CLIMATE VARIABILITY AND ITS EFFECT ON CROPPING PATTERN AND FARM INCOME : AN ECONOMIC ASSESSMENT IN DHARWAD DISTRICT OF KARNATAKA

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INTRODUCTION

"Climate variability" is defined as the inherent characteristic of climate which manifests itself in changes of climate with time. The term "climate variability" is often used to denote deviations of climate statistics over a given short period of time (such as a specific month, season or year) from the long-term climate statistics relating to the corresponding calendar period. In this sense, climate variability is measured by those deviations, which are usually termed anomalies.

On the other hand, climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2001). Climate change is one of the biggest challenges the world is facing today. The problem of human induced climate change first came into force and drew the attention of the scientists and policy makers when Inter-Governmental Panel on Climate Change (IPCC) was established.

A key difference between climate variability and climate change is in the persistence of "anomalous" conditions. In other words, events that used to be rare, occur more frequently (summertime maximum air temperatures increasingly break records each year), or vice-versa (duration and thickness of seasonal lake ice decreasing with time). Climate change indicates secular changes of meteorological elements, whereas climatic variability indicates their fluctuations on a shorter time-scale, say decadal scale or less.

Agriculture in India and entire world is mostly dependent on the persisting weather conditions. Climate change with its four dimensions, *viz.*, variability, impact, social vulnerability and adaptation, gives a holistic idea of its impact on the agrarian society. Social vulnerability to climate change is defined as the exposure of groups or individuals to stress as a result of the impacts of climate change and related climate extremes.

Climate Situation in Karnataka State

The Karnataka state enjoys three main types of climate. For agro-meteorological purposes, the state has been divided into 10 agro climatic zones, namely (1) North Eastern Transition Zone (2) North Eastern Dry Zone (3) Northern Dry Zone (4) Central Dry Zone (5) Eastern Dry Zone (6) Southern Dry Zone (7) Southern Transition Zone (8) Northern Transition Zone (9) Hilly Zone and (10) Coastal Zone.

Annual rainfall of coastal, north interior and south interior Karnataka is 3456 mm, 731 mm and 1126 mm, respectively. The Hilly and Coastal Zones received very high rainfall (2209 mm and 3893 mm, respectively) and Northern Dry Zone and Central Dry Zone received very low rainfall (585 mm and 611 mm, respectively). Out of 1140 mm of average annual rainfall of the State, about 805 mm (71%) is received in the period of October-December (North-East monsoon) and only 139 mm (12%) is received during January to May. June receives highest monthly rainfall of 283 mm followed by 190 mm in August. In total, the crop growth period in rainfed areas extends from June to October. There is definite declining trend in rainfall in Kodagu, Chikamagalur and Uttar Kannada districts. Few districts of the State have shown increasing trend in the annual rainfall, namely, Bengaluru, Kolar and Tumkur. Though the onset of monsoon occurs during the 1st week of June, the adequate rainfall for crop growing period is achieved by about 15 to 20 days. Hence crop growing season itself is shifted by 15-20 days over years.

Importance of Climate

Agricultural activities are very sensitive to climate variability and climate change. An agricultural decision-maker can either be at the mercy of these natural factors or try to benefit from them. The only way to profit from natural factors is to take them into account and learn to know them as well as possible. Agro-meteorological information, in practice mainly climate data, is essential in planning agricultural production. Before giving recommendations about land use it is necessary to know the environmental conditions. Parameters required to quantify these conditions are the rainfall data, temperature data, *etc.*

Real time meteorological information can also be effectively used in agricultural production process. The timing of different activities, e.g. sowing, ploughing, fertilizing and pest and disease control should be done when weather conditions are most favorable. For example the spreading of pesticide will succeed if weather is moist and warm (not hot) and not very rainy or windy. Hay should be made before a period of several dry days so that the hay has enough time to dry. The harvesting of wheat is also most effective during a dry period. If the wheat is threshed while it is damp it becomes predisposed to damages.

Although these examples concern agriculture in mild climates, the meaning of real time meteorological information can be broadened to activities in the tropics as well. Because climate conditions are different around the world, the importance of climatological information and real-time meteorological information is emphasized differently. In Finland, for example, real time weather information is more important than in central parts of Africa because the weather in Finland is less predictable. In fact, it is sometimes difficult to appreciate the importance of climatological information in Finland because this information is considered self-evident.

On the other hand, the climatological knowledge is often insufficient in the developing countries. The importance of climate, as an agricultural aspect, is even more crucial if the geographic situation of the developing countries and the global warming of the atmosphere are taken into account. If the climate of these regions becomes even more warm and dry, food production can be a tremendous problem. This is why climate-related knowledge should also be promoted in developing countries. Agrometeorological information can increase agricultural yield. The quality and quantity of agricultural production can be increased and production costs decreased, for example, with more optimized use of fertilizers and pesticides. If climatological data are available, the probability of unfavourable meteorological phenomena can be calculated and the related risks were estimated. Further, it is also possible to recognize bad weather conditions and to be more prepared to minimise the damage. Agricultural activities are weather-sensitive and it would be inefficient not to use climatological and meteorological information.

Impact of Climate on Agriculture Production

Climate is an important factor of agricultural productivity. Concern has been expressed by many organizations and others regarding the potential effects of climate change on agricultural productivity. Interest of this matter has motivated a substantial body of research on climate change and agriculture over the past decade. Climate change is expected to influence agricultural and livestock production, hydrologic balances, input supplies and other warming components of agricultural systems.

Climate change is caused by the release of ‘green-house’ gases into the atmosphere. These gases accumulate in the atmosphere, which result in global warming. The changes in greenhouse gases and aerosols, taken together, are projected to change regional and global climate and climate-related parameters such as temperature, precipitation, soil moisture and sea level. However, the reliability of the predictions on climate change is uncertain. There are no hard facts about what will definitely be the result of increases in the concentration of greenhouse gases within the atmosphere and no firm timescales are known. Agriculture is one sector, which is important to consider in terms of climate change. The agriculture sector both contributes to climate change, as well as will be affected by the changing climate.

Despite technological advances, such as improved varieties, genetically modified organisms and irrigation systems, weather is still a key factor in agricultural productivity, as well as soil properties and natural communities. The effect of climate on agriculture is related to variabilities in local climates rather than in global climate patterns. The Earth's average surface temperature has increased by 1.5℉ {0.83℃} since 1880. Consequently, agronomists consider any assessment has to be done individually considering each local area.

On the other hand, agricultural trade has grown in recent years and now provides significant amounts of food, on a national level to major importing countries, as well as comfortable income to exporting ones. The international aspect of trade and security in terms of food implies the need to also consider the effects of climate change on a global scale.

The Inter-Governmental Panel on Climate Change (IPCC) has produced several reports that have assessed the scientific literature on climate change. The IPCC third assessment report published in 2001 concluded that the poorest countries would be hardest hit, with reductions in crop yields in most tropical and sub-tropical regions due to decreased water availability and new or changed insect pest incidence. In Africa and Latin America many rainfed crops are near their maximum temperature tolerance, so that yields are likely to fall sharply for even small climate changes; falls in agricultural productivity up to 30 per cent over the 21st century are projected. Marine life and the fishing industry will also be severely affected in some places.

Climate change induced by increasing greenhouse gases is likely to affect crops differently from region to region. For example, average crop yield is expected to drop down to 50 per cent in Pakistan according to the UKMO scenario whereas corn production in Europe is expected to grow up to 25 per cent in optimum hydrologic conditions.

More favourable effects on yield tend to depend to a large extent on realization of the potentially beneficial effects of carbon dioxide on crop growth and increase of efficiency in water use. Decrease in potential yields is likely to be caused by shortening of the growing period, decrease in water availability and poor vernalization.

In the long run, the climatic change as herbicides, insecticides and fertilizers could affect agriculture in several ways:

1. Productivity, in terms of quantity and quality of crops;
2. Agricultural practices, through changes in water use (irrigation) and agricultural inputs;
3. Environmental effects, in particular in relation to frequency and intensity of soil drainage (leading to nitrogen leaching), soil erosion, reduction of crop diversity;
4. Rural space, through the loss and gain of cultivated lands, land speculation, land renunciation and hydraulic amenities; and
5. Adaptation: Organisms may become more or less competitive and humans may develop urgency to develop more competitive organisms, such as flood resistant or salt resistant varieties of rice.

They are large uncertainties to uncover, particularly because there is lack of information on many specific local regions and include the uncertainties on magnitude of climate change, the effects of technological changes on productivity, global food demands and the numerous possibilities of adaptation.

Most of the agronomists believe that agricultural production will be mostly affected by the severity and pace of climate change, not so much by gradual trends in climate. If change is gradual, there may be enough time for biota adjustment. Rapid climate change, however, could harm agriculture in many countries, especially those that are already suffering from rather poor soil and climate conditions, because there is less time for optimum natural selection and adoption.

The effects of climate variability are many folds. There is a need to create awareness about its impact on various sectors of agrarian economy. The present study proposes to analyze the climate variability and its effect on cropping pattern and farm income in Dharwad District of Karnataka, with the following specific objectives.

1.1 Specific Objectives of the Investigation

1. To examine the spatial and temporal variability in climate in Dharwad District of Karnataka;
2. To study the changes in cropping pattern in the study district by taluk as and estimate the relationship with climate variability;
3. To ascertain the causality, if any, between rainfall/climate variability and farm income; and
4. To document the farmers' perceptions to climate variability and elicit the coping mechanisms followed by farmers to mitigate the eventualities.

Hypotheses

1. There is significant variation in rainfall and temperature across space and time in the study region.
2. There have been fluctuations in the cropping pattern.
3. Cropping pattern changes are guided by climate variability.
4. Climate variation has adversely affected the farm incomes in the study region.
5. Farmers adopt various coping mechanisms to mitigate the eventualities of climate variability.

1.2 Presentation of the Study

The entire study has been presented in seven chapters. The first chapter elaborates importance and the current status of the present study. The specific objectives of the study have been indicated at the end of the chapter.

Chapter II deals with the review of the relevant research studies connected with the objectives of the present study.

Chapter III provides the main features of the study area and study out lines, the nature and sources from which relevant data have been collected and the various statistical tools and techniques employed in the study for evaluating the objectives.

Chapter IV is devoted to the analysis of the data wherein relevant details have been compressed and summarized under appropriate heads and presented in the tables.

Chapter V discusses the results presented in the previous chapter, drawing meaningful linkages amongst variables and establishing causality, wherever possible.

Chapter VI briefs the summary of the main findings along with the policy implications that emerged from the findings of the study.

Chapter VII, the final chapter alphabetically lists the references cited all through the thesis.

Special Features of the Investigation

The study is a four dimensional approach covering “variation, impact, vulnerability and adaptation (coping)”, so named as VIVA approach. It makes an assessment of variation in climate relating to its impact on agriculture, variability of the farmers and coping mechanisms adopted by them to mitigate the consequences of climate variability. Climate variability study at macro level has no significance in application or policy making. There is a need for grass root level study for understanding the real impact of climate variability on farmers. This study is a grass root level one which analyzes the impact of climate variability on agriculture. The parameters such as rainfall and maximum-minimum temperature have a direct effect on the productivity of the crop. The changing rainfall pattern makes the farmers to switch over cropping patterns specifically in semi-arid areas thus influencing the area and production. The study thus assesses to what extent the climate variability had affected the crop and socio-economic conditions of the farmers.

REVIEW OF LITERATURE

This chapter presents the summarized version of the apriori knowledge in terms of published literature relevant to the objectives of the study. It further links these studies with the present one and compares the findings which might compare or contrast. The understanding of the relevant literature is presented under the following headings.

2.1 Spatial and Temporal Variability in Climate in Dharwad District of Karnataka;

2.2 Changes in Cropping Pattern in the Study Districts by Talukas and Estimate the Relationship with Climate Variability;

2.3 Causality, if any between rainfall / climate variability and farm income; and

2.4 Farmers Perceptions to Climate Variability and Elicit the Coping Mechanisms followed by Farmers to Mitigate the Eventualities.

2.1 Spatial and Temporal Variability in Climate in Dharwad District of Karnataka

Fowler and Kilsby (2002), in their study on climate variability in northern England, examined precipitation data from seven long-term daily records around Yorkshire, UK for evidence of climate change. At all the stations, there was evidence of a decline in summer (JJA) precipitation amounts, dropping by 20 per cent on average since the late 1960s when compared with the 1937-96 average. This was the most marked at western sites, which also exhibited a concurrent increase in winter (DJF) precipitation totals since the mid 1970s.

Singh *et al.* (2004) studied spatial and temporal variability of soil moisture over India using IRS P4 MSMR data. The study revealed that spatial variations of soil moisture over the Indian region, which was affected by the monsoon and showed strong variability over different geological terrains.

De *et al.* (2005) conducted a study on extreme weather events over India in the last 100 years. The study revealed that the socio-economic impacts of the extreme weather events, *viz.*, floods, droughts, cyclones, hail storms, thunderstorms and heat and cold waves have been increasing due to large growth of population and its migration towards urban areas, which has led to greater vulnerability.

Amarnath *et al.* (2011) analysed the economic impact of climate change on selected crops of Tamil Nadu. The study aimed to analyse the effect of climate change by measuring the relationship between weather parameters of rainfall, maximum and minimum temperature on production and productivity of selected crops of Tamil Nadu. For the purpose of this study, secondary data on area, production and productivity of selected crops *viz.*, sorghum, bajra, maize, groundnut, cotton and sugarcane on rainfall and the maximum and minimum temperatures in Tamil Nadu were collected from published sources. The Cobb-Douglas production function showed that among the selected crops, production of sorghum and productivity of bajra were affected by maximum temperature negatively.

Arvind Kumar *et al.* (2011) conducted a study on impact of climate change on Karnataka's Agriculture. The study aims to analyse the impact of climate change on rainfall distribution pattern and crop productivity of major crops in Karnataka. The time series data on normal and actual rainfall, cropped area, production and productivity of major crops were collected for the period from 1979-80 to 2007-08. Tabular regression analysis was employed to analyze the data. The study documented the adverse effect of climate change on yield of major crops in the state.

Ashalatha and Munisamy (2011) conducted a study on the impact of climate change on Karnataka's Agriculture by spatial techniques in all districts of Karnataka state. It aims to examine the effect of fertilizer and labour inputs on crop productivity and to investigate the impact of climate variables such as rainfall and temperature. The study employed meteorology panel data by using stochastic frontier analysis and spatial lay using a 40 year district level panel data set covering all the districts of Karnataka state. The results revealed that the impact of weather parameters on Karnataka's agriculture is likely top be negative over the period.

Gauraha (2011) analysed the regional climate change and natural resources over decades. The study aims to examine the impact of climate change on natural resources in different agro-climatic sub zones in Chattisgath. The study was based on various studies conducted by the authors at different periods of time. The farmers' perception regarding degradation of natural resources and different causes of degradation of natural resources were collected through participatory rural appraisal method. The results of the study indicated that in the 1970s the degradation of natural resources especially the forest resources was observed to be more rapid as compared to land, water and other resources in almost all the sub-regions especially in tribal districts of Chattisgath. During 1970s, farmers opined that there was no severe effect of climate change on natural resources.

Guhathakurta *et al.* (2011) conducted a study on impact of climate change on extreme rainfall events and flood risk in India. The study revealed that the noticeable changes in the extreme rainfall events that occurred over India in the past century. The country experienced large spatial variations in annual normal rainfall days. Annual normal rainy days varied from 10 days over extreme western parts of Rajasthan to the high frequency of 130 days over northeastern parts of the country.

Hiremath and Shiyani (2011) carried out a Spatio-Temporal analysis of rainfall variability in Gujarat. The results revealed that the north-west arid zone was the most vulnerable zone among all the agro-climatic zones due to extreme deviations in rainfall pattern. This was followed by north Saurashtra, south Saurashtra and a middle Gujarat zones. The southern hills zone had the least per cent of years with extreme variations.

Pathania and Guleria (2011) have conducted a study to examine the implications of climate change on agriculture in Himachal Pradesh. They have analysed the change in different parameters that affect climate and determine the ability of farmers to detect change. The study was based on both secondary and primary data. In all, 80 farmers from three villages of Nagrote, Bagvan and Baijnah blocks of the study district were selected. The correlation analysis was done by using 80 farmers' data. The study observed that the area under wheat and rice have increased significantly in India, but area under pulses remained almost stagnant.

Rao *et al.* (2011) assessed the rainfall trends at micro and macro levels in Andhra Pradesh. Study revealed that climate change scenarios generated using GCM modes are mostly based on grid data for the entire country or for a given state. Most international organizations use this data in generating the scenarios for India. An attempt has been made to make a comparison of rainfall trends based on $1^0 \times 1^0$ grid data and data collected from a dense network of 11285 rain guage stations in Andhra Pradesh. No decreasing trend was noticed over the entire state with grid data. However, a clear decreasing trend in annual rainfall was found in the tract consisting of Medak, Nagaland. Krishna, East Godavari and West Godavari districts from block level data in these districts. In Prakasam district, declining trend was noticed in many blocks' level data, but increasing trend was seen with grid data. Like-wise in Rayalaseema some blocks showed increasing or decreasing trend with block level data while with grid data, no significant trend was observed.

Subash *et al.* (2011) assessed the vulnerability of farmers to climate change in agro-climate zones of North Karnataka. The vulnerability of farming communities to climate change in different agro-climatic zones of Northern Karnataka was analysed using primary and secondary data drawn from various sources. The 15 vulnerability criteria proxies were employed to study the extent of vulnerability. Each criterion was given an optimum value based on national / state average value and the value below or above the optimum indicated their degree of sensitiveness which was classified as severe vulnerability, moderate vulnerability and less vulnerability. The results of the study indicated that the north-eastern transitional zone was the most vulnerable agro-climatic zone followed by north-eastern dry zone, northern transitional zone, northern dry zone and hill coastal zone.

Zhang *et al.* (2011) studied the changes in precipitation extremes over eastern China simulated by the Beijing climate centre climate system model. The study revealed that performance of the Beijing climate center climate system model (BCC-CSM 1.0) in simulating the regional extreme precipitation change over eastern China east of 105^0E was evaluated. Daily observed precipitation data for 1956-2009 at 349 rain guage stations in China were used for comparison. The 20^{th} century simulation forced by observed greenhouse gases, aerosols, solar irradiance and volcanic aerosols shows that (a) BCC-CSM 1.0 can reproduce the basic feature of observed climatology of annual total precipitation and extreme precipitation over the 95^{th} percentile with spatial correlation of 0.77 for both of them (b) BCC-CSM 1.0 is also able to capture the main change patterns of yearly accumulated extreme precipitation above the 95^{th} percentile, although there are some model biases in the spatial extension and strength.

Das *et al.* (2012) analysed the 20^{th} century rainfall change over Gangetic West Bengal and its neighbourhood. There was a widespread concern that greenhouse gases were accumulating in the Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise. Plenty of studies related to observational data and the simulations from Global Circulation Models (GCMs) clearly indicated the evidence of climate change in the last century on global and regional scales. An analysis was carried out to investigate the past and current climate change signals (if any) over the Gangetic West Bengal (GWB) and its neighbourhood region extending from 20-26° N to 83-89° E using observed rainfall data for the 20^{th} century. The past observational records revealed that the regionally averaged rainfall (averaged over all available stations) during monsoon season was 1002+200 mm, 1037+175 mm and 1052+157 mm for the periods 1901-30, 1931-60 and 1961-90, respectively, indicating an enhanced rainfall of 3.5 per cent and 4.9 per cent in the periods 1931-60 and 1961-90 w.r.t 1901-30. There was a noticeable enhanced rainfall of 22 per cent and 82 per cent for the post-monsoon seasons for the years 1931-60 and 1961-90 w.r.t. 1901-30, indicating the shift of monsoon towards the months October and November. The observed winter season rainfall showed a deficit (6%) for the period 1931-60, while it was surplus by 46 per cent for the period 1961-90 w.r.t. 1901-30.

Guhathakurta and Saji (2012) estimated the trends and variability of monthly, seasonal and annual rainfall for the districts of Maharashtra and undertook spatial analysis of seasonality index in identifying the changes in rainfall regime. The results revealed that there was a significant decreasing trend in monthly rainfall, being observed in many areas (districts) from the month of January (Seven districts) to May (three districts) with maximum decrease in February (15 districts). Not a single district of Maharashtra reported increasing trend in rainfall from the month of January to May. These changing patterns are very crucial in agriculture.

Joseph (2012) analysed the rainfall seasonality in the Niger delta Belt, Nigeria. The study revealed that over 95 per cent of the rainfall was received in the wet season, while less than 5 per cent was received in the dry season. Rainfall starts in February / March and terminates in November / December. The phenomenon of the little dry season dominates the mid wet season. Both the annual and the wet season rainfall decreased in amount from the south-northward in the western part of the Niger Delta, but increased in the eastern side, especially from Degema northward. Apart from the Inter-Tropical Discontinuity (ITD), other factors controlling rainfall in the region include ocean – atmosphere interaction, relief, line squall and other features. These factors were noted to be responsible for the variation of rainfall in this area. The study of rainfall seasonality is very important for agricultural planning and for other socio-economic activities.

Kashyapi *et al* (2012) reviewed the agromet services for sustainable development under changing climatic scenario. Increase in atmospheric CO_2 and other green-house gases reduce earth's radiation that escapes to space with consequent warming of atmosphere. Simultaneously, increase in frequency of extreme events was reported. IMD data revealed increasing trend in global mean surface temperature, land and ocean temperatures, since 1985. Annual mean temperature anomalies (1901 – 2006) showed increasing trend especially during 1991 onwards. Annual maximum and minimum temperature anomalies (1901-2006) also showed increasing trend 1991 onwards. Impact of climate change and projected changes (*viz.* increase in temperature, changes in precipitation, increase in CO_2 level, sea level rise) affect many aspects of biodiversity including agriculture. Hence this study aimed (a) to review and summarize key climate change variability and their impact on agriculture and (b) to identify adaptive measures for sustainable agricultural development with reference to Integrated Agromet Advisory Services (IAAS) as a tool towards Integrated Crop Management (ICM). Agriculture is likely to be adversely affected by climate change and production of rice, maize and wheat was expected to decline in many parts of Asia. Hence, a pattern of resource use was thought, which aimed at meeting human needs while preserving environment. Modern era IAAS uses services of all service providers from MoES to NAASC, SDAs, SAUs, MCs, AMFUs, different NGOs, KVKs, MSSRF *etc.* (from Tier I to Tier V). The extended range of district level forecast with value addition from MCs served the need for ideal MRF. Agromet advisories were issued through a network of 130 AMFUs located at various agroclimatic zones in SAUs throughout country. Location and crop specific advisories on real time basis are ultimate goal towards sustainable agricultural development. Simultaneously, R & D support to generate appropriate agromet products and their application would assist in combating negative impact of climate change.

Kulkarni *et al.* (2012) analysed the effect of spatial correlation on regional trends in rain events over India. The study revealed that without considering the spatial correlation, it is easy to falsely interpret the significance of trends as, for instance, existence of the strong decreasing trend particularly in the case of moderate rainfall events assuming only the independence and identical distribution of these events.

Kusre and Singh (2012) conducted a study on spatial and temporal distribution of rainfall in Nagaland (India). The study revealed that there exists a wide variation in the rainfall amounts with variation ranging from 859 mm to 2123 mm. Annual rainfall pattern indicates that northern part received higher rainfall as compared to eastern and western side of the state. Similarly, for July and monsoon season, northern side receives higher rainfall. However, during December, northern side receives less rainfall as compared to eastern and western part of the state.

Lunagaria *et al.* (2012) conducted a study on climate trends in Gujarat and its likely impact on different crops. The study revealed that maximum temperature, minimum temperature and rainfall of Anand, Junagadh, Mahuva, Navasari and SK Nagar stations of Gujarat were analysed on seasonal and annual time scales using long period data. Linear regression/least squares time series slope (parametric) and Theil-sen slope (non-parametric) were used to investigate the trends of climate variability. Parametric and non-parametric trend analysis showed fair agreement in result except some cases where the non-parametric approach revealed very high magnitude in slope. During winter season minimum temperature increased and maximum temperature decreased at Junagadh. At Mahuva, minimum temperature decreased and maximum temperature increased during summer. Only Anand station showed statistically significant increasing annual trend for minimum and maximum temperatures. There was no significant trend for any temperature time series of SK Nagar station. The rainfall of Saurashtra region (Junagadh and Mahuva) showed increasing trend. The impact of increasing temperature was found positive in most of the crops studied.

