RAINFALL VARIABILITY AND PROBABILITY ANALYSIS OF DISTRICT HEAD QUARTERS OF DIFFERENT AGRO-CLIMATIC ZONES OF CHHATISGARH

M.Sc. (Ag.) THESIS

by

NEERAJ KUMAR BANCHHOR

DEPARTMENT OF AGROMETEOROLOGY
COLLEGE Of AGRICULTURE
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NEERAJ KUMAR BANCHHOR

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CERTIFICATE - I

This is to certify that the thesis entitled **RAINFALL VARIABILITY AND PROBABILITY ANALYSIS OF DISTRICT HEAD QUARTERS OF DIFFERENT AGRO-CLIMATIC ZONES OF CHHATTISGARH** submitted in partial fulfilment of the requirements for the degree of **"Master of science in Agriculture"** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **NEERAJ KUMAR BANCHHOR** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate, awarded etc.) or has been published/ published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

Date: **(Dr .S. R. Patel)**

Chairman of Advisory Committee

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Chairman: Dr. S. R. Patel ________________________

Member : Shri Ramagya Singh ________________________

Member : Dr. (Smt.) G. Chandrakar ________________________

Member : Dr. R. K. Sahu ________________________

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This is to certify that the thesis entitled "**RAINFALL VARIABILITY AND PROBABILITY ANALYSIS OF DISTRICT HEAD QUARTERS OF DIFFERENT AGRO-CLIMATIC ZONES OF CHHATTISGARH"** submitted by **NEERAJ KUMAR BANCHHOR** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) in partial fulfilment of the requirements for the degree of **M.Sc. (Ag.)** in the **Department of Agrometeorology** has been approved by the external examiner and Student's Advisory Committee after an oral examination.

Date: **External Examiner**

(Name----------------------------------)

Major Advisor ______________________

Head of the Department/ Section ______________________

Dean/Dean Faculty ______________________

Director of Instructions ______________________

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"Education plays vital role in personal and social development and teacher plays a fundamental role in imparting education. Teachers have crucial role in shaping young people not only to face the future with confidence but also to build up it with aim and responsibility. There is no substitute for teacher pupil relationship".

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Date: **(Neeraj Kumar Banchhor)**

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CHAPTER-I

INTRODUCTION

The hydrologic phenomena which directly influence the interest of agricultural personnel are rainfall, runoff, flood and drought. Rainfall is one of the most important hydrologic events which plays significant role in many of agricultural and non agricultural operations. Rainfall varies not only with time but also with geographical area and altitude in space. The knowledge of total rainfall and its distribution through out the year is extremely useful and important for better planning of cropping pattern and developing irrigation and drainage plans of an area.

Excepting the south eastern part of the peninsula and Jammu and Kashmir the south west monsoon (June – Sept.) is the principle source of rain. The months of July and August received major portion of rains. During this period more than 75% of annual rainfall is received over a major portion of the country. With this in the view the present study is limited to this part (June – Sept.) of the year and hence called as “active period” forthwith.

In rainfed areas rainwater, the only source of water supply should be stored in the soil profile up to its optimum capacity. In hilly catchments areas, the priority should be given for better conservation and utilization of water/called for the probabilistic estimates of rainfall values over a short period such as weekly fortnightly and monthly are required to provide basic data for planning irrigation and other water resources project. This is especially true in connection with the analysis of droughts and irrigation. The water requirement of crops can be met either by rainfall or by irrigation. Periods when rainfall exceeds the potential evapotranspiration require storage and drainage of excess water.

Similarly when the potential evapotranspiration exceeds the probable rainfall, it requires provision for additional water resources. This is directly related to rainfall. Keeping this in view the analysis of rainfall data and determination of excess and deficit periods have been performed on the different districts head quarters of different agro-climatic zones of Chhattisgarh state.

Chhattisgarh state stretches between 80˚ 15′ E longitude to 84˚ 24′ E longitude and 17˚ 46′ N to 24˚ 5′ N latitude with total area of about 13.5 million hectares. The state has a great variety and diversity of weather condition subject to this consideration. Three major agro climatic zones have been demarcated. These zones are (1) Chhattisgarh plain with headquarter at Raipur (2) Baster plateau with headquarter at Jagdalpur and (3) Northern hill region of Chhattisgarh with headquarter at Ambikapur (592.62 meter above mean sea level,23˚ 8’ North latitude and 83˚15’ East longitude). Northern Hill region of Chhattisgarh has an average annual rainfall of about 1400 mm with about 95 percent of the area exposed to rainfed ecology.

The climate of chhattisgarh is characterized as dry sub-humid with an average annual rainfall is about 1400 mm which is largely contributed by south-west monsoon receiving about 95 percent rainfall during the period from June-September. The onset of monsoon is around 10th June in the southern most tip of Bastar plateau and extends over the entire area by 25th June .The monsoon starts withdrawing from northern parts from mid September and by 25th September it is completely withdrawn from the entire state.

Daily rainfall plays a great role in weather phenomena in tropical countries and helps to determine the agricultural land use potential and in hydrological investigations. Although many parameters of daily rainfall is important for this investigation, forecasting of the annual and temporal patterns of monsoon rainfall occurrence is of utmost importance.

Hydrologic modeling and water resources assessments depend upon knowledge of the form and amount of rainfall occurring in a region of concern over a time period of interest. Rainfall varies geographically, temporally and seasonally. It should be understood that both seasonal and temporal variation in rainfall are important in water resources planning and hydrologic studies.

A precise understanding of agro climatic condition is a prerequisite for efficient crop planning in any given region. This type of understanding is of more relevance in rainfed area where crop productions depend on vagaries of monsoon and other climatic parameters. Amongst the different parameters, rainfall varies the most in its amount, frequency and distribution. Therefore, rainfall distribution pattern is a major determinant of crop yield in rainfed areas. In this context, collection scrutiny and analysis of historical weather data available in the region are essential to characterize the agricultural climate of the region.

The detailed rainfall analyses are essential for optimal management of rain water at various levels/uses, land and crop management and crop planning etc. Martin Smith (2000) also emphasized the application of climatic data for planning and management of sustainable rainfed and irrigated crop production by adopting Penman-Monteith approach of ET calculation. The amount of rainfall and number of rainy days of a place, over a period of time, determine the need and design both for rain water harvesting or structure to recharge ground water aquifers. The rainfall probability with respect to given amount of rainfall is extremely useful for agriculture operation and crop planning. In crop growing seasons many times decision have to taken based on weekly probabilities of receiving certain amount of rainfall computed as initial probability [P(W)] and conditional probabilities on wet [P(W/W)] and dry [P(W/D)] basis. These probabilities at various degree of wetness i.e. amount of rainfall (5, 10, 20 and 50 mm) has been found more useful for agricultural operation and crop planning in Semi Arid India. Keeping these points in view present research work was carried out at Raipur, Chhattisgarh, and using daily rainfall data with the following objectives:

(1) To find out the rainfall variability in three districts of Chhattisgarh i.e. Raipur, Jagdalpur and Ambikapur.

(2) To find out the rainfall probability in aforesaid three districts of Chhattisgarh.

(3) To obtain the length of growing period for crop planning.

CHAPTER II

REVIEW OF LITERATURE

In this chapter, a review of the literature pertaining to Rainfall analysis carried out by researchers in India and abroad was done on different aspects like rainfall analysis, rainfall probability studies, rainfall variability studies, Water balance studies, climatological studies and the length of growing period relationship are briefly mentioned.

2.1 Rainfall analysis

Raghvendra (1974) studied the trends and periodicities of rainfall in sub- divisions of Maharashtra State viz., Konkan, Madya Maharashtra, Marthwada and Vidarbha sub- divisions. They found that the coefficient of variations was about 20 percent for the annual and monsoon rainfall except, in Marathwada where it was 25 percent. The annual and monsoon rainfall in the state followed the normal distribution for their yearly frequencies. The trend as revealed by fitting of orthogonal polynomials is showed as a quadratic curve for the annual and monsoon rainfall of Konkan and Madhya Maharashtra, sub-divisions on either side of the Western Ghats.

Subramaniam and Rao (1984) conducted rainfall studies of Prakasam district, Andra Pradhesh by analyzing the monthly rainfall data for 12 rain gauge stations for the period of 1901-1983. Their study revealed that annual rainfall varied from 1116 mm at Chirala to 660 mm at erragondapalem. On an average, there were 43 rainy days (i.e. days with rainfall of 2.5 mm or more) in a year in the district. The number of rainy days varied from 50 at Chirala-the coastal plain to 37 at Darbi and Podili.

Subramaniam and Rao (1989) studied rainfall variability over Prakasam and Nellore districts of Andhra Pradesh. They found that the annual rainfall variation was higher along the coastal strip and relatively lower in the interior parts. The Kandukur region had highest coefficient of variation (33%) and lowest was found at Giddalur region (23.5%). Further they observed that the coastal stations, which registered high amount of rainfall, had higher variabilities compared to the inland stations, which receive lower rainfall.

Subramaniam and Rao (1989) carried rainfall studies over Prakasam and Nellore districts of Andhra Pradesh. They found that the average number of rainy days per year over the study region indicated that the Darsi, Podili areas of Prakasam district experienced less number of rainy days. During the Kharif season, Giddalur experienced more than 30 days, whereas, in other places it varied from 10 to24 days. The pattern during Rabi season was found opposite to that of rabi season.

Saxena *et al.,* (1989) conducted climatologically studies on rainfall over Bombay. The rainfall data of Colaba and Santa Cruz observatories were used for the period of 32 years from 1950 to 1981 and the analysis was made for seasonal, monthly, pentad and daily rainfall was examined. It was noticed that the mean seasonal rainfall of Santa Cruz was more than that of Colaba but the standard deviation was less. They also reported that mean monthly rainfall was more at Santa Cruz than Colaba, except, in June for which the difference was marginal.While workingout 10 years running means for the seasonal rainfall at Colaba and Santa Cruz for the study period (1950 to 1981), a decreasing trend was noted from 1957-1985 at both stations.

Subramniam and Srimannarayana (1991) carried rainfall analysis in Madhya Pradesh. It was found that the coefficient of variations of annual rainfall was less than 20 percent for the eastern and southwestern district of east Madhya Pradesh and that of in west Madhya Pradesh the coefficient of variations of annual rainfall ranged from 25 percent over Seoni district in the east to nearly 40 percent in Morena district in the extreme north west. Further, they concluded that the coefficient of variations of rainfall was very high in winter, hot weather and post-monsoon season over the state.

Ghadekar and Thakare (1991) studied characterization of rainfall of Nagpur region for crop production and cropping patterns. They concluded that the mean rainfall of the Kharif season was 831.5 mm (CV 20.8%) with 52.3(CV 17.3%) rainy days. Further, it was found that cropping seasons of 13 weeks (25^{th} to 36 SMW) with dependable rainfall at 75, 80, 85 and 95 percent probability levels were most assured and risk free.

Baghel and Sastri (1992) studied the impact of regional climatic change and its influence on agriculture in Chhattisgarh region of Madhya Pradesh. They found that the quantum of annual rainfall was in decreasing trend in some pockets.

Subramaniam (1994) used the rainfall data of 90 years period from 1901-1990 to examine the possibilities of various meteorological sub-divisions to recover its June- July deficiency during the later half of the south-west monsoon period. He found that east Madhya Pradesh recovers its June-July rainfall deficiency in September with a relatively high percentage (21%) whereas; in the Madhya Pradesh the deficiency worsens further in September (-7%).

Suresh (1996) analyzed the inter-seasonal and inter-annual rainfall of 9 meteorological sub divisions in Tamilnadu, Kerala, Andhra Pradesh and Karnataka states for the period of 1901-1992. The large scale excess and deficit rainfall years were identified for all sub-divisions. The increasing and decreasing trend of rainfall activities were statically examined and periodicities of the rainfall, time series was worked out by employing spectrum analysis. So for as the statistical parameters and properties of various meteorological sub-divisions is concerned it was observed that there was a significant decreasing trend in south-west, north-east monsoon and annual rainfall in respect of Kerala from 1976. The performance of south-west monsoon and there by annual rainfall activity was on the increasing trend in Telangana, north interior Karnataka from 1953.

Jadav *et.al*. (1999) analyzed the rainfall probability for crop planning in scarcity zone of Maharashtra. The rainfall data of 30 years (1966-1995) was analyzed for rainfall amount at various probability levels (30, 60, 70 and 90%) for weekly, monthly, seasonal and annual trends at Solapur. They found that on an average annual rainfall of Solapur region was 723.4 mm received in 43 rainy days. The mean monthly rainfall of Solapur was 113.3, 127.7, 140.3 and 172.3 mm in the months of June, July, August and September respectively with the total monsoon rainfall of 553.8 mm. The seasonal rainfall for these months accounts for 76 percent of the annual rainfall. The monthly coefficient of variations ranged between 55-226 percent.

Hundal and Kaur (2002a) examined annual and seasonal climatic variability at different locations of Punjab state..The rainfall variabilities were analyzed from historical daily meteorological data for Amritsar (1970-98), Patiala (1970-98), Ludhina (1970-99) and Bathinda (1977-98). It was found that the annual as well as seasonal rainfall exhibited high standard deviation and coefficient of variations indicating large variations in rainfall at all stations. The five yearly moving average trends in rainfall showed an overall increase of about 120 mm at Amritsar, 150 mm at Ludhiana, 150 mm at Patiala and 140 mm at Batinda.

2.2 Probability Analysis

Probability analysis of drought and monthly rainfall: -

The rainfall frequency analysis was computed using weibull' method (chow, 1964). The probability p in percent was expressed as:

$$P = m/(n+1) * 100$$

Where, m = rank number of the data arranged in decreasing order and n = total number of years of data.

To Probability analysis can be used for prediction of occurrence of future events from available records of rainfall. Based on theoretical probability distributions, it would be possible to forecast the rainfall of various magnitudes with different return periods. Several distributions have been used for hydrological analysis.

Rao *et.al.* (1988) investigated daily rainfall data (1969-1984) for Anantapur, Nandyal and Lam to assess the probability of receiving adequate rain for successful crop establishment. The 10 day periods in which accumulated rainfall reached 200 mm were calculated for each year, together with the probability of 2 consecutive dry 10 day periods occurring. The implications for crop production are discussed and the probability of receiving a minimum, monthly rainfall of 50, 75 or 100 mm at each location was calculated.

Weerasinghe (1989) Studied daily rainfall data of the Mapalana Meteorological Station for 35 consecutive years (1950-85).These were analysed by the Markov chain probabilities for weekly rainfall. The rainfall availability of the location was assessed in relation to rice cropping in the yala season (2 wet months, May and June) and the maha season (rainy months Sep-Nov.). A rainfall probability of >10 mm (75% probability level) and a moisture availability index >0.5 were considered suitable values for determining cropping periods in the 2 seasons. It was recommended that crop establishment should commence around 16 April. and 10 September in the yala and maha seasons, respectively. The rainfall availability in the period 1-15 Apr. appeared to affect yala season crop success, while dry conditions in October. could delay maha season crop establishment until late October. in 5 out of 10 years.

Chakraborty *et al.,* (1990) made an agroclimatic study in the Hooghly district of West Bengal for 1920-85. Assured rainfall analysis, probability of having a specified amount of 20 mm rainfall/week (one-third the potential evapotranspiration rate of the region) and a water-balance approach were found quite effective to assess the water availability period for crop planning under rainfed condition. Tossa jute (Corchorus olitorius) and rice can be sown during 17-22 weeks and 22-24 weeks, respectively when the values for the actual evapotranspiration : potential evapotranspiration ratios starting at 0.33 approached 1.0. Double cropping in the Hooghly district was possible in all types of soils, except in sandy loam soils having an available water-holding capacity of 100 mm.

Chakraborty (1990) made Markov chain probability analysis as applied to precipitation data (1976-85) for 4 locations in West Bengal to predict the probabilities of a given amount of weekly rainfall (> 20, 30, 40 or 50 mm) and the probabilities of consecutive wet weeks and of dry weeks following wet weeks. The results are discussed in relation to the sowing dates of various crops.

Saleh and Bhuiyan (1993) investigated farming practise in north central Luzon, Philippines, and found that 50-75% of farmers grow a second crop following wet season rice on 20-70% of their land. The second crop is usually mung beans [Vigna radiata] due to its drought tolerance and early maturity. However mung bean yields are low. In trials conducted in 1991-93, dry-seeding of rice enabled earlier sowing of mung beans by about 2 weeks, which resulted in over 50% higher water availability and 55% higher mung bean yield as compared with the crop that was grown after harvest of transplanted rice. Rainfall probability analysis suggested that on an average year, crop water availability from rainfall would be increased by 78% if rice could be harvested 20 days earlier than the average harvest date of transplanted rice, which is possible through dry seeding of rice. At present, farmers make marginal profits from mung beans but the return above cash cost is high because of employment of family labour for harvesting and threshing operations.

Kalita (1999) conducted a field experiment was conducted at Jorhat to investigate suitable sowing dates for wheat cv. Sonalika. Six sowing dates between 1 and 28 November 1995 were compared, with the highest yield of 3.21 t/ha given by sowing on 13 November. An analysis of weekly rainfall data for 1976-95 is also presented. Total annual rainfall was 1990 mm, out of which 59.29% was received during the 23rd to 38th week of each calendar year, with moisture stress periods occurring from the 45th to 52nd week and throughout January. The rainfall intensity was maximum during July-August.

Kar (2005) analysed 30 years (1966-95) of rainfall data from 5 coastal stations of Orissa [Balasore, Cuttack, Ganjam (Gopalpur), Puri, and Bhubaneswar] to compute the seasonal distribution of rainfall, coefficient of variability of monthly rainfall and probability of monthly and weekly rainfall. At these stations, the number of rainy days ranges from 55-75 days. Results showed that the total rainfall ranged from 1209 mm in Ganjam (Gopalpur) to 1688 mm in Balasore. Among the seasons, the southwest monsoon rainfall (June to September) varied from 718.9 mm in Ganjam (Gopalpur) to 1186 mm in Cuttack, contributing 59.5 to 76.1% of the total annual rainfall. July was found to be the wettest month with the lowest coefficient of variation, ranging between 39% in Cuttack to 79% in Ganjam (Gopalpur). Results also showed that the initial and conditional probabilities of getting 10, 20 and 30 mm rainfall during the 24th to 38th SMW were more than 50% in coastal stations. In general, from the weekly rainfall probability analysis, it can be inferred that: (1) at all the coastal stations, dependable rainfall occurs between the 24th and 38th SMW; (2) rainfed crops can successfully be grown during the *kharif* season while growing of rabi crops in winter season without supplementary irrigation could be risky; (3) in coastal region pre-monsoon showers may occur around the 18th-20th SMW.

Dutta and Khan (2005 a) studied on weekly rainfall data from 1936 to 2000, for Cooch Behar district of West Bengal to compute the assured rainfall (AR) amounts by incomplete gamma distribution technique at different probability levels for crop planning under rainfed condition. At 10% probability level, more than 20 mm of rainfall per week could be expected from week 12 (19-25 March) to week 43 (22-28 October). In 25 years out of 100 years, there was a chance of getting more than 20 mm of rainfall per week from week 13 (26 March-1 April) to week 42 (15-21 October). At 50% probability level, one can expect more than 20 mm of rainfall per week from week 17 (23-29 April) to week 41 (14-20 May) in at least 50% of the years out of 100 years. At 50% probability level with 20 mm threshold rainfall, the length of the growing period was 25 weeks extending from week 17 (23-29 April) to week 41 (8-14 October), whereas at 75% probability level, it reduced to 19 weeks starting from week 20 (14-20 May) to week 38 (17-23 September). The crop growing period as estimated through AR values showed that sowing of upland crops such as jute and rice cannot be possible before week 13th SMW (26 March-1 April). The sowing of upland rice and jute in the district of Cooch Behar can be scheduled in week 17th SMW (23-29 April), because from this period there is a chance of obtaining at least 20 mm of rainfall per week..

Dutta and Khan (2005 b) conducted an agrometeorological study in Cooch Behar district of West Bengal, India, to determine the water availability period by characterizing the continuous wet and dry periods, which influence the crop performance under rainfed condition. By using the weekly total rainfall data for the period 1936-2000, the initial and conditional probabilities of getting threshold weekly rainfall of >=5, 10, 20, 30 and 50 mm per week were estimated for crop planning. The initial probability of receiving more than 20 mm of threshold rainfall limit per week became more than 75% during week 18th SMW (30 April-6 May) to week 38th SMW (17-23 September), while the conditional probability of getting more than 20 mm per week being more than 75% also prevailed between 18th SMW (30 April-6 May) and 38th SMW. Hence it is a safe period for rainfed upland crops. By considering 20 mm as threshold rainfall, the long-term rainfall probability analysis showed that the time for sowing of upland jute and rice in the district can be scheduled at 13th SMW (26 March-1 April) and onwards. At 13th SMW the conditional probability of receiving wet week preceded by another wet week was 75% at 20 mm threshold rainfall, which was considered as the minimum water needed for initiating sowing of upland crops. When 55 mm rainfall per week was considered as the threshold limit of rainfall, the probability of receiving wet week became more than 75% during 22nd SMW (28 May-3 June) to 30th SMW (23-29 July), which coincided with the rice crop phase requiring the highest amount of water. However, for better success in Cooch Behar district without applying pre-sowing irrigation, the sowing of upland rice and jute as pre-kharif crops can be scheduled from 18th SMW (30 April-6 May) followed by aman rice (cv. Kshitish) in kharif season and Lathyrus as rabi crop. Compared to the average rainfall during a particular period, the probability of receiving a certain amount of threshold rainfall during the corresponding period was proved to be useful for determining water availability for crop production and for irrigation planning during dry periods.

2.3 VARIABILITY ANALYSIS

Gaikwad *et al.,* (1996) carried out the analysis of daily rainfall data for 30 years (1963-92) recorded at Dry Farming Research Station, Solapur, Maharashtra Annual, seasonal, monthly and weekly rainfalls and weekly rainfall probabilities (> = 20 mm rainfall/week) were worked out. The mean annual rainfall was 723 mm, out of this 76% was received during southwest monsoon and 15% from northeast monsoon season. Trend values were around the mean. There was a 40% chance of getting more than normal rainfall. Sowing of seeds commenced from 20 May onward with occurrence of rain. The water availability period consists of 140 days. Comparatively less variation in weekly rainfall was observed during 11-24 June and 23-29 July (CV 79-87%) in monsoon season and during mid-September to early October in the rabi [winter] season. Initial probabilities exceeded P = 0.6 during 11-17 June and 17-23 September and conditional probabilities (w/w) in September and early October. Medium to long duration dry spells are of common occurrence during monsoon seasons.

Srivastava and Chaudhary (1998) in Chhattisgarh region found that inadequate and poor distribution of rainfall has reduced rice yields. Rice is grown in this region in about 4 million hectares. Rainfall data for the period 1901-90 are presented, and strategies for harvesting water are discussed.

Mzezewa and Gotosa (1999) narrated that Zimbabwe is divided into five Natural Regions (NRs) based on rainfall amount and variability. The dry-area production systems or semi-arid environments of Zimbabwe fall in NRs III, IV, and V. These three NRs constitute ~ 83% geographical area of the country. Rainfall onset and length of growing period are unpredictable and highly variable, making crop production in the semi-arid areas risky and unstable. However, crop production by small-scale farmers in these areas continues to depend on the limited rainfall and its success depends on using management techniques that conserve and increase the total soil water available to crops. This paper is a review of past and current research on soil water-use efficiency and ways to improve it in low-rainfall dryland production systems. Gaps in the research on optimizing soil water use are identified (e.g. crop water use and crop water-use efficiency) and suggestions for further research presented.

Chaudhary and Sastri (1999) stated that rice is grown in ~3.8 million hectare in chhattisgarh of which more than 80% is rainfed. The average productivity of rice in this region is ~1.2 t/ha which is very low. A study on temporal variations of rainfall and rainy days was made for different districts of Chhattisgarh region from the beginning of this century. The results showed that there was an alarming decreasing trend of rainfall in some pockets in this region. Not only the quantum of rainfall, but also the number of rainy days is decreasing during the cropping season. The decreasing trend of annual rainfall is observed in Raipur, Durg, Bilaspur, and Rajnandgaon districts. As regards the number of annual rainy days, which determine the length of growing season, decreasing trend over the decades could be seen at Durg, Raigarh and Bilaspur districts. It was noted that the rate of decrease for these stations in the recent decades is much higher than in the previous decades. The implication of this conclusion is that future agricultural planning must take into account this decreasing trend. Short duration but high yielding crop varieties need to be developed and brought under cultivation for successful agriculture including weather package as an input. The study on storage index attempts to understand the water harvesting potential of the Chhattisgarh plains region in different months which is falling in the recent years during the months of September and October. In districts like Raipur and Bilaspur and Balaghat where there is a significant increase in irrigation resources, rice productivity has significantly increased over the decades

Chaudhary (1999) studied the variations of rainfall, rainy days etc. for understanding and adopting the suitable cropping system and scope for application of modern techniques for increased cropping intensity and crop productivity were. The coefficient of variation of monsoon rainfall was least in the Sukma, Bijapur and Jagdalpur regions indicating that rice production will be more sustainable in these regions. The high values of coefficient of variation around Dantewara during both monsoonal and post- monsoonal season indicated that this is a highly unstable region for rice production. There is much scope for increasing fertilizer consumption in this area.

Gare *et al.*, (2000) investigated the daily rainfall data for 28 years (1969-96) recorded at the Agricultural Research Station Gadhinglaj, in Maharashtra. They analysed data for annual, seasonal, monthly and weekly periods and weekly rainfall probabilities. The mean annual rainfall was 931.1 mm; 75% of this was received from June to September (southwest monsoon), and 14% was received from October to November (northeast monsoon). In 39% of the 28 years, more than average amount of rainfall was received. Comparatively less variation in the weekly rainfall was observed during 28^{th} to 32^{nd} SMW (CV 73 to 98%) and 39^{th} SMW (CV 68%) in the kharif and rabi seasons, respectively. Initial probabilities indicated that >75% probability rain could be expected from MW 28 to 31 during the kharif season and MW 39 during the rabi season. Rainfall probabilities of <50% from 34 to 37 MW indicated the chance of dry spells during the kharif season. Conditional probabilities (W/D) exceeding 80% in MW 29 showed the suitability of the 29th MW for dry sowing.

