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Vulnerability to Climate Change: Adaptation Strategies and Layers of Resilience

Agro-climatic analysis of Climatic Trends in Semi-Arid Tropics of India (Andhra Pradesh and Maharashtra)

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Vulnerability to Climate Change: Adaptation Strategies and Layers of Resilience

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List of Abbreviations

AICRPAM	All India Coordinated Research Project on Agrometeorology
CRIDA	Central Research Institute for Dryland Agriculture
CV	Coefficient of variation
GCM	Global Climate Model
ICAR	Indian Council of Agriculture Research
IMD	India Meteorological Department
NEM	Northeast monsoon
NPCC	Network Project on Climate Change
RCM	Regional Climate model
SAT	Semi-Arid Tropics
SD	Standard deviation
SWM	Southwest monsoon

Definition of Key Concepts

Climate: Average weather or pattern of weather in a given period of time

Climate Change: The change in climate attributed directly or indirectly to human activity that alters the composition of global atmosphere and which is in addition to natural variability observed over comparable time periods. (UNFCCC)

Vulnerability: An indication of peoples' exposure to external risks, shocks and stress, and their ability to cope with and recover from the impacts. (DFID)

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. (IPCC)

Global warming: Greenhouse gases (GHGs) such as carbon dioxide, carbon monoxide and methane that are emitted into the atmosphere through human activities act like blanket to heat, which escape from the surface of the earth.

Biodiversity: The variety of living things on earth and their interactions with the environment. Scientists often categorize biodiversity into three components, ie, species, genes and ecosystems.

Ecosystem: A dynamic complex of plants, animals and micro organisms and their non-living environment interacting as a unit.

Exposure: The degree of climate stress upon a particular unit analysis; it may be represented as either long-term change in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events (IPCC).

Sensitivity: Sensitivity is the degree to which a system will be affected by, or responsive to climate stimuli (Smith et al. 2001).

Adaptive capacity: Adaptive capacity refers to the potential or capability of a system to adjust to climate change, including climate variability and extremes, so as to moderate potential damages, to take advantage of opportunities, or to cope with consequences (Smit and Pilifosova 2001).

Executive Summary

Climate resources inventory using micro-regional weather data is essential to understand and prepare the strategies to cope up with climate change/vulnerability over a region. Semi-arid Tropical (SAT) regions in India are vulnerable to climate extremes and the food grain production of these regions is often affected. Therefore, to prepare viable adaptation strategies to cope with climate risks, we carried out detailed climatic analysis with respect to rainfall and temperature variability in respect of four vulnerable districts, two in Andhra Pradesh (Anantapur and Mahbubnagar) and two in Maharashtra (Akola and Solapur). Before attempting to analyse the sub-district level data in these four districts, country- and state-wise (Andhra Pradesh and Maharashtra) climatic information was collected. Thematic maps showing the distribution of rainfall (on annual basis as well as in different seasons), and temperature maps, and maps on length of growing period, were prepared. The spatial distribution of the annual rainfall map in the SAT region indicates that for the most part, areas receive between 600 and 1000 mm rainfall, except in some pockets where it exceeds more than 1000 mm. In these regions, almost 80% of the annual rainfall is received during the southwest monsoon period (June-September). The length of growing period varied from 90 to 120 days in major parts of the SAT region of India. Trend analysis of the last 140 years of rainfall data showed no significant change in annual and seasonal rainfall. The projections of precipitation under A1B scenario as given by NATCOM 2010 indicate a 3–7% overall increase in all-India summer monsoon rainfall by the year 2030 with respect to the 1970s. However, on a seasonal scale, except in the Himalayan region, all regions are likely to have lower rainfall in the winter and pre-summer periods. Spatial patterns of monsoon rainfall indicate significant decrease over many regions except in some parts of the southern peninsula. PRECIS simulations for the 2030s indicate an all-round warming over the Indian subcontinent associated with increasing greenhouse gas concentrations. The annual mean surface air temperature rise by 2030 ranges from 1.7°C to 2°C. The season's temperature may increase by 2°C towards 2030. The variability of mean temperature may be more in winter months compared to summer months.

It is noticed from the state-wise rainfall analysis that the state of Maharashtra receives more annual rainfall (1240 mm) than Andhra Pradesh (940 mm). But, seasonal rainfall distribution indicated that Maharashtra receives almost 89% from the southwest monsoon (June – September) period and it is 68% in Andhra Pradesh as a significant amount of rainfall in Andhra Pradesh (22%) is received from the northeast monsoon (October–December) period. The future rainfall scenario indicated that in both the states annual rainfall would increase, but the increase would be more in Maharashtra than in Andhra Pradesh. Analysis of temperature data showed that maximum temperature (above 40°C) during summer was recorded in northern parts of both the states, and lowest minimum temperature was in northern Maharashtra. Future scenario of temperature shows that maximum temperature would rise by about 3.4°C in Maharashtra and 3.6°C in Andhra Pradesh at the end of this century compared to the base line period (1961-1990). However, the annual minimum temperature increase will be around 4.5°C in both states, and the highest increase would be during northeast monsoon period.

Climatic data for four agromet stations, Anantapur, Mahbubnagar, Akola and Solapur representing the districts of the study area, was collected for the period 1971-2010. Station-wise climatic trends with respect to rainfall and temperatures, probabilities of occurrence of meteorological and agricultural droughts, occurrence of extreme events and climatic shifts have been analyzed. Rainfall analysis revealed that the lowest annual rainfall (547 mm) is received in Anantapur and highest in

Mahbubnagar (786 mm), while Akola and Solapur receive around 720 mm annual rainfall. A five-year moving average of rainfall indicated a cyclic pattern in annual rainfall at all locations except in Solapur, where a short-term fluctuation in rainfall was found. The findings from these analyses show conformity with the findings at national and regional levels. At all the four locations, the main rainy season is the southwest monsoon, and almost 86% of the annual rainfall is received during this season at Akola. It is around 70–75% for Mahbubnagar and Solapur. Anantapur receives 61% of the rainfall from the southwest monsoon and 27% from the northeast monsoon. Regarding the trend of annual maximum temperature, all locations showed an increasing trend (at 1% significant level) except in Akola where a declining trend was observed (at 5% significant level). The trend in annual minimum temperature indicated that other than Anantapur, all the three stations exhibited an increasing trend (at 5% significant level). Meteorological drought analysis revealed that the probability of occurrence of mild drought is highest in Akola (21%) and Solapur (21%) and lowest in Anantapur (13%), and in the case of moderate drought, the highest probability is found in Solapur (23%) followed by Mahbubnagar (16%) and Anantapur and Akola (13%). Perhaps better rainfall conditions in the early as well in the last decade at Anantapur contributed to the recording of fewer numbers of meteorological droughts. However, a chance occurrence of severe drought is more at Anantapur (11%). The trend in heavy rainfall events indicated that there is no evidence of increasing or decreasing trend at Anantapur and Akola. But the frequency of days with rainfall of 25–50 mm/day and 50–75 mm/day in Mahbubnagar and 75–100 mm/day in Solapur has increased in recent decades compared to earlier decades. Extreme temperature event analysis revealed that frequency of days with day time temperature above 40°C during summer (Mar – June) has increased in recent decades at Anantapur, Mahbubnagar and Solpaur. This is in conformity with the increased number of warmest years in the recent decade. On the other hand, at Akola, the occurrence of high temperature events has been declining in the past 40 years. Declining tendency in occurrence of extreme minimum temperature (7-10°C) during winter (Nov – Feb) at Solapur was noticed, whereas no such trend was noticed in the remaining three stations.

In order to study the spatial variability in rainfall and drought patterns within the district, sub-district (mandal) rainfall data for the period 1980-2009 was used and maps were prepared. The significance of the changes has been worked out using the Mann-Kendall test for different probability levels. The analysis of annual and southwest monsoon rainfall indicated that there is no significant increasing / decreasing trend in most of the mandals / tehsils of all four selected districts. However, the number of mandals that showed an increasing trend in annual rainfall were more in Anantapur district than in Mahbubnagar district. But in Akola and Solapur districts there was either a decreasing or no trend noticed. The spatial variability of different parameters suggests the need to generate micro regional data to capture the actual change that occurred at sub-district level, and which affected the agricultural production and the socio-economic conditions of the farming community. The climatic resource analysis would also help the authorities to prepare contingency plans for coping with climate risks by evolving suitable rural livelihood programs.

Climatic water balance analysis revealed that majority of times all the four stations, Akola, Solapur, Mahbubnagar and Anantapur remained well within their climate types and no permanent change from their normal climate type was observed. The changes in water requirements of crops for the years 2020, 2050 and 2080 have been worked out for the major crops - groundnut (Anantapur) and sorghum (Mahbubnagar). The results of the study clearly indicate that the impact of climate change could increase crop water requirements and influence negatively on yield levels unless their need is fulfilled through other resources. It is big challenge in the coming decades to increase the

food production with less water, particularly when the major river basins will have limited water resources and there is a reduction in ground water availability.