Rana *et al.* (2012) conducted a study on trends in climate variability over Himachal Pradesh. The study indicated warming signals in all the study sites except Shimla during 1969 to 1987. The study indicated of higher than averages signals of warming in Himachal Pradesh upland regions than low land regions, *viz.*, Fatepur and Palam valley in recent decades. The data analysed in terms of day and night temperatures indicated that the warming was predominantly due to an increase in maximum temperature. The annual rainfall in all the regions experienced decreasing trends.

Rao *et al.* (2012), in their study on climatic sensitivity of mustard crop in northern India, assessed the yields in future climates from real time data. Among all the oilseed crops, rapeseed-mustard had the highest area (74.3%) under irrigation and was subjected to a variety of environmental conditions. The study quantified the sensitivity of mustard to weather in two diverse environments using the data collected from Hisar and Anand under irrigated conditions. The daily weather data were arranged week-wise and the relation between weather parameters and yield was determined using statistical tools like correlation and regression. The results showed that Tmax around 30℃ and Tmin around 13℃ with 8 to 8.5 hours of BSS was critical for the crop and these conditions prevailed in Hisar in the initial stages of crop growth and at Anand during reproductive stage only. The crop responded favourably to temperature rise of different magnitudes in the early vegetative stage (1-6 WAS). However, the response to temperature rise in the later part of the crop season was vice versa and the magnitude of decline in yields was comparatively large at Anand than at Hisar. This hypothesis was tested for two different locations, *viz.*, Sirsa and Rajkot districts and found to be valid. The potential yields could be obtained by adjusting the sowing time so that the crop was exposed to optimum weather conditions for harnessing maximum yield.

Sushmita *et al.* (2012) evaluated the spatial and temporal pattern of rainfall and analysed the variability of agro climatic parameters using the climatological data of 30 years (1971 to 2000). Appropriate probability distribution function for monthly or annually rainfall of Morang and Sunsari districts, Chi-square test were performed for Normal, Log-normal and Gumbel distributions with the use of STATICA package. RAINBOW package was used to analyze and represent the rainfall distribution pattern. The annual rainfall summary indicated that it ranged from 1700 mm to 2400 mm and increased northward. Though, the 30 years mean rainfall ranged from 1716 mm to 2470 mm, sometimes it fluctuated from 900 mm to 3300 mm and this fluctuation repeated in 5 to 8 years. Nearly 80 percent of the total annual rainfall occurred in these four months of monsoon.

2.2 Changes in Cropping Pattern and Estimation of its Relationship with Climate Variability

James *et al.* (2009) estimated the impact of climate variability and change on economic growth and poverty in Zambia. The study revealed that the negative effect of climate variability was especially severe for maize, the country's main staple crop and that it therefore greatly threatened basic food security in both rural and urban areas.

Banafar and Chandrakar (2011) examined regional climate change, farmers perceptions, constraints and economics of pigeonpea production in Sehore district of Madhya Pradesh. A total 120 pigeonpea growers were randomly selected for detailed economic analysis from 12 villages from different farm size groups. Using primary data, the labour analysis were employed for data. The study revealed that the pigeonpea was the most important pulse crop of *kharif* season in the study area. The average cost of cultivation was Rs. 8813 per hectare of pigeonpea. The cost of cultivation pigeonpea per hectare showed arising trend with the increase in the farm size. The average yield of pigeonpea on sample farm was observed to be 8.67 quintals per hectare. The average input-output ratio was worked out to be 1:1.41.

Drine (2011) conducted a study on climate variability and agricultural productivity in MENA region. The study revealed that lower agricultural productivity and increased water competition added to the regions difficulties to feed its growing population.

Iheke and Oliver-Abali (2011) conducted a study on farm size, climate variability and arable crop production in Abia State, Nigeria. The study revealed that temperature had been on a steady increase with increasing amounts but changes in the timing of rains and that of temperature and farm size / cropped area were the major factors affecting output. Major problem of climate change experienced by farmers based on their perceptions were drought, heat, stress, flooding and reduced crop yield.

Shalander Kumar *et al.* (2011) conducted a study on sensitivity of yields of major rainfed crops to climate in India. The analysis of productivity trends of bajra, maize and sorghum crops clearly showed that there was wide gap between productivity in rainfed and irrigated regions except in case of sorghum, which was least irrigated. However, the similar behaviour of productivity trends in rainfed as well as irrigated regions in all the three selected crops clearly indicated that weather variables have major influence on the productivity of these crops in the irrigated region also. The analysis carried out for the crops of bajra, maize and sorghum showed that the increase in rainfall and number of rainy days would result in yield increment in most of the districts and vice versa. *Kharif* maximum temperature was found to influence the yields.

Sidhu *et al.* (2011) conducted a study on climate change impact and management strategies for sustainable water-energy-agriculture outcomes in Punjab. The study revealed that climate change trends and projections suggest that regional agriculture, wheat yields, water levels and energy use and consequently national food security and individual livelihood security were negatively impacted. Fall in precipitation had resulted into greater fall in groundwater resources and increased state subsidies on electricity. Similarly, increase in the temperature especially in winter had caused wheat productivity to decline.

Rana *et al.* (2012) analysed the impact of climate change on apple crop in Himachal Pradesh. The study examined the impact of climate change in recent years on apple shift to higher atlitude in Himachal Pradesh based on climate information and farmers' perceptions. It was evident that temperature in apple growing regions of Himachal Pradesh showed increasing trends whereas precipitation showed decreasing trend. The temperature trends in apple growing regions Kullu and Shimla indicated 1.8° to 4.1°C rise in the past two decades which reflected in decrease of chilling units (CU) hours accumulations. The annual snowfall decreasing rate of 36.8 mm with decreasing trends of snowfall during early winters (October and December) and late winters (March and April) clearly indicated the shrinking winter period in high hills. The CU hours showed decreasing trends upto 2400 meter above mean sea level (ams1) from Bijapura in district Kullu at 1221 m amsl to Sarbo in district Kinnaur at 2400 m ams1. The Dhundi station situated at 2700 m ams1 showed increasing trend of CU at the rate of 25.0 CUs per year. The increasing trends of CU upto 2700 m ams1 suggested that the area was becoming suitable for apple cultivation in higher altitude. These findings have also been supported by farmers' perception which clearly reflected that apple cultivation was expanding to higher altitude in Lahaul, Spitti and Kinnaur.

2.3 Causality between Rainfall/Climate Variability and Farm Income

Neelappa (2002) studied the costs and returns structure in cultivation of paddy in Tungabhadra command area (TBP) of North Karnataka. The profitability aspect of paddy cultivation in TBP was analyzed by computing per hectare cost and returns. The per hectare cost of cultivation of paddy was Rs. 26192, Rs. 25938 and Rs. 23822 for farmers in Bellary, Raichur districts and for prize-winning farmers, respectively. The variable costs constituted the major proportion of total cost of cultivation of paddy, which was about 85 per cent. The expenditure on human labour was found to be major item of variable cost. The gross return per hectare of paddy cultivation was Rs. 42851 (Bellary) and Rs. 40735 (Raichur), while it was Rs. 45350 for prize-winning farmers. The net returns per rupee spent in paddy were estimated to be Rs. 1.64 for farmers in Bellary, Rs. 1.57 for farmers in Raichur and Rs. 1.90 for prize-winning farmers.

Damte *et al.* (2003) conducted a study on change in costs and returns of major crops in Punjab. The data on cost, input use and returns at different periods of time for major crops, *viz.,* wheat, paddy and cotton in Punjab were collected during 1971-72 to 1973-74, 1981-82 to 1983-84 and 1992-93 to 1994-95. The results of the study showed that total cost of cultivation per hectare was increasing for wheat, paddy and cotton crop. Return (per hectare) for a particular crop depended on the productivity and prices of crop products. The study clearly brought out that the rising cost of cultivation and instability in returns were due to variability in yield and price. Variable cost was increasing due to cost of human labour, machine labour, fertilizers, *etc.* This implied that the increase in production and productivity of these crops in the state was achieved at a higher cost and there was urgent need for technology upgradation and farmer-friendly farm price policy for sustainable growth of farm sector.

Nelson and Kokic (2004) forecasted the regional impact of climate variability on Australian crop farm incomes. The study revealed that the incomes of Australian crop farms were highly sensitive to climate variability and tended to fall more in years with unfavourable seasonal conditions than they rose in years with favourable seasonal conditions. An ability to predict years in which farm incomes were more likely to be negatively affected by climatic variability had important implication for the development and implementation of future climate policy.

Sikander and Sandeep (2004) examined the profitability of paddy, maize and wheat crops grown in Himachal Pradesh for the year 2001-2002. In this study, different cost concepts, namely, Cost A1, Cost A2, Cost B and Cost C were calculated. As regard to Cost C, the per hectare cost was highest in paddy (Rs. 20835) followed by maize (Rs. 18709) and wheat (Rs. 17102). For all the crops, the lion's share of cost was incurred on labour. In respect of gross returns per hectare, it was the highest on paddy crop followed by wheat and maize. The study further found that net returns were positive on paddy crop as compared to the wheat and maize crop where net return was negative. The negative return was due to low yield. However, net profit per quintal was negative for all three crops.

Basavaraja *et al.* (2005) economically analysed cultivation of *kharif* sorghum in Karnataka. Sorghum, which once occupied more than 18 m ha of area in the country, had been on a continuous decline during the past two decades and had fallen down to 10.39 m ha. Most of the decline in area had occurred in *kharif* sorghum. This warranted critical examination of the changing scenario of *kharif* sorghum and identification of the reasons thereof. For the macro analysis, secondary data on various aspects of *kharif* sorghum were used, whereas the farm survey data were used to draw the inferences at the micro level with respect to changing scenario of *kharif* sorghum. The growth rates in area, production and productivity of *kharif* sorghum were computed. The Herfindahl index was computed to find out crop diversification in the sample districts of Dharwad and Belgaun. The deceleration in the *kharif* sorghum area in the overall period 1970-71 to 1997-98 and different sub-periods was found due to the diversion of *kharif* sorghum area to more remunerative crops like oilseeds (groundnut and sunflower) and pulses. Belgaum district displayed a moderate degree of crop diversification compared to that of Dharwad district. Unfavourable prices, declining yields, inadequate credit and adverse climatic conditions were identified as the major reasons for the replacement of *kharif* sorghum crop in the two sample districts. The net returns and benefit-cost ratio were found low in the cultivation of *kharif* sorghum compared to those of its competing crops, *viz.* cotton, green gram and groundnut.

Chahal and Katariya (2005) estimated the cost and returns of maize in Punjab. The total operation cost of hybrid maize was Rs. 8956/ha as compared to Rs. 6427/ha for local variety and Rs. 8009/ha for composite varieties. Human and animal labour cost contributed more than one third of the operational cost. Fertilizer accounted for 20 per cent of the operational cost in case of hybrid varieties. The estimated average yield of hybrid varieties were 36.26 q/ha. Both gross and net returns in case of hybrid maize amounted to be Rs. 19637.48 and Rs. 10681.65 per hectare, respectively.

Rama Rao and Reddy (2007) conducted a study on economics of crop production in different agro-climatic zones of Andhra Pradesh. A sample of 105 farmers were selected through multistage random sampling technique and the data were collected by personal interview. The data collected was processed by tabular analysis. The results of the study showed that farmers were following rice-rice cropping pattern in Krishna Godavari zone, jute was the major crop in coastal zone, groundnut and sugarcane were major in south zone and cassava was grown as much as 70 percentage of total cropped area in higher altitude of tribal zone. With respect to the economics of crop production, cost of cultivation of rice was found to be Rs. 20,300/ha. In north coastal zone, southern zone, drought prone southern Telangana zone the productivity of rice was found to be 45 q/ha, 55 q/ha, 50 q/ha respectively. In north Telangana zone, sunflower, sugarcane and chickpea were the important crops grown. The study concluded that returns to land from irrigated farming were found to be higher in all zones. Cultivation of rainfed crops was marginally profitable. There was a need to relook into the policies for technology generation and transfer and other policies.

Rao *et al.* (2011) assessed the rainfall trends at micro and macro level in Andhra Pradesh. Study revealed that climate change scenarios generated using GCM modes were mostly based on grid data for the entire country or for a given state. Most international organizations used this data in generating the scenarios for India. An attempt has been made to make a comparison of rainfall trends based on $1° \times 1°$ grid data and data collected from a dense network of 11285 rain gauge stations in Andhra Pradesh. No decreasing trend was noticed over the entire state with grid data. However, a clear decreasing trend in annual rainfall was found in the tract consisting of Medak, Nagaland. Krishna, East Godavari and West Godavari districts from block level data in these districts. In Prakasam district, declining trend in many blocks level data was noticed, but increasing trend was seen with grid data. Like-wise in Rayalaseema some blocks were showing increasing or decreasing trend at block level while with grid data, no significant trend was observed.

2.4 Farmers' Perceptions to Climate Variability and Coping/ Mitigation Mechanisms

For studying the economics of pulse production and identification of constraints in their production in Madhya Pradesh (Anonymous, 2000), out of three agro-climatic zones forming Madhya Pradesh, two districts from each zone were selected based on highest area under pulses and from each district five blocks were selected and from each block one village was selected and from each village ten farmers were selected. The primary data was collected from the farmers by personal interview method and secondary data was collected from various sources. The data so collected was analysed using regression and coefficient of variation. The results of the study revealed that pulses were cash crops which required lower inputs, increased the productivity of soil but they could not grow without irrigation. Unlike in rice and wheat, there were no high yielding varieties of pulses. Pulses had lower profitability; so they could not compete with other cereals. Pulses were susceptible to pest and diseases. So, there was a need to conduct field level studies for pulses. There was a need to supply high yielding varieties in adequate quantity and to adopt appropriate IPM measures.

Balaji *et al.* (2003) examined the problems and prospects in production and marketing of groundnut in Tiruvannamali district of Tamil Nadu. The sample respondents were selected by multistage random sampling technique. The primary data required for the study were collected from 120 farmers by personal interview method. Data were analysed by Garrett's ranking technique. The results of the study revealed that farmers were facing environmental constraints, technical constraints and socio-economic constraints which led to low production of groundnut and low marketable surplus. It was evidenced from the study that pest and disease, drought, non-availability of improved seed, fertilizers and plant protection chemicals in time and marketing problem were the major constraints limiting groundnut production. So there was a need to adopt integrated pest control measures, to make use of rainfall forecasts and to make available the market information to farmers in advance.

Recha *et al.* (2008) analysed the perception and use of climate forecast information amongst small holder farmers in semi-arid Kenya. The study revealed that within-season rainfall variability was a constraint to sustainable agriculture and effective application of forecast products and therefore a challenge to the climate community. It was evident that short rains not variability in inter-annual and intra-annual rainfall amounts, but also in dates of onset within-season rainfall variability led to loss of farm enterprises and elicited discontent among farmers towards climate forecast products and eroded forecast credibility.

Banafar and Chandrakar (2011) examined regional climate change, farmers' perceptions, constraints and economics of pigeonpea production in Sehore district of Madhya Pradesh. A total 120 pigeon pea growers were randomly selected for detailed economic analysis from 12 villages across different farm size groups. Using primary data, the labour analysis were employed for processing the data. The study revealed that pigeon pea was the most important pulse crop of *kharif* season in the study area. The average cost of cultivation per hectare of pigeon pea was Rs. 8813. The cost of cultivation of pigeon pea per hectare showed a rising trend with the increase in the farm size. The average yield of pigeon pea on sample farm was 8.67 q/ha. The average input-output ratio was 1:1.41.

Jaya *et al.* (2011) conducted a study on adaptation to climate change through efficient crop insurance. The study was undertaken to analyse the performance of crop insurance in Tamil Nadu. It aimed to analyse the performance of National Agricultural Insurance Scheme (NAIS) as an adaptation measure to overcome the adverse effect of climate change on the agriculture sector of Tamil Nadu. The study was based on primary data collected during the year 2009 from 180 rice farmers and 20 officials involved in the ground level implementations of the scheme. Study revealed that the positive influence of credit accessibility on adoption emphasized the rationale of credit linked crop insurance.

Saraswathy and Selvakumar (2011) assessed the climate change and its effects on agricultural sector in India. As climate was one of the main determinants of agricultural production, it might cause variability in agricultural production. The results of the study indicated that India's capacity to cope with or adapt to climate was severely limited by the fact that it was a low income country facing serious resource constraints. Without accelerated economic and social development, the future generations in India would remain extremely vulnerable to the impacts of climate change.

Moyo *et al.* (2012) conducted a study on farmers' perceptions on climate change and variability in semi-arid Zimbabwe in relation to climatology evidence. The study showed that farmers perceived climatic and weather patterns to have changed over the past decade or two, as indicated by erratic rainfall patterns, decreased rainfall and temperature increases, leading to crop productivity decline and increased livestock morbidity and mortality. Majority of respondents (75%; n=81) were highly risk averse, perceiving that most of the seasons in any ten given years could be poor.

Rana *et al.* (2012) analysed the impact of climate change on apple crop in Himachal Pradesh. The study examined the impact of climate change in recent years on apple shift to higher atlitude in Himachal Pradesh based on climate information and farmers' perceptions. It was evident that temperature in apple growing regions of Himachal Pradesh showed increasing trends whereas precipitation showed decreasing trend. The temperature trends in apple growing regions Kullu and Shimla indicated 1.8° to 4.1℃ rise in the past two decades which reflected in decrease of chilling units (CU) hours accumulations. The annual snowfall decreasing rate of 36.8 mm with decreasing trends of snowfall during early winters (October and December) and late winters (March and April) clearly indicated the shrinking winter period in high hills. The CU hours showed decreasing trends upto 2400 meter above mean sea level (ams1) from Bijapura in district Kullu at 1221 m amsl to Sarbo in district Kinnaur at 2400 m ams1. The Dhundi station situated at 2700 m ams1 showed increasing trend of CU at the rate of 25.0 CUs per year. The increasing trends of CUs upto 2700 m ams1 suggested that the area was becoming suitable for apple cultivation in higher altitude. These findings have also been supported by farmers' perception which clearly reflected that apple cultivation was expanding to higher altitude in Lahaul, Spitti and Kinnaur.

METHODOLOGY

Scientific study of any problem requires a systematic investigation using appropriate method and procedures in order to arrive at a reliable, unbiased and practical conclusion. Beginning with selection and a general description of the study area, the data base and the analytical tools and techniques used in the present study are discussed in this chapter. The presentation is arranged under the following broad headings.

3.1 Selection of the Study Area

3.2 Description of the Study Area

3.3 Nature and Sources of Data

3.4 Analytical Tools and Techniques

3.1 Selection of the Study Area

The study was conducted in Dharwad district of Karnataka. Dharwad taluk from Dharwad district was purposively selected owing to the presence of agro-climatic observatory, only in Dharwad taluk and not in other four talukas of the district. Four villages from amongst the villages falling within a radius of 20 km from the Meteorological Observatory were selected randomly. From each village, 30 farmers were chosen using proportionate sampling (probability proportionate to size of the sub-group). In all, 120 farmers spread across 4 villages in Dharwad taluka were finally chosen for achieving the objectives of the study. The details of the district, taluka, villages and number of respondents selected for the study are given in Table 3.1.

3.2 Description of the Study Area

Dharwad is one of the major districts located in the Northern part of Karnataka state. The district lies between East longitudes 75^0 20' and 75^0 00' and North Latitude 15^0 15' and 15^0 35'. The district comprises of five talukas, namely, Dharwad, Hubli, Navalgund, Kalghatagi and Kundagol. The total area of the district is 4763 square kilometers which accounts for 2.22 percent of the state's total area (Table 3.2). The district has a total land area of 427329 hectares of which 362874 hectares are cultivable. The irrigated land in the district is 43,569 ha. This is a little over 10 percent of the total area of land. Western parts of Dharwad and Kalghatgi taluk come under Malnad area. The average rainfall of the district is 772 mm per year. The population of the district was 16,03,794 as per 2001 census. The urban and rural population of the district was 8,81,726 and 7,22,068, respectively. The density of the population of the district was 377 per sq.km. and the literacy rate was 66 per cent as per 2001 census.

The major industrial areas of the district are connected with broad-gauge railway line. The district has as many as 11759 industrial units with an investment of Rs. 23,978.77 lakhs employing 2,22,723 persons. Apart from these SSI units, the district has 20 large/medium scale industries. There are 216 post offices in the Dharwad district, 157 telegraph offices and 61 telephone exchanges. The district has a total number of 222 bank offices of which 51 are in rural area and 25 in semi urban areas. The district has 35,235 ha. Of forest area which is about 8 percent of the total geographical area of the district. The district has a total number of 158 commercial banks and 997 co-operative societies. Of this agricultural cooperative credit societies were 257, dairy 85, housing 256, marketing 5 and others 594. The total numbers of Agricultural Produce Marketing Committees (APMC) in the district are 16 of which 5 main APMC are located each talukas and remaining 11 sub APMCs are located in the other major areas of the districts.

Dharwad taluk has an area of 1,032 sq.km and a total population of 2,18,961, with a population density of 219 per sq.km.

3.3 Nature and Sources of Data

Keeping in view the objectives of the study, primary and secondary data were obtained.

Primary Data

A structured interview schedule was developed to collect data on coping mechanisms and adaptation strategies adopted by farmers to mitigate climate change. The primary data were collected by personal interview method.

Table 3.1: Districts, Taluks, Villages and Respondents Selected for the Study

District	Taluk	Village	No. of Respondents
Dharwad	Dharwad	Narendra	30
		Chikmalligwad	30
		Somapur	30
		Hebballi	30
Total	**1**	**4**	**120**

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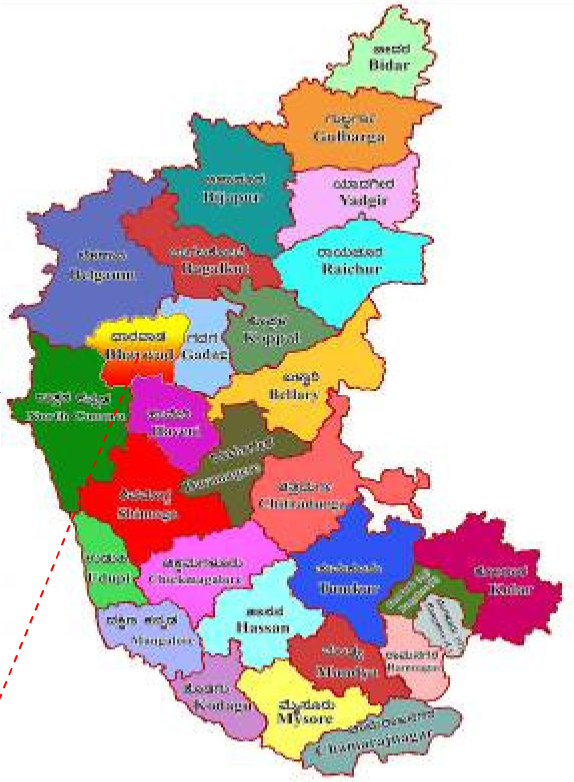
KARNATAKA STATE



DHARWAD DISTRICT

Fig. 3.1: Maps showing the Study Area

Table 3.2: General Features of Dharwad District (2010-11)

Sl. No.	Particulars	Value
1	Total geographical area (lakh ha)	4,763
2	Number of inhabited villages (No.)	2,97,494
3	Total population (No.)	18,46,993
4	Population density (persons/sq. km)	377
5	Literacy rate (%)	66
6	Total land area (ha)	4,27,329
7	Cultivable land (ha)	3,62,874
8	Average actual rainfall (mm)	772
9	Commercial banks (No.)	158
10	Number of co-operative societies (No.)	997
11	Number of regulated markets (No.)	16

Source: DES, 2012, Dharwad District at a Glance (2011-12), Directorate of Economics and Statistics, Dharwad.