Reddy *et al.*, (2001) studied drought-prone areas in Andhra Pradesh. These were identified using long-term weekly rainfall data. Seasonal variation in rainfall and percentage deviation from the mean, dry-spells during the crop growing season and the frequency of occurrence of drought were analysed. The length of growing period as an index for the period of soil moisture sufficiency was worked out using weekly rainfall, soil water storage, actual evaporation, potential evapotranspiration and moisture adequacy index. The drought-prone areas were further refined and categorized as mild, moderate, severe and chronic agricultural drought-prone zones based on the length of growing period, rainfall variability, frequency of recurrence of drought and number of dry spells. The study indicated that about 11.57 M ha (42%) covering 13 districts and spread over 64 taluks in the state are subjected to different degrees of agricultural drought either fully or partially. Mild drought-prone areas cover about 1.96 M ha, and the areas under moderate, severe and chronic are 4.73 M ha, 2.91 M ha and 1.93 M ha in the state, respectively. The regionwise distribution indicated that the largest drought-prone area is concentrated in Rayalaseema region (85%) followed by Telangana (33%) and the least in the coastal (21%) region.

Hundal and Kaur (2002b) observed annual and seasonal variabilities in maximum, minimum temperature and rainfall. These were analyzed from historical daily meteorological data for Amritsar (1970-

98), Patiala (1970-98), Ludhiana (1970-99) and Bathinda (1977-98). Two distinct crop growth season of *Kharif* (1^{st} May to 31^{st} Oct.) and Rabi (1st Nov. to 30^{th} Apr.) where characterized for seasonal trends. Both annual as well as seasonal maximum and minimum temperatures exhibited small standard deviation and coefficient of variation at all stations indicating minor variations in temperatures. The maximum temperature had remained near normal for all locations while showing a variation of up to + 0.6^0c from normal as revealed from the five yearly moving average. However, the minimum temperature had generally increased by as much as 0.4 to 1.6^0 above normal. The annual as well as seasonal rainfall exhibited high standard deviation and coefficients of variation indicating large variation in rainfall at all stations. The five yearly moving average trend in rainfall showed an overall increase of about 120 mm at Amritsar, 150 mm at Ludhiana, 150 mm at Patiala and 140 mm at Bathinda.

Mehta *et al.,* (2002) conducted analysis of the weekly rainfall data for 39 years (1958-1996) recorded at Main Dry Farming Research Station, Targhadia, Gujarat. They analysed for seasonal and weekly periods and weekly rainfall probabilities, and yield prediction models using rainfall and productivity (1960-1995) were worked out. The mean seasonal rainfall was 567 mm (coefficient of variation, CV, 52%), which was recorded for 27 rainy days. The seasonal rainfall indicated that there is 33% chance of drought of variable intensities and 38% chance of getting more than the normal rainfall. The mean weekly rainfall was 26 mm, with a CV of 73%. Initial probabilities, exceeding P=0.6, of receiving >20 mm rainfall/week was observed in SMW 27, with coefficient of variation. Sowing of kharif crops should be undertaken during this period. Significant and positive correlation between yield and rainfall was observed for groundnut, pearl millet, and sorghum. The predictability of crop productivity using seasonal rainfall is low at the centre for all the crops except groundnut, which explained 56% variation in productivity.

Santos *et al.* (2003) applied the application of wavelet analysis that was done with a long time series of the total monthly rainfall from several places from different regions of the world (i.e. Iberian Peninsula, Japan and north-eastern Brazil). Such an analysis was performed in order to fully characterize the distinct time-frequency rainfall variability observed in each of these areas. Besides the rainfall variability analysis, the main frequency components in the time series are studied by the global wavelet spectrum, revealing how the monthly rainfall frequency of each place is composed. This analysis is considered to be more accurate than the standard Fourier analysis. The modulation in separated bands was done in order to extract additional information; e.g. the 8-16-month band was examined by an average of all scales between 8 and 16 months, giving a measure of the average monthly variance versus time, where the periods with low or high variance could be identified.

Tapsoba *et al.,* (2004) proposed an approach for analyzing rainfall variability over West Africa during the 1950-90 period. Three grid boxes, corresponding to three selected areas over West Africa, have been constructed. For each area the set of annual grid maps are stored in 3D matrices, reflecting time and geographical position, called here space-time grid boxes. Each space-time grid box contains grid points corresponding to a given gauging year. The Bayesian procedure, based on a single-shifting model, is applied to grid points extracted from mean meridional and latitudinal cross sections of each space-time grid box. Two different problems are considered: the first is the detection of a change, while the second is the estimation of the changepoint and its amplitude under the assumption that a change has occurred. The Bayesian single-shift model is applied on grid points extracted from each cross section. A latitude-latitude and longitude-longitude analysis of the rainfall climatology changes is, thus, carried out. It is pointed out that the most significant rainfall climatological changes in the Sahel most probably occurred between 1965 and 1970 with the decrease of the mean level of annual rainfall. This deficit is very high over the coastal region of Senegal (25%) and over the central region of the Sahel (15%-20%). Under approximately 9^0 -10^0 N, over the humid West Africa region, a zone without any significant change extending from 6^0 to 10^0 N was highlighted. A similar zone with nonsignificant rainfall change was identified along the cross section at 1.5^0 E, which follow the border of Togo and Benin. However, over the zones in edge of the coast of Ivory Coast, a deficit about 17% is observed.

Kingra et *al.,* (2004) noted rainfall pattern of Ludhiana (Latitude 34^0 54'N, Longitude 75^0 48'E and Altitude 247m) has been analyzed for the period of 100-years (1901-2000) (source: India Meteorological Department and meteorological observatory, PAU Ludhiana). The variability, fluctuation and moving trend of rainfall on monsoon, seasonal and annual basis have been studied

Chaurasia and Mavi, (1973); Suresh and Sivaramakrishnan,(1997). Annual normal rainfall received at Ludhiana is 717 mm out of which 588 mm is received during irrigated *Kharif* cropping season (May to Oct.) whereas 129 mm of rainfall is received during irrigated *Rabi* cropping season (Nov. to April). In the past century, maximum annual rainfall of 1395 mm was received in 1971 followed by 1336 mm in 1988. The lowest annual rainfall of the century (260 mm) was experienced in 1974. Other years with low amounts of rainfall include 328 mm in 1969, 353 mm in 1938 and 384 mm in 1987.

Kotahri *et al.,* (2007) investigated rainfall data of Bhilwara district in Rajasthan state for a period of 45 years from two approaches viz.; 'Meteorological' approach and 'Onset of monsoon' approaches. The results revealed considerable difference in rainfall characteristics with respect to length of growing period, water surplus/deficit and probability of intervening dry spells due to these approaches. The 'Onset of monsoon' approach is more rational as it precisely describes the actual crop environment and provides information for varying onsets of monsoon as compared to 'Meteorological' approach. The results of water balance study revealed an increase of 142.6% in water deficit due to delay in onset (31st SMW) as compared to normal onset of monsoon (27th SMW), whereas an increase of 35.2% and decrease of 33.7% in water surplus was recorded due to late and early onset of monsoon. The correlation studies also reveal that onset of monsoon is inversely correlated (-0.91) with duration of rainy season while positively correlated (0.83) with water deficit. Thus, the 'onset of monsoon' approach should be considered for crop planning under rainfed regions to harness more profit per unit of rainfall.

Reddy *et al.,* (2008) stated that agricultural drought occurs when soil moisture and rainfall are inadequate during crop growth season to support healthy crop. The study pertains accounting agricultural drought and climate shift based on climate water balance method on seasonal basis in Bangalore region. The study revealed that the weekly water deficit during *Kharif* season varied from 1.18 to 13.04 mm and water surplus ranged from 1.03 to 48.83 mm accounting for total water surplus of 260.8 mm. The surplus water during Kharif season gives scope for rainwater harvesting, conservation and recycling during the stress period. Drought years where identified and their intensities were assessed by the help of departure of annual aridity indices. During the study period, Bangalore experienced 5 moderate (20%), 4 large (16%) and 4 severe (16%) drought years within a period of 25 years. Climate varied from most sub-humid to semi-arid whereas, dry sub-humid climate was found to be prominent one based on moisture index (Im) procedure.

2.4 LENGTH OF GROWING PERIOD

Naidu *et al.,* (1998) delineated agroecological zones of Andhra Pradesh, using soil resource information generated on a 1:250 000 scale and rainfall data from 700 rain gauge stations. Length of growing period was computed using both soil-water balance and a 0.7 potential evapotranspiration factor and a map depicting length of growing period was generated. This map was superimposed over soil and physiography layer maps using a geographical information system and a map defining 22 agroecological zones was generated. The map showing 7 agroclimatic zones of the Andhra Pradesh was superimposed over the map showing 22 agroecological zones for comparison and discussion. The length of growing period varied from as low as 70-90 days in the Rayalaseema plateau (covering ~6% of the state) and as high as 210-240 days in the eastern Ghats (north) and Delta plains which cover about 6% and 2% of the state, respectively. The crop growing season started earliest (last week of April) in zone 14 of the eastern Ghats (north) and very late (first week of August) in the southeast coastal plain. Soils in general were dominantly gravelly red, black and deltaic alluvial except in the eastern Ghats (north) where they are brown forest soils with a high humus content. The 22 agroecological zones when compared with the agroclimatic zones indicated wide variability with respect to physiography, soils and length of growing period with 2-4 agro-ecological zones within an each agroclimatic zones. Future research programmes should be based on the 22 agroecological zones for efficient use and conservation of natural resources and agrotechnology transfer

Chaudhary and Tomar (1999) determined rainfall patterns by analysis of 40 years rainfall data (1947-86) over 12 stations of Bastar district in Chhattisgarh. A relationships between rainfall and rice yield were investigated. Weekly mean rainfall of 50 mm for lowlands and 75 mm for uplands with a coefficient of variation of <100% was considered as the stable rainfall period for rice cultivation. The results are discussed in relation to rice productivity, crop planning and cultivar selection.

Srivastava *et al.*, (2000) studied the effect of drought on rice productivity by analyzing daily rainfall data collected in 27 rain gauge stations in Raipur district and three district headquarters (Raipur, Durg and Rajnandgaon) of Chhattisgarh. Stable rainfall periods for rice cultivation and frequency of droughts of varying intensities in Raipur and comparison of drought intensity and rice productivity in the three districts are tabulated.

Rao *et al.*, (2001) evaluted thirty-six newly released cashew cultivars in different agro-environments in India. Flowering of all cultivars and in all environments was stable. The length of the growing period varied from 90 to 270 days, depending on the agroclimatic conditions and cultivars. Results indicated that areas with different rainfall quantities, but similar available water capacity and length of growing period of cashew crops can be grouped together for making varietal recommendations. Two agroecological subregions were identified for each of the states of Kerala (extended to Karnataka, Goa and Maharashtra), Orissa, Andhra Pradesh, Tamil Nadu and West Bengal.

Sanbagavalli *et al.*, (2001) conducted a study to determine the length of growing period (LGP) for Coimbatore, Tamil Nadu, India, using FAO model. Rainfall data for 80 years (1905-85) were collected from India Meteorological Department, Pune, Maharashtra, India, for 52 standard weeks and mean striked out for each week. Thirty and fifty per cent initial probable weekly rainfall were computed from the weekly data collected across years for each standard week. LGP refers to the number of weeks when 30% probable rainfall exceeds 50% PET and falls below 50% PET + stored soil moisture support period. The LGP was from 38th standard weeks to 50th standard week if weekly mean rainfall was taken, while it was 38th week to 50th standard week for 30% probable rainfall and 40th week to 46th standard week for 50% probable rainfall. With respect of 30% probable weekly rainfall analysis, a growing period of 12 weeks was recorded. If 50% probable weekly rainfall was taken, the LGP would be around 6 weeks which is not in ground reality. Hence, it is suggested to use 30% probable weekly rainfall for computing LGP. The computed LGP for 30% probable rainfall was similar to mean rainfall, but it is risky resistant and the raising of following crops have been suggested: sorghum cultivars Co 25 and Co 26, maize cultivars CoH 1 and CoH 2 and sunflower cultivars Co 1, Co 2 and Morden.

Kingra *et al.*,(2004) assessed climatic water balance for 3 agroclimatic zones in Punjab using weather parameters such as rainfall, temperature, elevation, net radiation, wind effect, relative humidity and vapour pressure. Tabulated data are presented on the annual and seasonal climatic water balance and moisture index, and the monthly, seasonal and annual rainfall, potential evapotranspiration and moisture index for selected locations in Punjab. Statistical analyses indicated that annual as well as seasonal water deficit was maximum at Bathinda while it was minimum at Ballowal Saunkhari. Such analyses is helpful in working out the length of crop growing period, which can be used for contingent crop planning and diversification of crops for judicial use of limiting water resources.

Ingver and Koppel (2005) investigated the length of the periods from sowing to heading, from heading to maturity and total growing period from sowing to ripening of spring wheat. Three growing cycles were analysed: 1923-28, 1929-36 and 1999-2003. The data of the most widely cultivated cultivars of the period and the trial data of the Jogeva Plant Breeding Institute were used. In Estonian climatic conditions suitable length of the growing period is the first and one of the most important characteristics to which attention should be paid before introducing a new cultivar. By the data of the Estonian Variety List varieties (1999-2003), a positive correlation was observed between the length of the growing period and yield, whereas negative correlations were found between growing period and protein content, gluten content and Septoria ssp. infection. There were three groups of genes controlling the duration of the life cycle, i.e. genes that control sensitivity to vernalization (Vrn genes), genes that control the response to changes in daylength (Ppd genes), and genes that control developmental rate independent of vernalization and photoperiod (earliness per se genes).

Khan and Dutta (2005) performed an agroclimatic study following the water balance technique, using weekly total rainfall data from 1936 to 2000, normal potential evapotranspiration (PET) and values of available water holding capacity for determining the length of the growing period (LGP) for evaluation of multiple cropping under rainfed condition in Cooch Behar district of West Bengal. By using the concept of moisture adequacy index (the ratio between the actual evapotranspiration and PET) the LGP for different soils (sandy, sandy loam, loam and sandy clay loam) was determined, and suitable crops and cropping systems by matching with the LGP were suggested. The average LGP for sandy loam soil was 245 days starting from standard week 15 (30 April-6 May) to SMW 49 (5-11 November), which could be effectively used for double cropping having aus/jute as kharif crop, followed by pulses/oilseeds in rabi season in upland situation. The estimated growing period of 266-280 days in loam and sandy clay loam soils can be used for triple cropping having aus (cv. Parijat) as pre-kharif crop, followed by aman (cv. IET-4094) as kharif crop and rapeseed (cv. B9) as *Rabi* crop in medium land situation for further increasing crop production under rainfed condition in the district of Cooch Behar.

CHAPTER – III

MATERIALS AND METHODS

This chapter describes the various procedures, techniques, tools, used during the course of investigation, in order to fulfil the assigned objectives. The steps followed in doing so are described in a chronological manner.

3.1 Study Area

The present study is confined to Chhattisgarh, a newly created state which came in to existence on November 1, 2000 as a result of bifurcation of the Madhya Pradesh. Chhattisgarh, situated in eastern India, is located between 17˚ 46′ N and 24˚ 5′ N latitudes and 80˚ 15′ E and 84˚ 24′ E longitudes. It is surrounded M.P. and Maharashtra in the west by, in the north by M.P., in the east by Orissa and /Jharkhand (the new state separated from Bihar) and in the south by Andhra Pradesh.

The state has three agro climatic zones viz., Chhattisgarh plains, Bastar plateau and Northern hills region spreading over a geographical area of 13.60 millions hecters. The district and their co-ordinates that come under each agro climatic zone are shown below.

SN	Station	Latitude	Longitude
1.	Raipur	$21^0 14^,$ N	$81^0 39^,$ E
2.	Jagdalpur	$19^0 05^,$ N	$82^0 02^,$ E
3.	Ambikapur	$23^0 07^,$ N	$83^0 12^,$ E

3.2 Data Base

The daily data of weather parameters required for the study was collected from the data base of the department of agrometeorology.

S.N.	Station	Database
1.	Raipur	1971-2008
2.	Jagdalpur	1980-2008
3.	Ambikapur	1991-2008

3.3 Rainfall Analysis

3.3.1 Spatial variability

The basic data of rainfall i.e. I) Annual rainfall, II) Seasonal rainfall, III) Annual rainy days and IV) Seasonal rainy days were workedout at district head quarters level.

3.3.2Temporal variability

For analysis of temporal variability of rainfall at different districts head quarters of different agro-climatic zones of Chhattisgarh , the monthly and annual rainfall data of 3 districts head quarter having long-term records have been considered.

For temporal analysis of rainfall, the time trend equation for each station for the entire database was analyzed. The time trend equations are regression equations where the X – values are years like

$$Y = A + BX$$

Where,

Y = annual rainfall

X = year

A = intercept

B = slope

The slope indicates the trend of the rainfall over the study period.

3.4 Mean rainfall

The amount of rainfall collected by a given rain gauge in 24 hrs is known as daily rainfall (mm or cm) and the amount collected in one year in known as annual rainfall. The mean of the annual rainfall over of 35 years (in India) is known as mean annual rainfall (average annual rainfall or normal annual rainfall).

$$\text{Mean annual Rainfall} = \frac{\text{Total rainfall}}{\text{Number of Years}}$$

It does not take positive or negative signs unto consideration.

3.5. Standard Deviation (SD)

It is defined as the square root of the mean of the squares of deviations of the rainfall value from the arithmetic mean of all such rainfall. It is a measure of variability or the scatter or the dispersion about the mean value. It is calculated by the following formula.

$$SD = \frac{\sqrt{\sum(\overline{X}-X)}}{n}$$

X = Rainfall frequer

$\overline{X}$ = Mean rainfall

n = Number of year

3.6. Coefficient of variation

Assessment of rainfall variability through Coefficient of variation (CV %) appears to be simple. The CV can be obtained by dividing standard deviation by mean rainfall as indicated below.

$$CV\ \% = \frac{\text{Standard deviation}}{\text{Mean}} \times 100$$

The greater the CV, the lesser the dependability of receiving rainfall. Considering the annual CV, the IMD is using the following criteria for assessing the rainfall in a particular area.

3.7. Dependability of Rainfall

Dependability of Rainfall was computed using the following equation

$$Fa\,(m) = \frac{100\,m}{N+1}$$

Where Fa = level of %

m = rank number

n = No. of observation

3.8. INITIAL AND CONDITIONAL RAINFALL PROBABILITY (%):

3.8.1 Initial Rainfall Probability (%) (W)

Initial Rainfall Probability of getting specified amount of rainfall = Wx for example 20mm

$$\mathbf{Wx} = \frac{\text{Number of year during which > 20 mm rainfall in x week}}{\text{Total number of years}} \times 100$$

3.8.2 Conditional Rainfall Probability (%) (W/W)

Conditional Rainfall Probability (%) of getting specified amount of rainfall during next week for example 20mm and also when there was rainfall > 20 mm during this week (x)

$$\mathbf{W/Wx} = \frac{\text{Number of year during which next week received > 20 mm rainfall when this week also received > 20 mm rainfall}}{\text{Number of years during which this week (Wx) received > 20 mm rainfall}} \times 100$$

3.8.3 Conditional Rainfall Probability (%) (W/D)

Conditional Rainfall Probability (W/D) of getting specified amount of rainfall during next week when this week was dry i.e. the rainfall < 20 mm rainfall

$$\mathbf{W/Dx} = \frac{\text{Number of year during which next week received > 20 mm rainfall when this week (x) received < 20 mm rainfall}}{\text{Number of years during which this week was dry (< 20 mm rainfall)}} \times 100$$

3.9. RAINFALL ANLYSIS

Rainfall analysis was performed using software provided by CRIDA Hyderabad. The program gives the output as desired in terms of annual, seasonal, monthly or weekly with maximum, minimum, standard deviation and Coefficient of variation values.

3.10. Rainfall Trend

The moving average of 10 year annual rainfall was calculated to know the rainfall trend of a particular region. For this at least 30 to 50 year rainfall data is required. For example if the rainfall data is available from 1965 – 1995 and decennial averages from 1965-1974, 1966-1975, 1967-1976 etc. can be calculated and plotted in a graph from which the increasing and decreasing trend of rainfall can be detected.

3.11. Distribution of Rainfall

The amount of rainfall received at periodic intervals like weeks, month, season etc. indicate distribution. The distribution of rainfall can be known by rainy, length of day spells and wet spells. Distribution of rainfall is more important than total rainfall in a season for crop growth, development and yield. Yield levels are determined by the amount of rainfall above the minimum basic required by the crop to achieve maturity. However yields are not always directly proportional to the amount of precipitation.

3.12. Length of Growing Period (LGP)

Estimation of LGP is important in dry farming regions to select suitable crops. If LGP is less only a short duration crop can be recommended. If AE/PE is more than 0.5 for a period than growing season is said to prevail.

LGP can be calculated by estimating mean weekly rainfall and PET.

PET can be estimating by multiplying pan evaporation data with a pan coefficient of 0.7 or 0.8 according to season.

$$\text{LGP} = \frac{\text{Mean weekly rainfall}}{\text{Weekly PET}}$$

All the weeks having more than 0.5 ratio are summed to get the length of growing period.

3.13. Climatic Water Balance

The climatic water balance for different stations and for different years was computed using the book – keeping procedure of Thornthwaite's and Mather (1995). In the water balance computations, the inputs are rainfall and potential evapotranspiration. The potential evapotranspiration values required for the water balance computations were estimated using modified Penman Monteith equation.

3.14. Climatic Fluctuations

The climatic fluctutations on a temporal scale were studied using the moisture index (Im,%), which is a percentage ratio of the difference of annual water surplus and annual deficit to the annual potential evapotranspiration.

$$\text{Im} = \frac{\text{Annual water surplus} - \text{Annual water deficit}}{\text{Annual potential evapotranspiration}} \times 100$$

In another words, the Im is the difference between humidity index, (Ih) and the aridity index (Ia), Where

$$Ia = \frac{\text{Annual water deficit}}{\text{Annual potential evapotranspiration}} \times 100$$

$$Ih = \frac{\text{Annual water surplus}}{\text{Annual potential evapotranspiration}} \times 100$$

Thornthwaite (1948) delineatede different climatic types using the moisture index, (Im) as follows.

Im range (%)	Climatic type
>100	Perhumid
20 to 99	Humid
0 to 20	Moist sub-humid
0 to –33.3	Dry sub-humid
-33.3 to –66.6	Semi arid
>-66.6	Arid

Using this criterion the climatic shifts at different sessions in Chhattisgarh state were examined.

3.15. Water Availability Periods

The water availability periods are the periods where the rainfall is balanced against the evaporative demand of the atmosphere, which is called "potential evapotranspiration". The water availability periods as described by Cocheme and Franquin (1967) were worked out as follows.

Humid period: This is the period when rainfall is more than potential evapotranspiration (R>PE).

Moist period: This is the period when rainfall is less than potential evapotranspiration but it is more than half of PET (PET>R>PET/2). The moist period occurs twice in a year that is prior to and immediately after the humid period

ACRONYM

&	=	and
S.D.	=	standard deviation
AET	=	Actual evapotranspiration
CM	=	Centimeter
Contd.	=	continuous
Cv	=	coefficient of variation (%)
DAS	=	days after sowing
Fig	=	Figure
G	=	gram
Im	=	moisture index
IMA	=	index of moisture adequacy
Kg	=	kilogram
M	=	meter
Mm	=	millimeter
PET	=	potential evaporatransporation
SMW	=	standard meteorological weeks
SP	=	species
t	=	tonne
WD	=	water deficit
WS	=	water surplus

CHAPTER- IV

RESULTS AND DISCUSSION

4.1 Annual Rainfall and Rainy days

The mean annual rainfall and rainy days of different agro climatic zones are presented in (Table 4.1).The highest mean annual rainfall of 1429.2 mm was recorded in northern hilly zone (Ambikapur) over the period of 1991-2008. While the lowest mean annual rainfall of 1167.0 mm was recorded in Chhattisgarh plain agro climatic zone (Raipur).

Table 4.1(a): District wise annual rainfall, seasonal rainfall, annual rainy days and seasonal rainy days at selected station of Chhattisgarh

Station name	Annual rainfall (mm)	CV (%)	Seasonal rainfall (mm)	Annual rainy days	Seasonal rainy days	CV (%)
Raipur	**1167.0**	**23.0**	**1020.0**	**60**	**48**	**13.3**
Jagdalpur	**1383.7**	**19.1**	**1102.4**	**75**	**56**	**14.8**
Ambikapur	**1429.2**	**25.7**	**1259.9**	**70**	**56**	**12.3**

The highest mean annual rainy days of 75 days were recorded in Baster plateau agro climatic zone (Jagdalpur, 1980-2008) followed by northern hill, agro climatic zone (Ambikapur, 1991-2008) where the mean annual rainy days one of 70 days. Chhattisgarh plains agro climatic zones (Raipur) had lowest mean annual rainy days of 60. The total amount of rainfall received in a year over 38 years along with the seasonal distribution were calculated on the basis of daily rainfall data at (Raipur, Jagdalpur and Ambikapur) district headquarters of different agro climatic zones of Chhattisgarh.