1. Introduction

Climate is perceived to be changing continuously all over the world and it has always been a matter of great concern due to its adverse impacts on the farming community and developmental agencies. Extreme climate events together with increase in rate of change in climatic parameters could affect various livelihood sectors including water, agriculture, human health, tourism, transport and energy. Reducing vulnerability of the system to climate change by adaptation and mitigation processes through various potential options, emphasizes the importance of climatic data analysis. It has been understood that a wide array of adaptation options are available, but more extensive adaptation measures are required to reduce vulnerability of ecosystems to climate change. In the realm of climate change impacts and related unnerving environmental and socio-economic challenges, attempts have been made to protect available valuable natural resources - land, water and associated biological ecosystems - which are being degraded at a fast rate and are threatening the food security, especially of developing countries. Impacts of extreme weather events and disasters that could cause hunger and susceptibility to disease and poverty would affect the very existence of human life on earth. Hence, it is important to channelize natural resources to allow assessment of climatic trends that can impose great impacts on agriculture and its dependent sectors, and so influence the economies of rural populations. Analyzing current climate trends will certainly act as a precursor for the realization of future climate change and variability (CCV), targeting specific sectors/regions and prioritizing research needs to help rural farming communities cope with climate risk and associated impacts. Climatic analysis is thus essential to understand the variability and trends of various/important weather parameters and their impact on agricultural production systems.

1.1. The rationale – semi-arid tropics of India

In India, rainfed agriculture extends over 87 million ha and constitutes nearly 61% of the net cultivated area. Crop cultivation in semi-arid regions is risky due to the large variability in rainfall both in space and time. It is important to analyze the distribution of climatic resources in semi-arid regions of India for better agricultural crop planning and sustainable production (Sivakumar et al. 2005). In addition, it enables us to adjust our farming and non-farming management decisions to reduce the negative impact resulting from these changes. Approximately 380 million people (45% of total Indian population) live in the rural areas of the Indian SAT regions and are primarily dependent on farming for their livelihoods. (Figure 1).

1.2. How important is it to analyze past climate?

Climate trends are highly related to agricultural production, natural resources and economic status of the community. Farming in semi-arid tropical regions is highly rainfall dependent, and any fluctuation in its occurrence, with respect to its quantum and duration, affects the micro- and macro-economy of a country. Greater fluctuations in climate can drive the economy backwards, pushing down the country from a developing to an under-developed one. Farmers in arid and semi-arid tropics are highly climate sensitive compared to their counterparts in other agro-ecological regions of the country. Among the set of climatic parameters, rainfall has been crucial

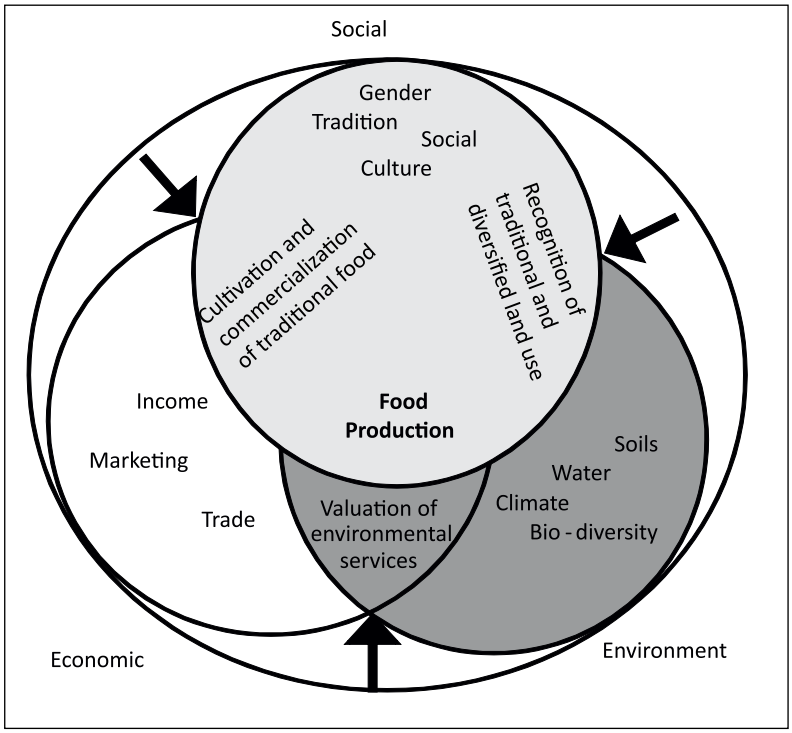


Figure 1. Multi-functionality of agriculture in SAT regions of India.

Source: IAASTD (2008)

in determining the extent of productivity from agricultural farming. Both excess and deficit rainfall patterns that result in floods or droughts hamper the farming output. A substantial amount of work with respect to rainfall and temperature variability trends in India at the macro level has already been carried out by various research organizations such as India Meteorological Department (IMD), Indian Institute of Tropical Meteorology (IITM) and the Indian Council of Agricultural Research (ICAR). However, little information is available at the micro-scale covering mandals/blocks. As variability in weather parameter is observed at the micro level, it is highly desirable to analyze the micro level (sub-districts) data for better understanding of the phenomena, and to work out suitable strategies to reduce the impacts due to climate extremes. To arrive at the best results of climatic analysis, it is desirable to have at least weather data sets for a minimum period of 20-30 years. However, there are limitations in obtaining the long term climatic data at sub-district level and it could be overambitious at the village level.

The primary objective of this study is to analyze long term climatic trends at the sub-district level in the representative study region of SAT India and relate it with agricultural output. With the objective of Impact Assessment, the probabilities of droughts of different intensities within regions prone to drought, have been worked out. Similarly, the changes in crop water demand was also computed. An attempt to summarize future climate factors such as atmospheric temperature, precipitation and atmospheric carbon-dioxide was carried out and the output was used to run crop simulation models to assess the impacts on production. Per se analyses of studies on the impact of climate change on semi-arid agriculture, and on available natural resources and associated socio-economic implications on rural farming household livelihoods in these regions have also been attempted.

2. Methodology

The India Meteorological Department (IMD) (Climatological Normals) has been the primary source for climatic normal of basic parameters viz. maximum temperature, minimum temperature, rainfall, relative humidity (morning & evening), sunshine hours and wind speed, for 300 stations spread across the country for the period 1951-1980. Application programs were developed for computing Potential Evapo-transpiration (PET) using a modified Penman method and water balance parameter computation using the Thornthwaite and Mather (1955) method. The derived climatic water balance parameter Index of Moisture Adequacy (IMA), defined as the ratio of Actual Evapo-transpiration (AET) of PET, has also been estimated. The map of the length of the growing period derived from climatic water balance computation for the Indian region was collected from the National Bureau of Soil Survey & Land Use Planning (NBSS & LUP) published source (Mandal et al. 1999). Thematic maps showing the spatial distribution of maximum and minimum temperature, rainfall and index of moisture adequacy (IMA) for the SAT Indian region have been prepared by superimposing the geo-referenced maps of the SAT regions over the climatic maps prepared for the whole country at the Central Research Institute for Dryland Agriculture (CRIDA) using the GIS spatial analysis program.

Long term observed climatic parameters of stations–Anantapur, Mahbubnagar, Akola and Solapur–from the All India Coordinated Research Project on Agro-meteorology (AICRPAM) of CRIDA, Hyderabad were collected. The basic climatic parameters, daily maximum and minimum temperatures, and rainfall for the period 1971-2009 were analyzed both on annual and seasonal basis, ie, winter (Jan-Feb), summer or pre-monsoon (Mar-May), southwest monsoon (Jun-Sep), northeast monsoon or post-monsoon (Oct-Dec). The weather data sets were subjected to different types of climatic analyses using the Weathercock utility program developed at the Central research Institute for Dryland Agriculture, Hyderabad (CRIDA 2009). Weekly rainfall data were analyzed for initial and conditional probabilities and the probability for consecutive wet and dry weeks. Drought analysis, including meteorological droughts on annual rainfall departure and agricultural drought based on periods of weeks that received less than 50% of normal rainfall continuously for a period of at least 4 weeks during southwest monsoon season and their probabilities, were analyzed. Climate variability and decadal changes in extreme events in temperature and rainfall were also analyzed for the study districts. Thematic maps, figures and tables showing trends and variability of different climatic parameters were made for better visual interpretations.

3. Semi-arid regions of India: General climatic characteristics

India is endowed with varied agro-climatic regions, ranging from tropical in the South to temperate and alpine in the Himalayan North, where higher altitude regions receive substantial snowfall in winter. Generally, major parts of India are covered by tropical wet and tropical dry climates. The semi-arid tropical (SAT) areas can be further classified into hot and cold. Some portions of the state of Jammu and Kashmir are covered by cold arid to semi-arid areas, while the hot semi-arid regions spread across 10 states–Andhra Pradesh, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh–where mostly rainfed agriculture is practiced. Crop cultivation in semi-arid regions is highly risky due to a higher coefficient of variation (CV) in rainfall both in space and time.

3.1. Rainfall distribution in SAT regions of India

The spatial distribution of annual rainfall in the SAT region indicates that most areas receive rainfall between 600 and 1000 mm, except in some pockets where it exceeds 1000 mm (Figure 2). In these regions, almost 80% of the annual rainfall is received during the southwest monsoon period (Jun-Sep) except in Tamil Nadu, which receives around 51% in the SWM period and the remaining 49% in the NEM period (Oct-Dec). The southwest monsoon season otherwise called as *kharif*, is the main crop growing season in the semi-arid regions. The normal onset and withdrawal of the southwest monsoon is shown in Figure 3 and 4. The onset of the monsoon season occurs in early June over the southern parts of SAT region, whereas its arrival in the states of Gujarat, Haryana, Madhya Pradesh, Punjab, Rajasthan and Uttar Pradesh is at the end of June. The withdrawal of the monsoon starts around the first week of September from northwestern parts and ends by mid-October in the southern parts of the SAT region. With the withdrawal of the SWM current, The NEM (Oct-Nov) sets in over the southern peninsular comprising the areas of south coastal Andhra Pradesh, Karnataka, Tamil Nadu and parts of Kerala. Insufficient amounts of rainfall are received during winter and summer seasons in the area under study. The mean monthly rainfall data revealed that July is the wettest month of the year, except in the state of Tamil Nadu, where the heaviest precipitation is seen in October/November.