Table 3.3: Salient Features of the Selected Taluks (2010-11)

Sl. No.	Particulars	Taluks				
		Dharwad	**Hubli**	**Navalgund**	**Kalaghatgi**	**Kundgol**
1.	Geographical area (sq.km)	1,032	631	1,080	682	648
2.	Total population (2001 census)	2,18,961	1,28,380	1,76,648	1,37,016	1,57,053
	a) Rural	2,02,671	1,28,380	1,28,736	1,22,336	1,40,213
	b) Urban	16,290	18,793	47,912	14,680	16,840
	c) Female	1,06,722	62,380	86,288	66,236	76,313
	d) Male	1,12,239	66,000	90,360	70,780	80,740
3.	Population density (per sq.km)	219	217	163	201	242
4.	Rainfall (mm):					
	a) Normal	865.0	732.0	643.0	980.0	716.0
	b) Actual	1,017.2	848.7	539.7	1,037.2	766.5

Source: DES, 2012, Dharwad District at a Glance (2011-12), Directorate of Economics and Statistics, Dharwad.

Secondary Data

Different weather parameters, namely, rainfall, temperature (minimum and maximum) and relative humidity (minimum and maximum) were collected from the meteorological station at Dharwad. The area under major crops at Dharwad district level and taluks' level were collected from various issues of 'Dharwad District at a Glance' published by the Directorate of Economics and Statistics, Bengaluru.

3.4 Analytical Tools and Techniques Used in the Study

The data collected from the respondents was edited, tabulated and analyzed using Compound Annual Growth Rate, Multiple Regression Models, Garrett's ranking technique, percentages, means, coefficient of variation, mean deviation, correlation matrix and other descriptive statistics. The tools used for the analysis of the data were discussed below.

3.4.1 Descriptive Analysis

Means, percentages, coefficient of variation, mean deviation, correlation matrix and other descriptive statistics were used for assessments and comparisons.

3.4.2 Exponential Model or Compound Annual Growth Rate Analysis

To analyse the growth in area sown to major crops (both food and non-food crops) in Dharwad district by taluks, the Exponential Model, as specified below, was used to estimate the Compound Annual Growth Rates of cropped area using the data from 1999-2000 to 2008-09.

$$Y = a * b^t \qquad \text{…(1)}$$

Where,

Y = Area under particular crop or crop-group

t = Time (in years)

a & b = Regression Coefficients

Using the slope regression coefficient 'b', the Compound Annual Growth Rate (g) was computed as follows:

$$g = (b-1) * 100 \qquad \text{…(2)}$$

Where,

g = Compound Annual Growth Rate of area under particular crop or crop-group

3.4.3 Multiple Regression Models

a) Acreage Response Model

To study the factors influencing changes in cropping pattern in Dharwad district a multiple linear regression analysis was carried out. In this analysis, area under the crop in question was taken as the dependent variable and the other independent variables used were actual rainfall, maximum temperature, minimum temperature and relative humidity – all during the cropping season. The functional form of regression equation used was

$$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + a_5X_5 + U_i \qquad \text{…(3)}$$

Where,

Y = Area under the crop under consideration (ha)

X_1 = Actual rainfall during the 2-months prior to the season (mm)

X_2 = Maximum temperature during a month prior to the season (°C)

X_3 = Minimum temperature during a month prior to the season (°C)

X_4 = Maximum relative humidity during a month prior to the season (%)

X_5 = Minimum relative humidity during a month prior to the season (%)

a_j = Regression Coefficients (j=0,1…5)

u_i = Random disturbance term (i=1,….n)

b) Net Returns Response Model

To study the factors influencing changes in net returns of selected crops in Dharwad district, a multi-linear regression model of the following form was used:

$$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + U_i \qquad \text{…(4)}$$

Where,

Y = Net returns from the crop under consideration (Rs/ha)

X_1 = Average actual rainfall during the season (mm)

X_2 = Average temperature during the season (°C)

X_3 = Average relative humidity during the season (%)

a_j = Regression Coefficients (j = 0,1…3)

u_i = Random disturbance term (i =1,….n)

3.4.4 Garrett Ranking Technique

Garrett ranking technique was adopted for documenting farmers' perceptions to climate variability. As many as twelve perceptions were identified and ranked using Garrett's ranking technique. In the first stage, ranking was given for farmers' perceptions on climate variability and it was analyzed. In the second stage, the ranks assigned by the individual respondents were converted into percent position value by using the following formula.

$$\text{Per cent position} = 100 \sum(R_{ij} - 0.5) / N_j \qquad \ldots(5)$$

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 the third stage, for each per cent position, scores were obtained with reference to Garrett ranking conversion table and each per cent position value was converted into scores by referring to Garrett's table. In the fourth stage, summation of these scores for each factor was worked out for the number of respondents who ranked for each factor. In the fifth stage, mean scores were calculated by dividing the total score by the number of respondents. In the last stage, the overall ranking was obtained by assigning ranks I, II, III, VI, *etc.* in the ascending order of the mean score.

RESULTS

In this chapter, the data collected from different sources were analysed and interpreted towards achieving the objectives of the study and the findings of the study are presented under the following headings.

4.1 Socio-Economic Profile of the Sample Households

4.2 Variability in Climate

4.3 Changes in Cropping Pattern by Taluks and their Relationship with Climate Variability

4.4 Causality between Climate Variability and Farm Income

4.5 Farmers' Perceptions of Climate Variability and Coping Mechanisms to Mitigate the Eventualities

4.1 Socio-Economic Profile of the Sample Households

The socio-economic profile of the sample respondents was presented under the following sub-sections. The distribution pattern of the sample respondents by age of the household head, educational status, caste group, family composition, experience in farming and land holding was furnished in Table 4.1.1.

4.1.1 Age Distribution

The distribution pattern of sample respondents by age indicated that majority of the respondents belonged to old age group (65 per cent) followed by middle age group (34 per cent) and the young ones accounted for one fourth (11 per cent) of the respondents in the study area, *viz.*, Dharwad district.

4.1.2 Educational Status

The analysis of educational status of sample households revealed that about 18.33 per cent of the respondents were illiterates followed by 49.17 per cent of them studied up to primary school, 17.50 per cent of them completed SSLC (Secondary School Leaving Certificate, equivalent to X standard) and equal proportion of them completed PUC (Pre-University Course, equivalent to Inter or 12th Standard). Hardly 6.67 per cent of the respondents possessed degree, while 0.83 per cent of them were postgraduates.

4.1.3 Caste Composition of Sample Respondents

Nearly two-thirds of the sample respondents belonged to the "Other Backward Caste" (OBC) (64.17 per cent), followed by "General Category" (12.5 per cent), "Scheduled Caste" (12.5 per cent) and "Scheduled Tribe" (10.83 per cent) groups.

4.1.4 Household Size

The average household size of the sample respondents was 8.39. A majority of the household members were males (38.38 per cent), while the females and children constituted 35.28 per cent and 26.34 per cent of the household, respectively.

4.1.5 Experience in Farming

Majority of the sample farmers (54 per cent) had less than 18 years of experience in farming, whereas about 31 per cent and 13 per cent of the sample households had farming experience in the range of 18-35 years and 36-50 years, respectively. Hardly 2.50 per cent of them had farming experience of more than 50 years.

4.1.7 Socio-Economic and Land Holding Pattern of Sample Respondents

It could be seen from table 4.1.2 that the average land holding of the sample respondents was 3.46 ha, of which 3.31 ha (95.66%) was owned land holding and 0.16 ha (4.62%) leased-in. Hardly 0.01 ha (0.29%) of the land holding was leased-out. Of the total land holding, nearly 85 per cent was rainfed, while the remaining holding was irrigated from various sources.

Table 4.2.1: Triennium Averages of Climate Factors in Dharwad District (1991-2010)

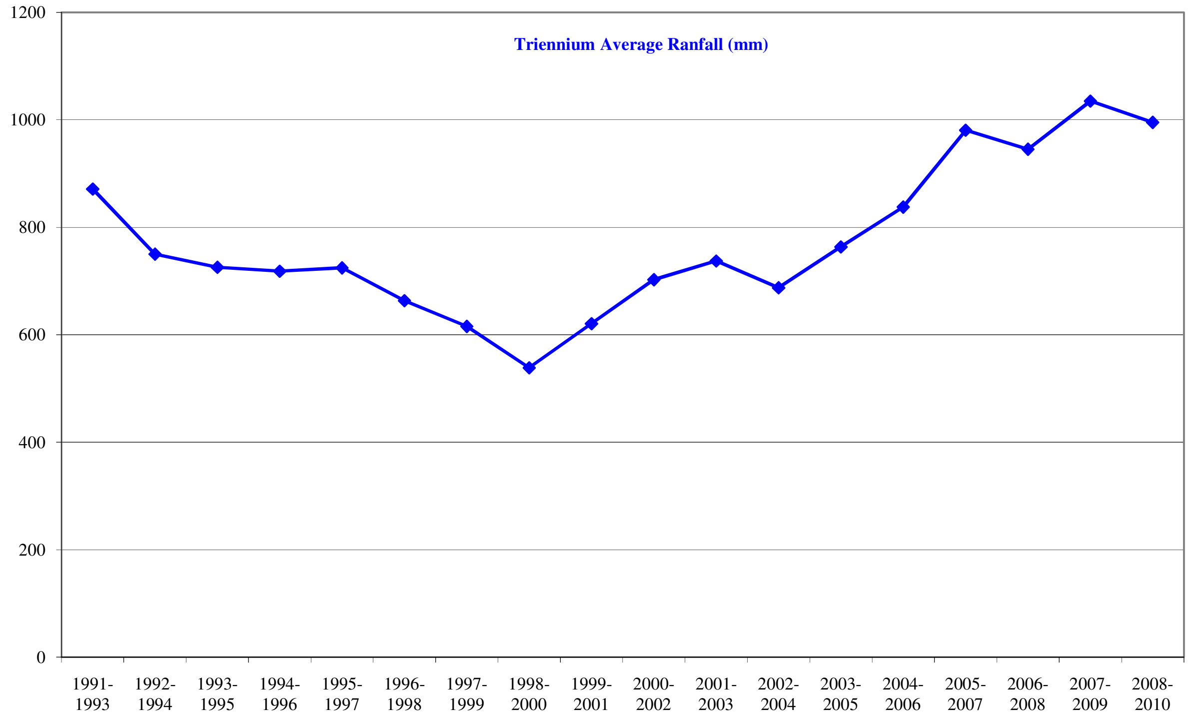
Triennium Averages of	Rainfall (mm)	Rainy Days (No.)	Maximum Temperature (°C)	Minimum Temperature (°C)	Relative Humidity (%)
1991-1993	871.2	66.3	39.4	9.3	79.0
1992-1994	750.1	65.3	39.6	9.5	79.7
1993-1995	725.6	66.7	39.6	10.0	79.0
1994-1996	718.2	60.0	39.4	10.0	78.2
1995-1997	724.5	57.7	39.0	10.3	76.8
1996-1998	663.5	49.7	39.6	10.2	76.2
1997-1999	615.6	46.7	39.3	10.6	75.0
1998-2000	538.6	38.3	39.8	10.6	71.5
1999-2001	620.7	48.3	39.1	10.5	67.2
2000-2002	702.5	59.7	39.1	10.7	64.0
2001-2003	737.4	62.0	38.8	11.0	63.3
2002-2004	687.5	60.3	39.1	11.0	63.3
2003-2005	763.6	61.7	39.6	10.3	63.0
2004-2006	837.7	72.7	40.2	9.7	63.3
2005-2007	980.6	73.7	40.2	9.4	65.3
2006-2008	945.3	68.3	39.0	9.7	66.3
2007-2009	1034.8	66.0	39.0	10.3	66.5
2008-2010	995.2	66.3	39.0	10.1	66.8

Table 4.1.1: Demographic Profile of Sample Respondents

Sl. No.	Particulars	Village Total	Percentage to Total
A	**Age group**		
1	Young (18-35 years)	13	10.83
2	Middle(36-50 years)	29	34.17
3	Old(> 50years)	78	65.00
	Total	**120**	**100.00**
B	**Education status**		
1	Illiterate	22	18.33
2	Primary (1-7)	59	49.17
3	Secondary (8-9)	9	7.50
4	SSLC (Matriculation)	21	17.50
5	PUC (Inter)	8	6.67
6	Degree	1	0.83
	Total	**120**	**100.00**
C	**Caste**		
1	General	15	12.50
2	Other Backward Caste (OBC)	77	64.17
3	Scheduled Caste (SC)	15	12.50
4	Scheduled Tribe (ST)	13	10.83
	Total	**120**	**100.00**
D	**Number of Family members**		
1	Male	3.22	38.38
2	Female	2.96	35.28
3	Children	2.21	26.34
	Total	**8.39**	**100.00**
E	**Experience in farming**		
1	Below 18 years	65	54.17
2	(18-35 years)	37	30.83
3	(36-50 years)	15	12.50
4	(> 50 years)	3	2.50
	Total	**120**	**100.00**

Table 4.1.2: Land Holding Status

Sl. No.	Particulars	Irrigated	Rainfed	Total	% to Total
1	Owned Land	0.53	2.78	3.31	**95.66**
2	Leased-in Land	0.00	0.16	0.16	**4.62**
3	Leased-out Land	0.01	0.00	0.01	**0.29**
	Total land holding	0.52	2.94	3.46	**100.00**
	% to Total	**15.03**	**84.97**	**100.00**	



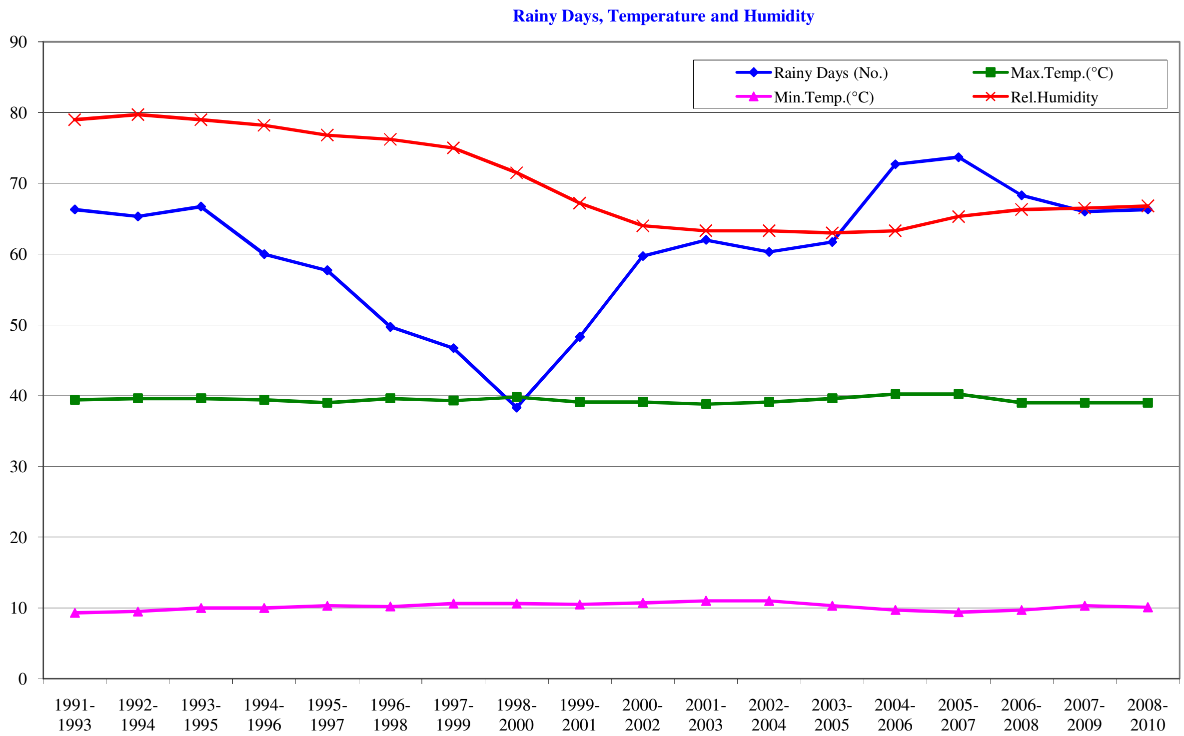


Fig. 4.2.1: Triennium Averages of Climate Factors in Dharwad District (1991-

Fig 4.2.1. Triennium Averages of Climate Factors in Dharwad District (1991-2010)

4.2 Variability in Climate

4.2.1 Triennium Averages of Climate Factors in Dharwad District (1991-2010)

The triennium averages of climate factors, namely, rainfall, rainy days, maximum temperature, minimum temperature and relative humidity in Dharwad district for the period of triennium (TE) 1993 to TE 2010 were presented in Table 4.2.1. The triennium average rainfall recorded a decreasing trend during TE 1993 (871.2 mm) to TE 1998-2000 (538.6 mm), while thereafter it registered a positive trend during the period till TE 2010, however, with minor year-to-year fluctuations. Highest rainfall (1034.8 mm) was received during the TE 2009. Similar trend was observed in terms of rainy days per annum. The lowest rainy days (less than 50) were observed in the period between TE 1998 – TE 2001, which ranged from 38 to 49 rainy days per annum, whereas during TE 1993 – TE 1997, the figures ranged from 57 to 67 and during TE 2002 – TE 2010, it varied from 59 to 74.

The maximum temperature in a year during the study period ranged from 38.8℃ (in TE 2003) to 40.2℃ (in TE 2006 and TE 2007). On the other hand, the minimum temperature ranged from 9.3℃ (in TE 1993) to 11.0℃ (in TE 2003 and TE 2004). Relative humidity had also declined over years. It ranged from a high of 79.7 per cent (TE 1994) to a low of 63.3 per cent (in TE 2003, 2004 and 2006).

4.2.2 Mean and Coefficient of Variation of Climate Variables

The mean and coefficient of variation of the climatic variables, namely, rainfall, maximum temperature, minimum temperature and relative humidity in Dharwad district were depicted in the Table 4.2.2.

The study area received an average annual rainfall of 796.48 mm during 20-year study period (1991-2010). It ranged from a lowest of 530 mm during the year 2000 to 1125 mm in the year 2009, with a coefficient of variation of 23.16 per cent.

The mean values of other important climatic factors, namely, maximum temperature, minimum temperature and relative humidity were 39.37℃, 10.12℃ and 70.57 per cent, respectively. However, the coefficients of variation of the aforesaid climatic factors were much less than the rainfall 2.40 per cent, 7.34 per cent and 9.55 per cent, respectively.

Thus, in terms of variability, rainfall showed the highest coefficient of variation, followed by relative humidity, minimum temperature and maximum temperature.

4.2.3 Seasonal Distribution of Rainfall in Dharwad District across Years

In this section, the intra-year or seasonal rainfall pattern in terms of quantum of rainfall received during pre-monsoon period, monsoon period and post- monsoon period in Dharwad district over the 20-year study period is estimated and presented. The mean values of pre-monsoon, monsoon and post-monsoon rainfall across years were found to be 110.49 mm, 684.80 mm and 143.90 mm respectively (Table 4.2.3). As indicated by the co-efficient of variation, highest variation was observed in pre- monsoon rainfall (49.89%), followed by post-monsoon rainfall (22.67%), while the least was in the case of monsoon rainfall (12.83%).

4.2.4 Variation in Annual and Seasonal Rainfall

The mean, standard deviation and coefficient of variation in annual and seasonal rainfall in the Dharwad district over the period of 1991-2010 were presented in Table 4.2.4. Amongst the seasons, *kharif* received the highest rainfall (491.06 mm), followed by *rabi* season (156.83 mm) and summer season (119.40 mm). The annual mean rainfall was 796.48 mm.

In terms of variability, summer rainfall was highest coefficient of variation (43.76%), followed by *rabi* (34.40%) and *kharif* (31.43%), whereas the annual rainfall had the lowest variability (23.16%).

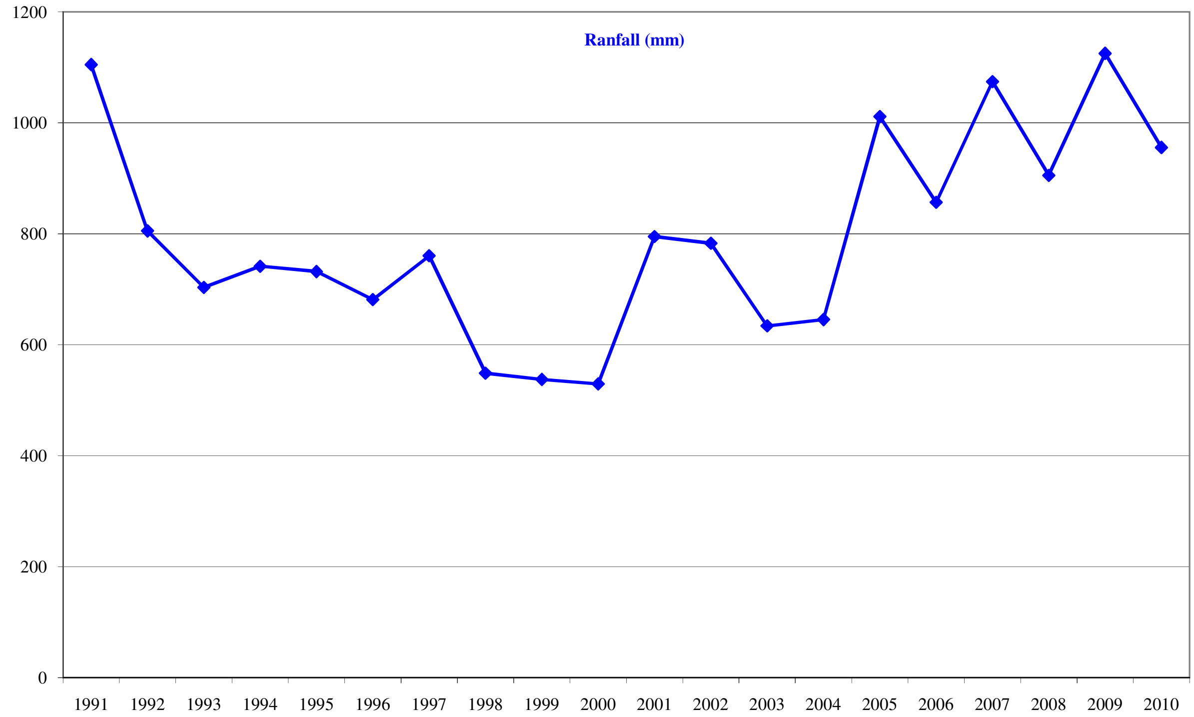
4.2.5 Deviation of Actual Annual Rainfall from Normal and Mean Rainfall

The extent of deviation of actual annual rainfall from the normal rainfall and mean rainfall in the Dharwad district was estimated using “mean deviation” and “per cent deviation from normal rainfall” and the results were presented in the Table 4.2.5.