4.1.1 Raipur

Rainfall data for the period of 38 years (1971-2008) showed that the total rainfall ranged from lowest of 709.1 mm during 1988 to as high as 1651.2 mm during 1980 with a mean of 1167 mm (Table.4.1b, c **and** Fig. 4.1)**. The number of rainy days also varied from 42 to 79. The mean annual rainy days were 60 with coefficient variation of 20.7 per cent and standard deviation of 12.4.**

Table 4.1(b): Minimum, Maximum, Mean and Standard Deviation and Coefficient of Variation of annual Rainfall at Selected Stations of Chhattisgarh

STATION	MINIMUM (mm)	MAXIMUM (mm)	MEAN (mm)	S.D. (mm)	C.V. (%)
RAIPUR (71-08)	**709.1**	**1651.2**	**1167**	**268.2**	**23.0**
JAGDALPUR (80-08)	**795.3**	**2285.9**	**1383.7**	**264.9**	**19.1**
AMBIKAPUR (91-08)	**892.1**	**2167.6**	**1429.2**	**367.8**	**25.7**

Table 4.1(c): Minimum, Maximum, Mean and Standard Deviation and Coefficient of Variation of annual Rainy day at selected stations of Chhattisgarh

STATION	MINIMUM	MAXIMUM	MEAN	S.D.	C.V.
RAIPUR (71-08)	**42**	**79**	**60**	**12.4**	**20.7**
JAGDALPUR (80-08)	**45**	**112**	**75**	**11.9**	**15.9**
AMBIKAPUR (91-08)	**55**	**86**	**70**	**11.7**	**16.7**

4.1.2 Jagdalpur

Rainfall data for the period of 29 years (1980-2008) show that the total rainfall ranged from lowest of 795.3 mm during 1990 with a mean of 1383.7 mm (Table 4.1(b) , (c) and Fig. 4.2)**. The coefficient variation was 19.1 per cent and standard deviation was 264.9 mm (Table 4.1). The number of rainy days also varied from 45 to 112. The mean annual rainy days were 75 with coefficient variation of 15.9 per cent and standard deviation of 15.9 (Table 4.1).**

4.1.3 Ambikapur

Rainfall data for the period of 18 years (1991-2008) show that the total rainfall ranged from lowest of 892.1 mm during 1993 to as high as 2167.6 mm during 2001 with a mean of 1429.2 mm (Table 4.1(b) , (c) **and** Fig. 4.3)**. The coefficient of variation was 25.7 per cent and standard deviation was 367.8 mm (Table 4.1). The number of rainy days also varied from 55 to 86. The mean annual rainy days were 70 with coefficient variation of 16.7 per cent and standard deviation of 11.7.**

4.2 Seasonal Rainfall

The seasonal rainfall and rainy days distribution of selected stations have been presented in table 4.2 to 4.7. Data showed that the south west monsoon contributed more than 90 per cent of annual rainfall in all the stations. Alike mean annual rainfall, (Ambikapur) northern hill agro climatic zone received the highest mean rainfall (1259.9 mm) during the south-west monsoon period. The lowest mean rains during south west monsoon recorded in Chhattisgarh plain zone (Raipur, 71-80) (1020.6 mm).

4.2.1 Raipur

The seasonal rainfall distribution and their statistical features over the study period (71-08) have been presented in Table 4.2**. Out of mean annual rainfall of 1167.0 mm, south west monsoon received 1020.6 mm with coefficient of variation of 24.30 per cent and standard deviation of 247.8 mm. Rest of seasons received rainfall less than 70.0 mm. The coefficient of variation was also more than 70 per cent in all seasons except south –west monsoon. The maximum seasonal rainfall was 1531.6 mm and minimum seasonal rainfall was 610.2 mm during south-west monsoon.**

The number of rainy days also varied from 35 to 61 mm with mean of 48 mm, coefficient of variation of 13.3 per cent and standard deviation 6.4 mm during south west monsoon period. Rest of seasons received mean rainy days less than 6 with coefficient of variation was more than 65 per cent and standard deviation was less than 4 mm (Table 4.3)**.**

Table 4.2 Minimum, Maximum, Mean, Standard Deviation and Coefficient of Variation of Seasonal Rainfall at Raipur (1971-2008)

Season	Minimum (mm)	Maximum (mm)	Mean (mm)	S.D. (mm)	C.V. (%)
SWM (June-sep.)	**610.2**	**1531.6**	**1020.6**	**247.8**	**24.3**
PM (Oct.-Dec)	**0.0**	**166.2**	**65.8**	**51.8**	**78.8**
WM (Jan.-Feb)	**0.0**	**135.4**	**27.9**	**28.9**	**103.5**
SM (Mar.-May)	**11.4**	**159.0**	**52.7**	**39.2**	**74.4**
Annual	**621.6**	**1992.2**	**1167.0**	**367.7**	**281.0**

Table 4.3: Minimum, Maximum, Mean, Standard Deviation and Coefficient of Variation of Seasonal (≥2.5mm) Rainy day at Raipur (1971-2008)

Season	Minimum (mm)	Maximum (mm)	Mean (mm)	S.D. (mm)	C.V. (%)
SWM (June-sep.)	**35**	**61**	**48**	**6.4**	**13.3**
PM (Oct.-Dec)	**0**	**12**	**4**	**3.3**	**82.2**
Winter (Jan.-Feb)	**0**	**7**	**2.7**	**2**	**75.4**
Summer (Mar.-May)	**1**	**13**	**5**	**3.4**	**67.5**
Annual	**36**	**93**	**59.7**	**15.1**	**238.4**

4.2.2 Jagdalpur

The seasonal rainfall distribution and their statistical features over the study period (1980-2008) have been presented in Table 4.4. The south west monsoon rainfall coefficient of variation is 18.3 per cent with standard deviation of 201.8 mm. This indicates more stable rainfall during rainy season compared with other two regions. However rest of season received the mean annual rainfall of less than 70 mm with coefficient of variation of more than 70 per cent and standard deviation was less than 60.0 mm. The maximum seasonal rainfall received was 1531.6 mm and minimum seasonal rainfall was 610.2 mm during south west monsoon.

The numbers of rainy days also varied from 35 to 61 mm with mean of 48 mm, coefficient variation of 13.3 per cent and standard deviation of 6.4 mm during south west monsoon period. Rest of seasons received mean rainy days less than 6 with coefficient of variation was more than 65 per cent and standard deviation was less than 4 mm (Table 4.5).

Table 4.4: Minimum, Maximum, Mean, Standard Deviation and Coefficient of Variation of Seasonal Rainfall at Jagdalpur (1980-2008)

Season	Minimum (mm)	Maximum (mm)	Mean (mm)	S.D. (mm)	C.V. (%)
SWM (June-sep.)	**660.3**	**1470.7**	**1102.4**	**201.8**	**18.3**
PM (Oct.-Dec)	**0.0**	**405.4**	**114.9**	**95.4**	**83.1**
WM (Jan.-Feb)	**0.0**	**72.9**	**21.9**	**22.3**	**101.6**
SM (Mar.-May)	**38.2**	**434.6**	**144.5**	**75.3**	**52.2**
Annual	**698.5**	**2383.6**	**1383.7**	**394.8**	**255.2**

Table 4.5: Minimum, Maximum, Mean, Standard Deviation and Coefficient of Variation of Seasonal (≥2.5mm) Rainy day at Jagdalpur (1980-2008)

Season	Minimum (mm)	Maximum (mm)	Mean (mm)	S.D. (mm)	C.V. (%)
SWM (June-sep.)	**35**	**76**	**56**	**8.3**	**14.8**
PM (Oct.-Dec)	**0**	**15**	**6**	**3.8**	**62.7**
WM (Jan.-Feb)	**0**	**8**	**1.9**	**2.1**	**109.5**
SM (Mar.-May)	**5**	**17**	**10**	**3.9**	**38.7**
Annual	**40**	**116**	**73.9**	**18.1**	**225.7**

4.2.3 Ambikapur

The seasonal rainfall distribution and their statistical features over the study period (1991-2008) showed that (Table 4.6, 4.7) the seasonal ranged from 765.7 to 1983.1 mm, with a mean of 1259.9, coefficient variation of 26.3 per cent and standard deviation of 331.4 mm during south west monsoon. Annual seasonal rainfall was 1429.1 mm recorded. Rest of season received the mean annual rainfall was less than 85 mm with coefficient variation was more than 80 per cent and standard deviation was less than 70.0 mm.

The numbers of rainy days also varied from 43 to 69 mm with mean of 56 mm, coefficient variation of 12.3 per cent and standard deviation of 6.9 mm during south west monsoon. However rest of season received mean rainy days was less than 6mm with coefficient variation more than 70.0 per cent and standard deviation less than 5.0 mm.

Table 4.6: Minimum, Maximum, Mean, Standard Deviation and Coefficient of Variation of Seasonal Rainfall at Ambikapur (1991-2008)

Season	Minimum (mm)	Maximum (mm)	Mean (mm)	S.D. (mm)	C.V. (%)
SWM (June-sep.)	**765.7**	**1983.1**	**1259.9**	**331.4**	**26.3**
PM (Oct.-Dec)	**1.8**	**233.2**	**80.9**	**68.0**	**84.1**
WM (Jan.-Feb)	**0.0**	**156.0**	**40.0**	**41.1**	**102.6**
SM (Mar.-May)	**2.4**	**196.8**	**48.3**	**45.3**	**93.6**
Annual	**769.9**	**2569.1**	**1429.1**	**485.8**	**306.6**

Table 4.7: Minimum, maximum, mean, standard deviation and coefficient of variation of seasonal (≥2.5mm) rainy day at Ambikapur (1991-2008)

Season	Minimum (mm)	Maximum (mm)	Mean (mm)	S.D. (mm)	C.V. (%)
SWM (June-sep.)	**43**	**69**	**56**	**6.9**	**12.3**
PM (Oct.-Dec)	**0**	**19**	**5**	**4.8**	**95.1**
WM (Jan.-Feb)	**0**	**7**	**3.3**	**2.5**	**74.9**
SM (Mar.-May)	**0**	**11**	**4**	**3.8**	**95.5**
Annual	**43**	**106**	**68.3**	**18**	**277.8**

4.3 Monthly Rainfall and Rainy Days

4.3.1 Raipur

The monthly rainfall and rainy days data (1971-2008) have been presented in Table 4.8 and Fig. 4.5 Data showed that the highest mean monthly rainfall received in the month of August and July was 333.1 mm and 309.1 mm, respectively It is noted that during south west monsoon season is June, July, August and September received maximum monthly rainfall and standard deviation where as January, March, April, November and December have more than 100 per cent coefficient of variation.

Table 4.8: Minimum, Maximum, Mean, Standard Deviation and Coefficient of Variation of Monthly Rainfall at Raipur (1971-2008)

Month	Minimum (mm)	Maximum (mm)	Mean (mm)	S.D. (mm)	C.V. (%)
January	**0.0**	**104.4**	**14.2**	**22.0**	**155.4**
February	**0.0**	**39.4**	**13.7**	**11.9**	**86.4**
March	**0.0**	**51.2**	**14.5**	**15.4**	**106.4**
April	**0.0**	**64.0**	**14.3**	**15.2**	**106.7**
May	**0.0**	**87.4**	**24.0**	**23.4**	**97.7**
June	**44.7**	**713.4**	**193.8**	**141.7**	**73.1**
July	**71.8**	**550.6**	**309.1**	**125.5**	**40.6**
August	**141.5**	**553.4**	**333.1**	**113.4**	**34.1**
September	**25.6**	**605.6**	**184.4**	**117.2**	**63.5**
October	**0.0**	**154.2**	**48.1**	**45.7**	**95.1**
November	**0.0**	**112.2**	**12.9**	**23.9**	**186.1**
December	**0.0**	**72.6**	**4.9**	**12.7**	**260.0**

The maximum mean rainy days of 15.1 (appendix-V) were recorded during July and August. The lowest coefficient variation of 17.7 per cent was recorded under august followed by 25.9 per cent in the month of July. The maximum numbers of rainy days (22) were recorded during the month of July and August in the year of 1984 and 2003 respectively.

4.3.2 Jagdalpur

The monthly rainfall and rainy days data (1980-2008) have been presented in Table 4.9 and Fig. 4.6. Data showed that the highest mean monthly rainfall received in the month of August and July was 345.5 mm and 336.4 mm. respectively It is noted that during south west month is June, July, August and September have recorded maximum monthly rainfall and standard deviation as well but January, March, April and November and December have more than 100 per cent coefficient of variation.

Table 4.9: Minimum, Maximum, Mean, Standard Deviation and Coefficient of Variation of Monthly Rainfall at Jagdalpur (1980-2008)

Month	**Minimum (mm)**	**Maximum (mm)**	**Mean (mm)**	**S.D. (mm)**	**C.V. (%)**
January	**0.0**	**54.1**	**10.9**	**16.9**	**154.2**
February	**0.0**	**68.9**	**11.0**	**17.3**	**158.0**
March	**0.0**	**146.8**	**20.9**	**30.3**	**145.1**
April	**0.0**	**103.3**	**42.9**	**31.4**	**73.3**
May	**0.0**	**355.3**	**80.7**	**65.9**	**81.7**
June	**71.3**	**511.8**	**231.2**	**105.3**	**45.5**
July	**189.3**	**481.7**	**336.4**	**96.6**	**28.7**
August	**178.0**	**600.7**	**345.5**	**105.5**	**30.6**
September	**46.3**	**291.4**	**189.3**	**70.0**	**37.0**
October	**0.0**	**322.6**	**86.6**	**84.1**	**97.1**
November	**0.0**	**95.0**	**21.9**	**32.0**	**145.7**
December	**0.0**	**82.8**	**6.4**	**18.7**	**293.4**

The maximum mean rainy days of 17 (appendix-VI) were recorded during July and August. The lowest coefficient variation of 16.9 per cent was recorded under august followed by 21.5 per cent in the month of July. The maximum numbers of rainy days (22) were recorded during the month of July and August in the year of 2004, 1990, 1991 and 1996 respectively.

4.3.3 Ambikapur

The monthly rainfall and rainy days data (1991-2008) have been presented in Table 4.10 **and** Fig. 4.7**.**

Table 4.10: Minimum, Maximum, Mean, Standard Deviation and Coefficient of Variation of Monthly Rainfall at Ambikapur (1991-2008)

Month	Minimum (mm)	Maximum (mm)	Mean (mm)	S.D. (mm)	C.V. (%)
January	**0.0**	**125.0**	**22.6**	**31.9**	**141.0**
February	**0.0**	**52.3**	**17.4**	**17.4**	**100.1**
March	**0.0**	**133.8**	**21.6**	**33.1**	**153.5**
April	**0.0**	**37.6**	**10.4**	**12.1**	**117.0**
May	**0.0**	**65.3**	**16.4**	**17.0**	**103.7**
June	**58.4**	**758.0**	**226.9**	**178.1**	**78.5**
July	**180.5**	**867.9**	**400.2**	**161.5**	**40.4**
August	**122.2**	**675.4**	**379.2**	**122.9**	**32.4**
September	**88**	**512.4**	**253.7**	**141.9**	**55.9**
October	**1.8**	**119.0**	**54.2**	**40.2**	**74.1**
November	**0.0**	**118.2**	**14.1**	**33.3**	**235.7**
December	**0.0**	**90.8**	**12.6**	**24.4**	**194.1**

Data showed that the highest mean monthly rainfall received in the month of July and August was 400.2 mm and 379.2 mm. It is noted that during south west months June, July, August and September have received maximum monthly rainfall and standard deviation as well. Rainfall during January, March, April and November and December have more than 100 per cent coefficient of variation. The maximum mean rainy days of 17 and 16 (appendix-VII) were recorded during July and August. The lowest coefficient variation of 19.3 per cent was recorded under July followed by 25.3 per cent in the month of August. The maximum numbers of rainy days (25) were recorded during the month of July in the year of 2001 respectively.

4.4 Weekly Rainfall and Rainy Days

4.4.1 Raipur

Mean weekly rainfall received during the year 1971-2008 and statistical features have been given in Table 4.11. The highest mean weekly rainfall of 93mm was recorded during standard meteorological week (SMW) 33 followed by 79.9mm in SMW 31 and 77.7 mm in SMW 32. The coefficient variation of rainfall SMW 28-29 and SMW 34 were only less than 75 per cent. The standard deviation of SMW 33 was 73.6 mm which was very high as comparison to other SMW.

Table: 4.11. Minimum, Maximum, Mean, Standard Deviation and Coefficient of Variation, weekly rainfall (mm) features at Raipur (1971-2008)

SWM	Period	Minimum (mm)	Maximum (mm)	Mean (mm)	S.D.(mm)	C.V. (%)
1	Jan 01-07	0	61	2.6	6.3	241.4
2	08-14	0	45.7	3.4	8.7	257.6
3	15-21	0	35.2	2.1	6.2	289.7
4	22-28	0	21	3.2	5.8	181.4
5	29-04	0	121.6	5.5	20.7	377.3
6	Feb 05-11	0	25.5	4.5	7	156
7	12-18	0	28	4.6	8.2	176.5
8	19-25	0	23.6	1.5	4.6	306.8
9	26-04	0	37.2	3.5	7.9	227.5
10	Mar 05-11	0	37	4.3	9.1	213.9
11	12-18	0	19.4	3	5.5	183.1
12	19-25	0	30.4	2	6.3	312.8
13	26-01	0	29.4	2.6	6.3	239.3
14	Apr 02-08	0	61.6	4.4	11	249
15	09-15	0	12.6	1.5	3.3	214.5
16	16-22	0	46.6	3.9	10	254.3
17	23-29	0	31.8	3.4	7	207.1
18	30-06	0	31.3	5.1	8.3	163.4
19	May 07-13	0	26.2	3.8	7.2	186.6
20	14-20	0	61.4	7.6	15.2	200.5
21	21-27	0	64.8	4.2	11.2	267.6
22	28-03	0	46.8	7.1	12.2	171.3
23	Jun 04-10	0	174.5	16.9	30.8	182.5
24	11-17	0	277.2	46.3	63.8	137.9
25	18-24	0	322.9	61.1	61.9	101.3
26	25-01	4.2	557.2	76.9	94.8	123.2
27	Jul 02-08	0	231.4	66.9	61.3	91.6
28	09-15	4.8	224.4	76.6	54.8	71.4
29	16-22	10.2	184.2	66.8	43.1	64.5
30	23-29	0	256.4	69.1	59.9	86.7
31	30-05	4.2	284.2	79.9	66.9	83.7
32	Aug 06-12	7	240.1	77.7	59.2	76.3
33	13-19	4.6	303.8	93	73.6	79.2
34	20-26	0	147.6	51.8	37.8	72.9
35	27-02	0.8	262.8	67.3	58.3	86.6
36	Sep 03-09	0	129.6	49.3	37.6	76.4
37	10-16	1.6	359	58.4	76.7	131.2
38	17-23	0	238.8	32.9	52.8	160.4
39	24-30	0	77.4	26.8	26	96.9
40	Oct 01-07	0	89	16.3	21.5	132
41	08-14	0	54	10	15.9	159.2
42	15-21	0	121.8	10.2	23.9	234.4
43	22-28	0	83.2	9.8	19.6	199.9
44	29-04	0	36.2	3.9	7.8	199.6
45	Nov 05-11	0	98.8	4.3	17.6	406.1
46	12-18	0	15.4	0.7	3	426.8
47	19-25	0	35.4	3.5	9.7	276.5
48	26-02	0	54.4	2.8	10.2	360.7
49	Dec 03-09	0	15.8	0.6	2.7	476.1
50	10-16	0	29	1.7	5.5	321.8
51	17-23	0	12.6	0.4	2.1	507.9
52	24-31	0	13	1.5	3.8	255.6
Total		0.72	149.60	31.50	117.9	374.37

Table: 4.12. Minimum, Maximum, Mean, Standard Deviation and Coefficient of Variation, weekly rainfall (mm) features Mean weekly rainfall (mm) features at Jagdalpur (1980-2008)

SWM	Period	Minimum (mm)	Maximum (mm)	Mean (mm)	S.D. (mm)	C.V. (%)
1	Jan 01-07	0	38.2	2.9	1.7	56.9
2	08-14	0	49.5	3.6	10.7	292.5
3	15-21	0	32.7	2	6.6	337.9
4	22-28	0	32.8	1.8	6.7	370.1
5	29-04	0	23.4	2.3	6.1	265.1
6	Feb 05-11	0	32	2.3	7.4	314.1
7	12-18	0	28	4.1	7.5	181.7
8	19-25	0	39.9	2.5	9.4	370.6
9	26-04	0	25.8	2	5.6	279.8
10	Mar 05-11	0	44.5	4.3	9.8	228.7
11	12-18	0	32	4	8	197.3
12	19-25	0	105.4	5.4	19.7	367.6
13	26-01	0	47.8	5.6	12.2	217.4
14	Apr 02-08	0	63.9	8.8	15.9	180.2
15	09-15	0	41.4	8	11.2	139.2
16	16-22	0	63.1	13.1	16.8	128.2
17	23-29	0	78	10.5	16.8	160.6
18	30-06	0	82.4	16	21.2	132.1
19	May 07-13	0	142.3	12.2	27.9	228.2
20	14-20	0	80.2	18.7	23.1	123
21	21-27	0	99.5	15	22.2	147.6
22	28-03	0	94.5	29	29.3	100.8
23	Jun 04-10	0	167.6	34.7	41	117.9
24	11-17	0	249.8	59.5	58	97.6
25	18-24	0.6	158.7	60.3	41.6	69
26	25-01	1.2	284.7	74.7	70.8	94.9
27	Jul 02-08	0	225	66.1	54.9	83.1
28	09-15	10.4	167.9	70.2	42	59.9
29	16-22	10.4	254	93.1	70.6	75.8
30	23-29	6.1	340.4	83.5	62.7	75.1
31	30-05	14.3	240.8	78.4	50	63.7
32	Aug 06-12	5.9	197.4	92	57	61.9
33	13-19	10.3	204	69.7	49	70.3
34	20-26	8.8	180.3	66.8	46.1	68.9
35	27-02	0	179.4	70.1	49.3	70.3
36	Sep 03-09	3.4	159.4	58.2	38.6	66.4
37	10-16	0.6	167.4	46.9	35.2	75
38	17-23	0	167.5	41.1	40.1	97.7
39	24-30	0	123.6	29	34.7	119.6
40	Oct 01-07	0	198.2	35.4	47.8	135.2
41	08-14	0	131.7	22.2	34.1	153.8
42	15-21	0	57.8	12	14.7	122.9
43	22-28	0	115	12.5	26.4	211.4
44	29-04	0	104.9	13.8	25.3	183.4
45	Nov 05-11	0	49	4.5	11.4	251.4
46	12-18	0	53.8	5.9	14.5	244.6
47	19-25	0	31.7	2.3	6.6	291.8
48	26-02	0	3.2	0.2	0.7	384.5
49	Dec 03-09	0	40.4	1.4	7.5	537.1
50	10-16	0	44.8	2.3	8.6	374
51	17-23	0	24.4	1.2	4.7	393.3
52	24-31	0	13.6	1.4	3.6	259.5
Total		1.38	146.14	35.86	118.5	330.57

Table: 4.13. Minimum, Maximum, Mean, Standard Deviation and Coefficient of Variation, weekly rainfall (mm) features Mean weekly rainfall (mm) features at Ambikapur (1991-2008)

SWM	Period	Minimum (mm)	Maximum (mm)	Mean (mm)	S.D.(mm)	C.V.(%)
1	Jan 01-07	0	4.8	0.7	0.8	4.5
2	08-14	0	46.6	4.3	12.9	297.1
3	15-21	0	36.5	5.3	11.6	218.4
4	22-28	0	71.6	6.4	17.1	264.8
5	29-04	0	71.8	6.5	17.1	262.5
6	Feb 05-11	0	27.2	6.4	9.1	140.8
7	12-18	0	19.8	2.9	6	205.8
8	19-25	0	24.8	2.6	6.8	262.3
9	26-04	0	43.4	4.5	10.5	233.1
10	Mar 05-11	0	53.6	6.9	15.2	222.1
11	12-18	0	87.2	8.1	21.2	262.8
12	19-25	0	13.4	2	4.6	233
13	26-01	0	46.2	3.4	10.8	320.3
14	Apr 02-08	0	30.8	3.2	8.4	261.3
15	09-15	0	11	2.2	2.9	131.6
16	16-22	0	19.8	3.3	7.4	223.5
17	23-29	0	8.9	1.3	2.9	232.5
18	30-06	0	27.8	4.1	8.7	210.2
19	May 07-13	0	27	4.4	8.6	197
20	14-20	0	31.8	3.2	7.5	236
21	21-27	0	11.4	3.2	4.3	133.6
22	28-03	0	12	2.5	3.7	151.3
23	Jun 04-10	0	92.2	14.8	23.6	158.6
24	11-17	0	201.6	50.5	60.4	119.6
25	18-24	1.3	285.2	76.9	77.8	101.3
26	25-01	0	312.8	96.3	88.9	92.4
27	Jul 02-08	0	148.6	56.7	41.8	73.6
28	09-15	5.6	392.4	92	94.9	103.2
29	16-22	10.8	202.2	98.8	61.9	62.7
30	23-29	3.4	441.2	116.3	100.8	86.7
31	30-05	12.6	189.5	90.8	54.1	59.6
32	Aug 06-12	1.2	265.2	99.2	68.9	69.4
33	13-19	19.6	287.5	86.3	66.1	76.6
34	20-26	21.3	245.8	76.2	67.1	88
35	27-02	3.8	273.1	78.7	70.2	89.2
36	Sep 03-09	15.2	256.2	100.2	74.1	74
37	10-16	0	143.1	47.7	42.7	89.5
38	17-23	0	190.3	54.1	56	103.6
39	24-30	0	99.3	23.6	30.7	130.1
40	Oct 01-07	0	85.2	19.8	23.9	120.8
41	08-14	0	70	14.7	23.4	158.4
42	15-21	0	47.2	6.4	13	205
43	22-28	0	92.3	11.2	29.6	264.4
44	29-04	0	55.8	5.7	14.2	246.9
45	Nov 05-11	0	28.2	1.7	6.6	380.9
46	12-18	0	61.6	4.8	15.2	314.1
47	19-25	0	28.2	2.1	6.6	316
48	26-02	0	44	2.4	10.4	424.3
49	Dec 03-09	0	6	0.3	1.4	424.3
50	10-16	0	36.8	2	8.7	424.3
51	17-23	0	12.8	0.8	3	377.3
52	24-31	0	36.8	8.1	13.7	168.3
Total		1.82	141.60	36.01	118.0	327.72

4.4.2 Jagdalpur

Mean weekly rainfall received during the year 1980-2008 and statistical features have been given in Table 4.12. The highest mean weekly rainfall of 93.1mm was recorded during standard meteorological week (SMW) 29 followed by 83.5mm in SMW 30 and 78.4 mm in SMW 31. The coefficient variation of SMW 28-31 and SMW 32 were only less than 65 per cent. The standard deviation of SMW 29 was 70.6 mm which was very high as comparison to other SMW.

