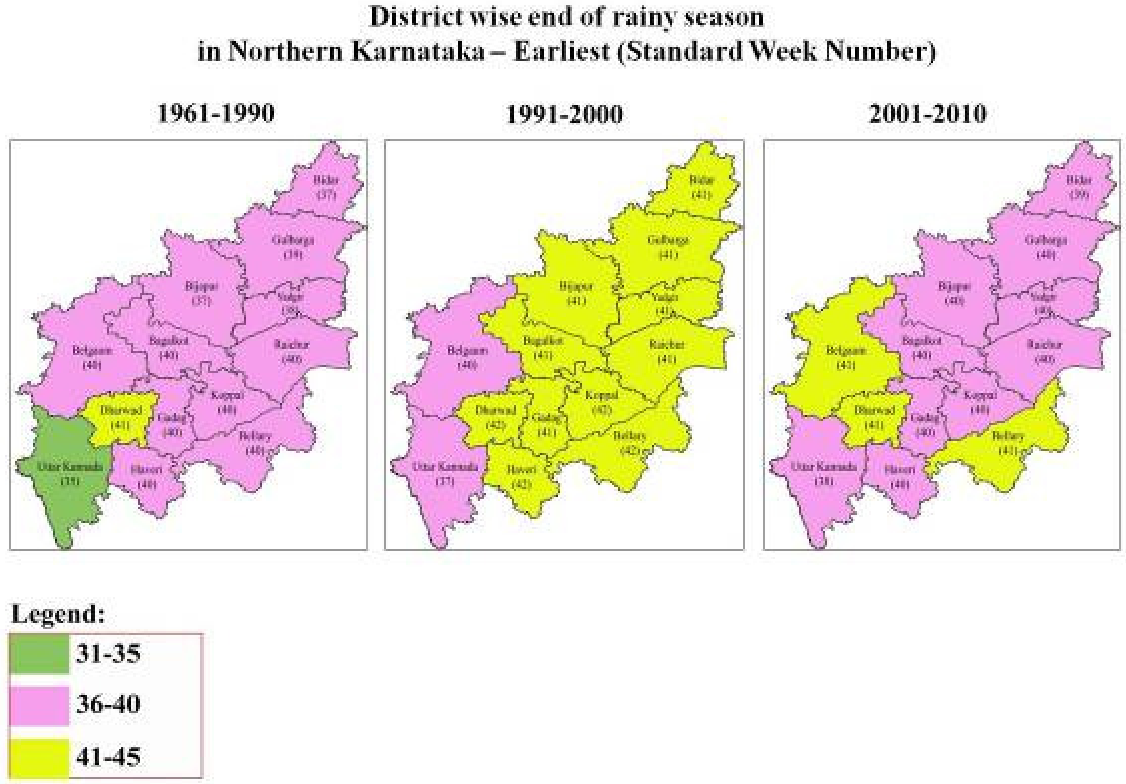
Appendix I. District-wise onset of rainy season in Northern Karnataka