The mean actual annual rainfall of Dharwad district over the study period was reported as 796.5 mm, ranging from 529.5 mm (in the year 2000) to 1125.0 mm (in the year 2009). The

Table 4.2.2: Mean and Coefficient of Variation of Climate Variables in Dharwad District (1991-2010)

Sl. No.	Year	Ranfall (mm)	Maximum Temperature (°C)	Minimum Temperature (°C)	Relative Humidity (%)
1	1991	1104.8	38.9	9.4	78.62
2	1992	805.2	38.6	9.3	79.3
3	1993	703.5	40.6	9.3	79.18
4	1994	741.5	39.7	9.8	80.65
5	1995	731.9	38.5	10.9	77.25
6	1996	681.3	40.1	9.3	76.59
7	1997	760.3	38.3	10.7	76.45
8	1998	548.8	40.3	10.7	75.5
9	1999	537.6	39.4	10.5	73.03
10	2000	529.5	39.6	10.5	65.83
11	2001	795.1	38.2	10.6	62.72
12	2002	782.9	39.4	11.1	63.37
13	2003	634.2	38.7	11.2	63.83
14	2004	645.5	39.2	10.6	62.77
15	2005	1011.1	40.9	9.0	62.35
16	2006	856.6	40.4	9.4	64.84
17	2007	1074.2	39.4	9.8	68.72
18	2008	905.1	37.2	10.0	65.31
19	2009	1125.0	40.5	11.1	65.61
20	2010	955.5	39.4	9.2	69.39
	Mean	**796.48**	**39.37**	**10.12**	**70.57**
	SD	**184.44**	**0.95**	**0.74**	**6.74**
	CV (%)	**23.16**	**2.40**	**7.34**	**9.55**



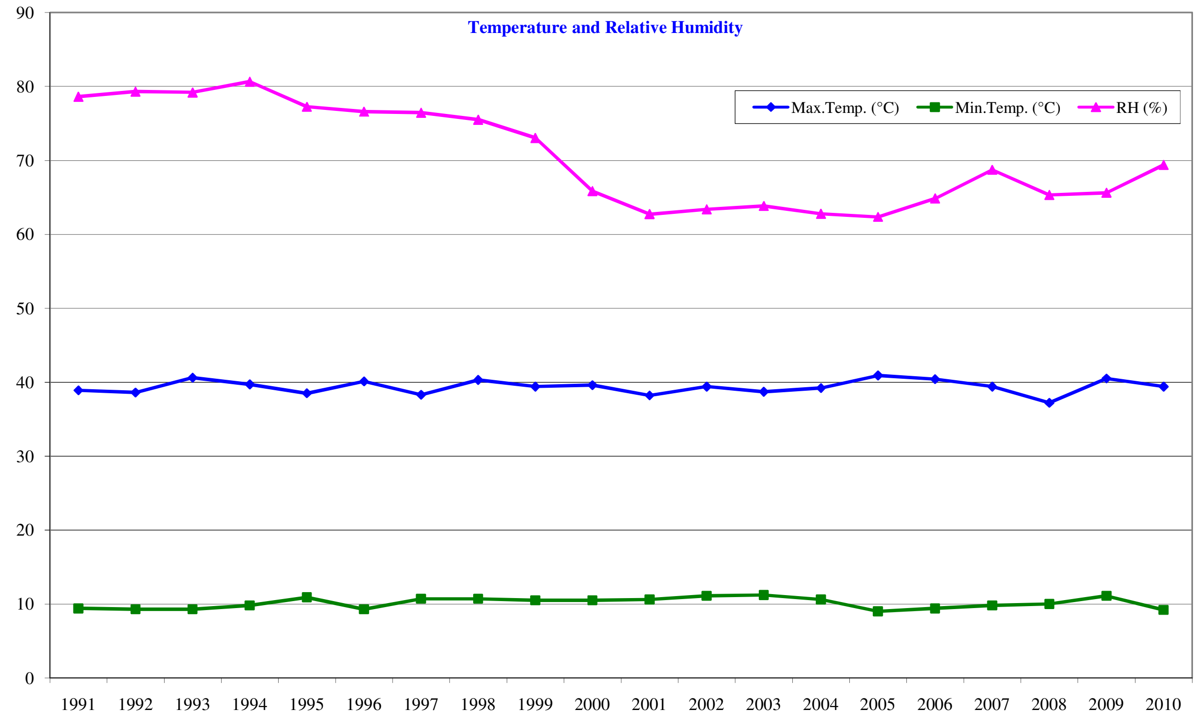


Fig. 4.2.2: Mean and Coefficient of Variation of Climate Variables in Dharwad District (1991-2010)

Fig 4.2.2. Mean and Coefficient of Variation of Climate Variables in Dharwad District (1991-2010)

Table 4.2.3: Seasonal Distribution of Rainfall in Dharwad District and its Variation across Years (1991-2010)

(Figures in mm)

Year	Pre-Monsoon	Monsoon	Post-Monsoon
1991	246.10	717.10	141.60
1992	99.40	798.00	203.60
1993	117.50	678.00	181.40
1994	89.60	598.00	164.20
1995	77.00	676.00	208.50
1996	64.40	562.00	166.40
1997	127.00	728.00	135.60
1998	68.00	584.00	130.30
1999	67.00	885.00	158.00
2000	78.50	675.00	102.40
2001	73.50	745.00	120.80
2002	82.60	582.00	110.40
2003	64.30	692.00	135.10
2004	70.20	634.00	108.60
2005	104.40	774.50	127.40
2006	171.90	585.50	94.00
2007	151.40	781.50	128.50
2008	87.10	574.40	132.60
2009	123.80	708.80	187.00
2010	246.10	717.10	141.60
Mean	**110.49**	**684.80**	**143.90**
SD	**55.12**	**87.87**	**32.62**
CV (%)	**49.89**	**12.83**	**22.67**

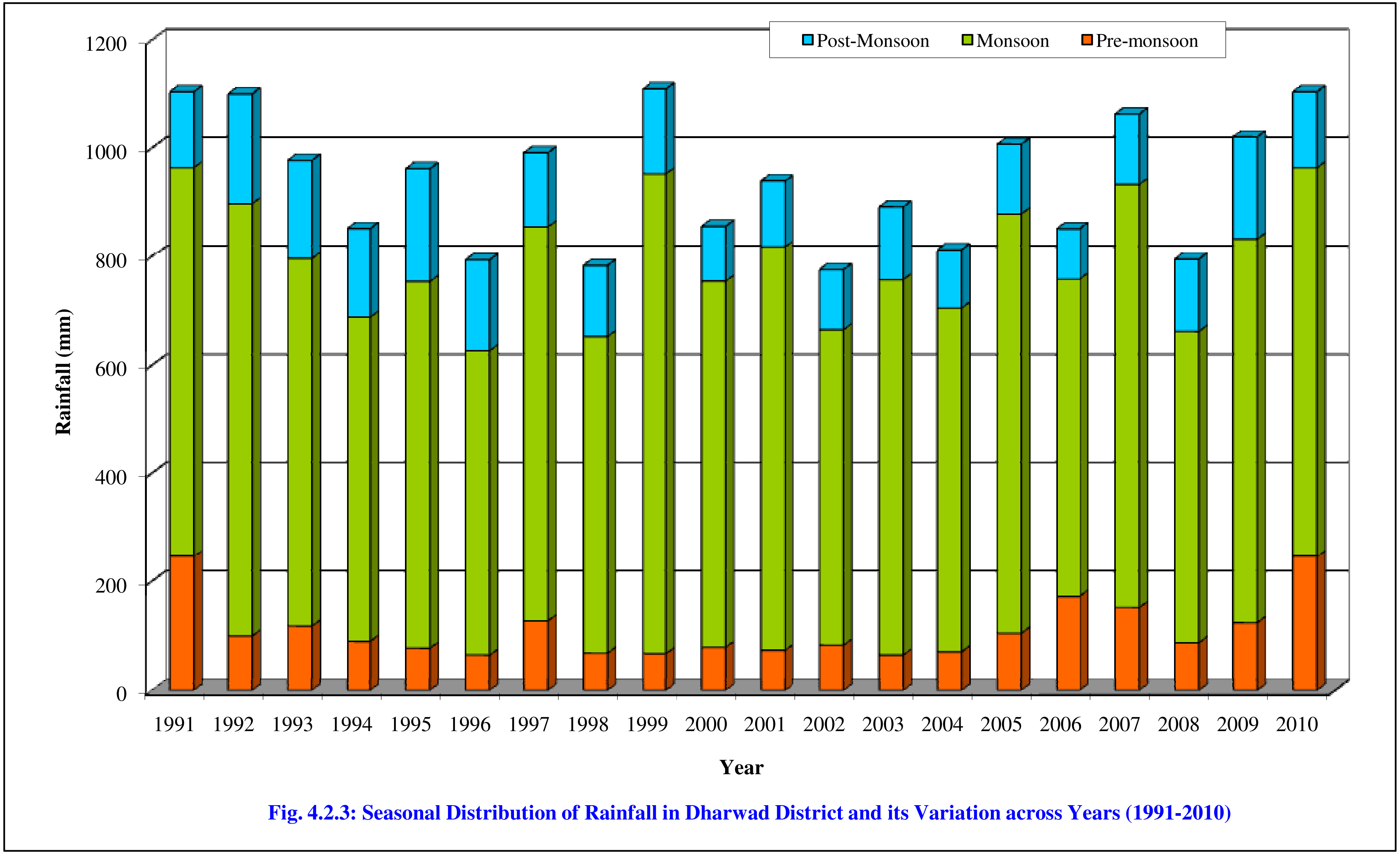


Fig 4.2.3. Seasonal Distribution of Rainfall in Dharwad District and its Variation across Years (1991-2010)

Table 4.2.4: Coefficient of Variation in Annual and Seasonal Rainfall in Dharwad District during 1991-2010

(Figures in mm)

Year	Annual	*Kharif*	*Rabi*	Summer
1991	1104.8	717.1	141.6	246.1
1992	805.2	502.2	203.6	99.4
1993	703.5	365.0	221.0	117.5
1994	741.5	479.7	172.2	89.6
1995	731.9	381.2	213.7	137.0
1996	681.3	425.5	186.4	69.4
1997	760.3	424.0	156.4	179.9
1998	548.8	363.7	130.3	54.8
1999	537.6	332.2	158.0	67.2
2000	529.5	359.7	91.3	78.5
2001	795.1	365.0	98.3	68.9
2002	782.9	330.4	110.4	121.5
2003	634.2	325.4	106.1	86.7
2004	645.5	450.4	95.8	65.6
2005	1011.1	774.5	132.2	104.4
2006	856.6	585.5	123.6	177.1
2007	1074.2	781.5	128.5	164.2
2008	905.1	574.4	132.6	198.1
2009	1125.0	708.8	263.4	152.8
2010	955.5	575.0	271.2	109.3
Mean	**796.48**	**491.06**	**156.83**	**119.40**
SD	**184.44**	**154.35**	**53.95**	**52.25**
CV (%)	**23.16**	**31.43**	**34.40**	**43.76**

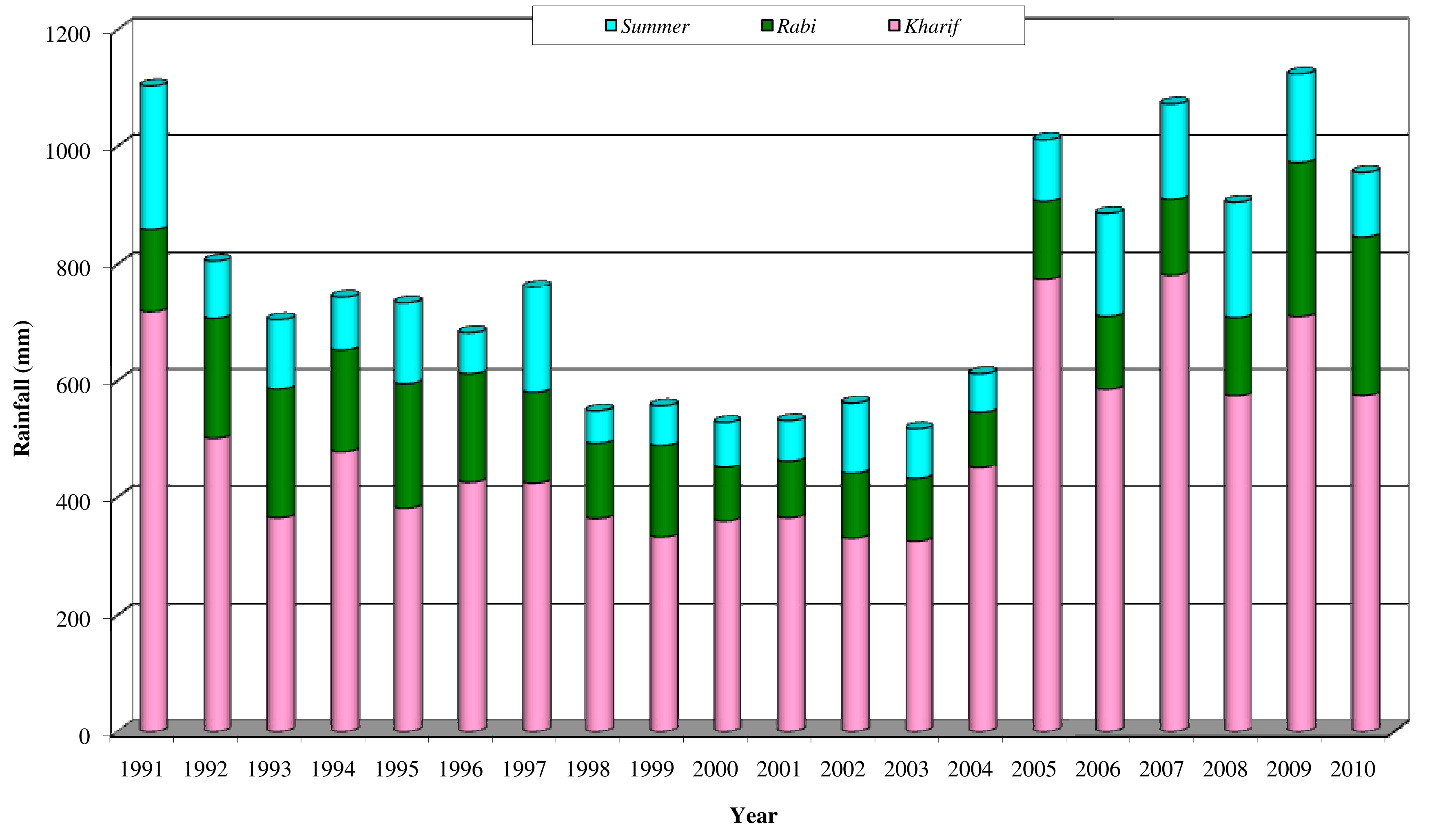


Fig. 4.2.4: Coefficient of Variation in Annual and Seasonal Rainfall in Dharwad District during 1991-2010

Fig 4.2.4. Coefficient of Variation in Annual and Seasonal Rainfall in Dharwad District during 1991-2010

Table 4.2.5: Deviation of Actual Annual Rainfall from Normal and Mean Rainfall in Dharwad District

Year	Rainfall (mm)	% deviation from Mean Rainfall	% deviation from Normal Rainfall
1991	1104.8	38.71	41.64
1992	805.2	1.09	3.23
1993	703.5	-11.68	-9.81
1994	741.5	-6.91	-4.94
1995	731.9	-8.11	-6.17
1996	681.3	-14.46	-12.65
1997	760.3	-4.54	-2.53
1998	548.8	-31.10	-29.64
1999	537.6	-32.50	-31.08
2000	529.5	-33.52	-32.12
2001	795.1	-0.18	1.94
2002	782.9	-1.71	0.37
2003	634.2	-20.38	-18.69
2004	645.5	-18.96	-17.24
2005	1011.1	26.94	29.63
2006	856.6	7.55	9.82
2007	1074.2	34.87	37.72
2008	905.1	13.63	16.04
2009	1125.0	41.24	44.23
2010	955.5	19.96	22.50
Mean	**796.5**	**0.00**	**2.12**

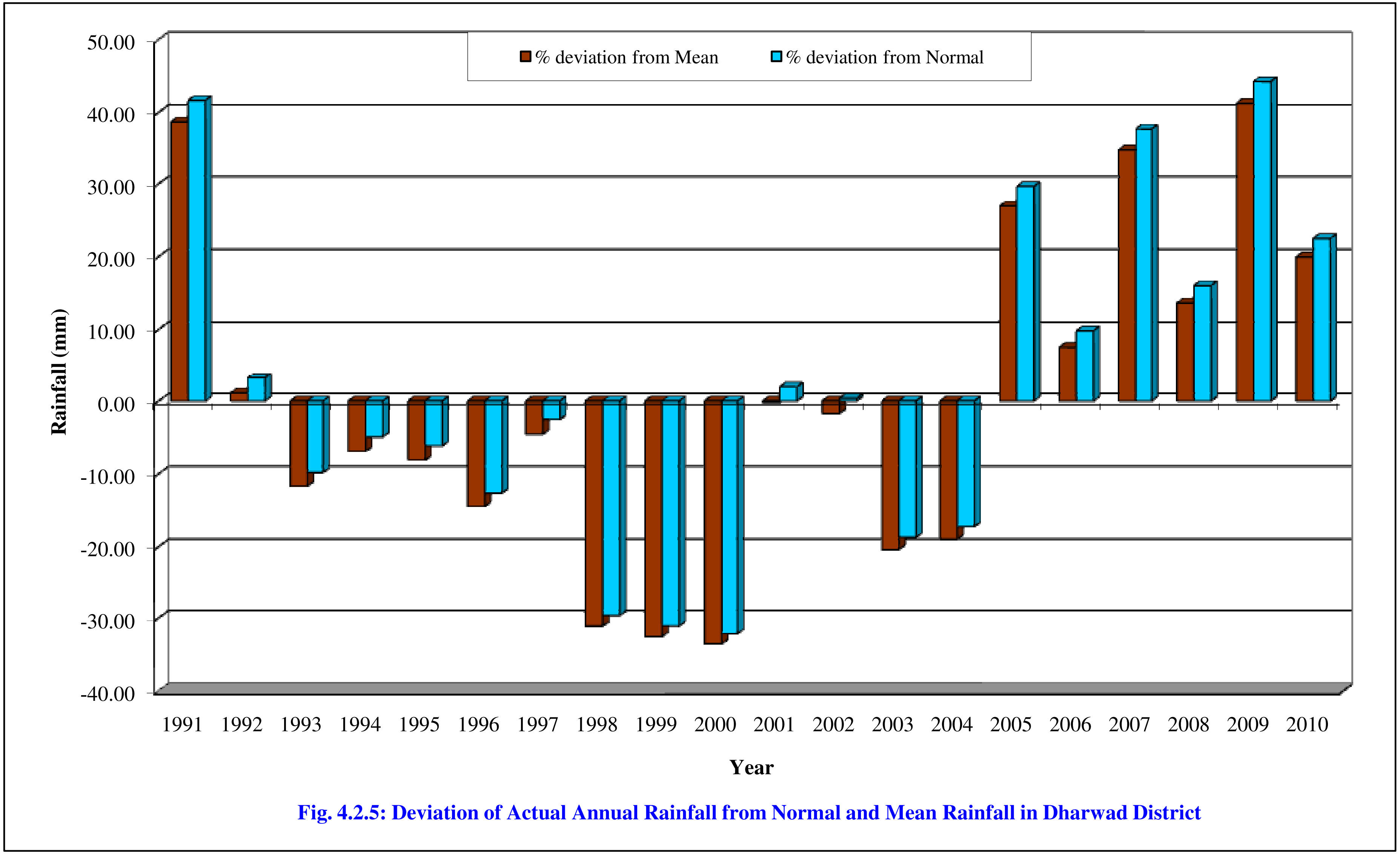


Fig 4.2.5. Deviation of Actual Annual Rainfall from Normal and Mean Rainfall in Dharwad District

percentage deviation of actual annual rainfall from the mean actual annual rainfall during the study period ranged from -33.52 per cent during 2000 to 41.24 per cent during 2009. The mean deviation was relatively much higher in 2005 and onwards.

Further, the percentage deviation of actual annual rainfall from the normal rainfall (780 mm) was also estimated. These figures also showed a similar pattern, with degree of deviation widening from the year 2005 onwards. The actual annual rainfall was as low as -32.12 per cent of normal rainfall (in the year 2000) to as high as 44.23 per cent (in the year 2009).

4.2.6 Spatial Variation in Rainfall across Taluks in Dharwad District

The mean, standard deviation and coefficient of variation of actual annual rainfall in all the five taluks of Dharwad district, namely, Dharwad, Hubli, Kalaghatgi, Kundgol and Navalgund across years and across taluks were estimated and presented in Table 4.2.6.

The temporal analysis of each taluk indicated that Kalaghatgi taluk received the highest mean rainfall (1007 mm), followed by Dharwad taluk (974 mm), Hubli taluk (798 mm), Kundgol (662 mm) and Navalgund (612 mm). The temporal variability over the 20-year study period was highest in the case of Kundgol taluk (26.24%), followed by Navalgund (25.16 %), Hubli (24.53%), Dharwad (22.20%) and Kalaghatgi (11.11%).

The spatial analysis of annual rainfall in each year of the study period revealed that the mean annual rainfall in each of the selected taluks was to the tune of about 811 mm. The spatial variability measured in terms of coefficient of variation ranged from 13.52 per cent (1992-93) to 47.11 per cent (2003-04). Among the 20 years under study, the variability was much higher during 1996-97, 1998-99, 2000-01, 2002-03 and 2005-06, ranging from 35 per cent to 47 per cent. The mean coefficient of variation across all years was to the tune of 21.95 per cent.

4.2.7 Correlation Matrices of Climate Variables across Taluks

For each of the climate variables (*viz.*, rainfall, maximum temperature, minimum temperature, average temperature, maximum relative humidity, minimum relative humidity and average relative humidity), the correlation across the selected taluks was estimated to see how the selected taluks move over time. The results of such an analysis were presented in the Table 4.2.7.

In the case of the rainfall, highest positive correlation was observed between Dharwad and Hubli taluk (0.8816), followed by Hubli-Kundgol (0.4446), Kundgol-Navalgund (0.4296) and Kalaghatgi-Kundgol (0.4174). Nowhere negative correlation was observed amongst the selected taluks.

Regarding maximum diurnal temperature, Kundgol-Navalgund bondage was highest and positive (0.7953), followed by Dharwad-Navalgund (0.6805), Dharwad-Kundgol (0.6212) and Dharwad-Hubli (0.6102), whereas it was negative and high correlation between Dharwad and Kalaghatgi (-0.4860). As far as minimum diurnal temperature is concerned, it was Kundgol-Navalgund which had highest positive correlation (0.5121), whereas Dharwad-Navalgund had a high negative correlation (-0.5672). If average diurnal temperature was considered, it was Dharwad-Hubli (0.6388), Dharwad-Navalgund (0.4741) and Kundgol-Navalgund (0.4600) which had a positive and high correlation.

So far as maximum diurnal relative humidity was concerned, Hubli-Navalgund (0.6029), Hubli-Kundgol (0.5777) and Kundgol-Navalgund (0.4647) had shown very high positive bondage, whereas Kalaghatgi-Kundgol (-0.4898) witnessed a high negative bondage. In terms of minimum diurnal relative humidity, no strong bondages across selected taluks were observed except Dharwad-Navalgund (0.5866) and Dharwad-Kalaghatgi (0.5178). Though there were negative bondages amongst few taluks, they were not that strong. The average diurnal relative humidity did not establish any strong linkages amongst selected taluks except Dharwad-Kalaghatgi (0.5443).

4.3 Changes in Cropping Pattern by Taluks and their Relationship with Climate Variability

4.3.1 Changes in Cropping Pattern in Dharwad District – by Taluks

The changes in cropping pattern in Dharwad district as well as in the selected taluks were studied by estimating the triennium average area under different crops for TE 2001-02 and TE 2008-09 and comparing them. For the district as a whole, the percentage change in area under different

Table 4.2.6: Spatial Variation in Rainfall across Taluks in Dharwad District

(Figures in mm)

Year	Dwd-RF	Hub-RF	Kgt-RF	Kdg-RF	Ngd-RF	Mean	SD	CV (%)
1992	939.70	915.58	1054.10	871.20	718.90	899.90	121.65	13.52
1993	1050.50	799.27	1123.80	794.30	689.70	891.51	185.69	20.83
1994	739.90	713.50	1112.80	858.20	650.50	814.98	182.72	22.42
1995	704.50	626.60	955.60	808.20	551.50	729.28	158.28	21.70
1996	1020.10	833.50	1005.10	841.80	708.05	881.71	130.82	14.84
1997	1455.70	1277.90	984.50	895.30	407.30	1004.14	402.28	40.06
1998	1249.15	1052.90	1124.70	706.40	831.00	992.83	220.75	22.23
1999	1166.70	810.80	1037.60	496.00	393.60	780.94	334.22	42.80
2000	926.30	656.10	1136.70	845.50	721.80	857.28	188.29	21.96
2001	1010.80	699.60	891.60	462.60	465.30	705.98	247.27	35.03
2002	989.46	750.30	779.10	450.20	673.30	728.47	194.70	26.73
2003	670.10	523.60	1045.60	401.50	341.00	596.36	280.95	47.11
2004	722.40	521.38	971.40	598.62	540.20	670.80	185.48	27.65
2005	1114.10	854.50	1169.90	689.90	589.80	883.64	254.84	28.84
2006	905.40	780.10	1070.90	369.30	444.50	714.04	299.93	42.00
2007	1208.62	1142.20	1097.90	774.70	750.20	994.72	215.84	21.70
2008	998.90	698.50	984.80	547.30	782.00	802.30	192.46	23.99
2009	1135.80	968.00	877.50	656.70	891.00	905.80	173.09	19.11
2010	849.80	714.20	917.40	698.80	582.90	752.62	132.07	17.55
2011	620.14	626.20	798.00	481.45	511.50	607.46	124.40	20.48
Mean	**973.90**	**798.24**	**1006.95**	**662.40**	**612.20**	**810.74**	**177.97**	**21.95**
SD	**216.16**	**195.78**	**111.85**	**173.79**	**154.01**			
CV (%)	**22.20**	**24.53**	**11.11**	**26.24**	**25.16**			

Note: Dwd=Dharwad, Hub=Hubli, Kgt=Kalaghatgi, Kdg=Kundgol, Ngd=Navalgund
RF=Rainfall, SD=Standard Deviation, CV=Coefficient of Variation.