4.4.3 Ambikapur

Mean weekly rainfall received during the year 1991-2008 and statistical features have been given in Table 4.13. The highest mean weekly rainfall of 116.3mm was recorded during standard meteorological week (SMW) 30 followed by 100.2 mm in SMW 36 and 99.2 mm in SMW 32. The coefficient variation of SMW 27-29 and SMW 36 were only less than 75 per cent. The standard deviation of SMW 30 was 100.8 mm which was very high as comparison to other SMW.

4.5 Rainfall Probabilities

4.5.1 Raipur

Expected amount of weekly rainfall at different probability level are presented in Table 4.14 and Fig. 4.8 which showed that the 38 mm and 36.3 mm of rainfall is expected during SMW 33 and 32 at 75 per cent probability level. Further, data showed that at 50 per cent probability level the chances of getting rainfall more than 10mm during SMW 23 to 41.

4.5.2 Jagdalpur

Expected amount of weekly rainfall at different probability level are presented in Table 4.15 and Fig. 4.9. Which showed that the 47.6 mm and 46.2 mm of rainfall is expected during SMW 32 and 31 at 75 per cent probability level. Further, data show that at 50 per cent probability level the chances of getting rainfall more than 10mm during SMW 17 to 42.

Table: 4.14- Expected weekly rainfall (mm) at different probability level at Raipur (1971-2008)

WEEK NO.	PRECIPITATION (mm) FOR DIFFERENT PROBABILITIES					MEAN
	90	75	50	25	10	
1	0.2	0.6	1.9	4.4	8.1	**2.2**
2	0.2	0.8	2.6	6.1	11.1	**3.4**
3	0.3	0.8	2.1	4.3	7.3	**2.1**
4	0.2	0.9	2.9	7	13	**4.1**
5	0.1	0.7	2.7	7.4	14.7	**4.5**
6	0	0.7	4.5	10.3	14.6	**4.5**
7	0	0.1	4.6	11.2	16.2	**4.6**
8	0	0	1.5	5.6	8.5	**1.5**
9	0.3	1	2.8	6.2	10.9	**3.5**
10	0.2	1	3	7.2	13.3	**4.3**
11	0.3	0.9	2.6	5.5	9.6	**3**
12	0.2	0.8	2	4.2	7.2	**2**
13	0.3	0.9	2.3	5	8.7	**2.6**
14	0.3	1	3.2	7.4	13.5	**4.4**
15	0.4	0.9	1.9	3.5	5.6	**1.5**
16	0.3	1	2.9	6.8	12.2	**3.9**
17	0.3	0.9	2.7	6	10.7	**3.4**
18	0.4	1.3	3.8	8.4	14.9	**5.1**
19	0.3	1.1	3.1	6.7	11.7	**3.8**
20	0.3	1.3	4.6	11.7	22.1	**7.6**
21	0.3	1.1	3.2	7.2	12.7	**4.2**
22	0.4	1.5	4.8	11.2	20.4	**7.1**
23	0.6	2.8	9.7	24.4	46.1	**16.9**
24	2.4	9	27.8	65	118.2	**46.3**
25	7.6	19.4	44.4	86	140.1	**61.1**
26	10.3	25.4	56.7	107.8	173.6	**76.9**
27	10.2	23.8	50.8	93.7	148.1	**66.9**
28	18.4	35	63.7	105.3	155.2	**76.6**
29	21.4	35.9	58.8	90	125.9	**66.8**
30	8.8	22.2	50.4	97.1	157.7	**69.1**
31	17.1	34.2	64.8	110.4	165.8	**79.9**
32	19.4	36.3	65.1	106.4	155.7	**77.7**
33	18.3	38	74.1	128.7	195.9	**93**
34	9.8	20.8	41.3	72.4	111	**51.8**
35	9.8	23.3	50.6	94.3	150.2	**67.3**
36	7.4	17.4	37.4	69.4	110.3	**49.3**
37	6.9	18	42	82.4	135.1	**58.4**
38	0.7	3.9	16.3	45.3	90.7	**32.9**
39	1.8	6.2	17.4	38.4	67.6	**26.8**
40	0.8	3.2	10	23.7	43.4	**16.3**
41	0.3	1.4	5.5	14.8	29	**10**
42	0.1	1	4.9	14.7	30.6	**10.2**
43	0.2	1.1	4.9	14.3	29.1	**9.8**
44	0.3	1	3	6.8	12.1	**3.9**
45	0.1	0.6	2.5	7.1	14.4	**4.3**
46	0.3	0.7	1.3	2.3	3.6	**0.7**
47	0.1	0.7	2.4	6.1	11.7	**3.5**
48	0.1	0.6	2.1	5.2	9.8	**2.8**
49	0.4	0.7	1.3	2.1	3.2	**0.6**
50	0.2	0.7	1.8	3.8	6.4	**1.7**
51	0.4	0.7	1.2	1.9	2.6	**0.4**
52	0.3	0.8	1.8	3.6	6	**1.6**
ANNUAL	838.2	976.4	1147.3	1337	1524.5	1167

Table: 4.15. Expected weekly rainfall (mm) at different probability level at Jagdalpur (1980-2008)

WEEK NO.	PRECIPITATION (mm) FOR DIFFERENT PROBABILITIES					MEAN
	90	75	50	25	10	
1	0.2	0.7	2.3	5.3	9.6	**2.8**
2	0.2	0.7	2.7	7	13.4	**4.2**
3	0.2	0.7	1.7	3.4	5.7	**1.5**
4	0.2	0.6	1.8	3.9	6.8	**1.8**
5	0.2	0.7	2	4.5	8.1	**2.3**
6	0	0	2.3	8.4	12.9	**2.3**
7	0	0	4.1	10.2	14.8	**4.1**
8	0	0	2.5	9.9	15.6	**2.5**
9	0.2	0.7	2	4.2	7.2	**2**
10	0.2	1	3	7.3	13.3	**4.3**
11	0.3	1.1	3.1	7	12.3	**4**
12	0.1	0.7	3	8.5	17.1	**5.4**
13	0.2	1	3.6	9	17	**5.6**
14	0.3	1.4	5.1	13.3	25.7	**8.8**
15	0.5	1.9	5.5	12.5	22.3	**8**
16	0.7	2.7	8.3	19.4	35.2	**13.1**
17	0.5	2	6.5	15.7	29.1	**10.5**
18	1	3.6	10.4	23.5	41.8	**16**
19	0.3	1.7	6.7	17.8	34.8	**12.2**
20	0.6	2.9	10.4	26.8	51.2	**18.7**
21	0.7	2.9	9.3	22	40.4	**15**
22	2.4	7.5	19.7	41.6	71.5	**29**
23	2.3	7.8	22.2	49.4	87.3	**34.7**
24	6.2	17.2	41.7	83.8	139.6	**59.5**
25	12.7	25.7	49	83.7	126.2	**60.3**
26	11.2	26.3	56.4	104.5	165.7	**74.7**
27	11.3	25	51.4	92.4	143.9	**66.1**
28	22.4	37.6	61.7	94.5	132.4	**70.2**
29	21.3	41.4	76.5	127.9	189.9	**93.1**
30	24.3	42.5	72	113.1	161.1	**83.5**
31	29.8	46.2	71	103.5	139.9	**78.4**
32	27.7	47.6	79.8	124.2	175.8	**92**
33	22.7	37.7	61.5	93.7	130.7	**69.7**
34	18.3	32.9	57.1	91.2	131.4	**66.8**
35	8.1	21.4	50.1	98.5	161.9	**70.1**
36	16.4	29.1	50.1	79.4	113.9	**58.2**
37	8.9	18.9	37.4	65.8	100.8	**46.9**
38	3.8	11.1	28.2	58.4	98.9	**41.1**
39	1.8	6.4	18.4	41.5	73.7	**29**
40	1.2	5.5	19.6	49.5	93.9	**35.4**
41	0.5	2.9	11.5	31.1	61.2	**22.2**
42	0.6	2.3	7.4	17.8	32.8	**12**
43	0.2	1.4	6.2	17.8	36.4	**12.5**
44	0.3	1.6	6.9	19.7	39.7	**13.8**
45	0.2	0.8	2.9	7.5	14.4	**4.5**
46	0.2	0.9	3.4	9.3	18.4	**5.9**
47	0.2	0.7	2.1	4.5	7.9	**2.3**
48	0.6	0.8	1.1	1.4	1.8	**0.2**
49	0.2	0.5	1.5	3.3	5.8	**1.4**
50	0.2	0.6	2	4.5	8.2	**2.3**
51	0.3	0.7	1.5	3	5	**1.2**
52	0.3	0.8	1.8	3.4	5.4	**1.4**
ANNUAL	1066.4	1203.3	1368.7	1548.8	1723.6	1383.7

Table: 4.16. Expected weekly rainfall (mm) at different probability level at Ambikapur (1991-2008)

WEEK NO.	PRECIPITATION (mm) FOR DIFFERENT PROBABILITIES					MEAN
	90	75	50	25	10	
1	0.2	0.7	2.1	4.9	8.7	**2.5**
2	0.1	0.6	2.5	7.1	14.3	**4.3**
3	0.2	1	3.7	9.4	18	**5.9**
4	0.1	0.8	3.3	9.1	18.3	**5.8**
5	0.2	1	3.7	10.1	19.8	**6.5**
6	0	1.3	6.4	13.6	19.1	**6.4**
7	0	0	2.9	8	11.7	**2.9**
8	0	0	2.6	8.2	12.4	**2.6**
9	0.3	1	3.2	7.6	13.9	**4.5**
10	0.1	0.9	3.7	10.5	21	**6.9**
11	0.1	0.8	3.9	11.8	24.9	**8.1**
12	0.3	0.8	2	4.1	7	**2**
13	0.2	0.8	2.5	6	11.1	**3.4**
14	0.2	0.8	2.5	5.8	10.6	**3.2**
15	0.7	1.4	2.6	4.4	6.7	**2.2**
16	0.2	0.8	2.5	5.9	10.8	**3.3**
17	0.3	0.8	1.7	3.1	4.9	**1.3**
18	0.3	1.1	3.1	7.1	12.7	**4.1**
19	0.2	1	3.1	7.3	13.5	**4.4**
20	0.3	1	2.7	5.8	9.9	**3.2**
21	0.5	1.3	3	5.8	9.6	**3.2**
22	0.5	1.2	2.5	4.8	7.6	**2.5**
23	0.6	2.5	8.7	21.6	40.6	**14.8**
24	2.9	10.6	31.2	71	127.2	**50.5**
25	9.5	24.3	55.7	107.8	175.6	**76.9**
26	9.4	26.6	66.1	134.9	226.6	**96.3**
27	10.1	22	44.6	79.4	122.8	**56.7**
28	12.8	31	68.2	128.5	205.9	**92**
29	24.4	45.8	82.4	135.1	198	**98.8**
30	22.8	47.4	92.5	160.6	244.4	**116.3**
31	28.5	48.1	79.3	122	171.3	**90.8**
32	15.9	36.1	75.7	138.2	217	**99.2**
33	27.2	45.9	75.5	116.1	162.9	**86.3**
34	19.8	36.4	64.4	104.3	151.6	**76.2**
35	14.2	30.7	61.8	109.5	168.8	**78.7**
36	25.4	47.1	84	136.8	199.6	**100.2**
37	3.8	11.8	31.6	67.5	116.5	**47.7**
38	4.9	14.5	36.9	76.3	129.4	**54.1**
39	0.8	3.8	13.3	33.5	63.5	**23.6**
40	1.2	4.2	12.5	28.6	51.3	**19.8**
41	0.4	2.2	8.1	21.3	41.2	**14.7**
42	0.3	1.2	4	10	18.9	**6.4**
43	0.1	0.7	4.5	15.4	34.4	**11.2**
44	0.2	0.9	3.4	9.1	17.7	**5.7**
45	0.2	0.6	1.7	3.8	6.6	**1.7**
46	0.1	0.6	2.7	7.7	15.7	**4.8**
47	0.2	0.7	2	4.3	7.4	**2.1**
48	0.1	0.5	1.9	4.7	8.9	**2.4**
49	0.5	0.8	1.2	1.7	2.4	**0.3**
50	0.1	0.5	1.7	4.2	7.7	**2**
51	0.3	0.7	1.4	2.5	3.8	**0.8**
52	0.2	1	4.5	13	26.5	**8.8**
ANNUAL	998.3	1177.6	1401	1651	1899.7	1429.2

4.5.3 Ambikapur

Expected amount of weekly rainfall at different probability level are presented in Table 4.16 and Fig. 4.10. Which showed that the 48.1 mm, 47.4 mm and 47.1 mm of rainfall is expected during SMW 31, 30 and 36 at 75 per cent probability level? Further, data show that at 50 per cent probability level the chances of getting rainfall more than 10mm during SMW 23 to 41

4.6 Initial and Conditional Probabilities of Rainfall

4.6.1 Raipur

The normal onset of monsoon is in MW 23 presented in Table 4.17 and Fig. 4.11 to 4.14. However, sufficient rains for sowing are received in MW 24 to 26. The probabilities of recording higher rains are less and a weakened activity in MW 27 is ideal for sowing the kharif crops. Once the crops are sown, the sufficient quantum of rainfall to meet the evapotranspirative demand, are received. The weakened activities of monsoon in MW 35, 37 and 38 are likely to pose moisture stress of varying degrees and this period coincides with the critical reproductive growth stages of major crops grown in this zone. Hence, it is advised to provide supplemental irrigation for the crop yield stability in this zone. However, considering higher probabilities of rainfall in Raipur agro climatic zone, the proper drainage may be adopted according to soil depth. The probability analysis pertaining to weekly rainfall indicated that the probability of 25 mm rainfall per week was found to be higher in MW 24. But, thereafter throughout the crop season the fluctuations are higher. This situation further worsens for higher depth of rainfall and therefore, the crop production in this zone is some what risky if irrigation is not provided.

4.6.2 Jagdalpur

The onset of monsoon in Jagdalpur region is noticed in MW 23 and good quantum of rainfall with higher depth (50 mm/week) is also higher in MW 24. Table 4.18 and Fig. 4.15 to 4.18. This indicates that ideal sowing time for crops is MW 24 or latest by MW 25. The withdrawal of monsoon is MW 40 to 41 in this zone.

However, continuous rainfall of higher depth may cause waterlogged condition interfering the intercultural operations. However, if excess rain water is drained which help in maintaining better soil conditions and drained water can be utilized for supplemental irrigation to crops during moisture stress period.

Table: 4.17 Initial and conditional probabilities of rainfall at Raipur

Std.	10MM			20MM			30MM			40MM			Mean
WEEK	P(W)	P(W/W)	P(W/D)	P(W)	P(W/W)	P(W/D)	P(W)	P(W/W)	P(W/D)	P(W)	P(W/W)	P(W/D)	(mm)
22	0.18	0.00	0.20	0.13	0.00	0.14	0.08	0.00	0.08	0.05	0.00	0.05	7.1
23	0.37	0.71	0.29	0.26	0.60	0.21	0.24	1.00	0.17	0.13	1.00	0.08	16.9
24	0.68	0.64	0.71	0.53	0.60	0.50	0.42	0.44	0.41	0.32	0.60	0.27	46.3
25	0.87	0.85	0.92	0.74	0.60	0.89	0.63	0.50	0.73	0.50	0.42	0.54	61.1
26	0.92	0.91	1.00	0.71	0.68	0.80	0.66	0.58	0.79	0.58	0.58	0.58	76.9
27	0.89	0.91	0.67	0.79	0.81	0.73	0.71	0.68	0.77	0.66	0.73	0.56	66.9
28	0.92	0.94	0.75	0.82	0.80	0.88	0.79	0.81	0.73	0.74	0.84	0.54	76.6
29	1.00	1.00	1.00	0.89	0.90	0.86	0.76	0.77	0.75	0.68	0.64	0.80	66.8
30	0.87	0.87	0.00	0.76	0.76	0.75	0.71	0.69	0.78	0.58	0.62	0.50	69.1
31	0.92	0.91	1.00	0.87	0.83	1.00	0.84	0.81	0.91	0.66	0.68	0.63	79.9
32	0.97	0.97	1.00	0.89	0.91	0.80	0.76	0.78	0.67	0.71	0.80	0.54	77.7
33	0.92	0.92	1.00	0.89	0.88	1.00	0.74	0.76	0.67	0.74	0.74	0.73	93.0
34	0.89	0.91	0.67	0.79	0.79	0.75	0.63	0.68	0.50	0.53	0.54	0.50	51.8
35	0.89	0.88	1.00	0.79	0.77	0.88	0.71	0.71	0.71	0.66	0.65	0.67	67.3
36	0.84	0.85	0.75	0.76	0.80	0.63	0.61	0.67	0.45	0.53	0.56	0.46	49.3
37	0.95	0.97	0.83	0.71	0.79	0.44	0.47	0.43	0.53	0.37	0.25	0.50	58.4
38	0.50	0.50	0.50	0.42	0.41	0.45	0.26	0.22	0.30	0.26	0.21	0.29	32.9
39	0.61	0.63	0.58	0.45	0.50	0.41	0.42	0.60	0.36	0.34	0.50	0.29	26.8
40	0.42	0.43	0.40	0.29	0.29	0.29	0.21	0.19	0.23	0.16	0.15	0.16	16.3
41	0.32	0.38	0.27	0.24	0.36	0.19	0.16	0.25	0.13	0.08	0.17	0.06	10.0
42	0.21	0.25	0.19	0.21	0.22	0.21	0.11	0.17	0.09	0.11	0.33	0.09	10.2
43	0.18	0.00	0.23	0.18	0.00	0.23	0.18	0.00	0.21	0.13	0.00	0.15	9.8
44	0.13	0.14	0.13	0.05	0.00	0.06	0.03	0.00	0.03	0.00	0.00	0.00	3.9
45	0.05	0.20	0.03	0.05	0.00	0.06	0.05	0.00	0.05	0.05	0.00	0.05	4.3
46	0.05	0.50	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.7
47	0.11	0.50	0.08	0.11	0.00	0.11	0.05	0.00	0.05	0.00	0.00	0.00	3.5
48	0.08	0.00	0.09	0.05	0.00	0.06	0.05	0.00	0.06	0.03	0.00	0.03	2.8
49	0.03	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.6
50	0.05	1.00	0.03	0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	1.7
51	0.03	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.4
52	0.11	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.5

Table: 4.18- Initial and conditional probabilities of rainfall at Jagdalpur

Std.	10MM			20MM			30MM			40MM			Mean
WEEK	**P(W)**	**P(W/W)**	**P(W/D)**	**P(W)**	**P(W/W)**	**P(W/D)**	**P(W)**	**P(W/W)**	**P(W/D)**	**P(W)**	**P(W/W)**	**P(W/D)**	**(mm)**
22	0.69	0.73	0.67	0.45	0.25	0.52	0.38	0.20	0.42	0.24	0.00	0.28	29.00
23	0.62	0.70	0.44	0.48	0.46	0.50	0.41	0.36	0.44	0.31	0.29	0.32	34.70
24	0.86	0.89	0.82	0.69	0.57	0.80	0.59	0.58	0.59	0.52	0.78	0.40	59.50
25	0.93	0.92	1.00	0.79	0.70	1.00	0.72	0.53	1.00	0.69	0.40	1.00	60.30
26	0.93	0.93	1.00	0.86	0.83	1.00	0.72	0.67	0.88	0.48	0.45	0.56	74.70
27	0.90	0.93	0.50	0.86	0.88	0.75	0.72	0.71	0.75	0.59	0.71	0.47	66.10
28	1.00	1.00	1.00	0.86	0.88	0.75	0.79	0.76	0.88	0.76	0.71	0.83	70.20
29	1.00	1.00	0.00	0.93	0.92	1.00	0.79	0.87	0.50	0.69	0.77	0.43	93.10
30	0.93	0.93	0.00	0.93	0.93	1.00	0.90	0.87	1.00	0.83	0.75	1.00	83.50
31	1.00	1.00	1.00	0.97	0.96	1.00	0.90	0.92	0.67	0.79	0.79	0.80	78.40
32	0.97	0.97	0.00	0.97	0.96	1.00	0.90	0.88	1.00	0.76	0.74	0.83	92.00
33	1.00	1.00	1.00	0.90	0.93	0.00	0.90	0.92	0.67	0.76	0.73	0.86	69.70
34	0.93	0.93	0.00	0.79	0.81	0.67	0.76	0.77	0.67	0.69	0.68	0.71	66.80
35	0.86	0.89	0.50	0.83	0.83	0.83	0.79	0.77	0.86	0.66	0.55	0.89	70.10
36	0.93	0.92	1.00	0.83	0.83	0.80	0.76	0.74	0.83	0.66	0.58	0.80	58.20
37	0.86	0.89	0.50	0.83	0.88	0.60	0.66	0.68	0.57	0.55	0.58	0.50	46.90
38	0.76	0.76	0.75	0.62	0.67	0.40	0.48	0.53	0.40	0.34	0.31	0.38	41.10
39	0.69	0.73	0.57	0.38	0.44	0.27	0.28	0.43	0.13	0.24	0.30	0.21	29.00
40	0.55	0.65	0.33	0.48	0.55	0.44	0.38	0.38	0.38	0.31	0.43	0.27	35.40
41	0.48	0.44	0.54	0.38	0.50	0.27	0.24	0.36	0.17	0.14	0.33	0.05	22.20
42	0.52	0.64	0.40	0.24	0.27	0.22	0.10	0.14	0.09	0.03	0.25	0.00	12.00
43	0.21	0.27	0.14	0.17	0.00	0.23	0.14	0.00	0.15	0.14	0.00	0.14	12.50
44	0.31	0.33	0.30	0.21	0.20	0.21	0.14	0.25	0.12	0.14	0.25	0.12	13.80
45	0.14	0.33	0.05	0.10	0.17	0.09	0.07	0.25	0.04	0.03	0.25	0.00	4.50
46	0.17	0.25	0.16	0.10	0.33	0.08	0.10	0.50	0.07	0.07	0.00	0.07	5.90
47	0.10	0.40	0.04	0.03	0.00	0.04	0.03	0.00	0.04	0.00	0.00	0.00	2.30
48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20
49	0.03	0.00	0.03	0.03	0.00	0.03	0.03	0.00	0.03	0.03	0.00	0.03	1.40
50	0.07	1.00	0.04	0.03	0.00	0.04	0.03	0.00	0.04	0.03	0.00	0.04	2.30
51	0.03	0.50	0.00	0.03	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20
52	0.07	1.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.40

Table: 4.19- Initial and conditional probabilities of rainfall at Ambikapur

Std.	10MM			20MM			30MM			40MM			Mean
WEEK	P(W)	P(W/W)	P(W/D)	P(W)	P(W/W)	P(W/D)	P(W)	P(W/W)	P(W/D)	P(W)	P(W/W)	P(W/D)	(mm)
22	0.06	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.5
23	0.33	0.00	0.35	0.28	0.00	0.28	0.17	0.00	0.17	0.11	0.00	0.11	14.8
24	0.72	0.83	0.67	0.61	0.80	0.54	0.56	1.00	0.47	0.39	0.00	0.44	50.5
25	0.83	0.92	0.60	0.83	1.00	0.57	0.61	0.80	0.38	0.56	0.71	0.45	76.9
26	0.89	0.87	1.00	0.83	0.80	1.00	0.67	0.73	0.57	0.67	0.80	0.50	96.3
27	0.94	0.94	1.00	0.78	0.80	0.67	0.61	0.67	0.50	0.61	0.67	0.50	56.7
28	0.94	0.94	1.00	0.78	0.71	1.00	0.72	0.64	0.86	0.67	0.64	0.71	92.0
29	1.00	1.00	1.00	0.94	0.93	1.00	0.72	0.62	1.00	0.72	0.58	1.00	98.8
30	0.94	0.94	0.00	0.89	0.88	1.00	0.89	0.85	1.00	0.89	0.85	1.00	116.3
31	1.00	1.00	1.00	0.89	0.88	1.00	0.83	0.81	1.00	0.83	0.81	1.00	90.8
32	0.89	0.89	0.00	0.89	0.88	1.00	0.83	0.87	0.67	0.83	0.87	0.67	99.2
33	1.00	1.00	1.00	0.94	0.94	1.00	0.89	0.87	1.00	0.78	0.73	1.00	86.3
34	1.00	1.00	0.00	1.00	1.00	1.00	0.83	0.81	1.00	0.56	0.57	0.50	76.2
35	0.94	0.94	0.00	0.89	0.89	0.00	0.72	0.73	0.67	0.61	0.50	0.75	78.7
36	1.00	1.00	1.00	0.89	0.88	1.00	0.83	0.85	0.80	0.78	0.91	0.57	100.2
37	0.72	0.72	0.00	0.67	0.69	0.50	0.50	0.53	0.33	0.44	0.43	0.50	47.7
38	0.78	0.77	0.80	0.67	0.58	0.83	0.61	0.56	0.67	0.50	0.38	0.60	54.1
39	0.50	0.57	0.25	0.44	0.42	0.50	0.17	0.09	0.29	0.17	0.00	0.33	23.6
40	0.50	0.67	0.33	0.39	0.63	0.20	0.22	0.33	0.20	0.11	0.33	0.07	19.8
41	0.39	0.44	0.33	0.17	0.29	0.09	0.17	0.25	0.14	0.17	0.00	0.19	14.7
42	0.17	0.00	0.27	0.11	0.00	0.13	0.11	0.00	0.13	0.06	0.00	0.07	6.4
43	0.17	0.00	0.20	0.11	0.00	0.13	0.11	0.00	0.13	0.11	0.00	0.12	11.2
44	0.11	0.33	0.07	0.11	0.00	0.13	0.06	0.00	0.06	0.06	0.00	0.06	5.7
45	0.06	0.00	0.06	0.06	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	1.7
46	0.11	0.00	0.12	0.11	0.00	0.12	0.06	0.00	0.06	0.06	0.00	0.06	4.8
47	0.06	0.50	0.00	0.06	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.1
48	0.06	1.00	0.00	0.06	1.00	0.00	0.06	0.00	0.06	0.06	0.00	0.06	2.4
49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.3
50	0.06	0.00	0.06	0.06	0.00	0.06	0.06	0.00	0.06	0.00	0.00	0.00	2.0
51	0.06	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.8
52	0.28	1.00	0.24	0.28	0.00	0.28	0.11	0.00	0.11	0.00	0.00	0.00	8.1

4.6.3 Ambikapur

The onset of monsoon in this zone is also noticed in MW 23 and good quantum of rainfall is received with higher depth (50 mm/week) is also higher in MW 24 in Ambikapur agro climatic zone presented in Table 4.19 **and** Fig. 4.19 to 4.22**. This indicates that ideal sowing time is MW 24 or latest by MW 25. The withdrawal of monsoon is MW 40 to 41 in this zone. However, continuous rainfall of higher amounts may cause waterlogged condition interfering the intercultural operations. However, if excess rain water is drained it world help in maintaining nice soil air / water proportion and the drained water can be utilized for crops during moisture stress period.**

4.7.1 Rainfall Trends

The time trend equations of rainfall from the data have been work out and are shown below.