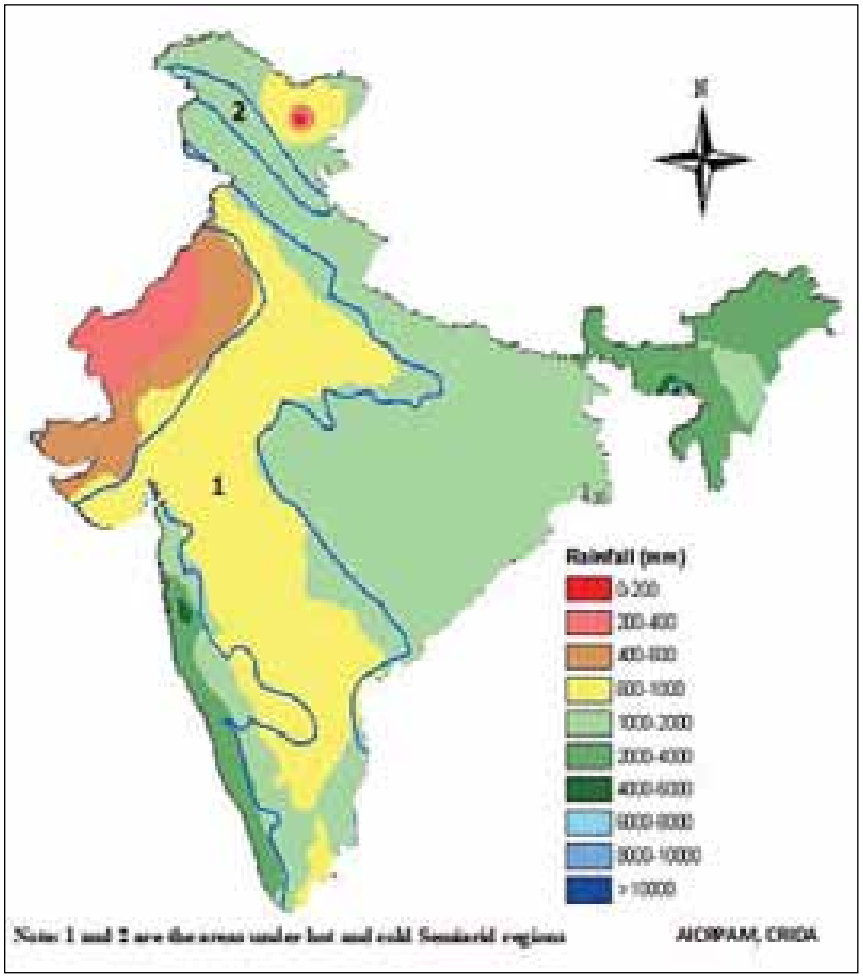
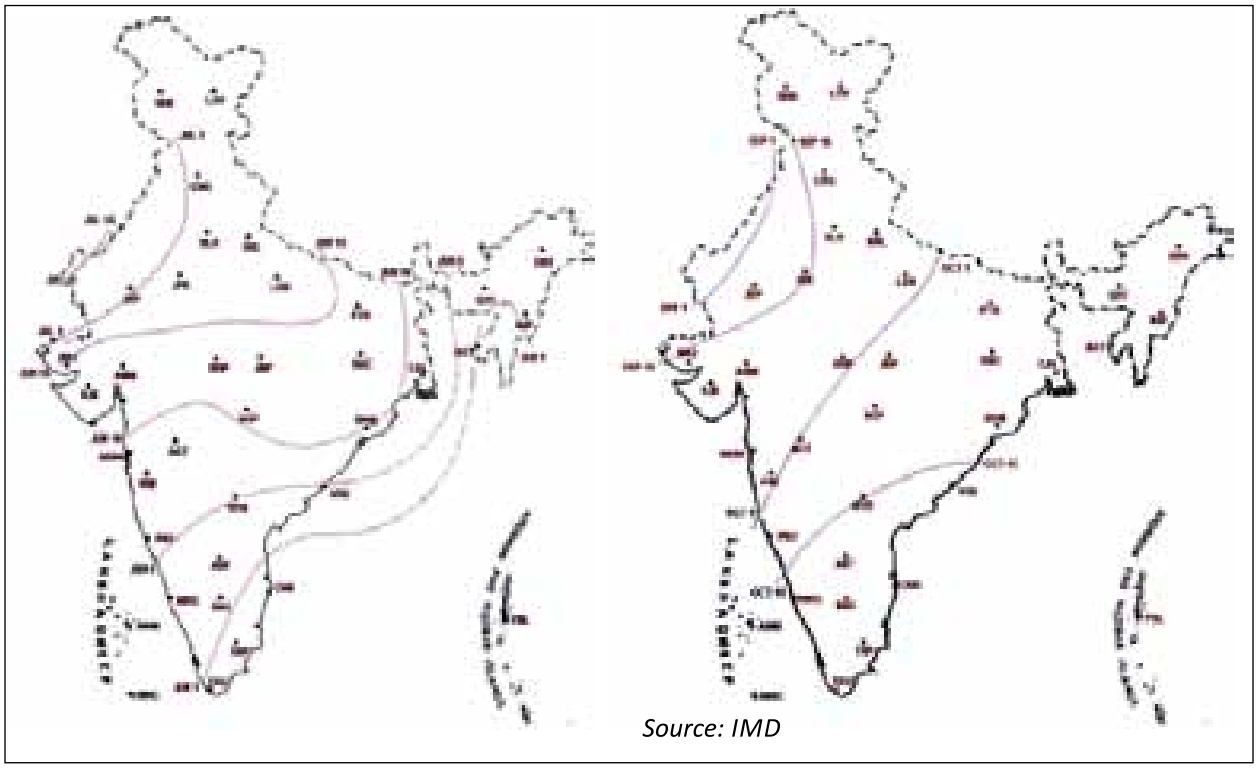


Figure 2. Mean annual rainfall distribution in SAT regions of India.



Source: IMD

Figures 3 and 4. Normal dates of onset and withdrawal of southwest monsoon over India.

3.2. Seasonal rainfall distribution

Rainfall distribution during the SWM, NEM, winter and summer seasons over the SAT region of India are shown in Figure 5. The principle rainy season of the country is the southwest monsoon period and most parts of semi-arid region receive rainfall in the 600–1000 mm range. However, some regions, ie, Rayalaseema in Andhra Pradesh, South interior Karnataka and Tamil Nadu, receive about 400-600 mm rainfall and some parts of coastal Tamil Nadu receive 200-400 mm rainfall.

The contribution of the NE monsoon rainfall during Oct-Nov is minimal over the greater part of the country, except in the SAT regions of Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu. During this period, the extreme south of the SAT region, ie, Tamil Nadu, receives 400-800 mm, which is half of the annual rainfall for that state. In Rayalaseema and South interior Karnataka, rainfall is about 200-400 mm during the post-monsoon season, and it is scanty during summer. Precipitation of around 200 mm due to convective/thunderstorm activity is received during summer season, while it is around 200-400 mm in some parts of Karnataka and Tamil Nadu. Though the occurrence of rain during winter is very infrequent, western disturbances during this season bring in less than 200 mm rainfall in the northern SAT regions.

3.3. Mean annual and seasonal rainy days in SAT region of India

The mean number of rainy days (≥ 2.5 mm /day) on an annual basis as well as season-wise over the country is given in Figure 6. The major part of the SAT region of the country receives the annual rainfall in 30 to 50 days. However, in the southern part it varies from 50-70 days as this region

receives rainfall from both SW and NE monsoons. The number of rainy days during winter varies from about 0 to 3 days except in the northern limit of the hot SAT regions where it varies from 3 to 6 days due to the western disturbance. In the cold SAT regions covering the states of Jammu and Kashmir and Himachal Pradesh, it varies from 9 to 12 days. The number of rainy days recorded during summer in the southern SAT regions is about 5-10 days due to better pre-monsoon activity as compared to the rest of the SAT region, where rainy days vary from 0 to 5 days. The number of rainy days during the monsoon season varies from 30 to 40 days in the parts of the North, central and southern SAT regions. The number of rainy days decreases to 20-30 days in parts of northwestern SAT and adjoining arid regions of the country, and also in the southern region comprising parts of southern Andhra Pradesh, Karnataka and Tamil Nadu. In the extreme southern parts, the number of rainy days continue to decrease to 10-20 days. During the NEM season, it is observed that the southern SAT regions receive higher number of rainy days (25-30) compared to the northern region, decreasing to 5-10 days in central parts and <5 days in rest of the region.