Table 4.2.7: Correlation Matrices of Climate Variables across Taluks

A) RAINFALL					
	Dwd-RF	***Hub-RF***	***Kgt-RF***	***Kdg-RF***	***Ngd-RF***
Dwd-RF	1				
Hub-RF	0.8817	1			
Kgt-RF	0.2403	0.2190	1		
Kdg-RF	0.2806	0.4446	0.4174	1	
Ngd-RF	0.2429	0.2927	0.1102	0.4296	1
B) TEMPERATURE (MAXIMUM)					
	Dwd-TP-Max	***Hub-TP-Max***	***Kgt-TP-Max***	***Kdg-TP-Max***	***Ngd-TP-Max***
Dwd-TP-Max	1				
Hub-TP-Max	0.6102	1			
Kgt-TP-Max	-0.4860	-0.2067	1		
Kdg-TP-Max	0.6212	0.2346	-0.1022	1	
Ngd-TP-Max	0.6805	0.3261	-0.0365	0.7953	1
C) TEMPERATURE (MINIMUM)					
	Dwd-TP-Min	***Hub-TP-Min***	***Kgt-TP-Min***	***Kdg-TP-Min***	***Ngd-TP-Min***
Dwd-TP-Min	1				
Hub-TP-Min	0.1558	1			
Kgt-TP-Min	0.2793	0.2498	1		
Kdg-TP-Min	-0.3731	-0.0261	-0.3437	1	
Ngd-TP-Min	-0.5672	0.2021	-0.0305	0.5121	1
D) TEMPERATURE (AVERAGE)					
	Dwd-TP-Avg	***Hub-TP-Avg***	***Kgt-TP-Avg***	***Kdg-TP-Avg***	***Ngd-TP-Avg***
Dwd-TP-Avg	1				
Hub-TP-Avg	0.6388	1			
Kgt-TP-Avg	-0.0755	0.1647	1		
Kdg-TP-Avg	-0.1693	-0.0875	-0.1770	1	
Ngd-TP-Avg	0.4741	0.2576	0.0090	0.4600	1

Contd……

E) RELATIVE HUMIDITY (MAXIMUM)					
	Dwd-RH-Max	***Hub-RH-Max***	***Kgt-RH-Max***	***Kdg-RH-Max***	***Ngd-RH-Max***
Dwd-RH-Max	1				
Hub-RH-Max	-0.0761	1			
Kgt-RH-Max	0.0538	-0.3433	1		
Kdg-RH-Max	-0.0300	0.5777	-0.4898	1	
Ngd-RH-Max	-0.1923	0.6029	-0.0213	0.4647	1
F) RELATIVE HUMIDITY (MINIMUM)					
	Dwd-RH-Min	***Hub-RH-Min***	***Kgt-RH-Min***	***Kdg-RH-Min***	***Ngd-RH-Min***
Dwd-RH-Min	1				
Hub-RH-Min	0.3859	1			
Kgt-RH-Min	0.5178	0.3821	1		
Kdg-RH-Min	0.0477	-0.1752	-0.0780	1	
Ngd-RH-Min	0.5866	0.3463	0.2002	0.0164	1
G) RELATIVE HUMIDITY (AVERAGE)					
	Dwd-RH-Avg	***Hub-RH-Avg***	***Kgt-RH-Avg***	***Kdg-RH-Avg***	***Ngd-RH-Avg***
Dwd-RH-Avg	1				
Hub-RH-Avg	0.1942	1			
Kgt-RH-Avg	0.5443	0.3349	1		
Kdg-RH-Avg	-0.3285	-0.0422	-0.3100	1	
Ngd-RH-Avg	0.3665	0.2462	0.2045	-0.0059	1

Table 4.3.1: Changes in Cropping Pattern in Dharwad District by Taluks

(Figures in ha)

Sl. No.	Crop	Dharwad Taluk		Hubli Taluk		Kalaghatgi Taluk		Kundgol Taluk		Navalgund Taluk		Dharwad District Total			
		TE* 2001-02	TE 2008-09	TE 2001-02	TE 2008-09	TE 2001-02	TE 2008-09	TE 2001-02	TE 2008-09	TE 2001-02	TE 2008-09	TE 2001-02	TE 2008-09	% Change	% to GCA*
1	Jowar	16697	11919	10333	8035	8140	5672	7768	9163	16371	13178	59310	47967	-19.12	9.39
2	Maize	2029	8004	1613	5649	272	2836	279	1206	17857	22044	22050	39738	80.22	7.78
3	Wheat	7761	7170	5632	4266	50	34	7612	8338	17668	19216	38724	39024	0.77	7.64
4	Paddy	13617	12516	1575	801	22404	14178	366	277	147	13	38109	27785	-27.09	5.44
A	**Total Cereals**	**42939**	**40528**	**20224**	**19810**	**26448**	**23015**	**14756**	**19312**	**53624**	**54454**	**157990**	**157119**	**-0.55**	**30.76**
5	Bengalgram	9962	17860	2318	3277	111	271	1496	2300	17743	23669	31630	47377	49.79	9.28
B	**Total Pulses**	**23491**	**32513**	**7644**	**9896**	**4510**	**3622**	**6184**	**7526**	**28847**	**36452**	**70676**	**90009**	**27.35**	**17.62**
C	**Total Food Grains**	**65525**	**73041**	**28402**	**29706**	**32479**	**26638**	**19922**	**26838**	**43022**	**90906**	**189349**	**247128**	**30.51**	**48.39**
6	Spices	1617	846	16727	11041	546	219	33699	28067	8087	12211	60676	52383	-13.67	10.26
7	Fruits	2182	3500	952	1854	1251	1195	122	319	47	59	4554	6926	52.09	1.36
8	Vegetables	8228	6926	7529	9834	540	336	5377	3582	20938	21310	42613	41988	-1.47	8.22
D	**Total Food Crops**	**80435**	**88241**	**49119**	**52535**	**36441**	**29605**	**59717**	**58806**	**129690**	**124519**	**355069**	**353706**	**-0.38**	**69.25**
9	Oilseeds	15497	17007	8405	16794	4126	12883	15873	21581	9117	14022	53039	82288	55.15	16.11
10	Cotton	11345	2410	18732	20327	7582	5269	26519	27668	23883	16970	88061	72643	-17.51	14.22
E	**Total Non-Food Crops**	**31667**	**19754**	**27946**	**37445**	**14656**	**19467**	**23662**	**49374**	**35570**	**31002**	**133500**	**157042**	**17.63**	**30.75**
F	**Gross Cropped Area**	**112102**	**107995**	**77065**	**89980**	**51097**	**49072**	**83379**	**108180**	**165260**	**155521**	**488569**	**510748**	**4.54**	**100.00**
G	**Area Sown more than once**	**32161**	**35082**	**29390**	**35106**	**9890**	**7509**	**28703**	**48261**	**60837**	**77077**	**160647**	**203035**	**26.39**	**39.75**
H	**Net Sown Area**	**79941**	**72913**	**47675**	**54874**	**41207**	**41563**	**54676**	**59919**	**104423**	**78444**	**327922**	**307713**	**-6.16**	**60.25**

* TE=Triennium Ending, GCA=Gross Cropped Area.

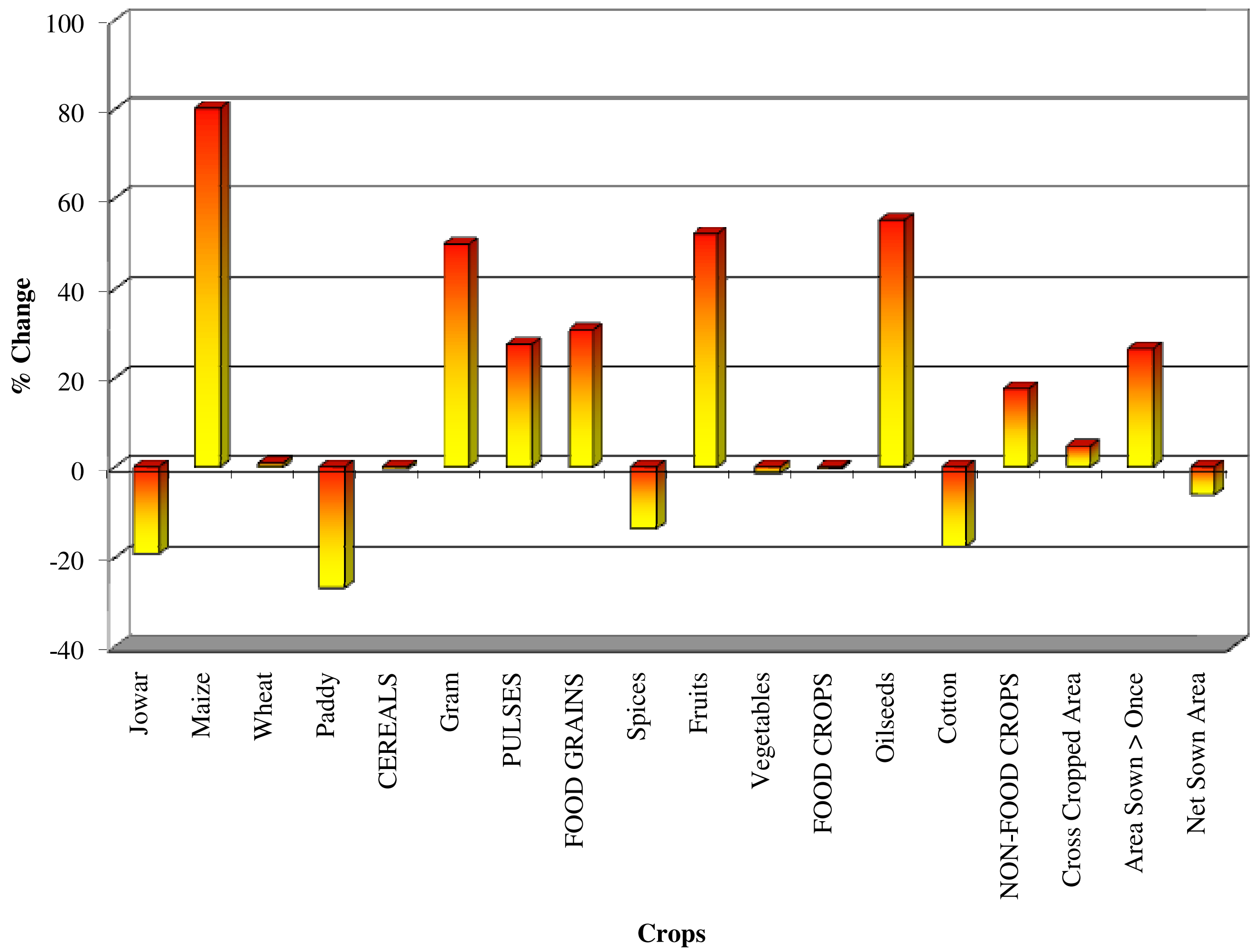


Fig. 4.3.1: Changes in Cropping Pattern in Dharwad District by Taluks

Fig 4.3.1. Changes in Cropping Pattern in Dharwad District by Taluks

crops between these two periods as well as percentage area under each crop to the gross cropped area (GCA) were estimated. The results were presented in Table 4.3.1.

During the TE 2008-09, the cropping pattern in the district was analysed with the help of area under each crop as a percentage of the GCA. Of the 5,10,748 ha of GCA, net sown area (NSA) accounted for 60.25 per cent, while the area sown more than once accounted for 39.75 per cent. The cropping intensity was 166 per cent.

Food crops occupied about 69 per cent of the GCA, while the remaining 31 per cent was occupied by non-food crops. Cereals and pulses constituted 30.76 per cent and 17.62 per cent, respectively, of the GCA, thus adding to 48.39 per cent for food grains. Jowar occupied the highest area (9.39%) among cereals, followed by maize (7.78%), wheat (7.64%) and paddy (5.44%), whereas among pulses, bengalgram was the major share holder (9.28%) in the cropped area. Spices and vegetables occupied 10.26 per cent and 8.22 per cent of the GCA. Amongst non-food crops, oilseeds and cotton were the major crops occupying 16.11 per cent and 14.22 per cent of the GCA. Thus, it could be seen that jowar was the single food crop occupying largest area in the district.

The changes in the cropped area between two points of time, *i.e.*, TE 2001-02 and TE 2008-09, reveal that the GCA has increased by 4.54 per cent, with NSA decreasing by 6.16 per cent and 'area sown more than once' increasing by 26.39 per cent. It is interesting to note that the area under food crops has fallen by 0.38 per cent, while that of non-food crops increased by 17.63 per cent. Among food crops, area under food grains has grown by 30.51 per cent and that of fruits increased by 52.09 per cent, whereas spices and vegetables witnessed a negative growth (-13.67 per cent and -1.47%, respectively). It is further interesting to note that cereals registered a negative growth in their area (-0.55 per cent), while pulses showed a positive and high growth (27.35%). Amongst cereals, maize had a significant positive growth (80.22%), while area under paddy and jowar showed a declining trend (-27.09 per cent and -19.12%). Amongst pulses, bengalgram had a record growth of 49.79 per cent during the study period.

Coming to individual taluks, the growth scenario was almost similar in all the crops except wheat, vegetables and cotton in Hubli taluk, fruits in Kalaghatgi taluk, jowar and cotton in Kundgol taluk and spices and vegetables in Navalgund taluk, wherein the trends were reverse of the trends at the district level.

4.3.2 Compound Annual Growth Rates of Cropped Area

Compound annual growth rates of area under different crops were calculated for the five taluks under consideration for the period from 1999-2000 to 2008-09 and the results were presented in Table 4.3.2.

For the Dharwad district as a whole, the compound annual growth rate was positive and the highest (10.17%) in the case of maize, followed by oilseeds (7.39%), fruits (6.13%), gram (4.83%), tur (4.03%) and wheat (0.27%). On the contrary, the growth rate was negative in the case of paddy (-4.79%) followed by jowar (-2.68%), cotton (-2.56%), spices (-2.04%) and vegetables (0.48%).

The results presented in the previous section (4.3.1) were reinforced by the results presented in this section. The GCA has grown at a moderate growth of 0.90 per cent per annum on compounding basis, while the NSA has declined at a rate of 0.89 per cent p.a. The area sown more than once has increased by a very high growth rate (3.84 per cent p.a.). This revealed that though the net sown area is declining over time, the GCA has increased owing to a high growth in 'area sown more than once'. In other words, the cropping intensity has increased considerably over time during the study period.

Coming to individual taluks, in Dharwad taluk, maize had the highest positive Compound annual growth rate of 21.07 per cent, followed by tur (8.05%), bengalgram (7.48%) and fruits (6.85%). Contrarily, cotton witnessed the highest negative growth rate (-18.94%), followed by spices (-9.82%) and jowar (-5.78%). In Hubli taluk, the crops that witnessed significant positive growth were maize (19.19%), oilseeds (10.66%) and fruits (10.01%), whereas the ones with significant negative growth were paddy (-10.90%) and spices (-5.70%). In Kalaghatgi, maize (40.19%) followed by oilseeds (17.80%) and gram (6.47%) witnessed significant positive growth, whereas there was significant negative growth in the case of spices (-13.01%) followed by paddy (-7.01%) and vegetables (-5.67%). In Kundgol, again area cropped to maize grew tremendously at a rate of 23.42 per cent followed by fruits (15.20%), tur (9.01%), gram (6.57%) and oilseeds (5.25%); however, only vegetables had a significant negative growth (-5.27%). Finally, in Navalgund, spices, oilseeds and maize had positive

Table 4.3.3.2: Response to Climate Variables by Area Sown to Maize

Sl. No.	Variable	Taluks					District Overall
		Dharwad	Hubli	Kalaghatgi	Kundgol	Navalgund	
1	Intercept	-33868.82** (14388.98)	7969.06 (14810.15)	-7230.94 (11590.32)	5041.60 (4509.95)	43854.60 (60168.04)	-116767.34 * (61233.01)
2	Rainfall	-4.86** (2.11)	1.16 (1.44)	-0.31 (2.17)	0.19 (0.50)	7.65 (9.21)	29.27 ** 10.49)
3	Maximum Temperature	167.25 (189.46)	221.52 (194.96)	-411.51*** (134.86)	-11.02 (125.89)	-950.36 (854.19)	1583.44 (1220.73)
4	Minimum Temperature	616.30** (231.68)	26.28 (245.03)	16.15 (106.73)	-6.26 (79.08)	-206.52 (2012.78)	650.73 (1842.34)
5	Maximum RH	347.75** (153.33)	-190.57* (94.89)	215.99* (100.50)	-49.24*** (13.15)	200.57 (548.64)	427.96 *** (444.82)
6	Minimum RH	-55.78 (54.68)	68.67 (56.32)	21.55 (20.59)	-6.82 (28.72)	-470.12 (349.67)	167.01 (391.64)
7	R^2	0.6937	0.6107	0.5834	0.7299	0.4514	0.6932
8	F-Value	5.8893***	4.0792**	3.6409**	7.0268***	2.1393	0.0047***
9	N	19					

Note: 1) Figures in parentheses indicate Standard Errors of respective Regression Coefficients.
2) ***, ** and * indicate significance at 1%, 5% and 10% probability levels, respectively.

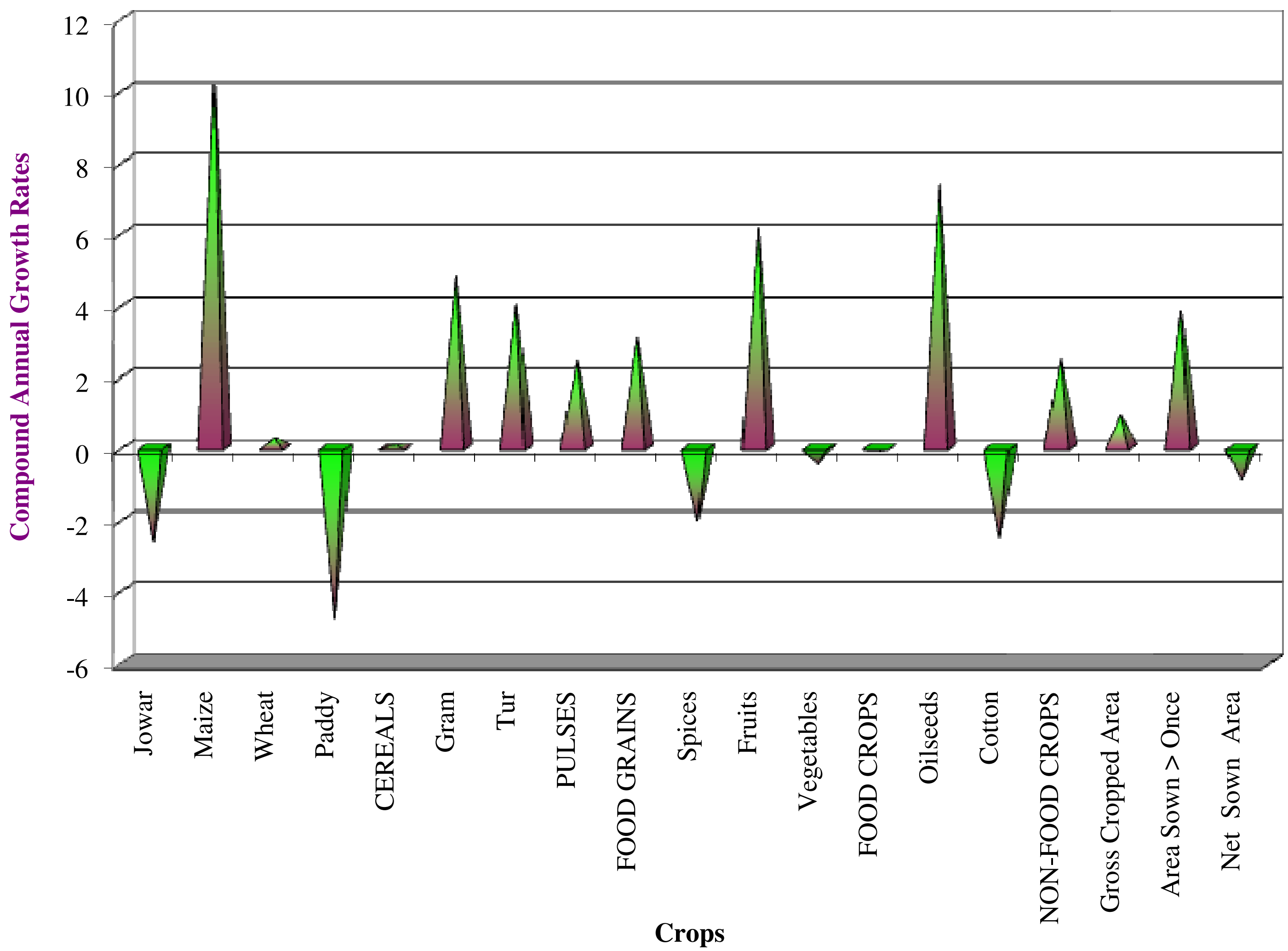


Fig. 4.3.2: Compound Annual Growth Rates of Changes in Cropping Pattern in Dharwad District by Taluks during 1999-2000 to 2008-09

significant growth, while significant negative growth was observed in paddy (-21.85%) followed by tur (-13.20%) and cotton (-5.13%).

4.3.3 Acreage Response to Climate Variables: Multiple Regression Models

The response of area under different crops to selected climatic variables was analysed using multiple linear regression model. In the model, area under crop in question was taken as dependent variable and different climatic variables, *viz.*, rainfall, maximum temperature, minimum temperature, maximum relative humidity and minimum relative humidity were taken as independent variables.

The results of the analysis are presented in Tables 4.3.3.1 through 4.3.3.5.

4.3.3.1 Paddy

The response of area under paddy to different climatic variables in Dharwad district as well as by taluks were presented in Table 4.3.3.1. For the district as a whole, the coefficient of multiple determination (R^2) of the model indicated that 74.78 per cent of the variation in the area under paddy was explained by the different climatic variables included in the model. However, none of the variables included in the model was significant as indicated by the 't' value.

As far as individual taluks were concerned, the R^2 was reasonably high in the case of Kalaghatgi and Kundgol (>60%), good in the case of Dharwad and Hubli (about 50%), but very low (<17%) in the case of Navalgund. 'F' value was significant in all the taluks except Navalgund.

The significance of variables included in the model also differed across taluks. The significant variables were maximum temperature in Dharwad, maximum relative humidity in Hubli, maximum temperature and maximum relative humidity in Kalaghatgi and maximum temperature in Kundgol. No variable was significant in Navalgund. Thus, it was interesting to note that rainfall, minimum temperature and minimum relative humidity were not significant in any of the taluks, even at 10 per cent significant level. Maximum temperature was significant in three out of five selected taluks, while maximum relative humidity was significant in two out of five selected taluks. Maximum temperature was significant and negative in the case of Dharwad and Kundgol while it was positive and significant in the case of Kalaghatgi. Maximum relative humidity was positive and significant in Hubli whereas it was negative and significant in Kalaghatgi.