Table 4.20: Time trend equations for each decade during the period 1971- 2008 for different districts of Chhattisgarh

SN	Station name	Decade	Time trend Equation	R^2
1.	Raipur	**1971-1980** **1981-1990** **1991-2000** **2001-2008**	**y = -2.4685x + 1187.7** **y = -19.068x + 1305.2** **y = -10.133x + 1161.9** **y = 26.865x + 1071.6**	**0.0008** **0.0477** **0.0139** **0.0414**
2.	Jagdalpur	**1980-1989** **1990-1999** **1999-2008**	**y = -13.677x + 1487.7** **y = -56.314x + 1637.1** **y = 16.227x + 1333.2**	**0.0848** **0.1894** **0.0447**
3.	Ambikapur	**1991-2000** **2001-2008**	**y = -0.1261x + 1471.1** **y = -100.43x + 1829.6**	**0.000** **0.3731**

4.7.2 Decadal Variability

In order to find out the decades where the rainfall variability was more pronounced, the decadal variability of annual rainfall in the three districts head quarters where long term rainfall records are available was analyzed and the time trend equation for each decade and each station are shown in Table 4.20 and Fig. 4.4 (a,b,c).

It was seen from table that there is a long term variation in the decadal rainfall pattern in different districts head quarters. At Raipur, the decadal rainfall was significant increasing trend during the decade. In the order decades, the trends of decadal rainfall are statistically not significant.

At Bastar and Surguja districts, the decadal trends of rainfall in the decades of the no significant trends. From the decadal analysis, it is clear that the decadal rainfall trends have no relation either among the decades (temporal scale) or among the stations (spatial scale).

4.7.3 Seasonal Rainfall Variability

Average and coefficient of variation (%) of rainfall during monsoon months (June-September) for different districts district head quarter of agro climatic zones of Chhattisgarh were shown in Table 4.21.

In the month of June the maximum average rainfall was observed at Jagdalpur (231.2mm) followed by Sarguja (226 mm) and Raipur (193.8 mm). The coefficient of variation (%) of rainfall during this month varied from 45.5 per cent to 78.5 per cent. The lowest coefficient of variation (%) was observed at Bastar (45.5%) and the highest was in Ambikapur (78.5%) district.

The seasonal rainfall pattern in this area is similar to annual rainfall as more than 90 per cent of annual rainfall is received during kharif season. In earlier studies Raghvendra (1974) noticed the spatial variability in sub-divisions of Maharashtra where the rainfall quantum varies in between 85 to 304 cm. He observed that the lower amounts of rainfall received in Konkan. It was also found that the annual rainfall decreases from east to west. Such types of variations were also observed by Subramaniam and Rao (1989) over Prakasam and Nellore districts of Andhra Pradesh.

Like rainfall amount, there is a considerable spatial variability of coefficient of variation in the state ranging from 20 per cent to 35.1 per cent. The higher coefficients of variation values are responsible for the instability in the productivity of rice. Similar studies were also carried by Subramaniam and Srimanarayana (1991) over Madhya Pradesh. They observed that coefficient of variation of annual was less than 20 per cent for eastern and south west districts of Madhya Pradesh. In other districts the coefficient of ranges from 22-25 per cent. When the trends of long term rainfall data in different districts of Chhattisgarh were studied, it was found that there are decreasing trends in the annual rainfall in most of the stations. It was found that at In Raipur districts though there is a decreasing trend is not statistically significant.

The decreasing trend in rainfall was observed in almost all the districts. In view of the decreasing trend, it is necessary to assess the impact on agricultural crops and crop varieties and if needed proper strategies need to be developed for crop diversification. Baghel and Sastri (1999) studied the regional climate changes and their influence on agriculture in Chhattisgarh. They found that rainfalls as well as rainy days are in decreasing trend in some districts of Chhattisgarh.

Table 4.21: Monthly variation of rainfall during monsoon season (June to September)

Station name	June		July		August		September		SW Monsoon	
	Avg.	CV (%)	Avg.	CV (%)	Avg.	CV (%)	Avg.	CV (%)	Avg.	CV (%)
Raipur (1971-2008)	**193.8**	**73.1**	**309.1**	**40.6**	**333.1**	**34.1**	**184.4**	**63.5**	**1167**	**23**
Jagdalpur (1980-2008)	**231.2**	**45.5**	**336.4**	**28.7**	**345.5**	**30.6**	**189.3**	**37**	**1383.7**	**19.1**
Ambikapur (1991-2008)	**226.9**	**78.5**	**400.2**	**40.4**	**379.2**	**32.4**	**253.7**	**55.9**	**1429.2**	**25.7**

4.8 Climate Water Balance

The climatic water balance using the weekly averages of rainfall and potential evapotranspiration was computed for 3 districts head quarter of agro climatic zones of Chhattisgarh state with the help of book keeping procedure of Thornthwaite and mather (1955).The water balance of 3 districts head quarter of agro climatic zones are shown in Table 4.22.

In general, it was observed that the rainfall exceeds the potential evapotranspiration value in all the districts head quarter of agro climatic zones form June onward when the monsoon sets in the state. But the rainfall in June to mid July is sufficient only to recharge the soil. After recharging the soil up to field capacity, the excess rainfall over the potential evapotranspiration values goes as surplus water. The surplus water moves out of the place either as run-off or as deep percolation losses depending upon the topography, slope, crop, vegetation etc. The surplus water is responsible either for ground water recharge or rainwater harvesting to alleviate drought conditions by providing supplemental irrigation.

After withdrawal of monsoon the soil moisture is utilized to meet the evapotranspiration demand partially and water deficit condition start developing in field. During the monsoon season, on an average conditions the potential evapotranspirational demand are met by rainfall and hence the actual evapotranspiration losses are equal to potential evapotranspiration during the monsoon months. Thus in Chhattisgarh state for better water management of kharif crops and for alleviating the drought conditions in the state, information on the water surplus and water deficit, both quantum and period are important. In view of this, the amounts of water surplus water deficit in each district head quarter are worked out by water balance. The results of the same for each of 3 districts head quarter of agro climatic zones of Chhattisgarh state are shown in Table 4.22. It was already discussed earlier about the spatial variability of rainfall but the actual evapotranspiration values are also vary spatially. The details are as follows.

Table 4.22: The different dates of beginning of water surplus, water deficit period and annual amount of AET, surplus and deficit

District	Rainfall (mm)	PET (mm)	AET (mm)	Water surplus		Water deficit	
				Amount	Starting period	Amount	Starting period
Raipur	**1154.4**	**1533.2**	**709.1**	**445.3**	**26 July**	**824.1**	**9 Oct.**
Jagdalpur	**1339.0**	**1411.9**	**788.9**	**551.6**	**21 July**	**623.1**	**20 Oct.**
Ambikapur	**1408.1**	**1342.0**	**710.0**	**697.0**	**13 July**	**632.6**	**13 Oct.**

4.8.1 Actual Evapotranspiration (AET)

The results of the same for each of 3 districts head quarter of agro climatic zones of Chhattisgarh state are shown in Table 4.22. The actual evapotranspiration shows spatial variability in different districts head quarter. The lowest annual average AET was observed in Raipur (709.1 mm) and highest in Jagdalpur (788.9 mm) followed by Ambikapur (710.0 mm). In majority of districts the AET ranges in between 700-800 mm, moderately high AET was observed in Surguja, Bastar.

4.8.2 Water Surplus

The water surplus in the amount as mentioned earlier that goes either as deep percolation or run-off depending upon the local hydrological conditions. In rice fields farmers usually accumulated 10-20cm of water and there after they let it off. Hence, under bunded rice field conditions most of the surplus water goes as percolation. But in other crops like soybean, groundnut and other pulses, which cannot sustain any water logging conditions, the surplus rain water is immediately drained out. Thus the role and method of water management in the district varies from crop to crop and also from field to field. It can be seen from the Table 4.22

There is a greater spatial variability in the quantum of surplus water, which varies from 400 mm to 700 mm. The lowest one occurs in Raipur district head quarter of agro climatic zones and the highest one occurs in Ambikapur district. This variability of surplus water is due to soil and rainfall variability. In Chhattisgarh state the soil types range sandy loam (locally called matasi) to deep black soils (locally called as kanher). Accordingly the filed capacity of these soil ranges from 150 mm to 300 mm.

The starting period of surplus water also varies considerably in the state. In general, the surplus water starts around 17 July in different districts. This gives general idea about the time and amount of rainwater that can be harvested in different cropped area to alleviate the drought conditions.

4.8.3 Water Deficit

For alleviating the drought conditions during kharif and also for providing supplemental irrigation, knowledge on the pattern of water deficit is most vital. It can be seen from the Table 4.22. That water deficit conditions start from the first week of October to mid of October in different districts. Water deficit conditions start from 20th October in Bastar district. But the tolerance of water deficit varies from crop to crop. Hence, the impact of water deficit varies differently in different crops. But, in general the deficit conditions go on accumulating till the onset of monsoon in the next year. The amount of water deficit depends upon the rainfall quantum and its distribution beside the potential evapotranspiration values. The annual water deficit amount in the state varies from 623.1 mm in Jagdalpur district to as high as 824.1 mm in Raipur district.

It can be seen from water balance diagrams that the AET ceases from mid January it self for almost all the districts. Also, after the withdrawal of monsoon, the actual evapotranspiration falls short of potential evapotranspiration values creating water deficit conditions. Similar variations in AET, water surplus and water deficit were observed by Krishnan and Thanvi (1969) over arid zone of Rajasthan, lower value of AET was at Jaisailmer (220 mm) and higher value of AET 300 mm was observed at Jodhpur and Sikar. Such water balance studies were carried by Jairam *et al*. (1973) for the arid region of southern India like Bellary district. They observed that there is a considerable difference between PET and AET, which becomes the water deficit. They recorded that the water deficit (PET- AET) at Bellary is 1369.2 mm which is relatively very high as compared to Bilaspur district. This is because Bellary is arid type of climate while Bilaspur is sub-humid type of climate.

Water deficit, which is difference between potential and actual evapotranspiration losses, is considered as the beginning of drought for rainfed rice crop as the lower limit of soil moisture for rice crop its field capacity. In water balance computations, the AET falls below PET as soon as the soil goes below field capacity; as such the beginning of water deficit is the beginning of drought condition for rainfed rice. Thus, when the starting date of water deficit in different districts of Chhattisgarh is examined (Table 4.4). It is clearly seen that in general water deficit condition begins from 4th October to 20th October in different districts. For making the varietals recommendations of rice or other crops the starting period of water deficit conditions should also be considered. Similarly the quantum and beginning of water surplus provides an insight in planning to alleviate intermitted drought conditions. The information on quantity of surplus water can help in developing strategies to alleviate the drought conditions by storing excess surplus water in tanks or farm ponds. A perusal of Table 4.4 revealed that mostly the water surplus starts accumulating from the 3rd week of July. Hence, any early season drought during seedling stage of rice or other crops can not occur at this stage. Subramaniam and Rao (1988) studied the agroclimatological aspects of Prakasam and Nellore districts in Andhra Pradesh. The observed that in Prakasam district, there was no surplus water, which can be harvested and recycled. They concluded that crop growing season is too short to grow two crops in these districts.

When the spatial variability of the quantity of water surplus of different districts was examined it was found that Ambikapur gets highest water surplus of 697.0 mm while Raipur receives only 445.3 mm of surplus water. Among 3 districts head quarter of agro climatic zones considered in Chhattisgarh state, Kawardha can be designated as most droughts prone to rice crop and alleviation of drought water harvesting and recycling is difficult in this district. In general the surplus water in different districts of Chhattisgarh ranges between 400-500 mm which can helps to provide one or two supplemental irrigations if proper water harvesting technology is adopted.

The surplus water computed through water balance is lost from the field either as run-off or deep percolation. If the surplus water goes as run-off water, it can be harvested and recycled. Sastri *et al.* (2002) worked out the water balance for bunded rice fields. Water balance of bunded rice field is the modification of climatic water balance with some more assumptions.

4.9. Water Availability Periods

The information of water availability periods is the vital for adjusting the crops in such a way that can avoid the moisture stress conditions during drought years. Hence, the water availability periods for different districts were worked out and results are given below.

The station-wise water availability periods of Chhattisgarh state *viz.*, moist-I, humid and moist-II are shown in Table 4.23.

The moist-I period start around 13-17th June in almost all the districts. Moist-I period was observed at Raipur, Jagdalpur (13 days). The humid period commences around 26 June-11 July in different districts and ceases in October. Jagdalpur have humid period greater than 120 days. These are followed by Raipur, Ambikapur (110-120 days).

The moist-II period varied from 11 to 23 days. The shortest duration was in Raipur while Jagdalpur has longest (23 days) followed by Ambikapur (22 days each).The length of total growing season for Chhattisgarh state ranges in between 129 to 168 days. The Jagdalpur district stands first with 168 days followed by Ambikapur (150 days each). The shortest length of growing season was observed in Raipur (138 days). The districts have water availability periods in between 140 to 150 days covering Ambikapur.

Table 4.23: Water availability period for different stations in Chhattisgarh

Station name	Moist-I	Humid	Moist-II	L.G.P.
Raipur	**13-25 June (13)**	**26 June-17 Oct (114)**	**18-28 Oct (11)**	**138**
Jagdalpur	**6 -18 June (13)**	**19 June-28 Oct (132)**	**29 Oct-20 Nov (23)**	**168**
Ambikapur	**16 June-30 June (15)**	**1 July-21 Oct (113)**	**22Oct-12 Nov (22)**	**150**

It was already mentioned in Chapter III that water availability periods like humid (R>PET) and moist (PET>R>PET / 2) periods, help in selecting crops, crop varieties and adjusting the date of planting to avoid water stress condition during deficit rainfall years. It was found from the analysis of the water availability periods that the moist-I periods was longer (13-15 days) in Ambikapur and Jagdalpur districts while moist-I periods suggests that the field preparation and sowing operations are to be done relatively in a shorter time in these districts with shorter span of moist-I period. Hence mechanization is a priority in these districts. Subramaniam and Rao (1983) also observed such variations in water availability periods. They found that the total number of days of water availability periods were most at Cuddapah (204 days) than at Annantpur (180 days) and Kurnool (198 days). They also observed that duration of humid period was more at Cuddapah (156 days) than at Kurnool (126 days) and Annantpur (72 days).

Regarding humid period, there are some districts where humid period is greater than 120 days. These districts are Bastar . Thus there is a clear cut difference of more than 30 days of humid period in these two groups of districts. Hence, the crop should be selected in such a way that their grand growth period should fall under this period. Similar studies were also made by Singh *et al*. (1999) in eastern India. According to their work the humid period was of highest duration in Assam (ranging from 191-270 days) and least humid period duration was in eastern Uttar Pradesh (ranging from 81-123 days).

CHAPTER-V

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH WORK

Chhattisgarh state in eastern India more than 80 percent of the population is dependent on agriculture for their livelihood. At present the state has 18 districts, which is formed by bifurcation of the Madhya Pradesh state. Earlier Chhattisgarh region which was under Madhya Pradesh state and had only 7 districts in the area. Thus after the formation of the state Chhattisgarh has 18 districts, and 3 agroclimatic zones. The data available for districts head quarters of different agroclimatic zones. Hence, the analysis of rainfall climatology, rainfall probability, rainfall variability, length of growing period of these districts was carried.

In Chhattisgarh state more than 90 percent of annual rainfall received during south west monsoon (June-Sept.). Mostly rice cultivation is rainfed. Farmers usually grow tall and long duration varieties, which flower in mid October and matured by mid November. But the monsoon usually withdraws by mid or 3rd week of Sept... As a consequence, the rice crop has to sustain for atleast 40-50 days without rainfall. Hence, drought is a recurring phenomenon in most of the districts head quarters of different agroclimatic zones.

Using the historical rainfall data the coefficient of variation of annual as well as seasonal, June Sept. was analyzed and it was found that high coefficient of variation (%) of annual rainfall was in ambikapur district head quarters of different agroclimatic zones regarding seasonal rainfall; the coefficient of variation was higher at Jagdalpur which receive maximum rainfall. This is an indication that the rainfall in CG state even in monsoon season, is not widespread but scattered.

While examining the rainfall trends in all the districts head quarters of different agroclimatic zones it was found that in most of the districts head quarters rainfall was in a decreasing trend. This decreasing trend of rainfall was statistically highly significant at. Similarly, decadal analysis of rainfall in different dist of the state revealed that there is a variation in rainfall pattern both in spatial and temporal scales. As a result the rainfall amount in different district varies differently even in given area. Such micro regional characteristics are important in developing locations specific technologies to diversify the existing cropping pattern in the state.

Studies on water balance revealed that the spatial variability of AET is in the range of 709.1mm in Raipur to 788.9mm in Jagdalpur. The water deficit condition starts after the withdrawal of the south west monsoon. In general, it starts from 4^{th} oct. onwards and in few dist it starts 15^{th} oct. thus the crops in general and the rainfed rice in particular experience drought from the 1^{st} week of oct. onwards.

Suggest for developing strategies for better water management practice for agricultural crops.

From the computation of water balance of one day ricefield in Raipur for the period of 1971-2000, it was observed that year 1979, 1987, 1988 and 2000 were drought years for rainfed rice as no rain water impounded in the fields to carry biasi operation. But the rice crop suffered from severe terminal drought conditions right from the beginning of flowering stage in the year 1979. Hence, the duration of drought was higher in 1979 as compared to 1987, 1988 and 2000. Similarly weekly water balance at different rainfall probability levels where also analyzed. It was observed that the CG average rainfall matches with 30-40% probability level of rainfall. This shows that under assured rainfall conditions where there is every chance that the biasi operation was delayed. Hence, if planning is carried out with average rainfall there is every possibility those 2 out of 3 years the rainfall may go below average.

Studies on the climate fluctuations in different districts reveal that the climate has shifted from dry sub humid to semiarid condition in most of the districts. Raipur in CG state is distinct example. of such change. In some district, the climate during last century fluctuated highly from moist sub humid to semiarid condition. In some district though there were fluctuations in the moisture index, they are limited within the range of dry sub humid climate.

An analysis of water availability periods at different districts and at the state revealed that the humid period varies from 98-132days in different dist.thus, the duration of crop varieties especially rainfed rice crop can be determined as per the water avaibility period thereby adjust the crop during these period to avoid the water stress during at any stage of the crop growth. From the analysis of water harvesting potential it was lowest at Raipur in excess, normal and deficit condition..

SUGESSIONS FOR FUTURE RESEARCH WORK

Based on the present study the following suggestion can be taken care for future research work.

1. This study was confined to the district head quarters of all the three agroclimatic zones of Chhattisgarh. Hence it is suggested that intensive studies for all the districts should be carried out.
2. The variability of rainfall was observed in study sites, hence intensive study on micro scale i.e. Tashsil and /or block level should be carried out.
3. Length of growing period should be worked out for different soil types as the water holding capacity of varies from soil to soil.

RAINFALL VARIABILITY AND PROBABILITY ANALYSIS OF DISTRICT HEAD QUARTERS OF DIFFERENT AGRO-CLIMATIC ZONES OF CHHATISGARH

by

NEERAJ KUMAR BANCHHOR

ABSTRACT

The present study was undertaken to workout the rainfall variability of district headquarters of all the three agroclimatic zones. The rainfall probability at different level was also carried out to know the rainfall amount at different probability level.

The mean annual rainfall ranged from 1167.0 mm in Raipur to 1429.2 mm in Ambikapur. The maximum rainy days of 75 were recorded in Jagdalpur. The south west monsoon contributed more than 90 percent of annual rainfall in all districts head quarters. The coefficient of variation and standard deviation for weekly, monthly, seasonal and annual rainfall were also computed for all districts. The chances of getting different amount of weekly rainfall all districts head quarters have been worked out. Expected amount of weekly rainfall at different probability levels for all districts head quarters have also been worked out. The mean onset of monsoon over districts head quarters of different agroclimatic zones of C.G. is between SMW 25 to SMW 26. It was found that the annual rainfall, seasonal rainfall as well as rainy days are higher at Ambikapur, followed by Jagdalpur and Raipur. On the other hand the potential evapotranspiration losses was higher at Raipur followed by Jagdalpur and Ambikapur. This showed that deficit amount is higher at Raipur. The distribution of rainfall at these three location was also studies and it was found that at jagdalpur the rainfall distribution is quite good as compared to Raipur and Ambikapur, the coefficient of variation is also lower than that of following two locations.

The length of growing period was found higher at Jagdalpur (168 days) where as, it was 150 days at Ambikapur. This showed that early duration rabi crop can be grown at Jagdalpur under rainfed condition in deep vertisols, but at Ambikapur second crop can be grown with supplement / limited irrigation. While at

Raipur rabi crop can not be grown without assured irrigation as the length of growing period was only 138 days.

College of Agriculture — Dr. S.R. Patel

IGAU, Raipur (C.G.) — **(Major Advisor)**

Date:

REFERENCES

Baghel, S.S. and Sastri, A.S.R.A.S. 1992. Regional climate change and its influence on agriculture- A case study for Chhattisgarh region of Madhya Pradesh. First *Agri. Sci. Congress*. pp. 213-222.

Chakraborty, P.K.1990. Rainfall probability analysis and its importance on agriculture practices for some of the locations of Nadia District, West Bengal. *Environment and Ecology*. **8**(2): 589-593.

Chakraborty, P.K., Huda, A.K.S., Chatterjee, B.N. and Khan, S.A. 1990. Rainfall and it impact on cropping pattern in Hooghly district of West Bengal. *Indian Journal of Agricultural Sciences*. **60**(2): 101-106.

Chaudhary, J.L. and Tomar, G.S. 1999. Agro climatic analysis of stable rainfall periods in undivided Bastar district of Chhattisgarh region of Madhya Pradesh, India. *Oryza*. **36**(1): 66-69.

Chaudhary, J.L. 1999. Agro climatic studies of Bastar district in Chhattisgarh region with special reference to production of rice. *Fertilizer News.* **44**(3): 33-38.

Chaudhary, J.L. and Sastri, A.S.R.A.S.1999. Regional climate change and climatic swings with special reference to production of rice and water resource potential in Chhattisgarh region of Central India .*Tropical Ecology*. **40**(1): 137-144.

Dutta, P. and Khan, A. 2005a. Probability analysis of rainfall for crop planning under rainfed condition. *Environment and Ecology*. **23**(2): 342-344.

Dutta, P. and Khan, A. 2005b. Agroclimatic study for determining sowing time in Cooch Behar district of West Bengal. *Environment and Ecology*. **23**(2): 282-287.

Gaikwad, C.B., Patil, J.D., Shewale, M.R., Jadhav, J.D., Mokashi, D.D. and Chavan, S.B. 1996. Rainfall variability analysis - a case study. *Journal of Maharashtra Agricultural Universities.* **21**(3): 442-445.

Gare, B.N., More, S.M., Jadhav, A.S., Burli, A.V. and Mokashi, D.D. 2000. Rainfall variability analysis at Gadhinglaj. *Journal of Maharashtra Agricultural Universities*. **25**(2): 198-201.

Ghadekar, S.R. and Thakare, K.K. 1991. Some studies on rainfall climatology of the Nagpur region. *Mausam*. **42**(1): 57-64.

Hundal, S.S. and Kaur, P. 2002. Annual and seasonal climatic variability of different location of Punjab state. *Journal of Agrometorology*. **4** (2): 113-125.

Ingver, A. and Koppel, R. 2005. Length of growing period of spring wheat. *Transactions of the Estonian Agricultural University*. **220**: 54-56.

Jadhav, J.D., Mokashi, D.D., Shewale,. M.R. and Patil, J.D.1999. Rainfall probability analysis for crop planning in scarcity zone of Maharashtra. *Journal of Agrometeorology*. **1**(1): 59-64.

Kalita, M.C. 1999. Rainfall probability analysis for identifying date of sowing of wheat in high rainfall areas. *Journal of the Agricultural Science Society of North East India.* **12**(1): 87-90.

Kar, G. 2005. Rainfall probability analysis for sustainable crop production strategies in coastal Orissa. *Journal of Agrometeorology*. **4**(2): 181-185.

Khan, S.A. and Dutta, P. 2005. Use of agrometeorological approach for evaluation of multiple cropping under rainfed condition. *Environment and Ecology*. **23**(2): 332-337.

Kingra, P.K., Mahi, G.S. and Hundal, S.S. 2004. Climatic water balance of different agroclimatic zones for contingent crop planning in Punjab. *Journal of Agrometeorology*. **6**: 66-71.

Kothari, A.K., Kumar,Virendra, Jain, P.M. and Purohit, R.C. 2007. Dynamic crop planning for enhancing the crop productivity under rainfed conditions. *Journal of Agricultural Engineering*. **44**(3): 55-62.