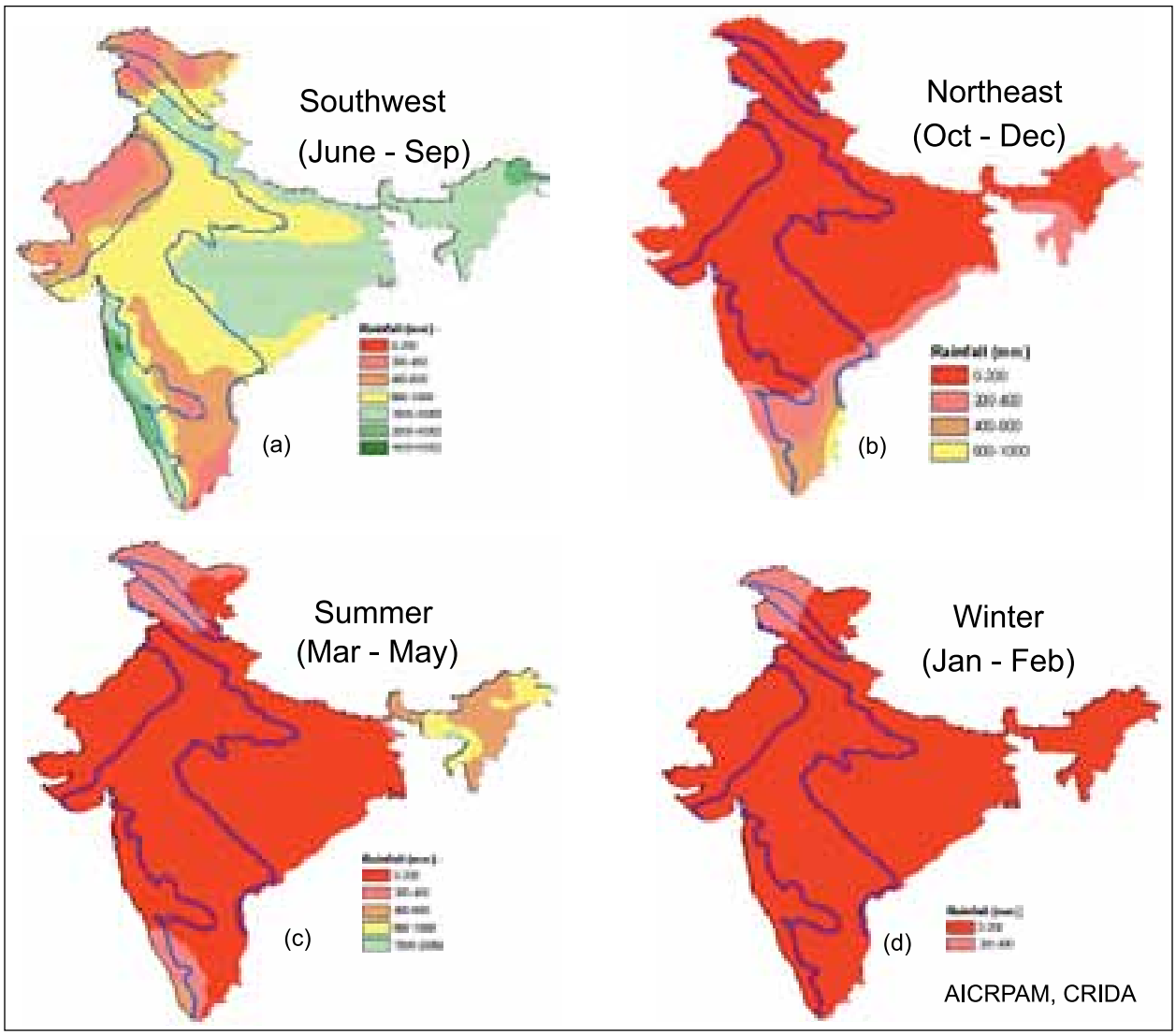


Figure 5. Seasonal rainfall distribution in SAT regions of India.

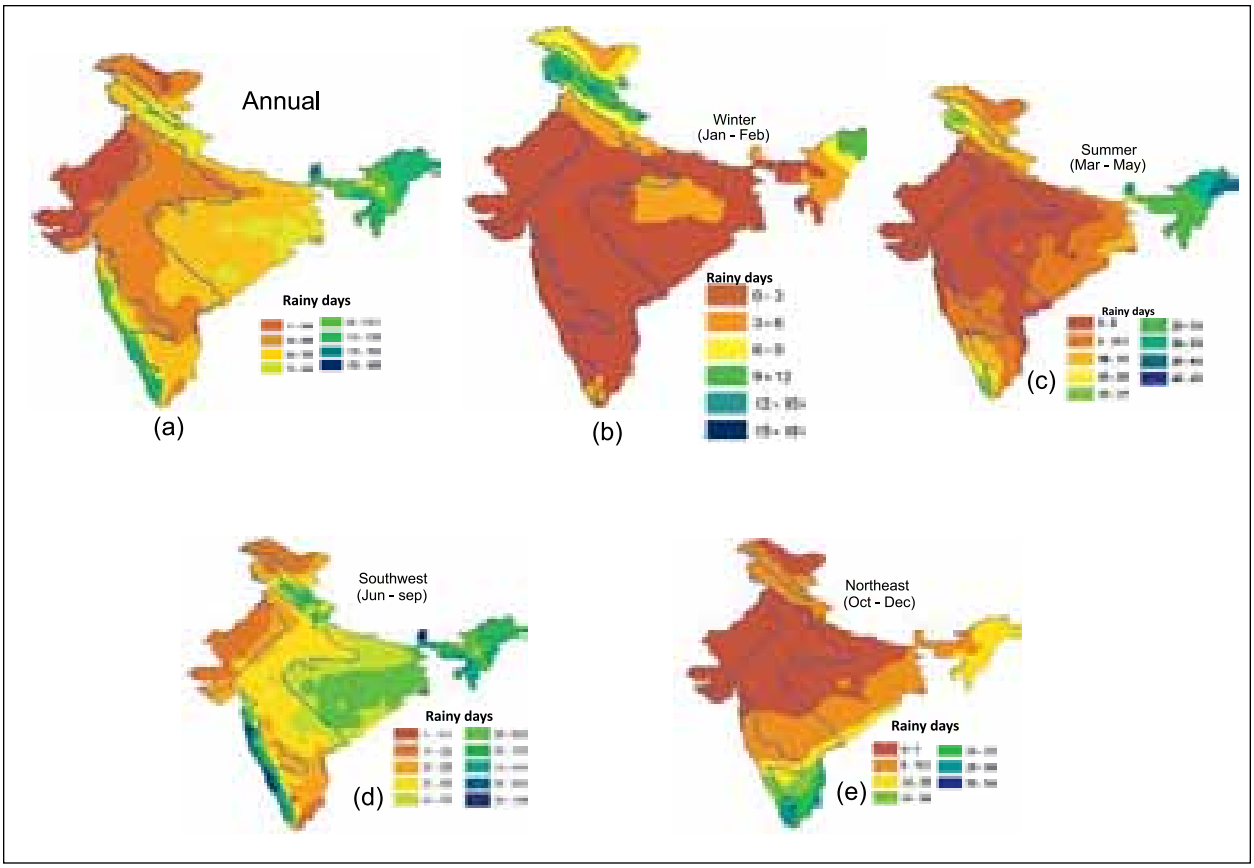


Figure 6. Mean annual and seasonal rainy days in SAT regions of India.

3.4. Distribution of maximum and minimum temperature

3.4.1. Maximum temperature

Spatial distribution of maximum temperature during January, May, July and October representing the seasons winter, summer, southwest monsoon and post-monsoon are shown in Figure 7. The distribution of maximum temperature during January reveals that it increases from 15-20°C in the northern part to 25-30°C in the southern part of the SAT region. May is the hottest month of the year and the average values during this period in northern parts of Maharashtra and Andhra Pradesh is in the range of 40-45°C. In other parts of the region values vary from 30 to 40°C. With the onset of the monsoons, the temperature over the entire SAT region reduces to the range of 30-35°C and in areas in the South adjacent to Kerala, Karnataka and Maharashtra, it is around 25-30°C. With the withdrawal of the monsoon, almost the same pattern of maximum temperatures of July is observed October in the entire SAT region. However some parts of Gujarat, adjacent to the arid region, recorded higher temperatures ranging from 35 to 40°C.