4.3.3.2 Maize

The acreage response of maize to different climate variables assessed through multi-linear regression models was presented in Table 4.3.3.2. A perusal of the results revealed that in Dharwad district as a whole, 69.32 per cent of variation in the area under maize was explained by the different climatic variables included in the model. 'F' value was significant at district level as well as taluk-wise regression functions except in the case of Navalgund function. Among the explanatory variables, maximum relative humidity was positively significant at one per cent probability level and rainfall was also positively significant at five per cent probability level.

The taluk-wise regressions reveal that maximum relative humidity was the only variable which was significant in four out of the five selected taluks (excepting Navalgund), of course, positively in Dharwad and Kalaghatgi and negatively in Hubli and Kundgol. The other significant variables were rainfall (negative) and minimum relative humidity (positive) in Dharwad and maximum temperature (negative) in Kalaghatgi. Interestingly, none of the variables was significant in Navalgund.

4.3.3.3 Jowar

The regression results of the response of area under jowar to different climatic variables were presented in Table 4.3.3.3. It could be seen from the table that, in Dharwad district as a whole, the co-efficient of determination was 0.3703 which implies that 37.03 per cent of variation in the area under jowar was explained by the different climatic variables included in the model. Interestingly, 'F' value was not significant nor any of the explanatory variables.

Coming to taluk level, 'F' value was not significant in all the selected taluks except Dharwad whereas it was significant at five per cent probability level, with an R^2 value of 0.6264. The significant variables were minimum temperature (negative) in Dharwad and maximum relative humidity (positive) in Navalgund.

Table 4.3.3.1: Response to Climate Variables by Area Sown to Paddy

Sl. No.	Variable	Taluks					District Overall
		Dharwad	Hubli	Kalaghatgi	Kundgol	Navalgund	
1	Intercept	36983.95*** (10606.48)	-2561.36 (5913.31)	132901.81* (64363.57)	2342.68* (1161.07)	-45.49 (158.64)	25586.29 (67610.64)
2	Rainfall	-0.0015 (1.56)	-0.0001 (0.57)	-4.46 (12.06)	0.10 (0.13)	0.001 (0.02)	-12.75 (11.58)
3	Maximum Temperature	-358.56** (139.65)	-54.66 (77.84)	2145.27** (748.89)	-73.05** (32.41)	-1.25 (2.25)	-1600.48 (1347.87)
4	Minimum Temperature	77.86 (170.78)	5.84 (97.84)	232.65 (592.70)	5.53 (20.36)	5.21 (5.31)	1268.40 (2034.23)
5	Maximum RH	-154.56 (113.03)	69.07* (37.89)	-1944.16*** (558.11)	1.71 (3.38)	0.15 (1.45)	452.90 (491.15)
6	Minimum RH	8.46 (40.30)	-23.25 (22.49)	7.62 (114.32)	5.02 (7.39)	0.36 (0.92)	507.31 (432.43)
7	R^2	0.5092	0.4898	0.6225	0.6818	0.1666	0.7478
8	F-Value	2.6978*	2.4957*	4.2871**	5.5712***	0.5198	7.7095 ***
9	N	19					

Note: 1) Figures in parentheses indicate Standard Errors of respective Regression Coefficients.
2) ***, ** and * indicate significance at 1%, 5% and 10% probability levels, respectively.

Table 4.3.3.2: Response to Climate Variables by Area Sown to Maize

Sl. No.	Variable	Taluks					District Overall
		Dharwad	Hubli	Kalaghatgi	Kundgol	Navalgund	
1	Intercept	-33868.82** (14388.98)	7969.06 (14810.15)	-7230.94 (11590.32)	5041.60 (4509.95)	43854.60 (60168.04)	-116767.34 * (61233.01)
2	Rainfall	-4.86** (2.11)	1.16 (1.44)	-0.31 (2.17)	0.19 (0.50)	7.65 (9.21)	29.27 ** 10.49)
3	Maximum Temperature	167.25 (189.46)	221.52 (194.96)	-411.51*** (134.86)	-11.02 (125.89)	-950.36 (854.19)	1583.44 (1220.73)
4	Minimum Temperature	616.30** (231.68)	26.28 (245.03)	16.15 (106.73)	-6.26 (79.08)	-206.52 (2012.78)	650.73 (1842.34)
5	Maximum RH	347.75** (153.33)	-190.57* (94.89)	215.99* (100.50)	-49.24*** (13.15)	200.57 (548.64)	427.96 *** (444.82)
6	Minimum RH	-55.78 (54.68)	68.67 (56.32)	21.55 (20.59)	-6.82 (28.72)	-470.12 (349.67)	167.01 (391.64)
7	R^2	0.6937	0.6107	0.5834	0.7299	0.4514	0.6932
8	F-Value	5.8893***	4.0792**	3.6409**	7.0268***	2.1393	0.0047***
9	N	19					

Note: 1) Figures in parentheses indicate Standard Errors of respective Regression Coefficients.
2) ***, ** and * indicate significance at 1%, 5% and 10% probability levels, respectively.

Table 4.3.3.3: Response to Climate Variables by Area Sown to Jowar

Sl. No.	Variable	Taluks					District Overall
		Dharwad	Hubli	Kalaghatgi	Kundgol	Navalgund	
1	Intercept	33413.21 (18905.63)	37927.55 (34294.12)	-149.85 (12882.33)	19978.48 (34903.34)	-7260.35 (21785.11)	88430.86 (88188.55)
2	Rainfall	-1.19 (2.77)	-2.69 (3.32)	3.05 (2.41)	-0.92 (3.87)	-0.88 (3.34)	-6.02 (15.11)
3	Maximum Temperature	155.99 (248.93)	-586.19 (451.44)	-66.62 (149.89)	-129.81 (974.25)	-237.88 (309.28)	-561.67 (1758.11)
4	Minimum Temperature	-1086.40*** (304.41)	-169.05 (567.39)	190.36 (118.63)	-161.88 (612.01)	-139.99 (728.77)	-265.93 (2653.36)
5	Maximum RH	-114.44 (201.46)	14.58 (219.72)	24.83 (111.70)	-5.19 (101.75)	380.82* (198.65)	-565.58 (640.63)
6	Minimum RH	68.04 (71.84)	-110.56 (130.42)	-22.94 (22.88)	-72.08 (222.26)	-65.93 (126.60)	701.17 (564.05)
7	R^2	0.6264	0.3953	0.3208	0.0770	0.3300	0.3703
8	F-Value	4.3594**	1.6994	1.2281	0.2169	1.2806	1.5288
9	N	19					

Note: 1) Figures in parentheses indicate Standard Errors of respective Regression Coefficients.
2) ***, ** and * indicate significance at 1%, 5% and 10% probability levels, respectively.

4.3.3.4 Soybean

It could be seen from the Table 4.3.3.4 that, the different climatic variables which were included in the model explained around 60.47 per cent of the variation in the area under soybean in Dharwad district. 'F' value was significant at five per cent probability level. None of the variables except rainfall was significant; rainfall was positively significant at 10 per cent probability level.

Taluk-wise regressions reveal that 'F' value was significant in all the taluks except Navalgund. The R^2 value ranged from 0.5013 (in Kalaghatgi) to 0.8218 (in Dharwad), excepting Navalgund wherein it was 0.3962. The significant variables were minimum temperature (positive) and maximum relative humidity (positive) in Dharwad, maximum relative humidity (positive) in Kalaghatgi, maximum relative humidity (negative) in Kundgol and minimum relative humidity (negative) in Navalgund.

4.3.3.5 Bengalgram

The regression results of the response of area under bengalgram to different climatic variables indicated that 77.99 per cent of variation in the area was explained by the variables included in the model (Table 4.3.3.5). 'F' value was very high and significant. For Dharwad district as a whole, only rainfall was found to significantly and positively influence the area under bengalgram.

Coming to taluk-level regressions, the 'F' value was highly significant in the case of Dharwad (at 1%) and significant at five per cent in the case of Kundgol and Navalgund, while it was non-significant in the case of Hubli and Kalaghatgi. The R^2 value was the highest for Dharwad (0.7934), followed by Kundgol (0.6018) and Navalgund (0.5974), while it was very low in the case of Hubli and Kalaghatgi.

In the case of Dharwad, maximum temperature, minimum temperature and minimum relative humidity were found to significantly influence the bengalgram area. In Kundgol, maximum relative humidity influenced the bengalgram area significant but negatively. Similarly, in Navalgund, maximum relative humidity influenced the bengalgram area significant and negatively, but minimum relative humidity was significant and positive. Interestingly, rainfall was not at all significant in any of the taluks.

4.4 Causality between Climate Variability and Farm Income

Multiple linear regression models were used to estimate the magnitude and direction of influence of the climate variables, namely, rainfall, temperature and relative humidity, on the net returns from different selected crops (paddy, maize, jowar, soybean and bengalgram) under rainfed situation. Please refer to the definitions of variables described in the Methodology Chapter under Section 3.4.3 (b). The regression results were presented in Tables 4.4.1 through 4.4.5.

4.4.1 Response of Net Returns in Paddy to Climate Variables

The response of net retunes in paddy to different climate variables was presented in the Table 4.4.1. As indicated by the coefficient of determination, nearly 95 per cent of the variation in the net returns from paddy was explained by the different climatic variables included in the model. 'F' value was highly significant (42.82) at one per cent probability level.

Among the different variables, rainfall (3.980) and temperature (953.003) were positively influencing the net returns obtained from the paddy and were found significant at five and one per cent respectively. Contrarily, relative humidity was non-significant.

4.4.2 Response of Net Returns in Maize to Climate Variables

With respect to maize, 89.65 per cent of the variation in the net returns was explained by the different climatic variables included in the model (Table 4.4.2). 'F' value was again significant at one per cent probability level.

Among the different variables, temperature and relative humidity were having significant positive impact on the net returns of maize and were found significant at one and five per cent, respectively. Unlike in the case of paddy, rainfall was non-significant.

4.4.3 Response of Net Returns in Jowar to Climate Variables

The impact of different climatic variables on the net returns of jowar was presented in Table 4.4.3. It could be seen from the Table that 89.11 per cent of variation in the net returns of jowar was explained by the various climatic variables included in the model. As in the case of maize, rainfall did

Table 4.3.3.4: Response to Climate Variables by Area Sown to Soybean

Sl. No.	Variable	Taluks					District Overall
		Dharwad	Hubli	Kalaghatgi	Kundgol	Navalgund	
1	Intercept	-39620.81** (13216.77)	60.90 (28916.25)	-81051.61 (48245.46)	13555.73** (6205.98)	-790.04 (708.69)	63541.68 (94716.62)
2	Rainfall	-1.11 (1.94)	2.66 (2.80)	12.32 (9.04)	0.33 (0.69)	-0.16 (0.11)	33.42* (16.23)
3	Maximum Temperature	174.45 (174.02)	673.20 (380.65)	-991.39 (561.35)	-198.98 (173.23)	5.93 (10.06)	-303.26 (1888.25)
4	Minimum Temperature	813.96*** (212.81)	507.54 (478.42)	570.65 (444.28)	19.44 (108.82)	5.93 (23.71)	-3063.25 (2849.78)
5	Maximum RH	268.77* (140.84)	-278.78 (185.27)	1060.62** (418.34)	-57.04*** (18.09)	11.12 (6.46)	-269.45 (688.05)
6	Minimum RH	64.66 (50.22)	-74.56 (109.97)	-43.84 (85.69)	-58.93 (39.52)	-8.22* (4.12)	-163.09 (605.80)
7	R^2	0.8218	0.5547	0.5013	0.7239	0.3962	0.6047
8	F-Value	11.9912***	3.2385**	2.6139*	6.8175***	1.7062	3.9765**
9	N	19					

Note: 1) Figures in parentheses indicate Standard Errors of respective Regression Coefficients.
2) ***, ** and * indicate significance at 1%, 5% and 10% probability levels, respectively.

Table 4.3.3.5: Response to Climate Variables by Area Sown to Bengalgram

Sl. No.	Variable	Taluks					District Overall
		Dharwad	Hubli	Kalaghatgi	Kundgol	Navalgund	
1	Intercept	-31705.81 (23693.41)	-5819.22 (20156.10)	495.70 (1668.46)	11244.49 (19000.64)	36296.59 (34411.23)	52697.30 81023.19)
2	Rainfall	-1.11 (3.48)	-2.07 (1.95)	0.38 (0.31)	-0.36 (2.11)	-0.17 (5.27)	29.66* 13.88)
3	Maximum Temperature	659.50* (311.97)	298.40 (265.33)	1.80 (19.41)	50.32 (530.36)	561.12 (488.53)	216.99 1615.26)
4	Minimum Temperature	854.96** (381.50)	-17.99 (333.48)	-2.53 (15.36)	109.30 (333.17)	-474.18 (1151.15)	2806.93 2437.78
5	Maximum RH	69.65 (252.48)	-30.42 (129.14)	-5.99 (14.47)	-147.98** (55.39)	-608.45* (313.78)	-814.32 588.58)
6	Minimum RH	177.09* (90.03)	88.72 (76.65)	-2.28 (2.96)	-30.68 (121.00)	439.24** (199.98)	-310.82 518.22)
7	R^2	0.7934	0.4312	0.2309	0.6018	0.5974	0.7799
8	F-Value	9.9834***	1.9713	0.7804	3.9300**	3.8578**	9.2108***
9	n	19					

Note: 1) Figures in parentheses indicate Standard Errors of respective Regression Coefficients.
2) ***, ** and * indicate significance at 1%, 5% and 10% probability levels, respectively.

Table 4.4.1: Response of Net Returns in Paddy to Climate Variables

Sl. No.	Variable	Regression Coefficient	Standard Error	't' Value
1	Intercept	-20715.3209***	3515.7145	-5.8922
2	Rainfall	3.9800**	1.3030	3.0545
3	Temperature	953.0034***	139.6142	6.8260
4	Relative Humidity	26.4860	32.1461	0.8239
5	R^2	0.9554		
6	F-Value	42.8170***		
7	n	10		

Note: *** and ** indicate significance at 1% and 5% probability levels, respectively.

Table 4.4.2: Response of Net Returns in Maize to Climate Variables

Sl. No.	Variable	Regression Coefficient	Standard Error	't' Value
1	Intercept	-18812.1552**	5598.4995	-3.3602
2	Rainfall	3.3390	2.0749	1.6092
3	Temperature	831.6383***	222.3246	3.7406
4	Relative Humidity	150.5399**	51.1902	2.9408
5	R^2	0.8965		
6	F-Value	17.3304***		
7	n	10		

Note: *** and ** indicate significance at 1% and 5% probability levels, respectively.

Table 4.4.3: Response of Net Returns in Jowar to Climate Variables

Sl. No.	Variable	Regression Coefficient	Standard Error	't' Value
1	Intercept	-20429.7375**	5932.5326	-3.4437
2	Rainfall	2.1205	2.1987	0.9644
3	Temperature	1044.9711***	235.5895	4.4356
4	Relative Humidity	115.3354*	54.2445	2.1262
5	R^2	0.8911		
6	F-Value	16.3694***		
7	n	10		

Note: ***, ** and * indicate significance at 1%, 5% and 10% probability levels, respectively.

not significantly influence the net returns from jowar. On the contrary, temperature and relative humidity were found to influence the net returns from jowar significantly and positively. However, temperature was significant at one per cent, while relative humidity was significant at 10 per cent probability level.

4.4.4 Response of Net Returns in Soybean to Climate Variables

The results of the response of net returns from soybean to various climate variables were presented in the Table 4.4.4. The Table reveals that 86.18 per cent of variation in net returns from soybean was explained by the different climatic variables included in the model. 'F' value was significant at one per cent probability level.

In the case of jowar, temperature and relative humidity were found to influence the net returns from jowar positively and significantly (one per cent and 10 per cent probability levels). Rainfall did not influence the net returns significantly.

4.4.5 Response of Net Returns in Bengalgram to Climate Variables

The functional estimates of the response of net returns from bengalgram to climate variables were presented in the Table 4.4.5. The analysis revealed that 62.72 per cent of variations in net returns from bengalgram were explained by the different climatic variables included in the function. 'F' value was significant at 10 per cent probability level.

Among the explanatory variables included in the model, only rainfall was found to be significant and negatively influence the net returns of bengalgram. Temperature and relative humidity were non-significant.

4.5 Farmers' Perceptions of Climate Variability and Coping Mechanisms to Mitigate the Eventualities

4.5.1 Farmers' Perceptions of Climate Variability

The farmer's perceptions of climate variability were elicited from the sample respondents and quantified in terms of Garrett Scores by using Garrett Ranking Method and the results were shown in Table 4.5.1.

The responses of the sample respondents were grouped into three heads, namely (a) Perceptions about climate variability (b) Perceptions about impact of climate variability on farming and (c) Perceptions about the impact of climate variability on specific crops. The Garrett's scores were computed for each of the perceptions and then ranked within each of these three groups in descending order of the value of Garrett Scores.

Majority of the sample respondents felt that rainfall has become highly erratic in the recent years (Garrett score = 60.21). The other important perceptions in order of priority were 'improper or undesirable distribution of rainfall' (54.73), 'fast evaporation of soil moisture' (47.29) and 'increased diurnal temperature' (38.35).

With respect to their perceptions about the impact of climate variability on farming in general, 'reduction in the yield' was the major impact as perceived by the majority of the sample farmers with a mean Garrett score of 59.58, followed by 'reduction in net income' (GS=56.29), 'pest and disease outbreak' (GS=51.57), 'total crop failure' (GS=45.93) and 'reduced/non-availability of fodder for livestock' (GS=35.55).

As regards the impact of climate variability on specific crops, a majority of the sample farmers expressed that jowar was the most impacted crop due to climate variability, as evidenced by the Garrett score of 58.71, followed by cotton (GS=49.68) and bengalgram (GS=41.61).

4.5.2 Farmers' Coping Mechanisms to Mitigate the Eventualities

The various coping mechanisms adopted by the farmers to mitigate the impact of climate variability was analysed using the Garrett's ranking technique and results of the analysis were depicted Table 4.5.2.

Again here, the responses of the sample respondents were grouped into three heads, namely (a) Coping mechanisms at farm level (b) Coping mechanisms at household level and (c) Coping mechanisms at society/government level. The Garrett Scores were computed for each of the

Table 4.4.4: Response of Net Returns in Soybean to Climate Variables

Sl. No.	Variable	Regression Coefficient	Standard Error	't' Value
1	Intercept	-159797.4725***	33442.7134	-4.7782
2	Rainfall	-2.6924	12.3944	-0.2172
3	Temperature	5949.5305***	1328.0590	4.4799
4	Relative Humidity	626.5270*	305.7854	2.0489
5	R^2	0.8618		
6	F-Value	12.4713***		
7	n	10		

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

Table 4.4.5: Response of Net Returns in Bengalgram to Climate Variables

Sl. No.	Variable	Regression Coefficient	Standard Error	't' Value
1	Intercept	-8468.7297	8465.7876	-1.0003
2	Rainfall	-21.2646*	10.0274	-2.1207
3	Temperature	377.0533	325.8570	1.1571
4	Relative Humidity	198.8274	131.0967	1.5166
5	R^2	0.627165		
6	F-Value	3.3643*		
7	n	10		

Note: * indicates significance at 10% probability level.

Table 4.5.1: Farmer's Perceptions of Climate Variability

Sl. No.	Perceptions	Garrett score	Rank
A	**About Climate Variability**		
1	Erratic rainfall	60.21	I
2	Improper or undesirable distribution of rainfall	54.73	II
3	Fast evaporation of soil moisture	47.29	III
4	Increased diurnal temperature	38.35	IV
B	**About Impact of Climate Variability on Farming in General**		
1	Reduction in yield	59.58	I
2	Reduction in net income	56.29	II
3	Pest and disease outbreak	51.57	III
4	Total crop failure	45.93	IV
5	Reduced/ Non-availability of fodder for livestock	35.55	V
C	**About Impact of Climate Variability on Specific Crops**		
1	Jowar	58.71	I
2	Cotton	49.68	II
3	Bengal gram	41.61	III

perceptions and then ranked within each of these three groups in descending order of the value of Garrett's scores.

The results revealed that at the farm level, "change in crop variety" was the major coping mechanism adopted by the majority of the respondents (2.38), followed by "change in crop" (49.84) and "mixed/intercropping" (48.73).

At the household level, "reduction in the consumption expenditure" was the major coping mechanism adopted by the majority of the sample farmers with a mean Garrett score of 50.32, followed by "shift to other business/profession" (50.32) and "borrowing loans" (43.83).

At the society or government level, a majority of the sample households participated in the Mahatma Gandhi National Rural Employment Guarantee Scheme (MNNREGS) to mitigate the climate variability (53.17). "Other support from government programmes" (53.60) and "financial help from son/daughter/other relatives" (41.93) were the other important mechanisms adopted by the farmers in the study area to cope with the adverse impact of climate variability.