Mehta, D.R., Kalola, A.D., Saradava, D.A. and Yusufzai, A.S. 2002. Rainfall variability analysis and its impact on crop productivity a case study. *Indian Journal of Agricultural Research.* **36**(1): 29-33.

Naidu, L.G.K., Reddy, R.S., Sah, K.D., Bhaskar, B.P., Datta, D., Niranjana, K.V. Dhanorkar, B.A., Srinivas, S. Nagaraju, M.S.S., Ray, S.K., Raghumohan, N.G. (1998) Mapping of agro-ecological zones of Andhra Pradesh through soil-resource data: *Indian Journal of Agricultural Sciences*. 68(10): 661-665.

Raghavendra, V.K. 1974. Trends and periodicities of rainfall in sub divisions of Maharashtra state. *Journal of meteorology and geophysics*. **25**(2):197-210.

Rao, E.B., Yadukumar, N. and Bhat, M.G. 2001. Agroecological regions and varietal classification of cashew developmental strategies. *Cashew* **15**(3): 27-37.

Rao, A.Y., Rao, K.K. and Rao, B.V.R .1988. Rainfall probability analysis of three stations in Andhra Pradesh for crop planning. *Indian Journal of Agricultural Sciences.* **58**(2): 133-135.

Reddy, R.S., Naidu, L.G.K., Srinivas, S., Niranjana, K.V., Ramesh, M., Harindranath, C.S., Shivaprasad, C.R., and Thayalan, S. 2001. Identification and categorization of agricultural drought prone zones of Andhra Pradesh. *Agropedology.* **11**(2): 101-109.

Saleh, A.F.M. and Bhuiyan, S.I. 1993. Improving the soil water regime for crop intensification in rainfed lowlands: the role of dry seeded rice. *Philippine Journal of Crop Science.* **18**(2): 89-98.

Sanbagavalli, S., Sumathi, I., Balasubramanian, T.N. and Ganesan, K. 2001. Computation of length of growing period (LGP) By FAO model. *Madras Agricultural Journal.* **88**(1/3): 130-132.

Santos, C.A.G., Galvao, C.O. and Trigo, R.M. 2003. Rainfall data analysis using wavelet transform. Hydrology in Mediterranean and semiarid regions: international conference, Montpellier, France, 1-4 April 2003.

Sastri, A. S. R. A. S. and Ramakrishna, Y. S. 1980. A modified scheme of drought classification applicable to the arid zone of western Rajasthan. *Annals of arid zone*. (1&2): 65-72.

Sastri, A. S. R. A. S. and Ramakrishna, Y. S. 1982. Drought the year 1979 over western Rajasthan: A climatic perspective. *Annals of arid zone*. **21** (1): 41-47.

Sastri, A. S. R. A. S., Rao, H.G., Naidu, D. and Yadav, S. 2002. Project report on drought analysis and its impact on rice productivity in Chhattisgarh, IGAU, **pp** 7-8.

Saxena, V. P. and Agrawal, Asha Lata. 1989. Rainfall over Bombay: A climatological study. *Vayumandal.* **19** (3-4): 105-109.

Sinha , K. C. and Shewal, M. P. 2001. Probability of occurrence of drought in various sub division of India. *Mausam.* **52** (3): 514 -546.

Srivastasva, A.K., Sastri, A. S. R.A.S. and Naidu, D. 2000. A note on drought and rice productivity in Chhattisgarh state. *Journal of agro meteorology*. **2**(1):75-81.

Srivastava, A.K. and Chaudhary, J.L. 1998. Long term and decadal variability of rainfall in Chhattisgarh plains of central India with special reference to production of rice. *Fertilizer News*. **43**(2): 53-57.

. Subramaniam, A.R. and Rao, G. S. L. H .V. 1980. Meridional variation of water balance in Rajasthan State. *Annals of arid zone.* **19** (1-2):51-57.

Subramaniam, A.R. and Rao, P.S. 1984. Rainfall studies of Prakasam District. Andhra Pradesh. Proc. Of the colloquium on " Precipitation Analysis and flood forecasting" I I TM , Pune. pp. 31-38

Subramaniam, A.R. and Rao, G.G.S.N. 1989. Bio - climatology of grasslands in the Indian arid region (western Rajasthan). Proceedings of the 11^{th} ISB- congress, USA., pp. 123-144.

Subramaniam, A.R. and Srimannarayana, T. 1991. Climate studies of Madhya Pradesh. *Trans Inst. Indian Geographers* .**13** (1):73-81.

Subrmanian, S.K. 1994. How far the rainfall deficiency in June-July is made up during second half of the south west monsoon period ? A sub- divisional analysis. Vayumandal. 24 (2-3): 73-81.

Suresh, R. 1996. Inter seasonal and inter annual rainfall variability of a meteorological sub-division in peninsular India. *Vayumandal*. 26 (1-2): 27-31

Tapsoba, D., Hache, M., Perreault, L. and Bobee, B. 2004. Bayesian rainfall variability analysis in West Africa along cross sections in space time grid boxes. *Journal of Climate.* **17**(5): 1069-1082.

Tiwari, A.K., Bhatt, A.K. and Srivastava, M.M.1998. Drought estimation through rainfall analysis for Bundelkhand Region. *Indian j. soil conservation*. **26** (3): 280-283.

Weerasinghe, K.D.N. 1989. The rainfall probability analysis of Mapalana and its application to agricultural production of the area. *Journal of the National Science Council of Sri Lanka.* **17**(2): 173-186.