3.4.2. Minimum temperature

Spatial distribution of mean monthly minimum temperature during January, May, July and October (Figure 8) indicated that during January the minimum temperature in the SAT region varies from 5-10°C in the northern parts, to 10-15°C in the central parts and 15-20°C in the southern parts. The southern coastal region of Tamil Nadu recorded minimum temperatures in the range 20-25°C in

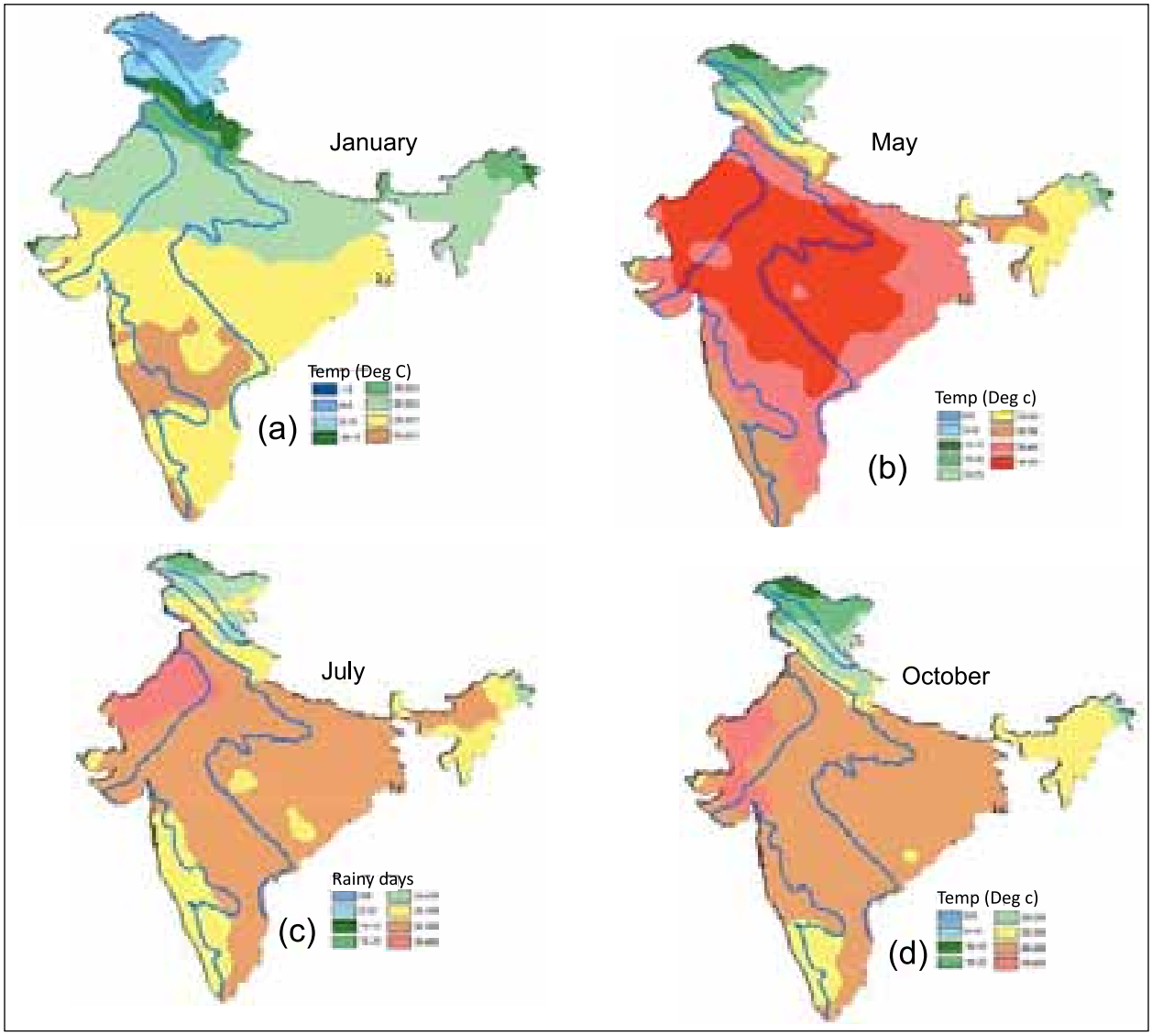


Figure 7. Mean monthly maximum temperature distribution in SAT regions of India.

January. During May, which is in the summer season, minimum temperature values over the greater part of SAT regions vary from 25 to 30°C. Also, lower temperature values of 20-25°C were recorded in the southern as well as in the northern part of the SAT regions.

During July, the central and southern part of the SAT region recorded the temperatures of 20-25°C, while higher values (25-30°C) were recorded in the northern part of the SAT region. During October, which is representative of the post-monsoon season, the temperatures in the northern and central part of the SAT region ranged between 15-20°C, while the rest of the area recorded temperatures around 20-25°C.

3.4.3. Index of Moisture Adequacy (IMA)

Index of Moisture Adequacy (IMA), which is defined as a ratio of actual evapotranspiration (AET) to the potential evapotranspiration (PET), is derived from water balance computation of procedure

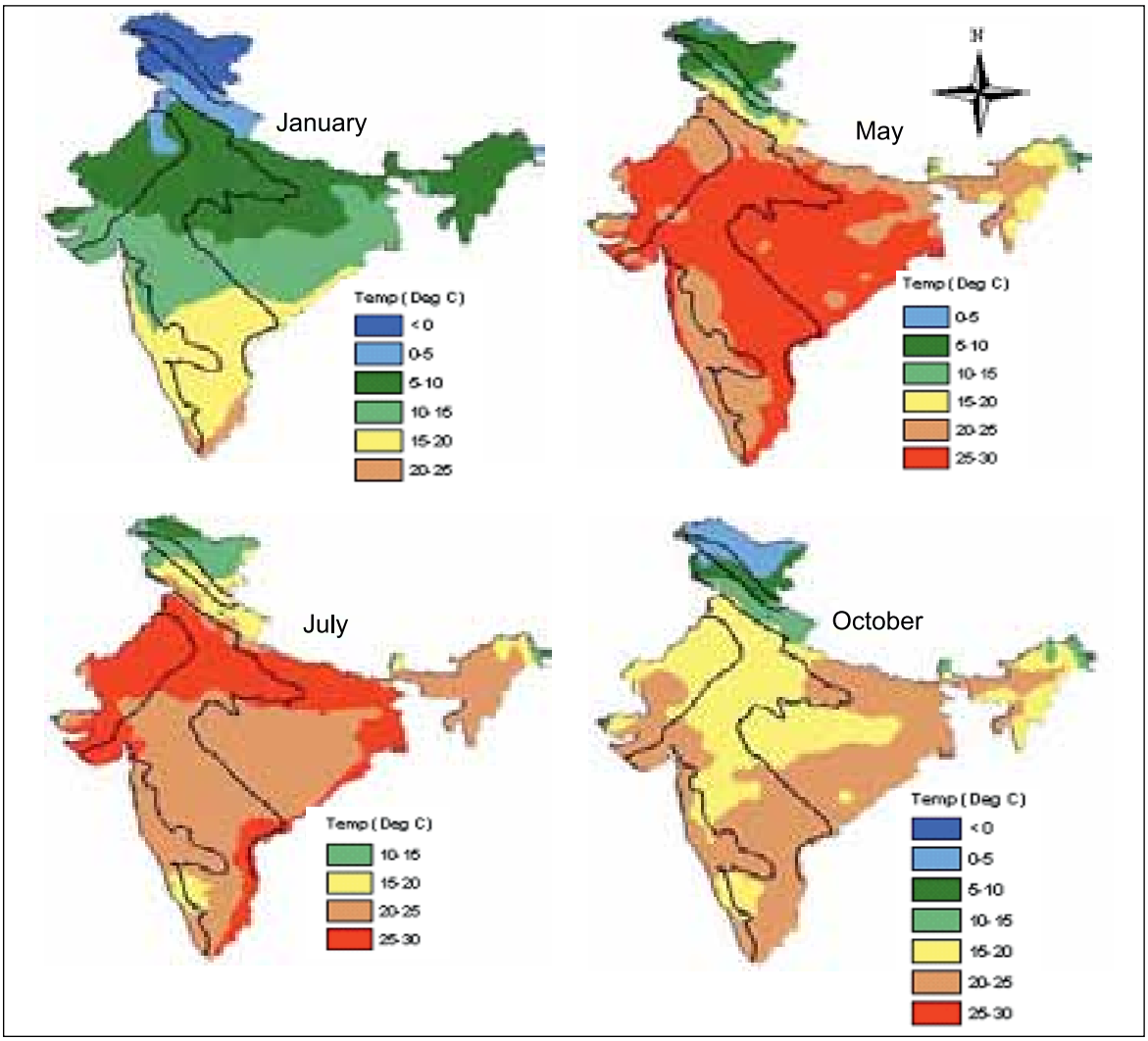


Figure 8. Mean monthly minimum temperature distribution in SAT regions of India.

of Thornthwaite and Mather (1955). The month-wise IMA values have been computed and spatial distribution IMA values, for the months of June, July, August and September, representing the southwest monsoon season, is shown in Figure 9. The IMA values during June were above 0.6 in the central portion of the SAT region, while the values decreased to 0.2 in the northern portion and 0.4 in the southern portion. In the coastal Tamil Nadu region, the values ranged from 0.2 to 0.4. With the advancement of the monsoon in July, the IMA values in the greater part of the SAT region ranged from 0.8 to 1.0 while it was less than 0.6 in the southern region. During August and September, the IMA values over the greater part of the SAT regions remained 0.8 to 1.0, except in the deep southern part where the values ranged from 0.4 to 0.6.

3.4.4. Length of growing period (LGP)

Length of Growing Period (LGP) is defined as the period during which rainfall is always more than half of the PET. This includes the period of soil moisture storage at the end of rainy season and winter rainfall. The National Bureau of Soil Survey and Land Use Planning estimated the LGP using monthly PET and rainfall as shown in Figure 10.

From Figure 10 it is observed that the LGP varies from 120-150 days in parts of Andhra Pradesh, Haryana, Karnataka, Madhya Pradesh, Punjab, Tamil Nadu and Uttar Pradesh. However, for the most part the LGP varied from 90-120 days.