Table 4.5.2: Coping Mechanisms Adopted by Farmers to Mitigate the Impact of Climate Variability

Sl. No.	Coping Mechanisms	Mean	Rank
A	**At Farm level**		
1	Change in crop variety	52.38	I
2	Change in crop	49.84	II
3	Mixed/ Intercropping	48.73	III
B	**At Household level**		
1	Reduce consumption expenditure	50.32	I
2	Shift to other business/ profession	50.32	II
3	Borrow loans	43.83	III
C	**At Society/ Government level**		
1	Participation in MNNREGS*	53.17	I
2	Other support from Govt. programmers	53.60	II
3	Financial help from son/daughter/other relatives	41.93	III

* Mahatma Gandhi National Rural Employment Guarantee Scheme

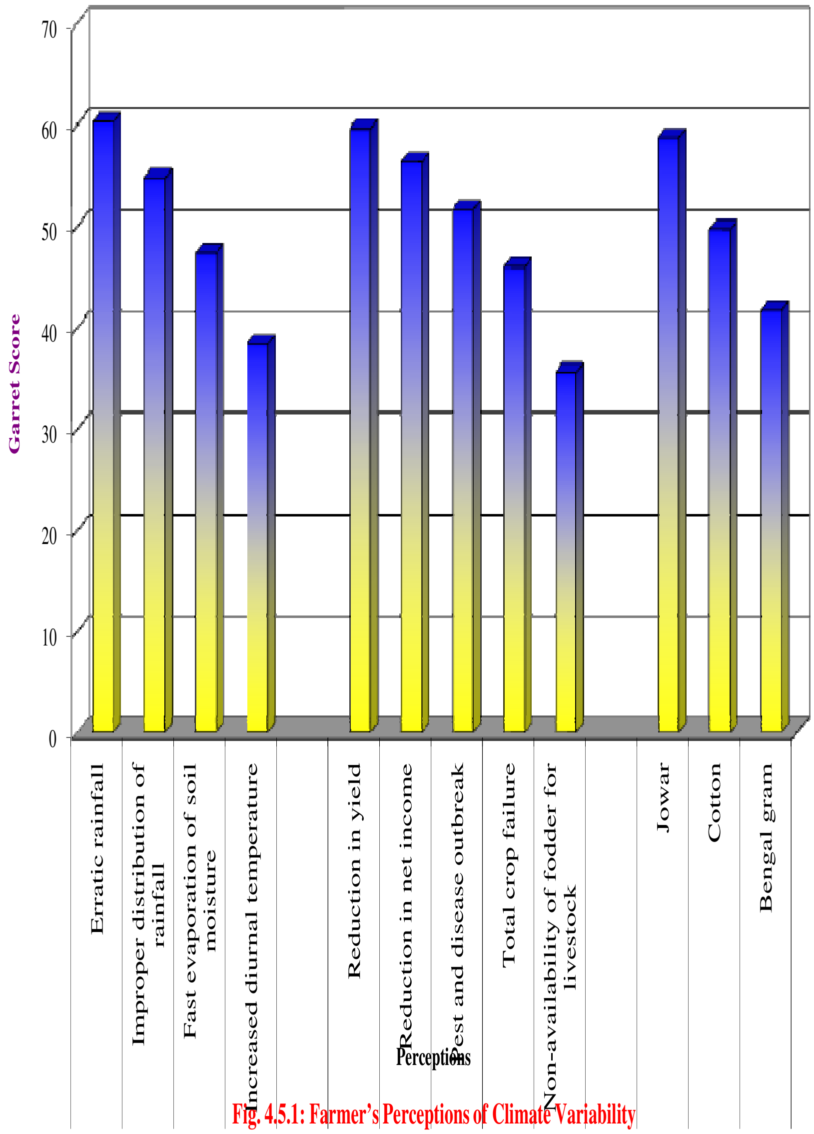


Fig. 4.5.1: Farmer's Perceptions of Climate Variability

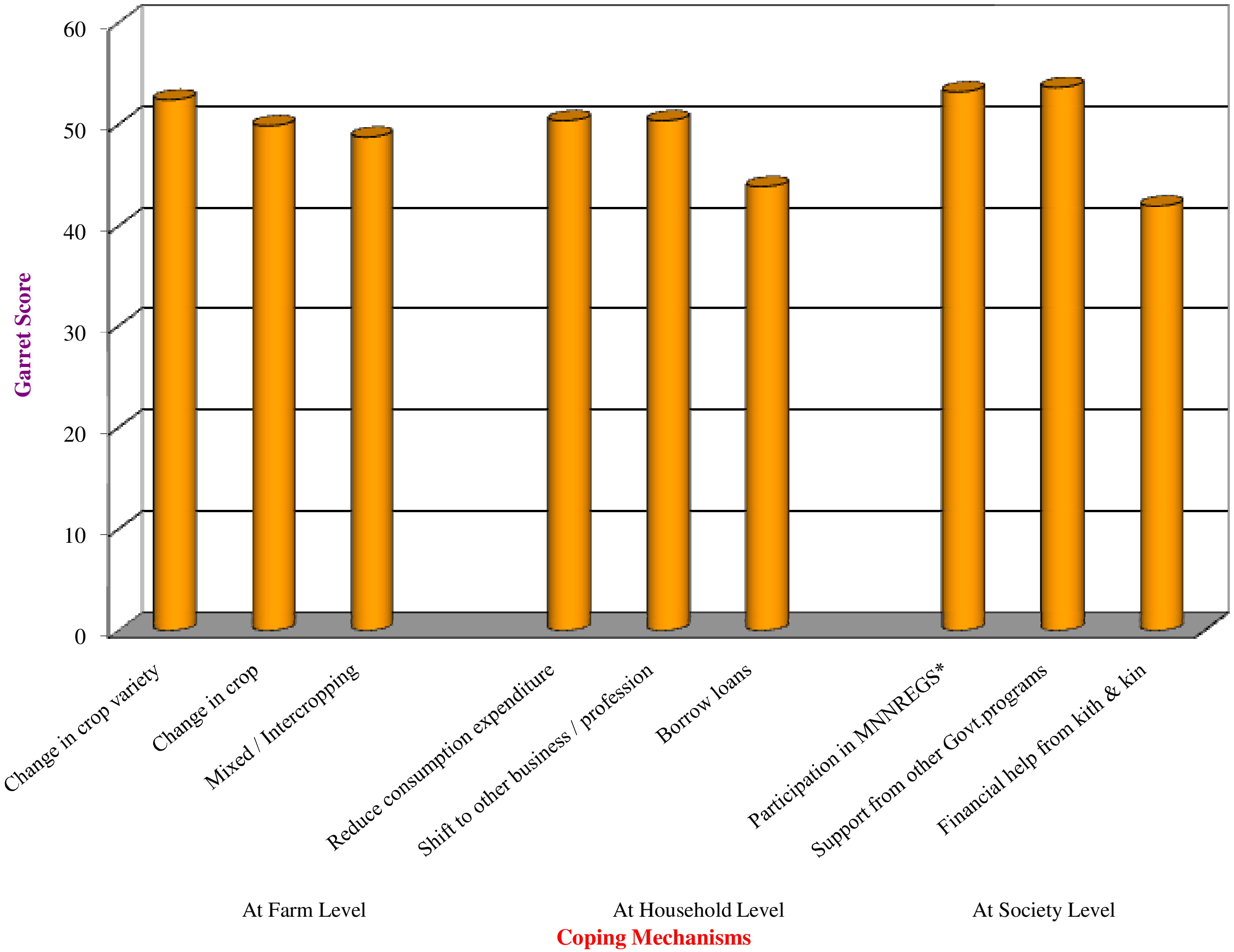


Fig. 4.5.2: Coping Mechanisms Adopted by Farmers to Mitigate the Impact of Climate Variability

DISCUSSION

This chapter discusses the findings of the study presented in the previous chapter, through a meaningful interpretation consistent with the objectives of the study, under the following headings.

5.1 Socio-Economic Profile of the Sample Households

5.2 Variability in Climate

5.3 Changes in Cropping Pattern by Taluks and their Relationship with Climate Variability

5.4 Causality between Climate Variability and Farm Income

5.5 Farmers' Perceptions of Climate Variability and Coping Mechanisms to Mitigate the Eventualities

5.1 Socio-Economic Profile of the Sample Households

The socio-economic profile of the sample respondents, presented in Table 4.1.1, was discussed under the following sub-sections.

5.1.1 Age Distribution

Since a majority of the respondents belonged to the age groups of 36-50 years (65 per cent) and 18-35 years (34 per cent), data on perceptions of climate variability, its impact on farming in general and individual crops in particular and coping mechanisms to mitigate the eventualities could be easier as they had sufficient experience in farming. Further, this age factor could help them in stabilising their farming practices owing to their gambling with nature over a long period of time.

5.1.2 Educational Status

More than 80 per cent of the sample respondents were literates, nearly 50 per cent of them had primary education and about 18 per cent of them were matriculates. Hardly about one per cent of them were graduates. This high literacy rate could be possible due to better educational facilities in the form of proximity to schools and road connectivity to schools. Still, extent of higher education (graduation and post-graduation) is not up to satisfactory level. Education plays an important role in understanding the behaviour of climate, adaption to climate change/variability and developing/implementing contingent crop plans, among others. Hence, necessary education facilities should be provided by the Government for the farmers to pursue at least up to their graduation, if not post-graduation.

5.1.3 Caste Composition of Sample Respondents

As of now, the discrimination based on caste and communities has almost vanished at village level. Moreover, Government programmes adequately support the vulnerable groups including scheduled castes, scheduled tribes and other backward castes; women and children have also been adequately supported across caste/community groups. In the study area, hardly 23 per cent of the sample households belonged to the scheduled castes and tribes.

5.1.4 Household Size

The sample household on an average consisted of 8-9 members, of whom 3-4 members were males, 3-4 females and 2-3 children. The average household size of the sample respondents was 8.39. This meant that several households in the study villages were joint families (with members ranging from 10 to 18), unlike nuclear families mostly found in urban areas. It is supposed that joint families with diversified livelihood activities could have better capability to adapt to climate change/variability.

5.1.5 Experience in Farming

Farming experience and adaptive capacity (to climate change/variability) were supposed to be positively correlated. In the study area, more than half of the sample households had less than 18 years of experience in farming, whereas about 31 per cent and 13 per cent of the sample households had farming experience in the range of 18-35 years and 36-50 years, respectively. Hardly 2.50 per cent of them had farming experience of more than 50 years. Thus, it could be seen that in the study area, a little more than half of the sample households had lesser experience indicating that they had lesser adaptive capacity.

5.1.7 Socio-Economic and Land Holding Pattern of Sample Respondents

Of the total land holding of 3.46 ha, about 96 per cent was owned land and the remaining was the net leased-in land. Nearly 85 per cent of the total land holding was rainfed, while the remaining 15 per cent was irrigated, through various sources. Since most of the land holding was owned, there was enough scope for investment on permanent improvements to land and water resources in order to conserve these resources against adverse climate effects. Further, a major chunk of the land holding was rainfed; a very high rainfall risk was faced by the sample farmers.

5.2 Variability in Climate

5.2.1 Triennium Averages of Climate Factors in Dharwad District

During the first decade (1991-2000) of the study period, there was a declining trend in rainfall, while in the second decade (2001-2010) increasing trend was observed, with minor year-to-year fluctuations. If it goes by the same pattern, then the ensuing decade (2011-2020) would witness a declining trend. Similar trend was observed in terms of rainy days per annum.

The lowest rainy days (less than 50) were observed in the period between TE 1998 – TE 2001, which ranged from 38 to 49 rainy days per annum; whereas prior to and after this period, the rainy days were higher in number – 57 to 67 during TE 1993 to TE 1997 and 59 to 74 during TE 2002 to TE 2010. Again going by this trend, the next 4-5 years (2011-2016) might witness a shortfall in number of rainy days.

The diurnal maximum and minimum temperatures in a year during the study period were 1.4 °C and 1.7°C, respectively. This, perhaps, was not a serious matter of concern. However, the relative humidity has declined over years. It varied by 16 per cent (79.7 per cent in TE 1994 to 63.3 per cent in TE 2003, 2004 and 2006). The breadths of these troughs and peaks are important for the crop growth and its impact on yields. In other words, how long these peaks persist during the cropping season determines the crop growth and productivity. This needs analysis of climate variables on daily-basis and its linkages with critical stages of crop growth. This analysis could not be done due to certain resource constraints; hence, this is a limitation of this study.

5.2.2 Mean and Coefficient of Variation of Climate Variables

The average annual rainfall of the study area was 796.48 mm during the 20-year study period (1991-2010). It ranged from a lowest of 530 mm during the year 2000 to 1125 mm in the year 2009, with a coefficient of variation of 23.16 per cent. Thus, there was a huge variation in rainfall on annual basis, making farming a more risky business. However, seasonal/monthly distribution of rainfall needs to be seen to understand its impact on crop growth and productivity.

The mean values of other important climatic factors, namely, maximum temperature, minimum temperature and relative humidity were 39.37°C, 10.12°C and 70.57 per cent, respectively. However, the coefficients of variation of the aforesaid climatic factors were much less than the rainfall - 2.40 per cent, 7.34 per cent and 9.55 per cent, respectively. Thus, in terms of variability, rainfall showed the highest coefficient of variation, followed by relative humidity, minimum temperature and maximum temperature. This situation, understandably, could lead to varied pest and disease build up on crops. The localised effect may be the reason for such rainfall variation (Kusre and Singh, 2012).

5.2.3 Seasonal Distribution of Rainfall in Dharwad District

Distribution of rainfall across seasons in a year has got a huge bearing on the crop growth and productivity. The intra-year or seasonal rainfall pattern in terms of quantum of rainfall received during pre-monsoon period, monsoon period and post- monsoon period in Dharwad district over the 20-year study period revealed that the mean values of pre-monsoon, monsoon and post-monsoon across the period were found to be 110.49 mm, 684.80 mm and 143.90 mm respectively. The highest variation was observed in pre- monsoon rainfall (CV=49.89%), followed by post-monsoon rainfall (CV=22.67%), while the least was in the case of monsoon rainfall (CV=12.83%). Similar results were obtained by Kaur (2011) in a study in Punjab.

The high variation in pre-monsoon rainfall causes a huge risk for the farmers in terms of decision making with respect to selection of crop and variety for *kharif* season crop and that in monsoon period creates uncertainty for *rabi* season crop.

5.2.4 Variation in Annual and Seasonal Rainfall

Amongst the seasons, *kharif* received the highest rainfall (491.06 mm), followed by *rabi* season (156.83 mm) and summer season (119.40 mm), the annual mean rainfall being 796.48 mm. In terms of variability, summer rainfall tops the list with highest coefficient of variation (43.76%), followed by *rabi* (34.40%) and *kharif* (31.43%), whereas the annual rainfall had the lowest variability (23.16%). Thus, while the quantum of annual rainfall received did not vary much across years, the intra-year variability was relatively very high, not to talk of intra-season variability. The variability in summer rainfall was distinctly higher than that of *rabi* and *kharif*. Hence, crop cultivation during summer was relatively much riskier in the absence of irrigation facility at least during critical stages of crop growth. The findings were in line with those of Kusre and Singh (2012).

5.2.5 Deviation of Actual Annual Rainfall from Normal and Mean Rainfall

The mean actual annual rainfall of Dharwad district over the study period was reported as 796.5 mm, ranging from 529.5 mm (in the year 2000) to 1125.0 mm (in the year 2009). The percentage deviation of actual annual rainfall from the mean actual annual rainfall during the study period ranged from -32.52 per cent during 2000 to 41.24 per cent during 2009. The mean deviation was relatively much higher in 2005 and onwards. Similarly, the percentage deviation of rainfall from the normal rainfall across years also followed similar pattern of deviation as in the case of mean deviation. Occurrence of severe drought during 2001-02, 2002-03 and 2003-04 could be the possible reason for such deviations. The findings of the study are in line with that of Jha and Tripathi (2011).

5.2.6 Spatial Variation in Rainfall across Taluks in Dharwad District

The mean, standard deviation and coefficient of variation of actual annual rainfall in all the five taluks of Dharwad district, namely, Dharwad, Hubli, Kalaghatgi, Kundgol and Navalgund, across years and across taluks were estimated. The temporal analysis of each taluk indicated that Kalaghatgi taluk received the highest mean rainfall (1007 mm), followed by Dharwad (974 mm), Hubli (798 mm), Kundgol (662 mm) and Navalgund (612 mm) taluks. Kalaghatgi taluk falls in the Hilly Zone and has very good forest cover, which thus, contributed to heavy rainfall. However, the rainfall variability was lowest in Kalaghatgi taluk. The spatial analysis of annual rainfall in each year of the study period revealed that the mean annual rainfall in the selected taluks was to the tune of about 811 mm. The spatial variability measured in terms of coefficient of variation ranged from 13.52 per cent (1992-93) to 47.11 per cent (2003-04), owing to the occurrence of drought during that period. Similar findings were obtained by Kaur (2011) across various regions in Punjab.

5.2.7 Correlation Matrices of Climate Variables across Taluks

Dharwad and Hubli taluks had highest positive correlation (0.8816) in terms of annual rainfall, followed by Hubli-Kundgol (0.4446), Kundgol-Navalgund (0.4296) and Kalaghatgi-Kundgol (0.4174). Nowhere negative correlation was observed amongst the selected taluks. Proximity between places and similarity in geographical conditions, probably, could be the most important reasons for this phenomenon. The highest positive correlation (0.7953) with respect to maximum diurnal temperature and minimum temperature (0.5121) was observed between Kundgol and Navalgund, since both the taluks had similar altitude and vegetation.

So far as maximum diurnal relative humidity was concerned, Hubli-Navalgund (0.6029), Hubli-Kundgol (0.5777) and Kundgol-Navalgund (0.4647) had shown very high positive bondage, whereas Kalaghatgi-Kundgol (-0.4898) witnessed a high negative bondage. Though there were negative bondages amongst few taluks, they were not that strong. In all, Kalaghatgi taluk stands distinctly different from other taluks as its geography is different in terms of altitude, terrain and forest cover.

5.3 Changes in Cropping Pattern by Taluks and their Relationship with Climate Variability

5.3.1 Changes in Cropping Pattern in Dharwad District – by Taluks

In case of GCA, net sown area (NSA) accounted for 60.25 per cent, while the area sown more than once accounted for 39.72 per cent, the cropping intensity being 166 per cent. Of the GCA, food crops occupied about 69 per cent, cereals and pulses together constituted 48.39 per cent. Jowar occupied the highest area amongst cereals, followed by maize, wheat and paddy, whereas amongst pulses, bengalgram was the major share holder in the cropped area. Among the non-food crops, oilseeds and cotton were the major ones. Thus, it could be concluded that jowar was the single food crop occupying largest area in the district.

The changes in the cropped area between two points of time, *i.e.*, TE 2001-02 and TE 2008-09, reveal that the GCA has increased by 4.54 per cent, with NSA decreasing by 6.16 per cent and 'area sown more than once' increasing by 26.39 per cent. It is interesting to note that the area under food crops has fallen by 0.38 per cent, while that of non-food crops increased by 17.63 per cent. Among food crops, area under food grains has grown by 30.51 per cent and that of fruits increased by 52.09 per cent, whereas spices and vegetables witnessed a negative growth. It is further interesting to note that cereals registered a negative growth in their area, while pulses showed a positive and high growth (27.35%). Among cereals, maize had a significant positive growth (80.22%), while area under paddy and jowar showed a declining trend (-27.09 per cent and -19.12%). Among pulses, gram had a record growth of 49.79 per cent during the study period. Because of heterogeneity in climatic conditions in the district, the cropping pattern of the area is more diverse relative to other parts of the state and comprises of crops like paddy, wheat, maize, jowar, fruits, oilseeds, pulses and vegetables. Similar results were obtained by Kaur (2011).

5.3.2 Compound Annual Growth Rates of Cropped Area

For the Dharwad district as a whole, the compound annual growth rate was positive and the highest (10.17%) in the case of maize, followed by oilseeds, fruits, gram, tur and wheat. On the contrary, the growth rate was negative and the highest in the case of paddy (-4.79%), followed by jowar, cotton, spices and vegetables.

The GCA has grown at a moderate growth of 0.90 per cent per annum on compounding basis, while the NSA has declined at a rate of 0.89 per cent p.a. The area sown more than once has increased by a very high growth rate (3.84 per cent p.a.). This revealed that though the net sown area was declining over time, the GCA had increased owing to a high growth in 'area sown more than once'. In other words, the cropping intensity has increased considerably over time during the study period.

Coming to individual taluks, in Dharwad taluk, maize had the highest positive growth of 21.07 per cent, followed by tur, gram and fruits. Contrarily, cotton witnessed the highest negative growth rate (-18.94%), followed by spices and jowar. In Hubli taluk, the crops that witnessed significant positive growth were maize, oilseeds and fruits, whereas paddy and spices were significant and negative growth. In Kalaghatgi, maize, oilseeds and gram witnessed significant positive growth, whereas spices, paddy and vegetables were significant negative growth. In Kundgol, again area cropped to maize grew tremendously at a rate of 23.42 per cent, followed by fruits, tur, gram and oilseeds; however, only vegetables had a significant negative growth. Finally, in Navalgund, spices, oilseeds and maize had positive significant growth, while significant negative growth was observed in paddy, tur and cotton.

It was interesting to note that maize, gram and oilseeds were the only crops with positive growth in all the taluks during the study period; on the contrary, paddy and vegetables witnessed negative growth in all the taluks. In four out of five taluks, fruits witnessed positive growth, while jowar and spices had negative growth.

These results revealed that the agricultural sector in Dharwad district has undergone considerable changes. A shift in the cropping pattern in favor of maize and commercial crops at the expense of gram and jowar was noticed. These conclusions are consistent with the observations of Vivekananda and Sathyapriya (1994). Some earlier studies concluded that in many instances, agriculture would be the most disadvantaged sector, while some predict unequal impacts of global warming on agriculture across the regions. It would have an overall negative impact on the Indian agriculture, with varying seasonal and regional implications (Kalamkar, 2011). Similar results were obtained by the study conducted by Shalander *et al.* (2011) with respect to yield levels of bajra, sorghum and maize in Andhra Pradesh.

5.3.3 Acreage Response to Climate Variables: Multiple Regression Models

The response of area under different crops to selected climatic variables was analysed using multiple linear regression model. In the model, area under crop in question was taken as dependent variable and different climatic variables, *viz.*, rainfall, maximum temperature, minimum temperature, maximum relative humidity and minimum relative humidity were taken as independent variables. Please refer to the definitions of variables described in the methodology chapter under section 3.4.3

(a), because the discussion of the results needs to be perceived in the light of the definitions of these variables.

The results of the analysis are presented in Tables 4.3.3.1 through 4.3.3.5.

5.3.3.1 Paddy

The model was a good fit as indicted by the R^2 (74.78%) and 'F' value. However, none of the variables included in the model (for the district as a whole) was significant as indicated by the 't' value. So far as individual taluks were concerned, the R^2 was reasonably high and 'F' value was significant in the case of all the taluks except Navalgund.

At taluk level, the significant variables were maximum temperature in Dharwad, maximum relative humidity in Hubli, maximum temperature and maximum relative humidity in Kalaghatgi and maximum temperature in Kundgol. No variable was significant in Navalgund. Thus, it was interesting to note that rainfall, minimum temperature and minimum relative humidity were not significant in any of the taluks, even at 10 per cent significant level. Maximum temperature was significant in three out of five selected taluks, while maximum relative humidity was significant in two out of five selected taluks. Maximum temperature was significant and negative in the case of Dharwad and Kundgol while it was positive and significant in the case of Kalaghatgi. Maximum relative humidity was positive and significant in Hubli whereas it was negative and significant in Kalaghatgi.

Rainfall and maximum temperature showed negative effect on the area under paddy and all the variables were found non-significant. It required optimum temperature during initial stages of growth and during flowering stage, more temperature would affect the flowering and in turn the yield.

5.3.3.2 Maize

In maize too, the model was reasonably a 'good-fit' as indicated by its R^2 and 'F' value. R^2 and 'F' values were significant at taluk level regression functions except in the case of Navalgund. Among the explanatory variables, maximum relative humidity was positively significant at one per cent probability level and rainfall was also positively significant at five per cent probability level. The taluk-wise regressions reveal that maximum relative humidity was the only variable which was significant in four out of the five selected taluks (excepting Navalgund), of course, positively in Dharwad and Kalaghatgi and negatively in Hubli and Kundgol. The other significant variables were rainfall (negative) and minimum relative humidity (positive) in Dharwad and maximum temperature (negative) in Kalaghatgi. Interestingly, none of the variables was significant in Navalgund.

5.3.3.3 Jowar

The regression results of the response of area under jowar to different climatic variables are not impressive at all. The R^2 was reasonably good only in the case of Dharwad taluk. At district level, none of the explanatory variables was significant. Similarly, 'F' value was not significant for Dharwad district as well as sample taluks, except Dharwad. The significant variables were minimum temperature (positive) in Dharwad and maximum relative humidity (negative) in Navalgund. Since jowar is sensitive to rainfall and temperature, the crop is mainly grown during the *rabi* season in the area. Due to more pronounced change and variability in climate, especially temperature during winter season, jowar yield has been impacted adversely.

5.3.3.4 Soybean

The different climatic variables which were included in the model explained around 60.47 per cent of the variation in the area under soybean in Dharwad district. 'F' value was significant at five per cent probability level. None of the variables except rainfall was significant; rainfall was positively significant at 10 per cent probability level. Taluk-wise regressions reveal that 'F' value was significant in all the taluks except Navalgund. The R^2 value ranged from 0.5013 (in Kalaghatgi) to 0.8218 (in Dharwad), excepting Navalgund wherein it was 0.3962. The significant variables were minimum temperature (positive) and maximum relative humidity (positive) in Dharwad, maximum relative humidity (positive) in Kalaghatgi, maximum relative humidity (negative) in Kundgol and minimum relative humidity (negative) in Navalgund. Minimum temperature and maximum relative humidity were the important variables affecting acreage under soybean.

5.3.3.5 Bengalgram

The results of the regression model for area under bengalgram were significant as indicated by an impressive R^2 and a highly significant 'F' value. For Dharwad district as a whole, only rainfall was found to significantly and positively influence the area under bengalgram. Coming to taluk-level regressions, the ‘F’ value was highly significant in the case of Dharwad (at 1%) and significant at five per cent in the case of Kundgol and Navalgund, while it was non-significant in the case of Hubli and Kalaghatgi.

In the case of Dharwad, maximum temperature, minimum temperature and minimum relative humidity were found to significantly influence the bengalgram area. In Kundgol, maximum relative humidity influenced the bengalgram area significant but negatively. Similarly, in Navalgund, maximum relative humidity influenced the bengalgram area significant and negatively, but minimum relative humidity was significant and positive. Interestingly, rainfall was not at all significant in any of the taluks. It could be noticed that maximum relative humidity was a deterring factor for acreage under the selected crops, probably because of its probable negative impact on the crop growth, especially on pest and disease attack.

Within agriculture, it is the rainfed agriculture that would be the most impacted by climate change mainly because of the people dependent on rainfed agriculture are less endowed in terms of financial, physical, human and social capital limiting their capacity to adopt to the changing climate (Shalander Kumar *et al.*, 2011).