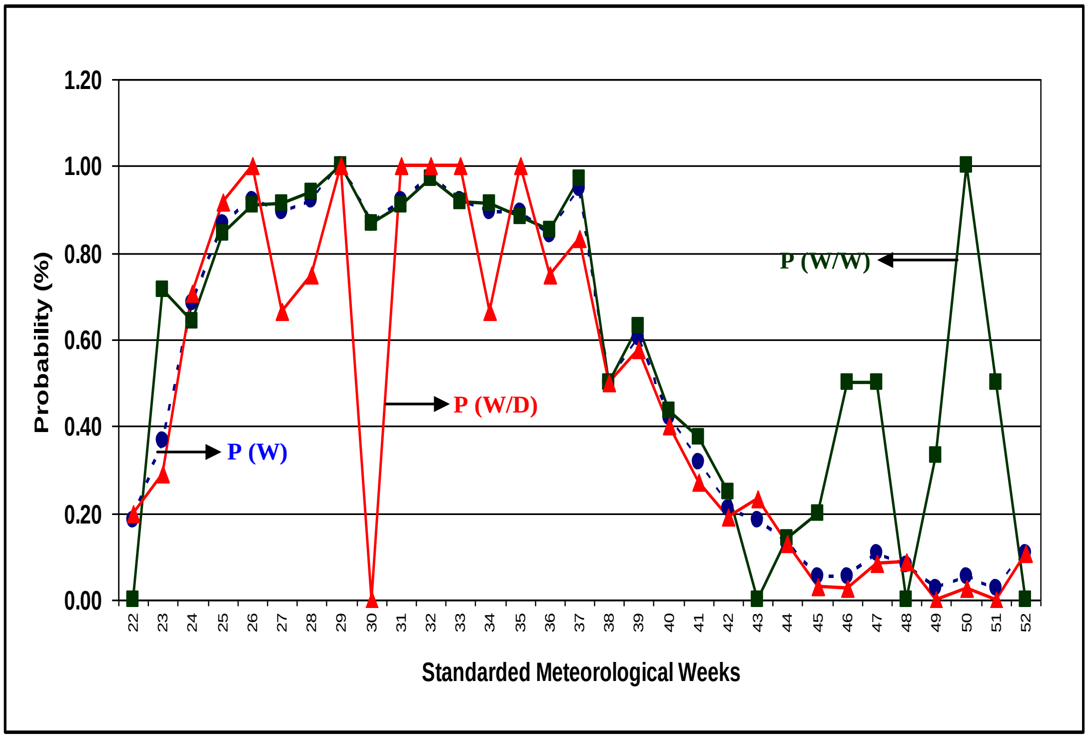


Fig. 4.11: Initial and conditional probabilities 10mm at Raipur

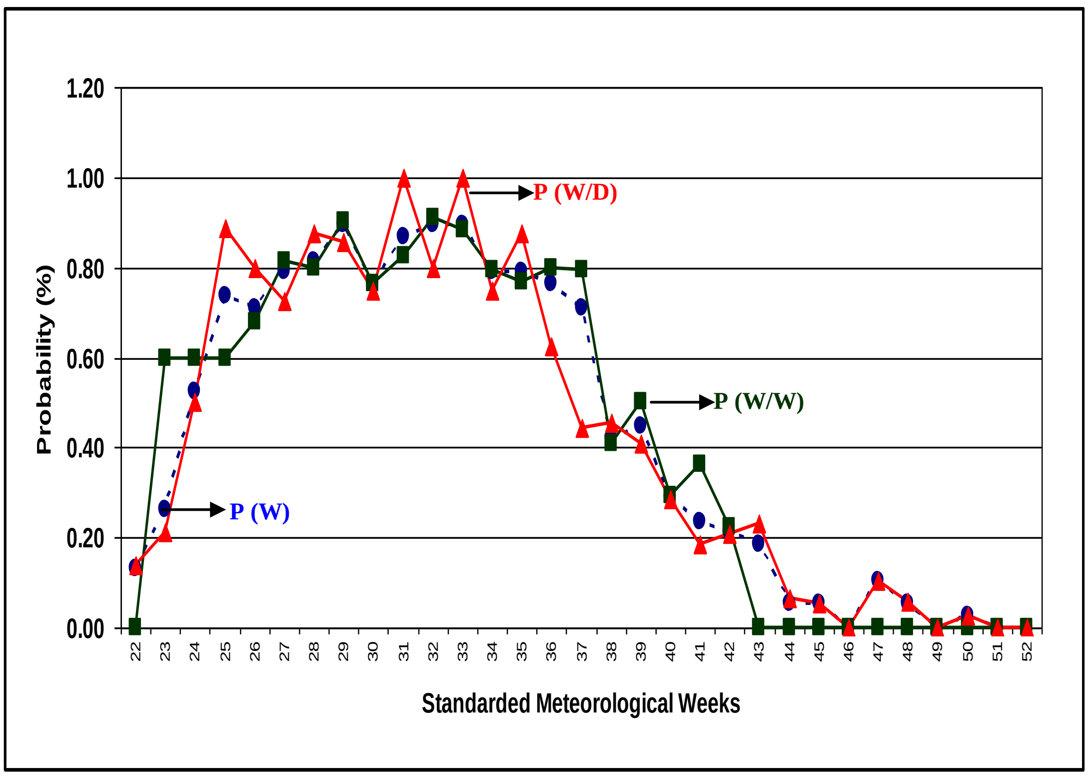


Fig. 4.12: Initial and conditional probabilities 20mm at Raipur

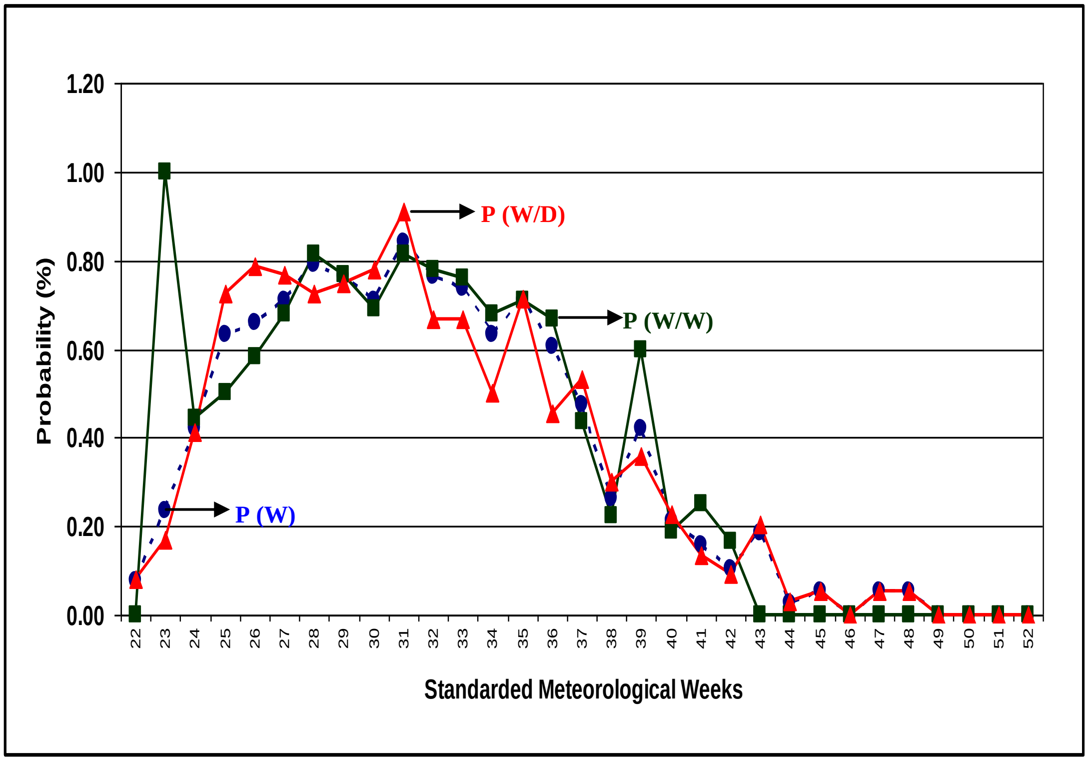


Fig. 4.13: Initial and conditional probabilities 30mm at Raipur

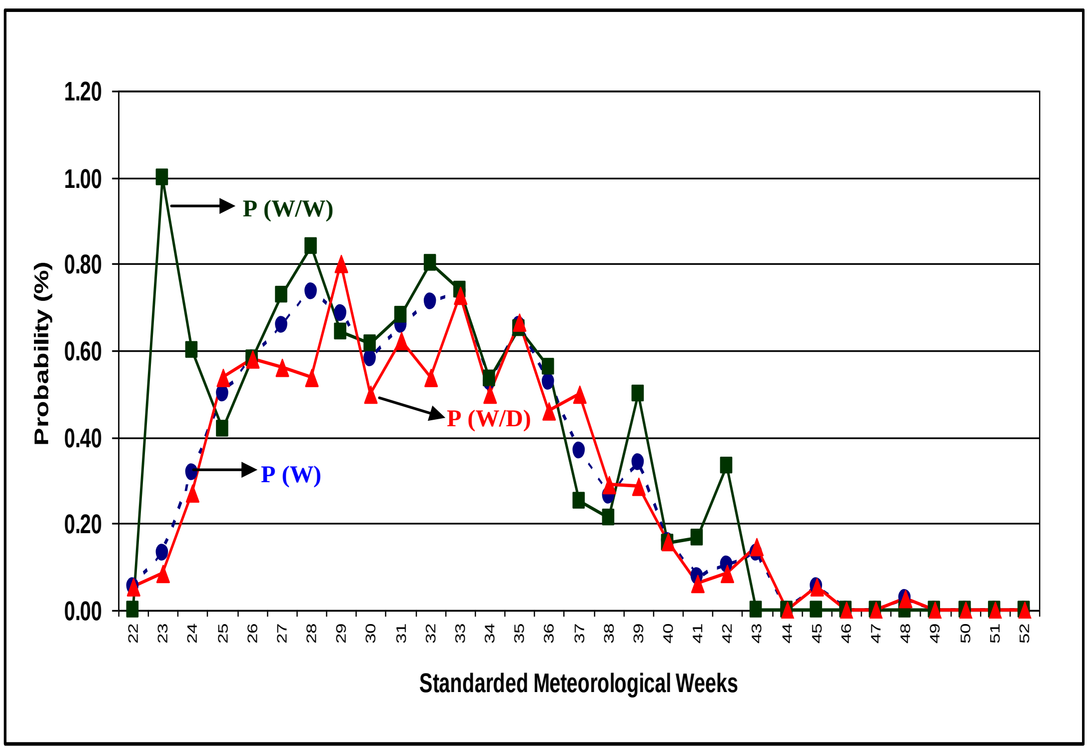


Fig. 4.14: Initial and conditional probabilities 40mm at Raipur

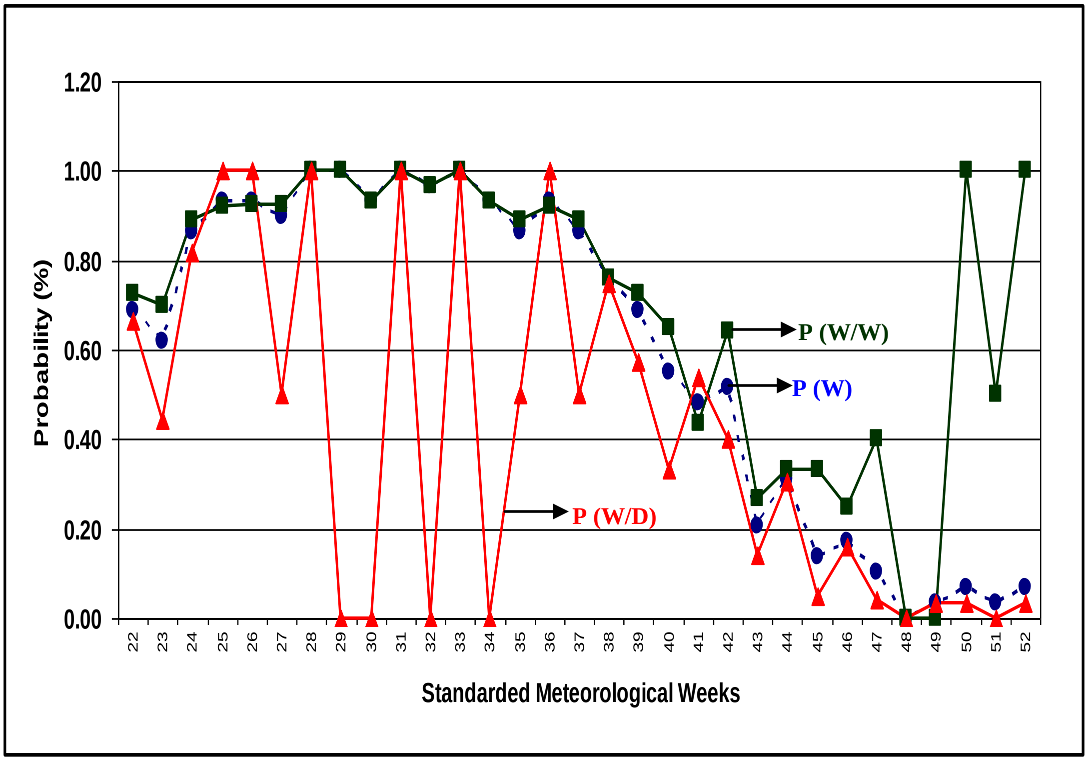


Fig. 4.15: Initial and conditional probabilities 10mm at Jagdalpur

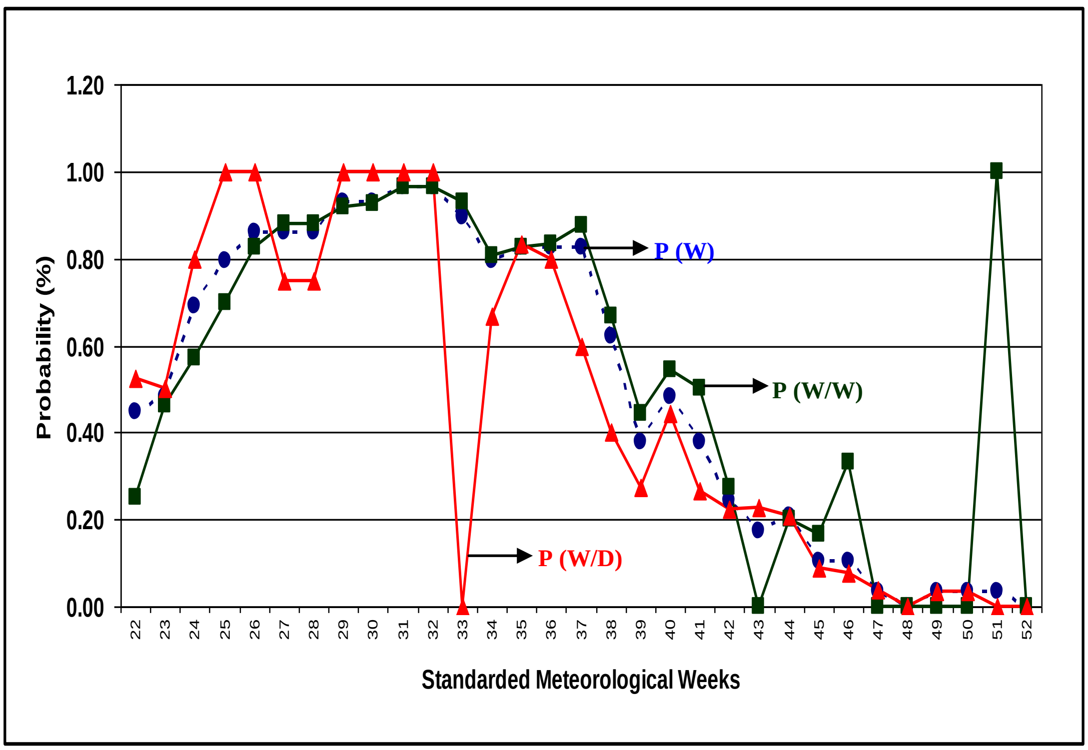


Fig. 4.16: Initial and conditional probabilities 20mm at Jagdalpur

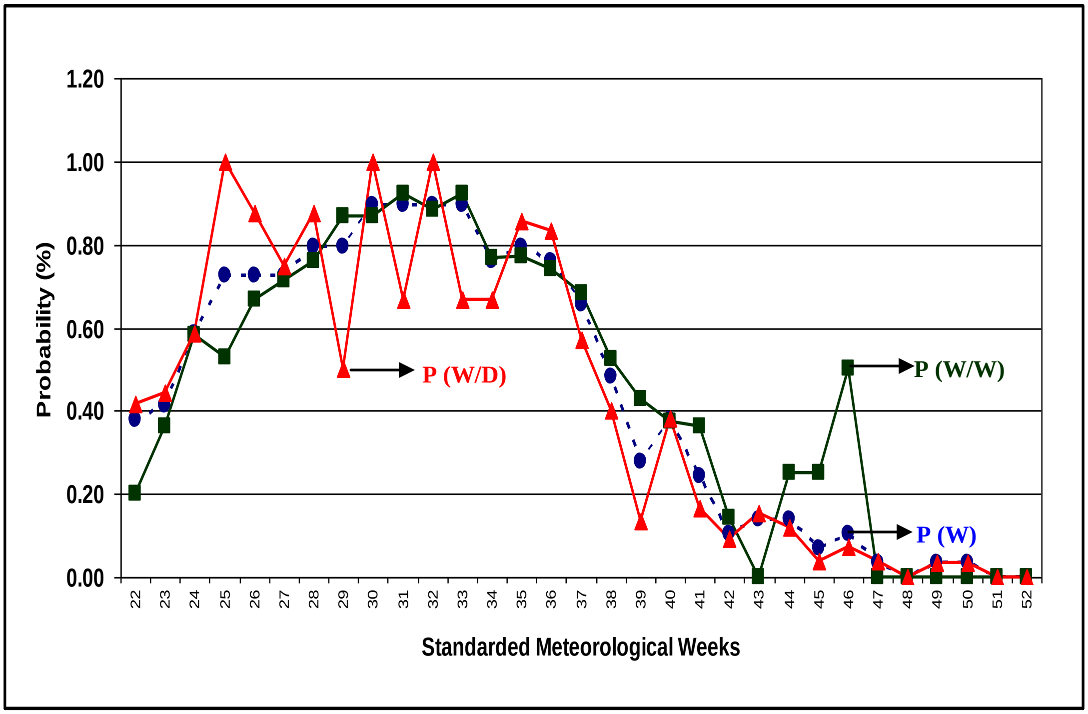


Fig. 4.17: Initial and conditional probabilities 30mm at Jagdalpur

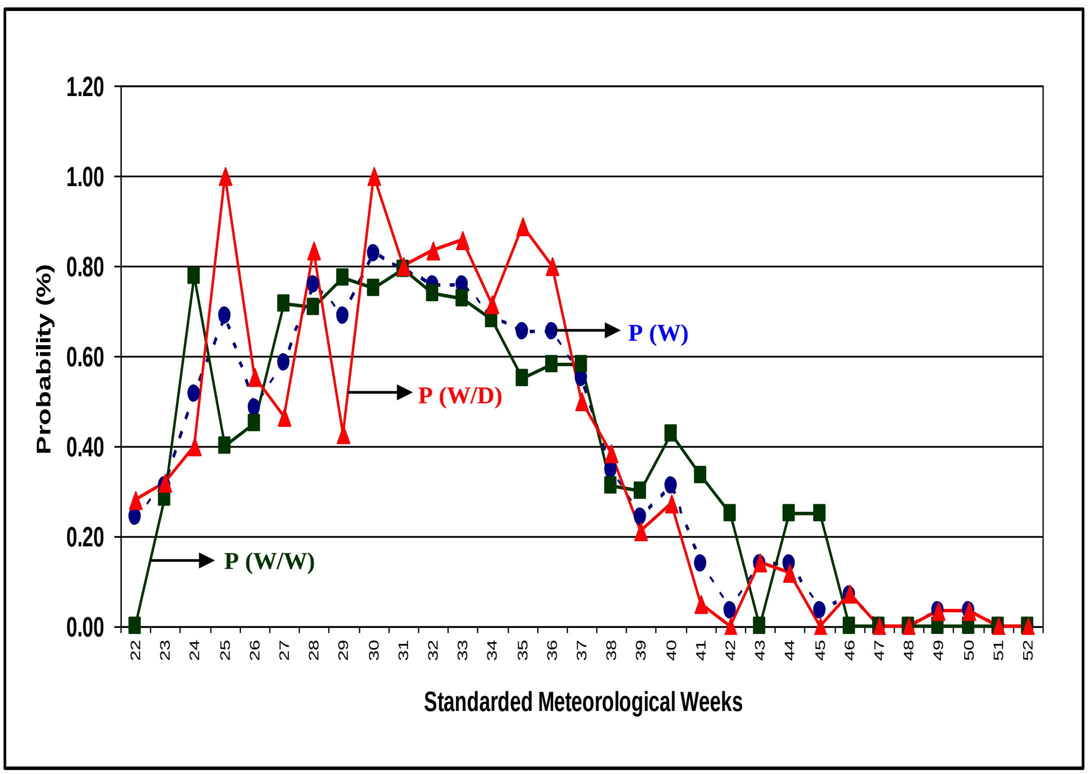


Fig. 4.18: Initial and conditional probabilities 40mm at Jagdalpur

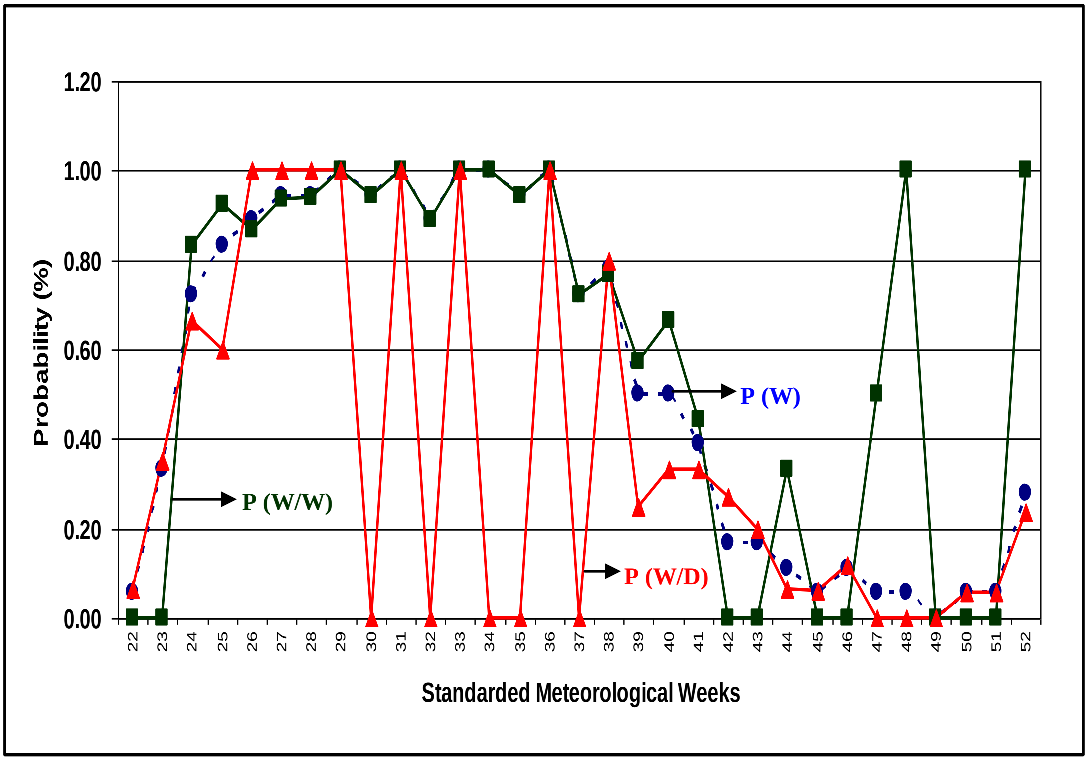


Fig. 4.19: Initial and conditional probabilities 10mm at Ambikapur

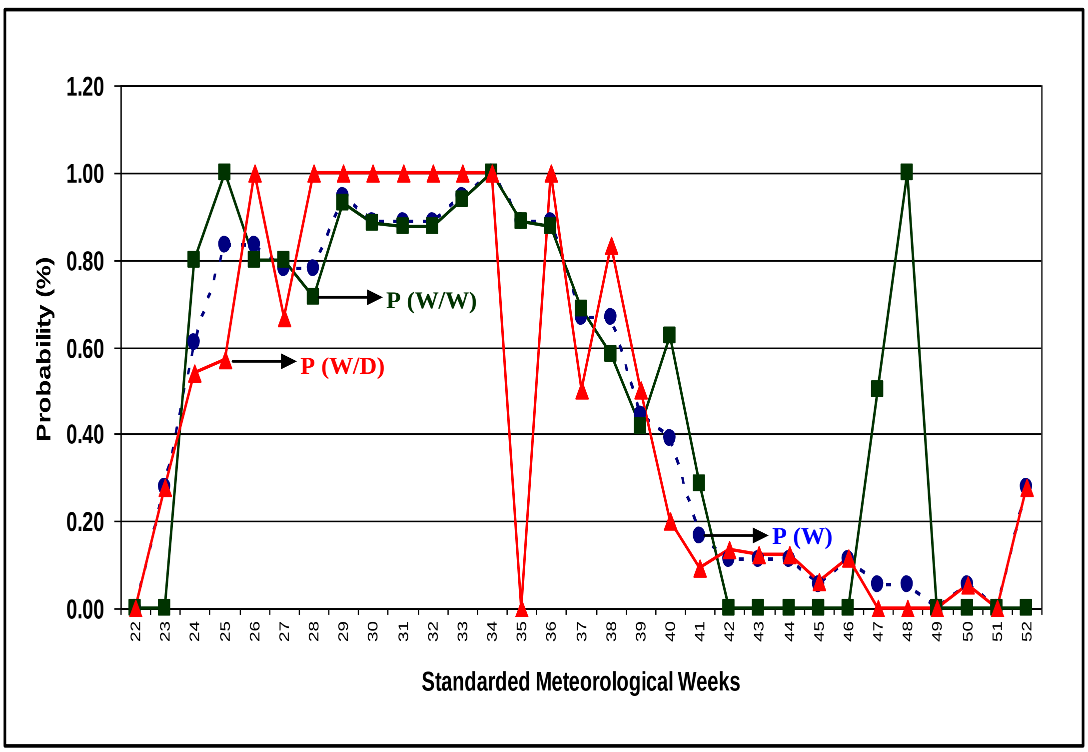


Fig.4.20: Initial and conditional probabilities 20mm at Ambikapur

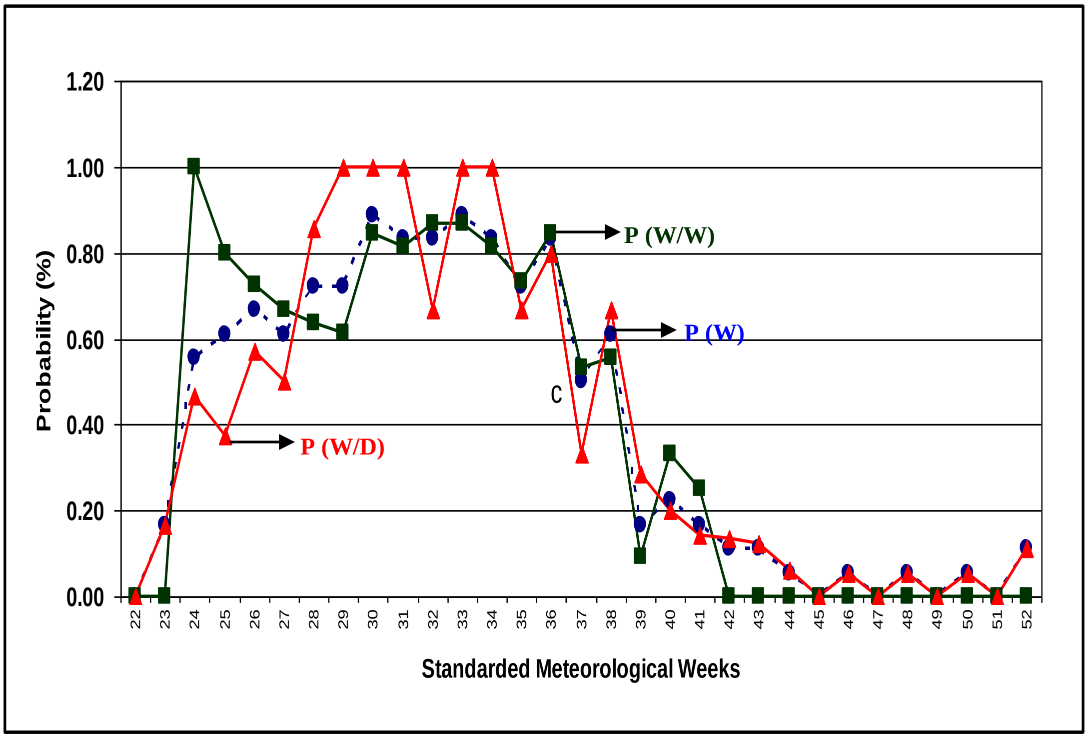


Fig. 4.21: Initial and conditional probabilities 30mm at Ambikapur

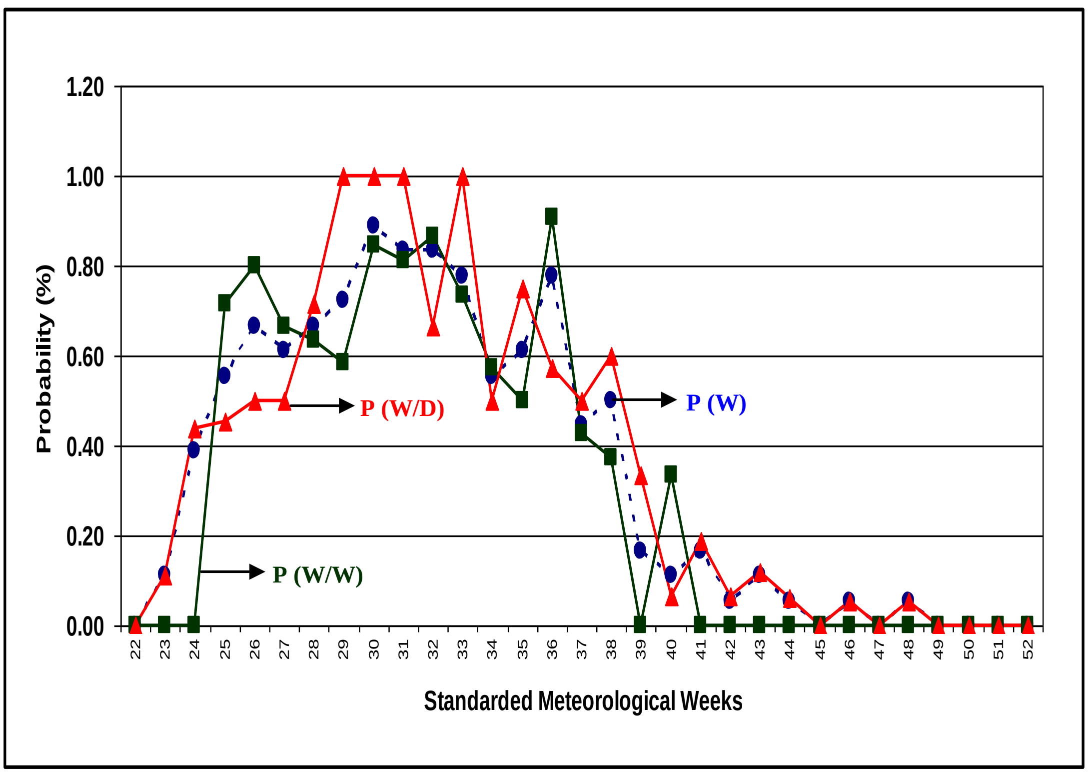


Fig. 4.22: Initial and conditional probabilities 40mm at Ambikapur

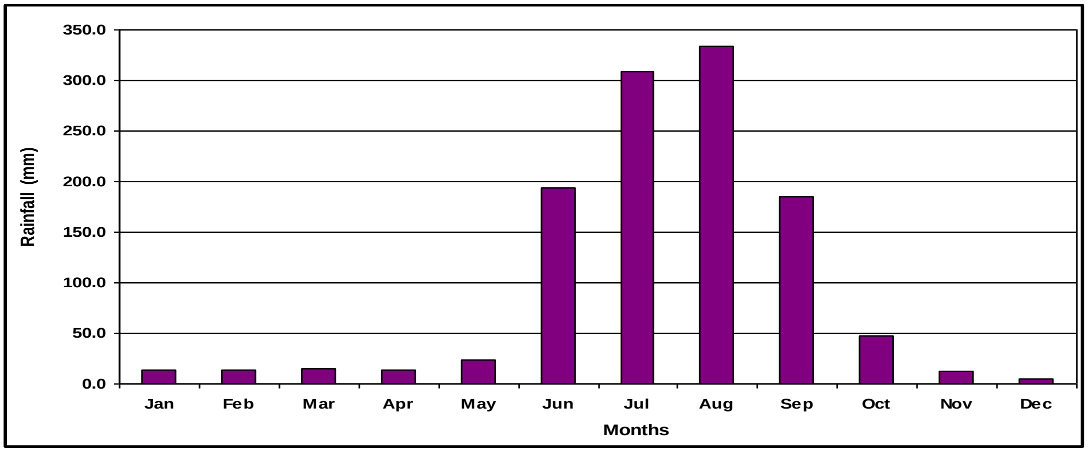


Fig. 4.5: Monthly mean rainfall (mm) at Raipur (1971-2008)

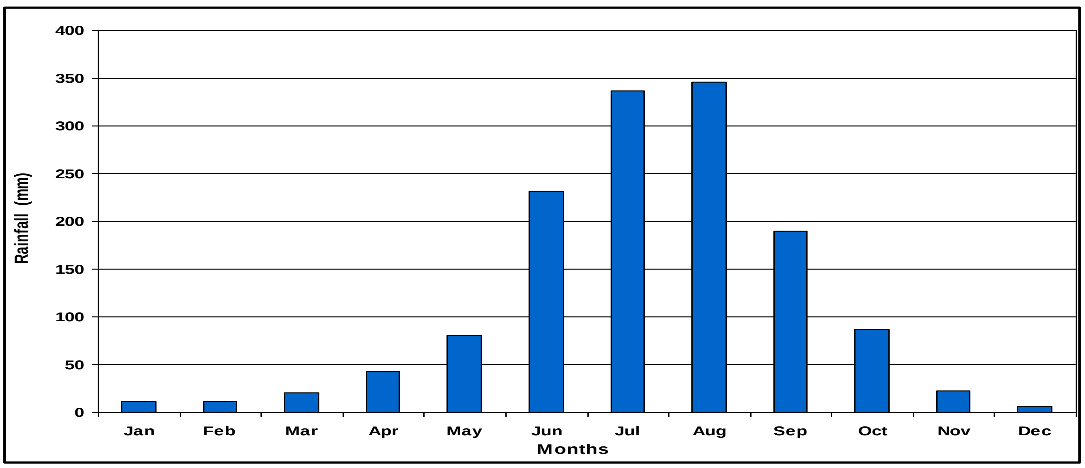


Fig. 4.6: Monthly mean rainfall (mm) at Jagdalpur (1980-2008)

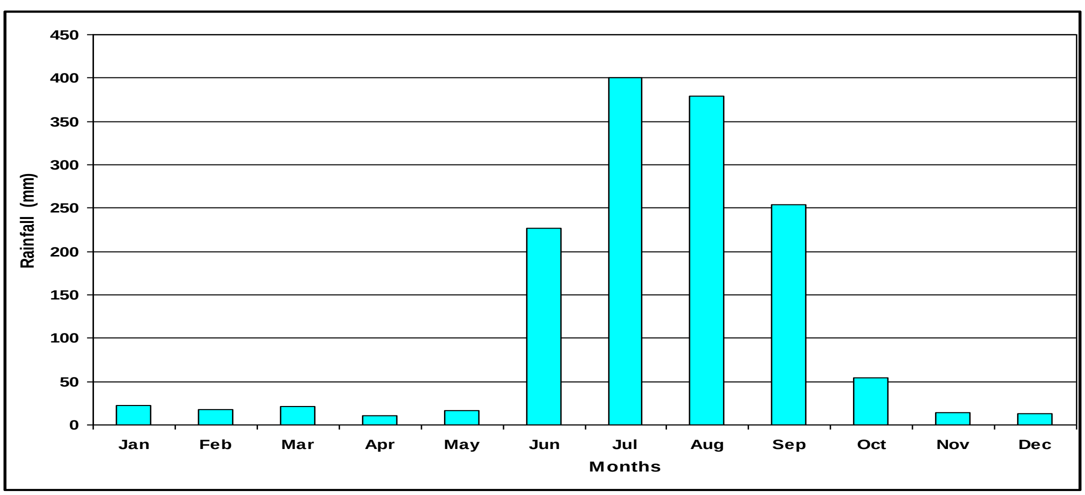


Fig. 4.7: Monthly mean rainfall (mm) at Ambikapur (1991-2008)

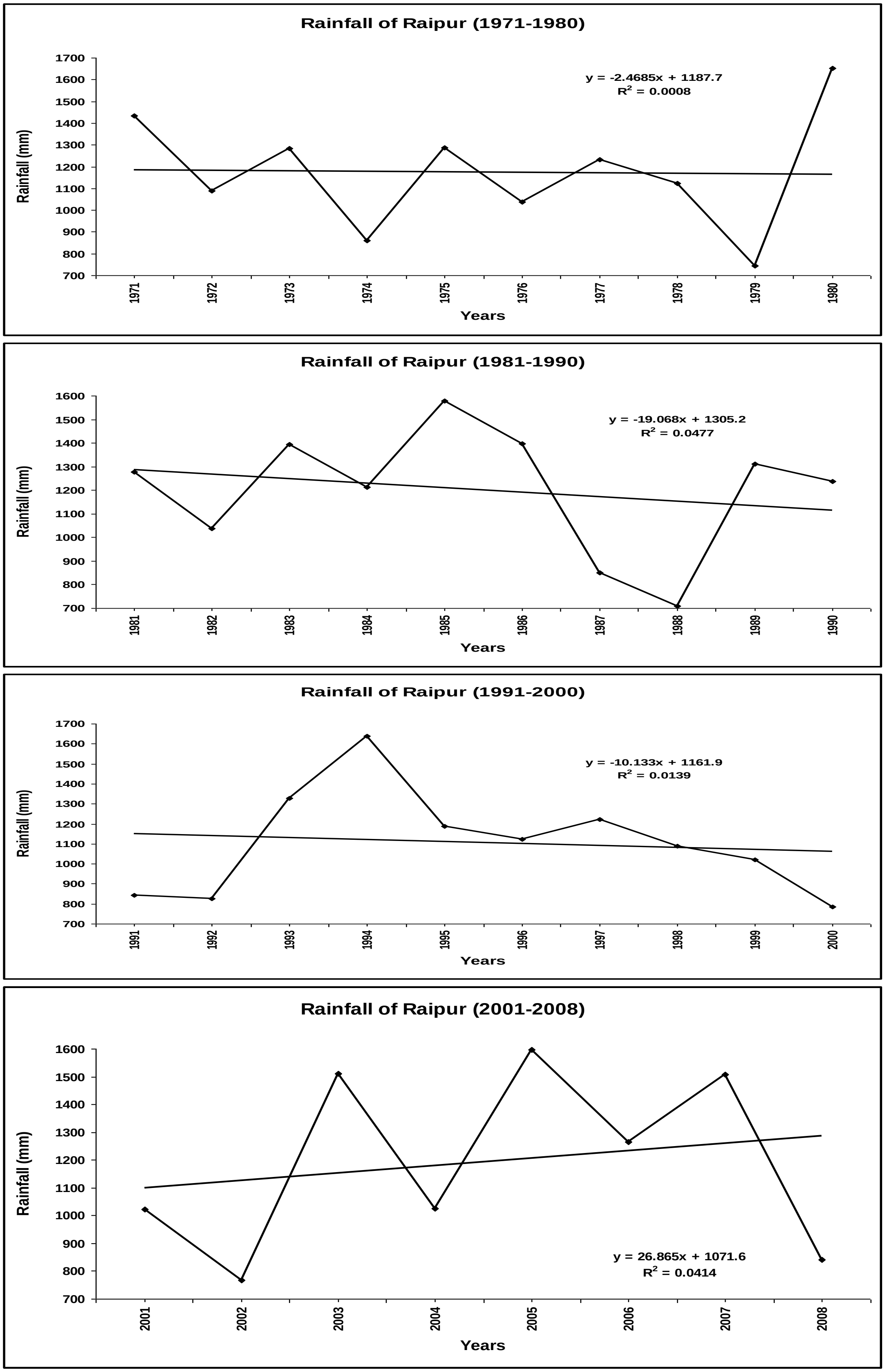


Fig 4.4 (a) : Annual decadal rainfall trend at Raipur

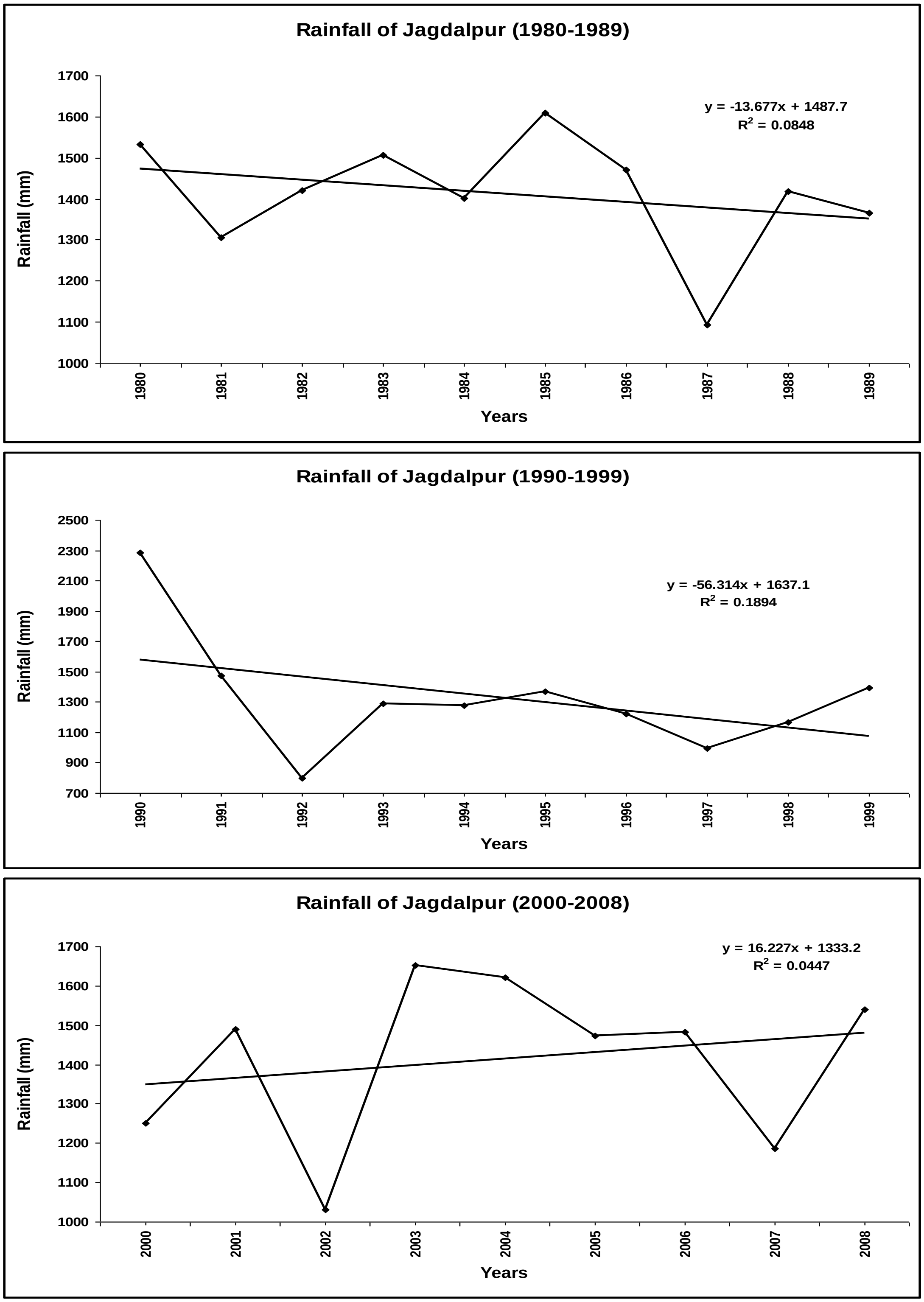
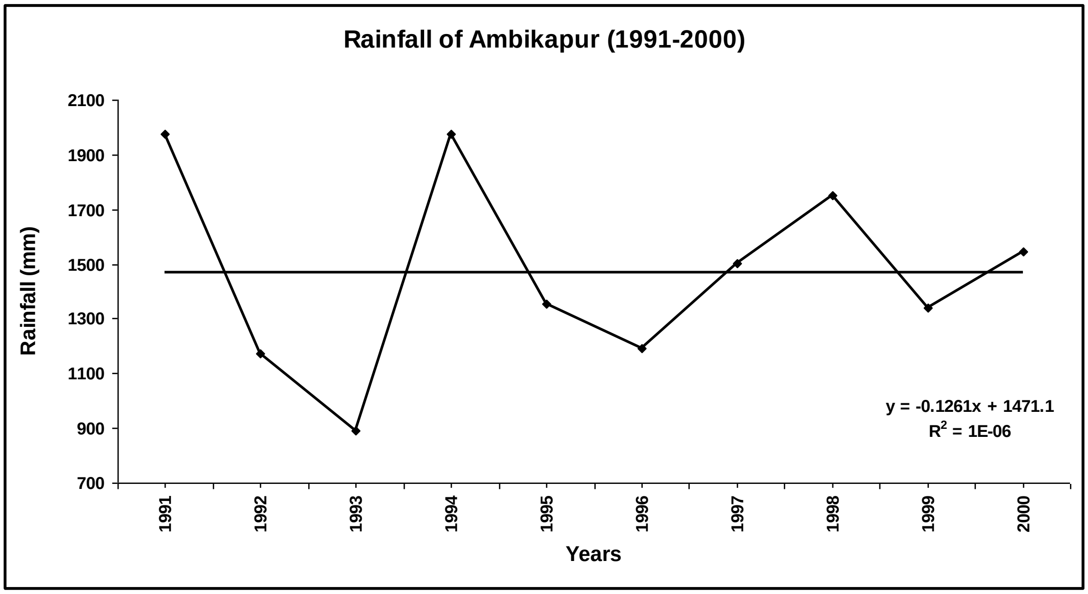