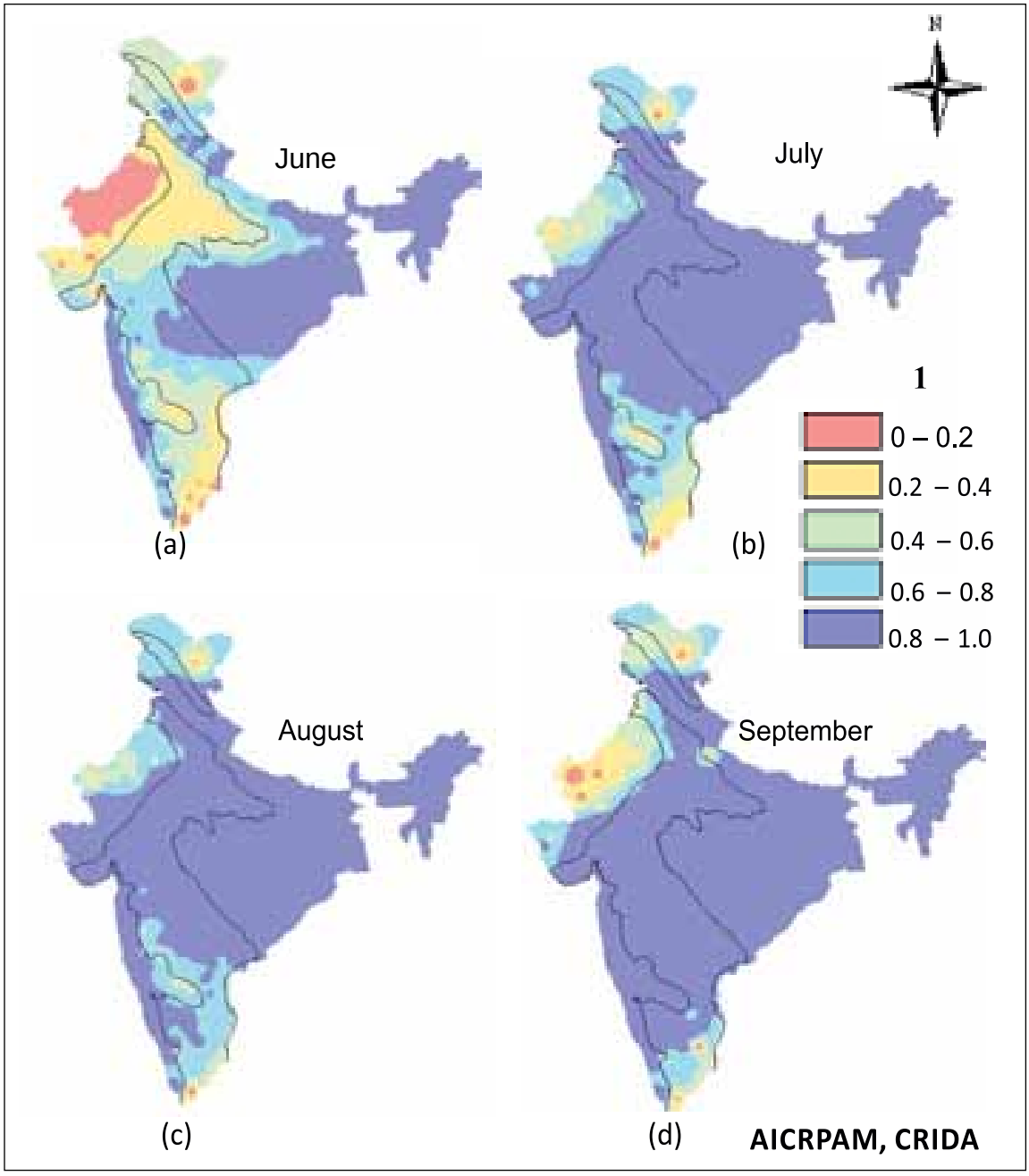


Figure 9. Index of Moisture Adequacy (IMA) distribution over SAT regions of India.

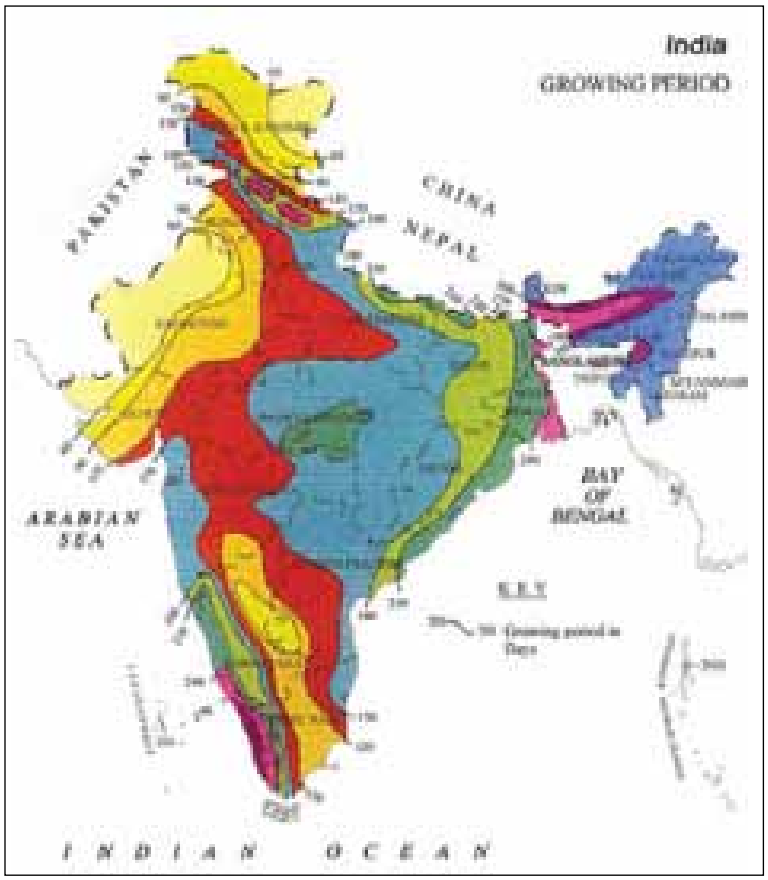


Figure 10. Length of growing period (LGP) distribution over India.

4. Agro-climatic analysis for Andhra Pradesh State

The state of Andhra Pradesh is geographically located in Southern Plateau and Hills agro-climatic region and coastal districts under East Coast Plains and Hills region. The climatic type of Andhra Pradesh is predominantly semi-arid to arid, except in the coastal belt, which has a sub-humid to humid climate. The state has been classified into three regions, a) Telangana (northwest), b) Rayalseema (southwest), and c) coastal Andhra (eastern region).

4.1. Annual rainfall distribution

The spatial distribution of average annual rainfall in the state is shown in Figure 11. The normal annual rainfall of the state is 941 mm, which varies from about 500 mm in Anantapur district of Rayalaseema to 1200 mm in north coastal and northern Telangana districts of the state.

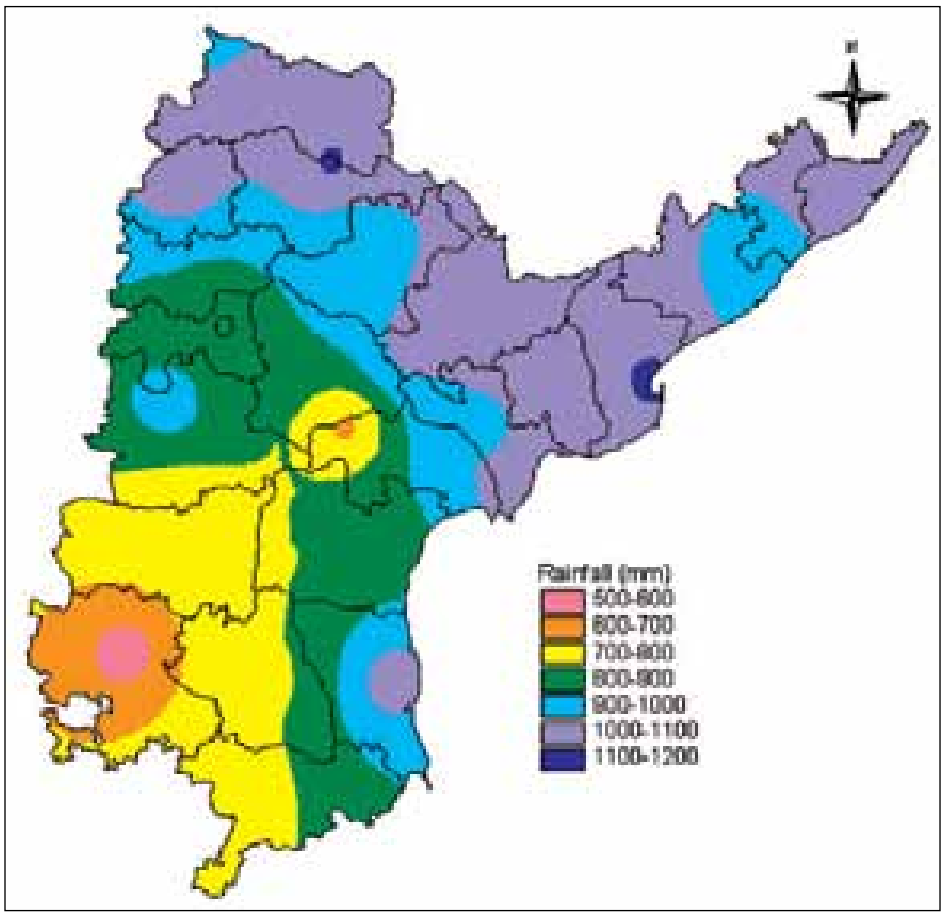


Figure 11. Mean annual rainfall distribution in Andhra Pradesh.