5.4 Causality between Climate Variability and Farm Income

As in the case of acreage response, the multiple linear regression models were used to estimate the magnitude and direction of influence of the climate variables, namely, rainfall, temperature and relative humidity, on the net returns from different selected crops (paddy, maize, jowar, soybean and bengalgram) under rainfed situation. Please refer to the definitions of variables described in the Methodology Chapter under Section 3.4.3 (b), because discussion of the results needs to be perceived in the light of the definitions of these variables.

The regression results were presented in Tables 4.4.1 through 4.4.5.

Nearly 95 per cent of the variation in the net returns from paddy was explained by the different climatic variables included in the model. ‘F’ value was highly significant at one per cent probability level. Among the different variables, rainfall and temperature were positively influencing the net returns obtained from the paddy and were found significant at five and one per cent respectively. Contrarily, relative humidity was non-significant.

With respect to maize, 89.65 per cent of the variation in the net returns was explained by the different climatic variables included in the model. ‘F’ value was again significant at one per cent probability level. Among the different variables, temperature and relative humidity were having significant positive impact on the net returns of maize. Unlike in the case of paddy, rainfall was non-significant in the case of maize.

It could be seen in the case of jowar that 89.11 per cent of variation in the net returns of jowar was explained by the various climatic variables included in the model. ‘F’ was highly significant. As in the case of maize, rainfall did not significantly influence the net returns from jowar. On the contrary, temperature and relative humidity were found to influence the net returns from jowar significantly and positively.

In the case of soybean, 86.18 per cent of variation in net returns from soybean was explained by the different climatic variables included in the model. ‘F’ value was significant at one per cent probability level. Like in the case of jowar, temperature and relative humidity were found to influence the net returns from soybean positively and significantly. Rainfall did not influence the net returns significantly.

Similar analysis of bengalgram revealed that 62.72 per cent of variation in the net returns from bengalgram was explained by the different climatic variables included in the function. ‘F’ value was significant at 10 per cent probability level. Among the explanatory variables included in the model, only rainfall was found to significantly influence the net returns from bengalgram, but surprisingly negatively. Temperature and relative humidity were non-significant.

The frequent climate change and variability had started impacting cost and returns structure of the farming sector especially rainfed agriculture. The fall and variability in precipitation during summer monsoon had resulted into an increase in the cost of cultivation due to increased expenditure on diesel for irrigating crops and has further increased the livelihood vulnerability of the small and marginal farmers. The economic viability of the farmers was an important concern in the district due to increasing production risks to climate change, emerging water scarcity and increased incidence of diseases and pests. This ultimately affected the net returns obtained from the cultivation of crops. The crop returns even in the rainfed areas were also influenced by factors other than weather variables, namely, technology, market and managerial factors.

5.5 Farmers' Perceptions of Climate Variability and Coping Mechanisms to Mitigate the Eventualities

5.5.1 Farmers' Perceptions of Climate Variability

The farmer's perceptions of climate variability were elicited from the sample respondents and quantified in terms of Garrett's scores by using Garrett Ranking Method. The responses of the sample respondents were grouped into three heads, namely (a) perceptions about climate variability (b) perceptions about impact of climate variability on farming and (c) perceptions about the impact of climate variability on specific crops. The Garrett's scores were computed for each of the perceptions and then ranked.

Majority of the sample respondents felt that rainfall has become highly erratic in the recent years. The other important perceptions in order of priority were 'improper or undesirable distribution of rainfall', 'fast evaporation of soil moisture' and 'increased diurnal temperature'. With respect to their perceptions about the impact of climate variability on farming in general, 'reduction in the yield' was the major impact as perceived by the majority of the sample farmers, followed by 'reduction in net income', 'pest and disease outbreak', 'total crop failure' and 'reduced/non-availability of fodder for livestock'. As regards the impact of climate variability on specific crops, a majority of the sample farmers expressed that jowar was the most impacted crop due to climate variability, followed by cotton and bengalgram. This was because jowar crop was grown under rainfed situation in the district that too during *rabi* season.

From the findings it is clear that the level of the farmer's perception on the climate change was reasonably good. Some of the farmers were also of the view that deforestation in the local area was also an important contributing factor for increase in the temperature over the years. They also felt that currently the summer season was longer than in the earlier years and this was adversely affecting the agriculture. Similar findings were obtained by Panda and Ninan (2011).

5.5.2 Farmers' Coping Mechanisms to Mitigate the Eventualities

The various coping mechanisms adopted by the farmers to mitigate the impact of climate variability was analysed using the Garrett's ranking technique. Again here, the responses of the sample respondents were grouped into three heads, namely (a) Coping mechanisms at farm level (b) Coping mechanisms at household level and (c) Coping mechanisms at society/government level. The Garrett's scores were computed for each of the perceptions and then ranked.

"Change in crop variety" was the major coping mechanism adopted by the majority of the respondents, followed by "change in crop" and "mixed/intercropping". At the household level, "reduction in the consumption expenditure" was the major coping mechanism adopted by the majority of the sample farmers, followed by "shift to other business/profession" and "borrowing loans". At the society or government level, a majority of the sample households participated in the Mahatma Gandhi National Rural Employment Guarantee Scheme (MNNREGS) to mitigate the climate variability. The other important mechanisms adopted by the farmers in the study area to cope with the adverse impact of climate variability were "Other support from government programmes" and "financial help from son/daughter/other relatives".

When there was significant deviation in the climate either in terms of rainfall or temperature from the normal conditions, there would be reduction in yield and net income of the farmers. To mitigate the reduction in income, farmers showed adopt some socio-economic strategies to sustain their life. The farmers already acted to the climatic shocks/ changes both by adopting the technological coping mechanisms on the positive side and negatively through shifting to other professions. The results of the study are in line with those of Sakamma *et al.* (2011).

SUMMARY AND POLICY IMPLICATIONS

Climate change is one of the biggest challenges the world is facing today. The problem of human induced climate change first came into force and drew the attention of the scientists and policy makers when Inter-Governmental Panel on Climate Change (IPCC) was established. Climate change indicates secular changes of meteorological elements, whereas climatic variability indicates their fluctuations on a shorter time-scale, say decadal scale or less. The IPCC has concluded that the poorest countries would be hardest hit, with reductions in crop yields in most tropical and sub-tropical regions due to decreased water availability and new or changed insect pest incidence. In Africa and Latin America many rainfed crops are near their maximum temperature tolerance, so that yields are likely to fall sharply for even small climate changes; falls in agricultural productivity of up to 30 per cent over the 21st century are projected.

Agriculture in India and entire world is mostly dependent on the persisting weather conditions. The Karnataka state enjoys three main types of climate. For agro-meteorological purposes, the state has been divided into 10 agro climatic zones, namely, North Eastern Transition Zone, North Eastern Dry Zone, Northern Dry Zone, Central Dry Zone, Eastern Dry Zone, Southern Dry Zone, Southern Transition Zone, Northern Transition Zone, Hilly Zone and Coastal Zone. Out of 1140 mm of average annual rainfall of the State, about 805 mm (71%) is received in the period of October-December (North-East monsoon) and only 139 mm (12%) is received during January to May. In total, the crop growth period in rainfed areas extends from June to October.

Agro-meteorological information, in practice mainly climate data, is essential in planning agricultural production. The timing of different activities, e.g. sowing, ploughing, fertilizing and pest and disease control should be done when weather conditions are most favorable. If climatological data are available, the probability of unfavourable meteorological phenomena can be calculated and the related risks estimated. With climatological data it is also possible to recognize bad weather conditions and to be more prepared to minimise the damage.

Despite technological advances, such as improved varieties, genetically modified organisms and irrigation systems, weather is still a key factor in agricultural productivity, as well as soil properties and natural communities. The effect of climate on agriculture is related to variability in local climates rather than in global climate patterns. Most agronomists believe that agricultural production will be mostly affected by the severity and pace of climate change (called "climate variability"), not so much by gradual trends in climate (called "climate change"). If change is gradual, there may be enough time for biota adjustment. Rapid climate change, however, could harm agriculture in many countries, especially those that are already suffering from rather poor soil and climate conditions, because there is less time for optimum natural selection and adaption. The effects of climate variability are many folds. There is a need to create awareness about its impact on various sectors of agrarian economy. The present study analyzed the climate variability and its effect on cropping pattern and farm income in Dharwad District of Karnataka.

6.1 Objectives

1. To examine the spatial and temporal variability in climate in Dharwad District of Karnataka;
2. To study the changes in cropping pattern in the study district by talukas and estimate the relationship with climate variability;
3. To ascertain the causality, if any, between rainfall/climate variability and farm income; and
4. To document the farmers' perceptions to climate variability and elicit the coping mechanisms followed by farmers to mitigate the eventualities.

6.2 Methodology

6.2.1 Selection of the Study Area

The study was conducted in Dharwad district of Karnataka. Dharwad taluka from Dharwad district was purposively selected owing to the presence of agro-climatic observatory. Four villages from amongst the villages falling within a radius of 20 km from the meteorological observatory were selected randomly. From each village, 30 farmers were chosen using proportionate sampling (probability proportionate to size of the sub-group). In all, 120 farmers spread across 4 villages in Dharwad taluka were finally chosen for achieving the objectives of the study.

6.2.2 The Data

Keeping in view the objectives of the study, primary and secondary data were obtained. A structured interview schedule was developed to collect primary data on coping mechanisms and adaptation strategies adopted by farmers to mitigate climate change. The primary data were collected by personal interview method. The secondary data on different weather parameters, namely, rainfall, temperature (minimum and maximum) and relative humidity (minimum and maximum) were collected from the meteorological station at Dharwad. The area under major crops at Dharwad district level and taluks' level were collected from various issues of 'Dharwad District at a Glance' published by the Directorate of Economics and Statistics, Bengaluru.

6.2.3 Analytical tools and techniques used in the study

The data collected from the respondents were edited, tabulated and analyzed by using compound annual growth rate, multiple regression models, Garrett's ranking technique, percentages, means, coefficient of variation, mean deviation, correlation matrix and other descriptive statistics.

6.3 Major Findings

6.3.1 Variability in Climate

- During the first decade (1991-2000) of the study period, there was a declining trend in rainfall, while in the second decade (2001-2010) increasing trend was observed, with minor year-to-year fluctuations. If it goes by the same pattern, then the ensuing decade (2011-2020) would witness a declining trend. Similar trend was observed in terms of rainy days per annum.
- The diurnal maximum and minimum temperatures in a year during the study period 1.4 °C and 1.7°C, respectively. This, perhaps, was not a serious matter of concern. However, the relative humidity has declined over years. It varied by 16 per cent (79.7 per cent in TE 1994 to 63.3 per cent in TE 2003, 2004 and 2006). The breadths of these troughs and peaks are important for the crop growth and its impact on yields. In other words, how long these peaks persist during the cropping season determines the crop growth and productivity.
- The average annual rainfall of the study area was 796.48 mm during the 20-year study period (1991-2010). It ranged from a lowest of 530 mm during the year 2000 to 1125 mm in the year 2009, with a coefficient of variation of 23.16 per cent. Thus, there was a huge variation in rainfall on annual basis, making farming a more risky business. However, seasonal/monthly distribution of rainfall needs to be seen to understand its impact on crop growth and productivity.
- In terms of variability, rainfall showed the highest coefficient of variation, followed by relative humidity, minimum temperature and maximum temperature. This situation, understandably, could lead to varied pest and disease build up on crops.
- Distribution of rainfall across seasons in a year has got a huge bearing on the crop growth and productivity. The highest mean rainfall was received during monsoon, post-monsoon and pre-monsoon periods across the study. The highest variation was observed in pre- monsoon rainfall, followed by post-monsoon rainfall, while the least was in the case of monsoon rainfall.
- The high variation in pre-monsoon rainfall causes a huge risk for the farmers in terms of decision making with respect to selection of crop and variety for *kharif* season crop and that in monsoon period creates uncertainty for *rabi* season crop.
- Amongst the seasons, *kharif* received the highest rainfall (491.06 mm), followed by *rabi* season (156.83 mm) and summer season (119.40 mm), the annual mean rainfall being 796.48 mm. In terms of variability, summer rainfall tops the list with highest coefficient of variation (43.76%), followed by *rabi* (34.40%) and *kharif* (31.43%), whereas the annual rainfall had the lowest variability (23.16%).
- While the quantum of annual rainfall received did not vary much across years, the intra-year variability was relatively very high, not to talk of intra-season variability. The variability in summer rainfall was distinctly higher than that of *rabi* and *kharif*.

- The mean actual annual rainfall of Dharwad district over the study period was reported as 796.5 mm, ranging from 529.5 mm (in the year 2000) to 1125.0 mm (in the year 2009). The percentage deviation of actual annual rainfall from the mean actual annual rainfall during the study period ranged from -32.52 per cent during 2000 to 41.24 per cent during 2009. The mean deviation was relatively much higher in 2005 and onwards.
- The temporal analysis of each taluk indicated that Kalaghatgi taluk received the highest mean rainfall (1007 mm), followed by Dharwad (974 mm), Hubli (798 mm), Kundgol (662 mm) and Navalgund (612 mm) taluks. Kalaghatgi taluk falls in the Hilly Zone and has very good forest cover, which thus, could contribute to heavy rainfall. However, the rainfall variability was lowest in Kalaghatgi taluk.
- The spatial variability measured in terms of coefficient of variation ranged from 13.52 per cent (1992-93) to 47.11 per cent (2003-04), owing to the occurrence of drought during that period.
- Dharwad and Hubli taluks had highest positive correlation (0.8816) in terms of annual rainfall, followed by Hubli-Kundgol (0.4446), Kundgol-Navalgund (0.4296) and Kalaghatgi-Kundgol (0.4174). Nowhere negative correlation was observed amongst the selected taluks. Proximity between places and similarity in geographical conditions, probably, could be the most important reasons for this phenomenon.

6.3.2 Climate Variability and Cropping Pattern

- Of the GCA, net sown area (NSA) accounted for 60.25 per cent, while the area sown more than once accounted for 39.72 per cent, the cropping intensity being 166 per cent. Of the GCA, food crops occupied about 69 per cent, cereals and pulses together constituted 48.39 per cent.
- Jowar occupied the highest area amongst cereals, followed by maize, wheat and paddy, whereas amongst pulses, bengalgram was the major share holder in the cropped area. Amongst non-food crops, oilseeds and cotton were the major ones. Thus, it could be seen that jowar was the single food crop occupying largest area in the district.
- The GCA has increased by 4.54 per cent, with NSA decreasing by 6.16 per cent and ‘area sown more than once’ increasing by 26.39 per cent. It is interesting to note that the area under food crops has fallen by 0.38 per cent, while that of non-food crops increased by 17.63 per cent. Amongst food crops, area under food grains has grown by 30.51 per cent and that of fruits increased by 52.09 per cent, whereas spices and vegetables witnessed a negative growth.
- Cereals registered a negative growth in their area, while pulses showed a positive and high growth (27.35%). Amongst cereals, maize had a significant positive growth (80.22%), while area under paddy and jowar showed a declining trend (-27.09 per cent and -19.12%). Amongst pulses, gram had a record growth of 49.79 per cent during the study period.
- For the Dharwad district as a whole, the compound annual growth rate was positive and the highest (10.17%) in the case of maize, followed by oilseeds, fruits, gram, tur and wheat. On the contrary, the growth rate was negative and the highest in the case of paddy (-4.79%), followed by jowar, cotton, spices and vegetables.
- The GCA has grown at a moderate growth of 0.90 per cent per annum on compounding basis, while the NSA has declined at a rate of 0.89 per cent p.a. The area sown more than once has increased by a very high growth rate (3.84 per cent p.a.). This revealed that though the net sown area is declining over time, the GCA has increased owing to a high growth in ‘area sown more than once’. In other words, the cropping intensity has increased considerably over time during the study period.
- It was interesting to note that maize, gram and oilseeds were the only crops with positive growth in all the taluks during the study period; on the contrary, paddy and vegetables witnessed negative growth in all the taluks. In four out of five taluks, fruits witnessed positive growth, while jowar and spices had negative growth.

6.3.3 Acreage Response to Climate Variables

- The acreage response model of paddy was a good fit as indicted by the R^2 (74.78%) and ‘F’ value. However, none of the variables included in the model (for the district as a whole) was significant as indicated by the ‘t’ value. So far as individual taluks were concerned, the R^2 was reasonably high and ‘F’ value was significant in the case of all the taluks except Navalgund. Paddy required optimum temperature during initial stages of growth and during flowering stage, more temperature would affect the flowering and in turn the yield.
- In maize too, the model was reasonably a ‘good-fit’ as indicated by its R^2 and ‘F’ value. R^2 and ‘F’ values were significant at taluk level regression functions except in the case of Navalgund. Among the explanatory variables, maximum relative humidity and rainfall were positively significant. The taluk-wise maize regressions reveal that maximum relative humidity was the only variable which was significant in four out of the five selected taluks (excepting Navalgund), of course, positively in Dharwad and Kalaghatgi and negatively in Hubli and Kundgol. Interestingly, none of the variables was significant in Navalgund.
- The regression results of the response of area under jowar to different climatic variables are not impressive at all. The R^2 was reasonably good only in the case of Dharwad taluk. At district level, none of the explanatory variables was significant. Similarly, ‘F’ value was not significant for Dharwad district as well as sample taluks, except Dharwad.
- For soybean, ‘F’ value was significant at five per cent probability level and none of the variables except rainfall was significant at district level. Taluk-wise regressions reveal that ‘F’ value was significant in all the taluks except Navalgund. Minimum temperature and maximum relative humidity were the important variables affecting acreage under soybean.
- In the case of bengalgram, acreage response was very impressive with high R^2 and highly significant ‘F’ value. For Dharwad district as a whole, only rainfall was found to significantly and positively influence the area under bengalgram.
- Rainfall was not at all significant in any of the taluks. It could be noticed that maximum relative humidity was a deterring factor for acreage under the selected crops, probably because of its probable negative impact on the crop growth, especially on pest and disease attack.

6.3.4 Climate Variability and Farm Income

- Nearly 95 per cent of the variation in the net returns from paddy was explained by the different climatic variables included in the model. ‘F’ value was highly significant. Among the different variables, rainfall and temperature positively influenced the net returns obtained from the paddy; relative humidity was non-significant.
- With respect to maize, 89.65 per cent of the variation in the net returns was explained by the different climatic variables included in the model. ‘F’ value was again significant at one per cent probability level. Among the different variables, temperature and relative humidity had significant positive impact on the net returns of maize; rainfall was non-significant.
- In the case of jowar, 89.11 per cent of variation in the net returns of jowar was explained by the various climatic variables included in the model. ‘F’ was highly significant. Rainfall did not significantly influence the net returns; temperature and relative humidity influenced the net returns significantly and positively.
- In the case of soybean, 86.18 per cent of variation in net returns was explained by the different climatic variables included in the model. ‘F’ value was significant. Temperature and relative humidity influenced the net returns positively and significantly; rainfall did not influence the net returns significantly.
- The net returns from bengalgram were significantly influenced by rainfall, but surprisingly negatively. Temperature and relative humidity were non-significant.
- The fall and variability in precipitation during summer monsoon had resulted into an increase in the cost of cultivation due to increased expenditure on diesel for irrigating crops and has further increased the livelihood vulnerability of the small and marginal farmers.

6.3.5 Farmers' Perceptions of Climate Variability and Coping Mechanisms

- Majority of the sample respondents felt that rainfall had become highly erratic in the recent years. The other important perceptions in order of priority were improper or undesirable distribution of rainfall, fast evaporation of soil moisture and increased diurnal temperature.
- With respect to their perceptions about the impact of climate variability on farming in general, reduction in the yield was the major impact as perceived by the majority of the sample farmers, followed by reduction in net income, pest and disease outbreak, total crop failure and reduced/non-availability of fodder for livestock.
- As regards the impact of climate variability on specific crops, a majority of the sample farmers expressed that jowar was the most impacted crop due to climate variability, followed by cotton and bengalgram. This was because jowar crop was grown under rainfed situation in the district that too during *rabi* season.
- Some farmers also opined that deforestation in the local area was also an important contributing factor for increase in the temperature over the years. They also felt that currently the summer season was longer than in the earlier years and this was adversely affecting the agriculture.
- "Change in crop variety" was the major coping mechanism adopted by the majority of the respondents, followed by "change in crop" and "mixed/intercropping". At the household level, "reduction in the consumption expenditure" was the major coping mechanism adopted by the majority of the sample farmers, followed by "shift to other business/profession" and "borrowing loans". At the society or government level, a majority of the sample households participated in the Mahatma Gandhi National Rural Employment Guarantee Scheme (MNNREGS) to mitigate the climate variability.

6.4 Policy Implications

- Coefficient of variation is highest in rainfall, followed by relative humidity, minimum temperature and maximum temperature. Climate ready crops/technologies need to be developed and adopted in future, since climate variability is on the increase (than decrease).
- Highest rainfall is received during monsoon, followed by post-monsoon and pre-monsoon. However, variability is highest in pre-monsoon rainfall, followed by monsoon and post-monsoon. This needs a sound 'Contingent Farm Planning' by the farmers supported by the extension agencies.
- Across cropping seasons, highest rainfall was received during *kharif*, followed by *rabi* and summer. On the contrary, the rainfall variability was highest during summer, followed *rabi* and *kharif*. Thus, risk of cultivation of crops is highest in summer followed by *rabi* and *kharif*, so far as rainfall was concerned.
- Across taluks, highest rainfall was received in Kalaghatgi taluka, followed by Dharwad, Hubli, Kundgol and Navalgund. Even the variability in rainfall was highest in Kundgol and Navalgund. Hence, researchers' attention is most needed for evolving suitable technologies for the drylands of these talukas.
- The high correlations between regions (taluks) in terms of rainfall could be used for forecasting the amount of rainfall and rainy days across regions.
- Area sown to selected crops was not significantly influenced by rainfall, but by maximum temperature and maximum relative humidity, in general. Crop-specific exceptions exist. Similar was the response of net returns. Hence, maximum temperature and maximum relative humidity are the problem creators for crops, which need to tackled in future crop improvement and crop management programmes.
- Erratic rainfall and distribution are the major problems resulting in reduction in yield and net returns and pest occurrence as well. The effect was mostly seen on jowar, followed by cotton and bengalgram. Hence R&D efforts need to be concentrated on these crops, in that order.

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CLIMATE VARIABILITY AND ITS EFFECT ON CROPPING PATTERN AND FARM INCOME : AN ECONOMIC ASSESSMENT IN DHARWAD DISTRICT OF KARNATAKA

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ABSTRACT

Climate change is one of the biggest challenges the world is facing today. Despite technological advances, weather is still a key factor in agricultural productivity. The effect of climate on agriculture is related to variability in local climates rather than in global climate patterns. Most agronomists believe that agricultural production will be mostly affected by the severity and pace of climate change (called “climate variability”), not so much by gradual trends in climate (called “climate change”). The effects of climate variability are many folds. There is a need to create awareness about its impact on various sectors of agrarian economy.

The present study analyzed the climate variability and its effect on cropping pattern and farm income in Dharwad District of Karnataka. The study is based on both secondary and primary data. Primary data were collected from Dharwad taluka of Dharwad district, which was purposively selected owing to the presence of agro-climatic observatory. The sample consisted of 120 farm households randomly selected from four villages spread within a radius of 20 km from the meteorological observatory. The data thus collected were analyzed by using compound annual growth rate, multiple regression models, Garrett’s ranking technique, percentages, means, coefficient of variation, mean deviation, correlation matrix and other descriptive statistics.

In terms of variability, rainfall showed the highest coefficient of variation, followed by relative humidity, minimum temperature and maximum temperature. The highest mean rainfall was received during monsoon, post-monsoon and pre-monsoon periods across the study. The highest variation was observed in pre- monsoon rainfall, followed by post-monsoon rainfall, while the least was in the case of monsoon rainfall. This needs a sound ‘Contingent Farm Planning’ by the farmers supported by the extension agencies. Dharwad and Hubli taluks had highest positive correlation (0.8816) in terms of annual rainfall, followed by Hubli-Kundgol, Kundgol-Navalgund and Kalaghatgi-Kundgol.