Fig 4.4 (b): Annual decadal rainfall trend at Jagdalpur



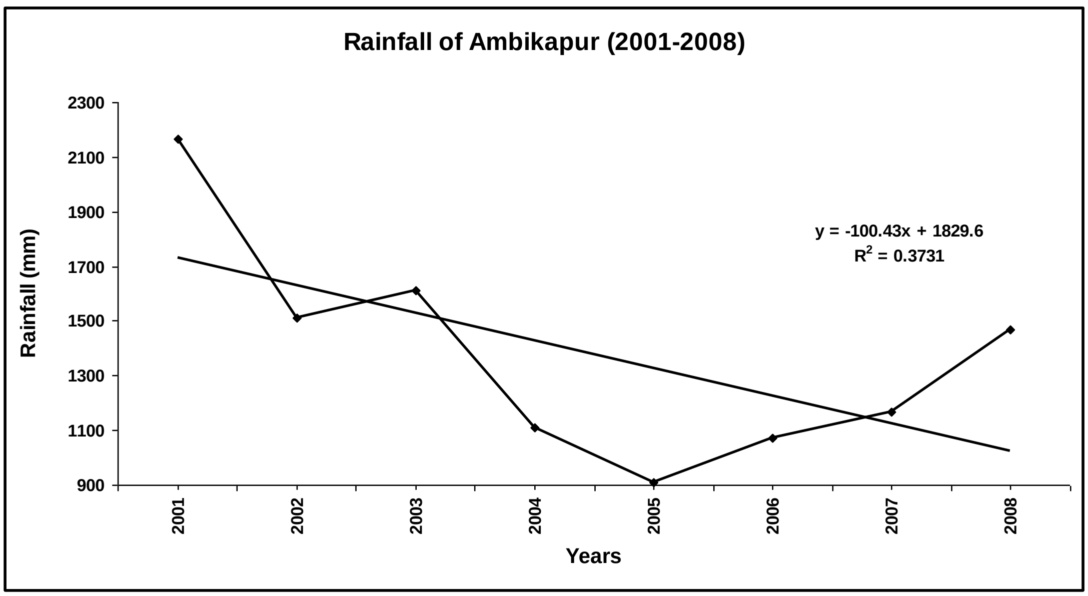
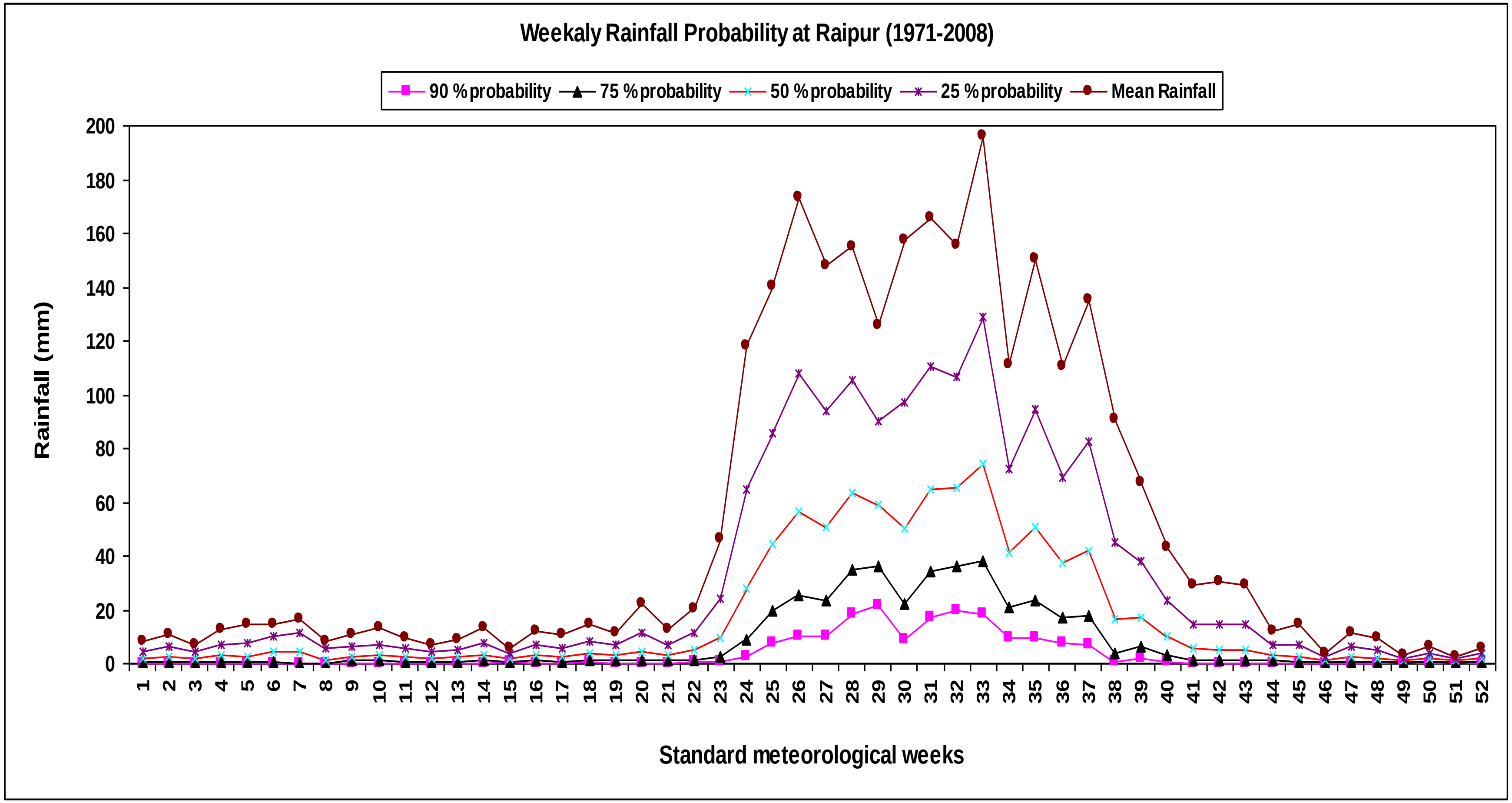


Fig 4.4 (c): Annual decadal rainfall trend at Ambikapur



Weekaly Rainfall Probability at Raipur (1971-2008)
90 % probability
75 % probability
50 % probability
25 % probability
Mean Rainfall
Rainfall (mm)
Standard meteorological weeks

Fig 4.8: Weekly rainfall probability at Raipur (1971-2008)

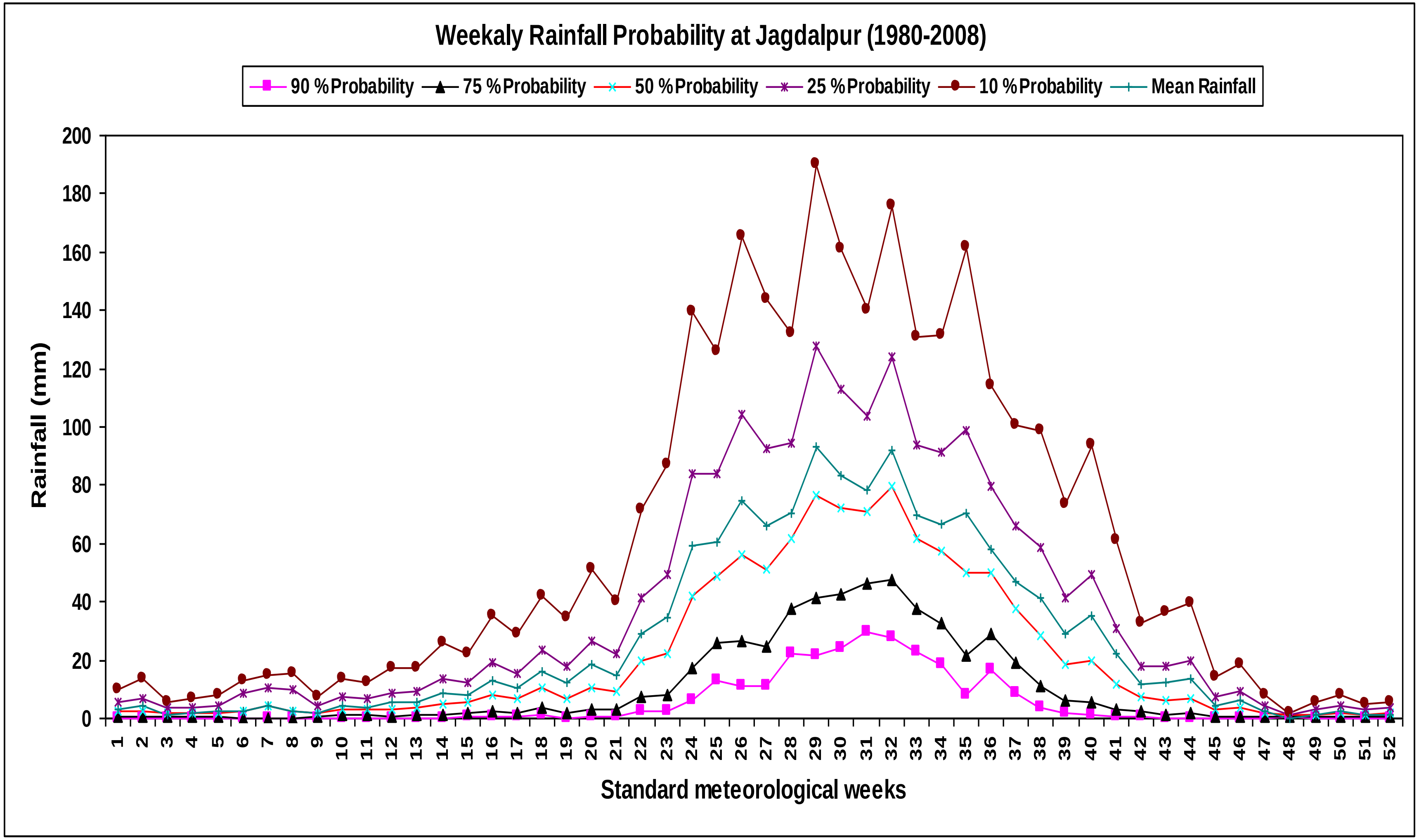


Fig 4.9:Weekly rainfall probability at Jagdalpur (1980-2008)

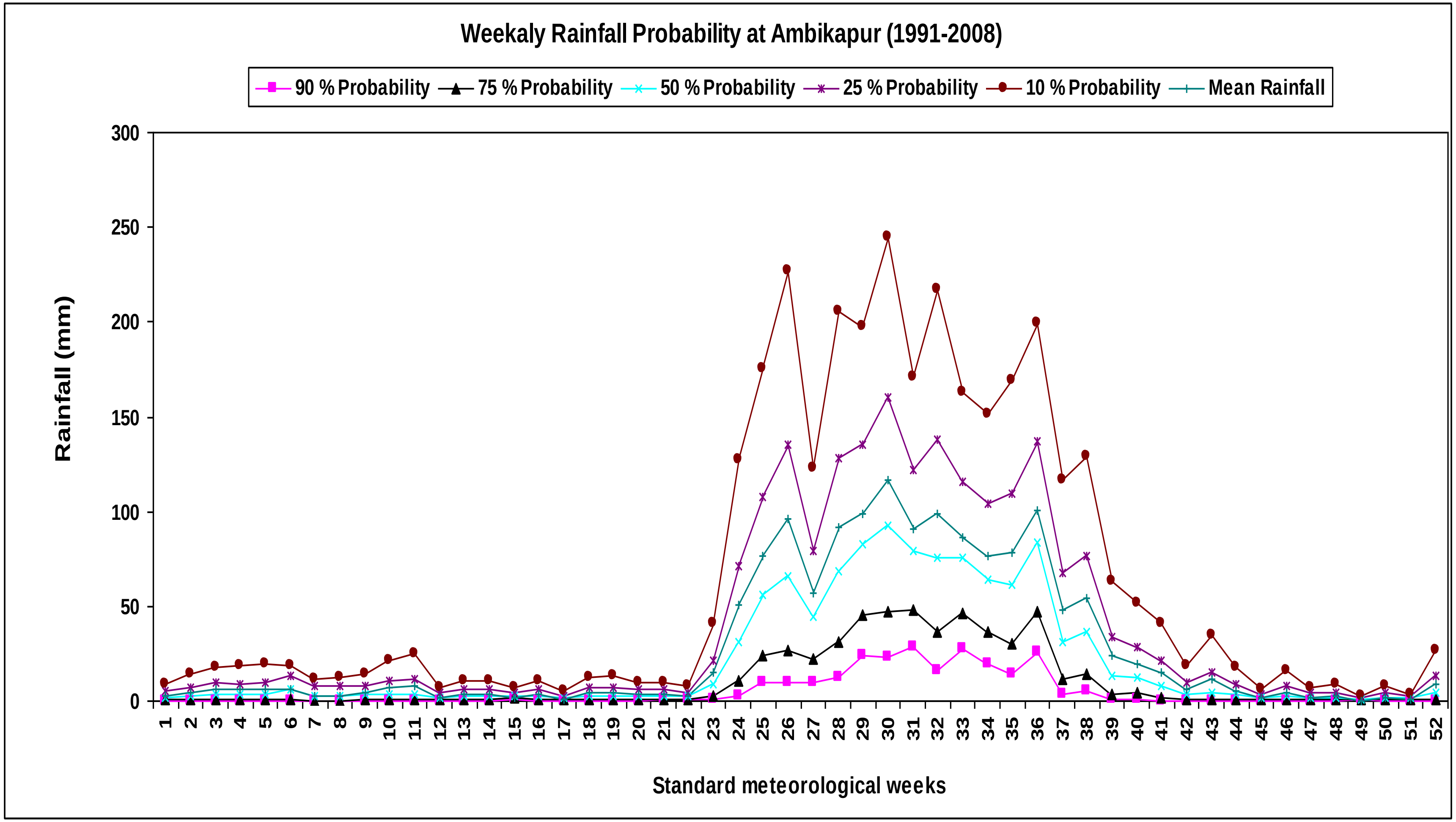


Fig 4.10: Weekly rainfall probability at Ambikapur (1991-2008)

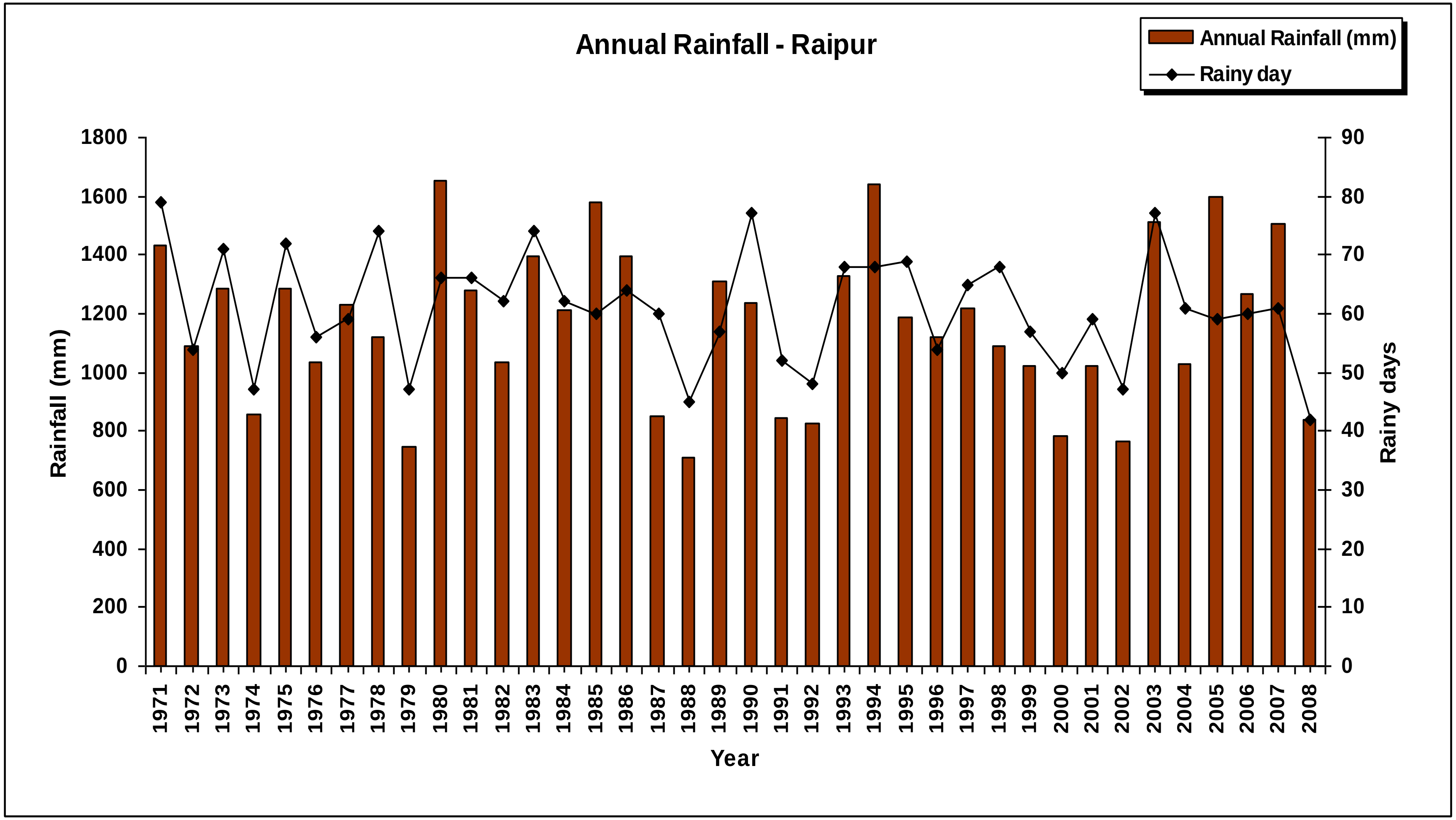


Fig. 4.1: Annual Rainfall-Raipur.

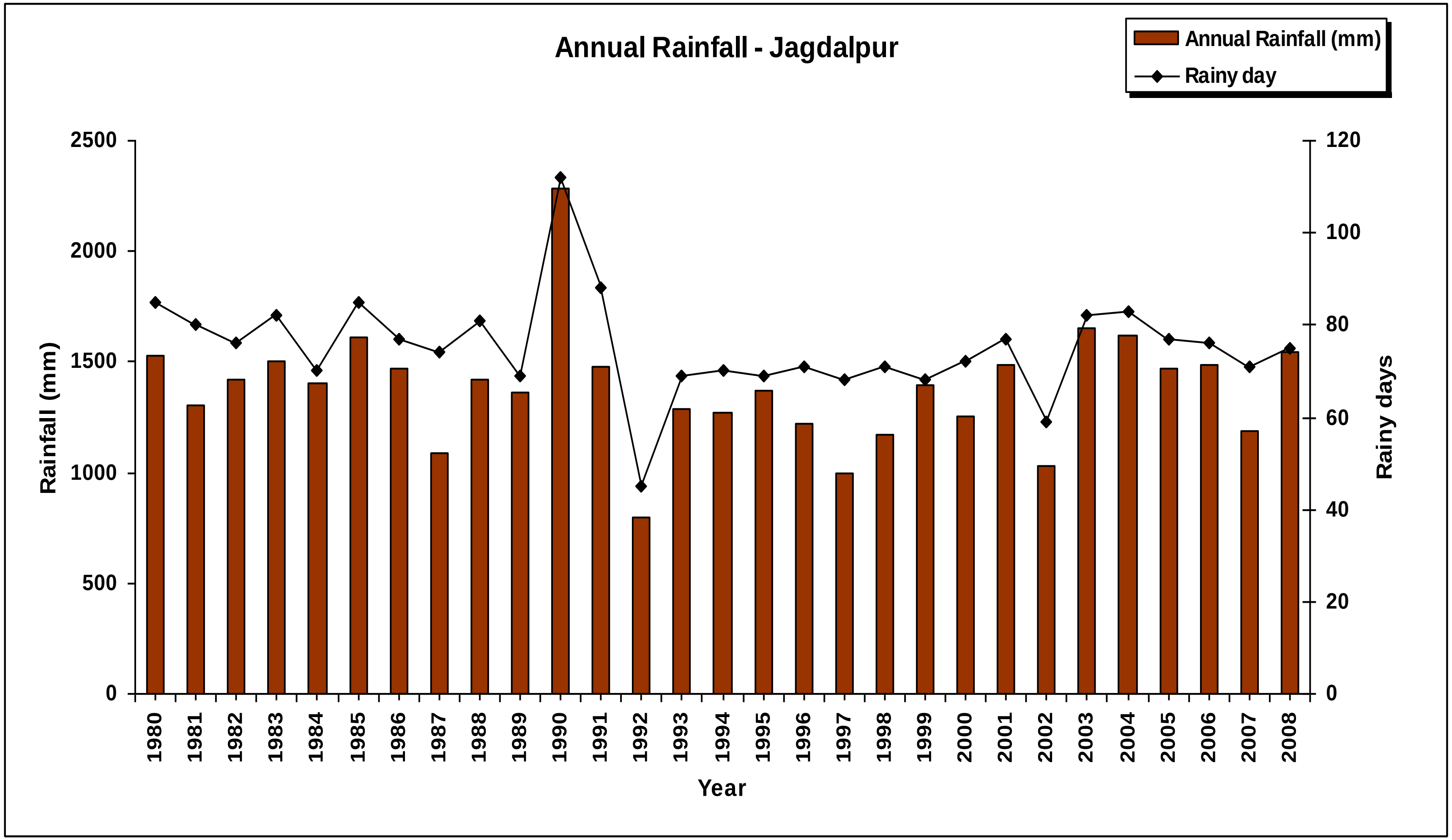


Fig. 4.2: Annual Rainfall-Jagdalpur.

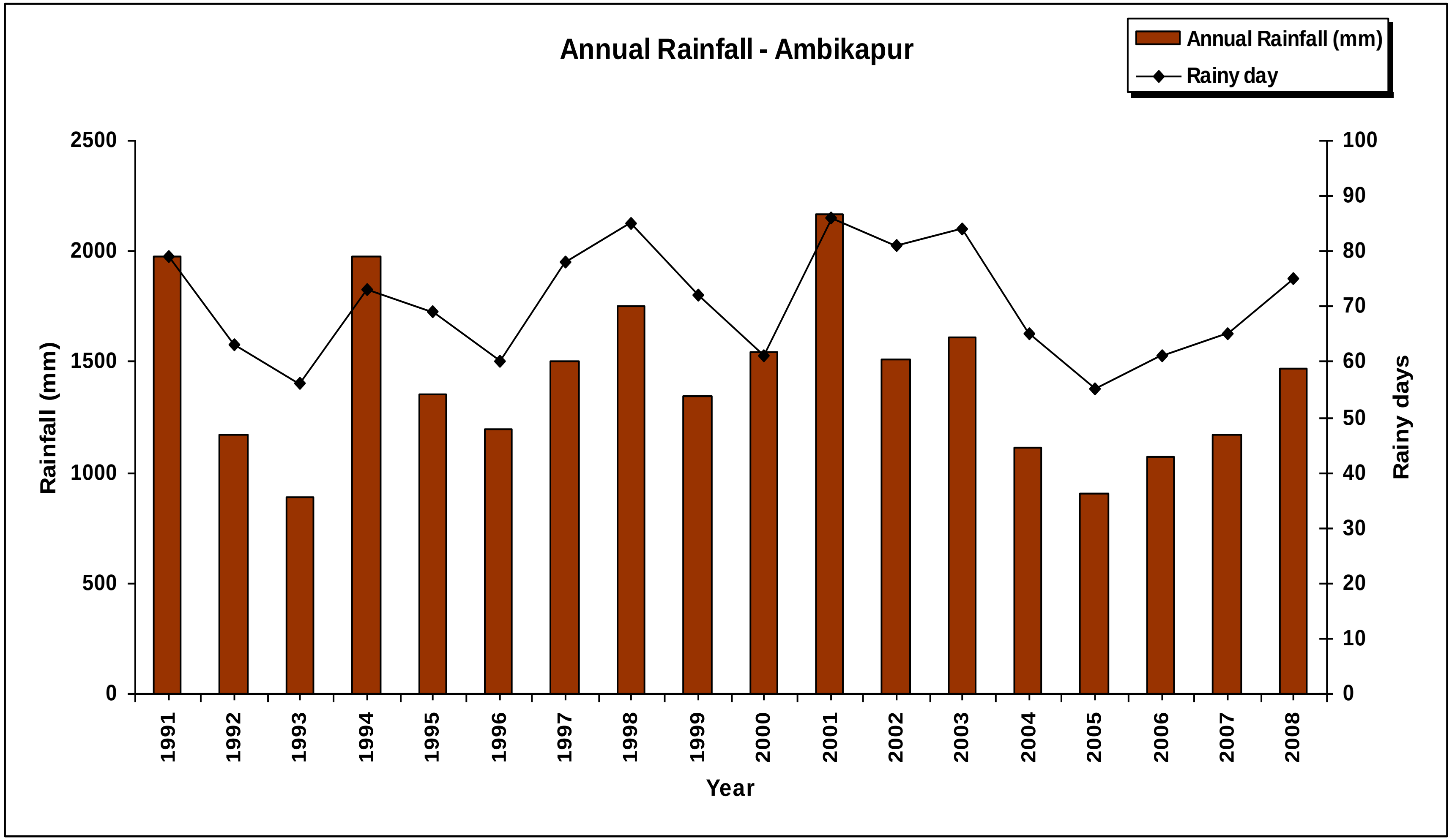


Fig. 4.3: Annual Rainfall-Ambikapur.