Table 1. Rainfall characteristics of Andhra Pradesh.

	% of contribution of seasonal rainfall to annual rainfall		
State / Region	Southwest monsoon (June–Sept)	Northeast monsoon (Oct–Dec)	Winter (Jan–Feb) and Summer (Mar–May)
Total Andhra	65	24	11
Coastal Andhra	82	11	7
Telangana	59	30	11
Rayalaseema	55	30	15

Rainfall characterization of Andhra Pradesh (Table 1) indicates that the cumulative contribution to annual rainfall of the state from different seasons is about 65% during the SWM, 24% from the NEM, and the remaining 11% from the winter and hot weather periods. Region-wise rainfall data indicates that Telangana (north), coastal and Rayalaseema (south) regions of the state receive 82, 59 and 55% of the annual rainfall respectively during the southwest monsoon period. The northeast monsoon contributes only 11% in Telangana, while the Coastal and Rayalaseema region receive over 30% of the annual rainfall.

4.2. Seasonal rainfall distribution

The seasonal distribution of rainfall is shown in Figure 12. The winter seasonal rainfall is almost nil (<20 mm) throughout the state and is mostly limited to the northern districts. Rainfall during summer (March-May) is mostly associated with local thunderstorms and it varies from 50 mm in the North Telangana districts to 100 mm in the southern Rayalaseema and coastal districts. The monsoon seasonal rainfall (June-September) varies from 300 to 400 mm in southern districts to around 900 mm in the North Telangana districts. North coastal districts recorded more rainfall during this season compared to South coastal districts. Post-monsoon season rainfall varies from about 100 mm in the Telangana region to above 300 mm in the coastal districts. However, the highest rainfall was recorded in Nellore district where the rainfall was above 400 mm. The data of mean monthly rainfall of various districts of the state revealed that July and August are generally the wettest months. The south coastal districts receive high rainfall during October-December due to the influence of depressions / cyclones that originate in the Bay of Bengal and move over the adjoining land surface.

4.3. Maximum and minimum temperature distribution

Mean monthly maximum and minimum temperatures for the months of January, May, July and October, representing winter, southwest monsoon and post-monsoon seasons, are shown in Figures 13 and 14. During January the maximum temperature in the entire coastal belt and parts of Telangana region is around 30°C, and is 30-32°C for other parts of the state. The highest temperatures of above 40°C are seen in the northern Telangana region and some parts of Kurnool district during the month of May. With the onset of the monsoon rains, a fall in temperature is noticed, ranging between 30 and 36°C during the season. Southern coastal districts recorded higher temperatures compared to other places. During the month of October, the maximum temperature varies from 32-34°C in major parts of the state, and in some parts of Rayalaseema, Telangana and coastal districts, it was 30-32°C.

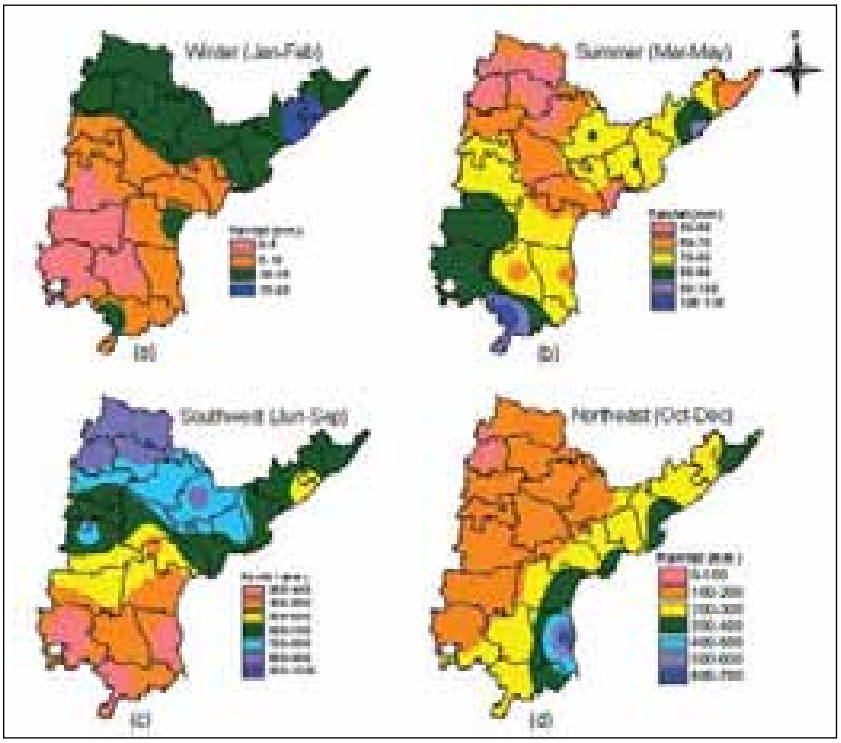


Figure 12. Mean seasonal rainfall distribution in Andhra Pradesh.

Minimum temperatures of ≤ 18°C are recorded during January in most parts of the state except in coastal districts, Nellore, Prakasam, Guntur, Krishna, West and East Godavari and Vishakapatnam, where temperatures vary between 18 and 20°C (Figure 14). The mean minimum temperature during the summer months varies between 26 and 28°C in the month of May. During the southwest monsoon season, minimum temperatures vary between 22 and 26°C in different districts of the state. Minimum temperature is around 22-24°C in October in all major districts of the state, except in some parts of Telangana and the coastal region, where the minimum temperature is close to 20-22°C and 24-26°C respectively.

4.4. Length of the growing period

The lowest length of growing period (LGP), less than 10 weeks, was found in some isolated regions of Anantapur district. It was between 10 and 15 weeks in the remaining areas, which shows that Anantapur can only support short duration crops of cereals and pulses. The major portions of Rayalaseema and South Telangana regions have 15-20 weeks of growing period, whereas in all districts of North Telangana and in coastal districts it is around 20-25 weeks. The LGP is more than 25 weeks in North coastal districts and in some parts of East Godavari, Vishakapatnam, Vizianagaram and Srikakulam districts.

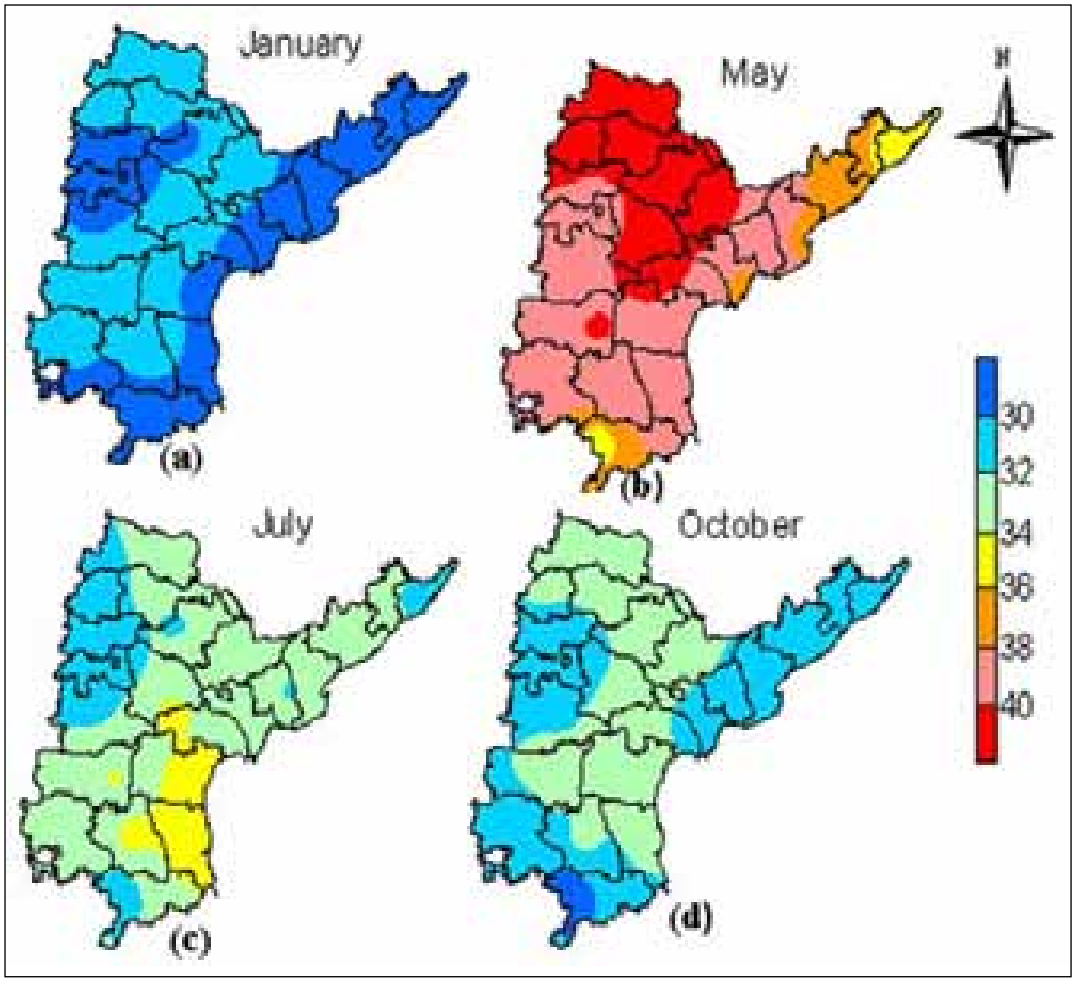


Figure 13. Mean monthly maximum temperature distribution in Andhra Pradesh.