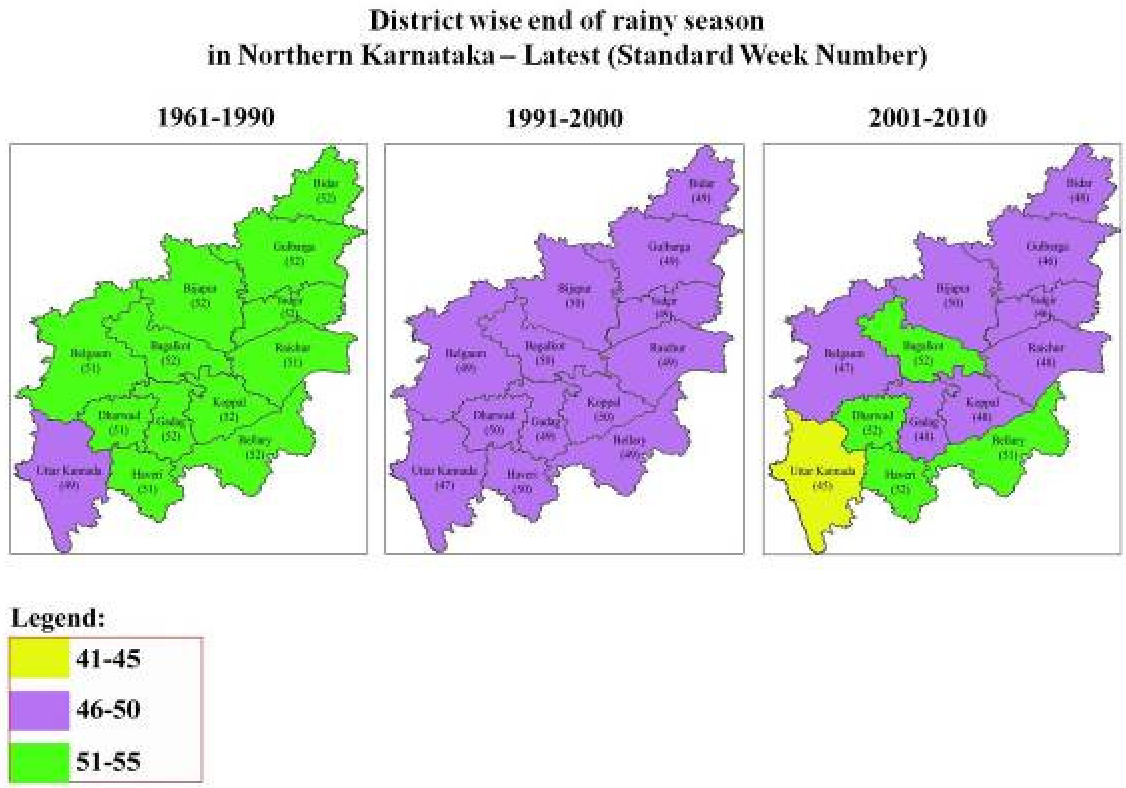




Source : Annual Report, 2012, AICRP on Agrometeorology, Vijayapura

Appendix II. District-wise end of rainy season in Northern Karnataka





Source : Annual Report, 2012, AICRP on Agrometeorology, Vijayapura

IMPACT OF CLIMATE VARIABILITY ON AGRICULTURE IN NORTH KARNATAKA-AN ECONOMIC ANALYSIS

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ABSTRACT

Climate and agriculture are inextricably linked. Climate change will affect crop yield per hectare causing food insecurity and loss of livelihood. Therefore, present study was undertaken to analyze the impact of climate variability, weather extremities and impact of weather based farming on farm income in north Karnataka. Results revealed that, in Bellary, Bidar, Vijayapura, Kalaburagi and Raichur districts rainfall showed decreasing trend whereas in Belagavi, Dharwad and Uttara Kannda districts rainfall showed an increasing trend during 1983-2013. Maximum deviation in the magnitude of average rainfall between the driest and wettest years was observed for Uttara Kannada district *i.e.* 385.7 mm, followed by Belagavi (382.7 mm) and Bidar (332.7 mm) districts. Vulnerability analysis revealed that, Bidar ranked first in the overall vulnerability to climate change among the districts of north Karnataka between 1990 to 2013. Agricultural and occupational sector played a significant role to make Bidar district as highly vulnerable. Belagavi and Vijayapura were selected as drought affected areas. It was observed that yield of bajra, tur, sorghum and greengram were significantly affected due to drought in Vijayapura. Whereas, in Belagavi district sugarcane, safflower, bengalgram and cotton yield were affected significantly due to drought. Farmers were not able to cultivate 14.95 per cent and 27.73 per cent of area in Vijayapura and Belagavi districts respectively during drought. To address these problems farmers from Belagavi district using Agromet Advisory Service (AAS) were surveyed. Farmers were using AAS during spraying of plant protection chemicals followed by irrigation (66.67 %), sowing (43.33 %) and fertilizer application (13.33 %). Net returns obtained by AAS farmers was observed to be more in case of soybean (29.46 %) followed by cotton (28.44 %), wheat (26.49 %), greengram (26.45 %), sorghum (25.42 %), bengalgram (24.54%), sunflower (23.24 %), groundnut (20.92 %) and maize (19.44 %) compared to non-AAS farmers.