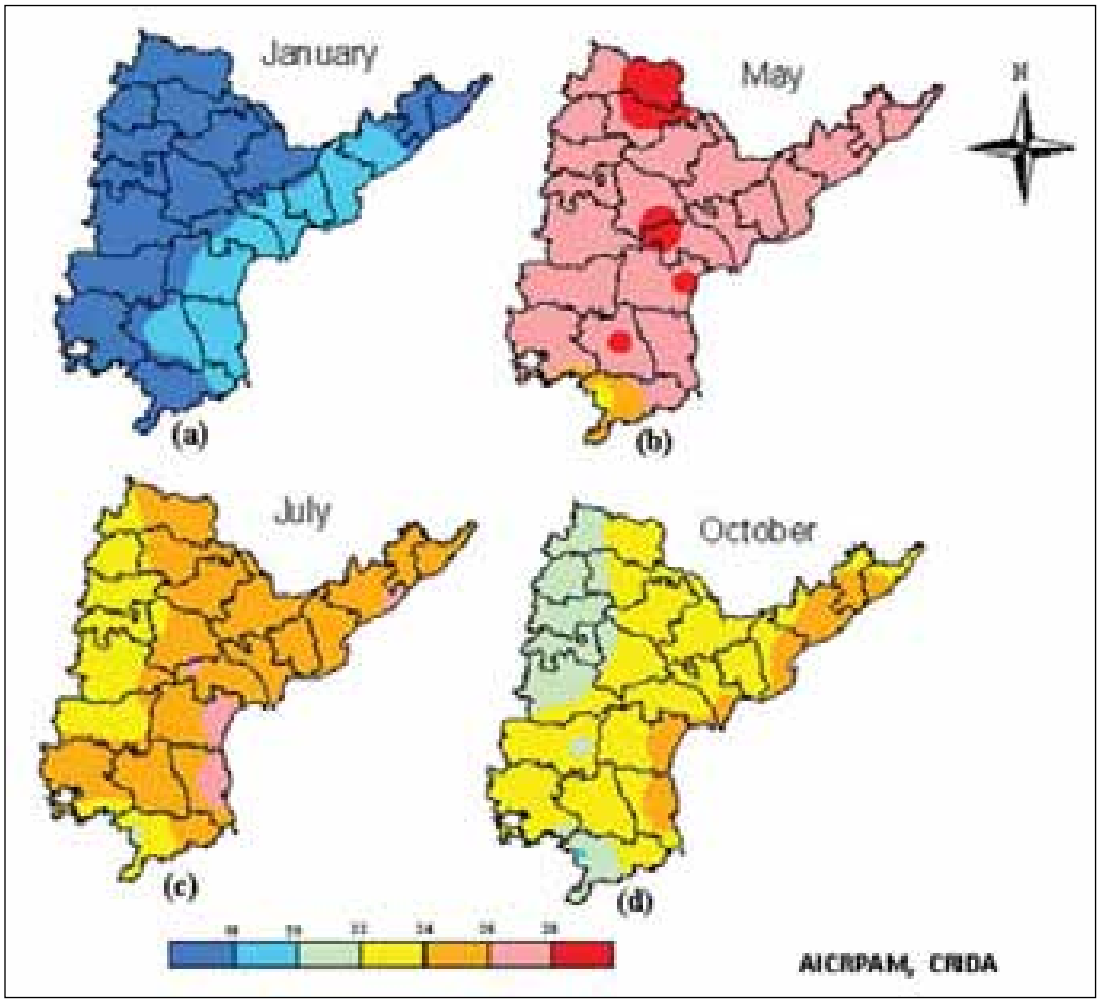


Figure 14. Mean monthly minimum temperature distribution in Andhra Pradesh.

5. Agro-climatic analysis for Maharashtra state

Maharashtra state is broadly covered under three agro-climatic regions - the West Coast Plain and Ghats (thin portion of coastal districts), Western Plateau and Hills (Madhya Maharashtra, Marathawada and western parts of Vidharbha) and Eastern Plateau and Hills (eastern parts of Vidharbha). The major climatic characteristic of the state is semi-arid and dry sub-humid. In the coastal belt (western ghats), in a humid to perhumid climate, copious rainfall is received during the southwest monsoon period (June-September). The annual rainfall in Maharashtra is influenced greatly by the southwest monsoon (about 90%) and the remaining 10% of the rainfall is received from the post-monsoon, winter and summer seasons.

5.1. Annual rainfall distribution

The spatial distribution of rainfall in Maharashtra is highly variable. It varies from about 600 mm in Ahmednagar district to as high as 3300 mm in Ratnagiri district (Figure 15). The normal rainfall of the state is 1240 mm/year. Of the cumulative distribution of annual rainfall in the state, about 89% of it is received during the southwest monsoon, 8% during the northeast monsoon and 3-4%

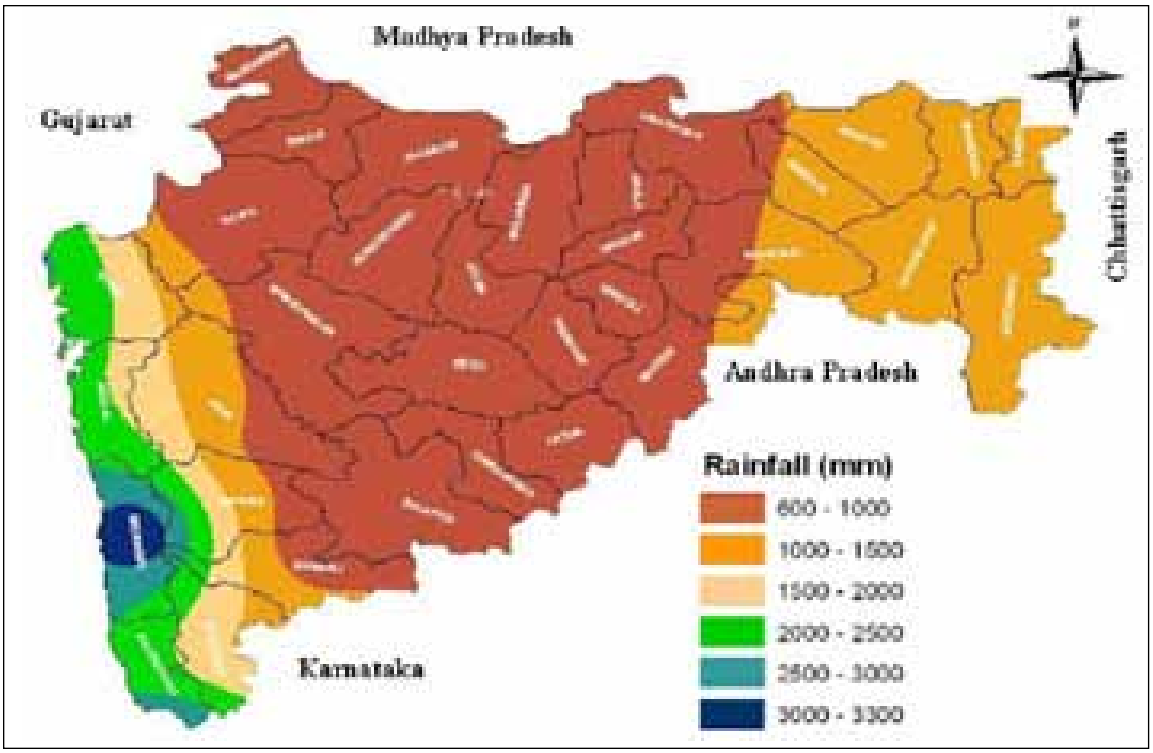


Figure 15. Mean annual rainfall distribution in Maharashtra.

during winter and summer seasons. Konkan (coastal), Madhya Maharashtra (central), Marathawada (southeast) and Vidharbha (eastern) region of the state receive 94, 83, 84 and 88% of the annual rainfall respectively during the southwest monsoon period. The contribution of northeast monsoon is little and it amounts to only 5% in coastal, 7% in Vidharbha and 11% in Marathawada and Madhya Maharashtra regions.

5.2. Seasonal rainfall distribution

Rainfall during the winter season (January-February) is less than in the other three seasons. Only the eastern part of the state receives rainfall of 20-30 mm during winter (Figure 16). Rainfall during the summer season (March-May) is mostly through convective activity and it varies from 50 to 100 mm in southwestern parts of the state; the remaining parts receive 10-50 mm of rainfall in summer. On an average, 90% of the annual rainfall is received from the southwest monsoon season in the state, which ranges between 500–1000 mm in central parts of the state to 2500–3000 mm in the coastal districts, as in Ratnagiri. Rainfall distribution during the post-monsoon period varies from 50 to 70 mm in northern parts to 130–160 mm in the southwest part. Mean monthly rainfall distribution of various districts of the state reveal that July (382 mm) is the wettest month followed by August (303 mm) and June (226 mm).

5.3. Maximum and minimum temperature distribution

The distribution of mean monthly maximum and minimum temperatures during winter, summer, rainy season and post-monsoon seasons, represented by the four months January, May, July and October is given in Figures 17 and 18. Maximum temperature during January varies between 30 and

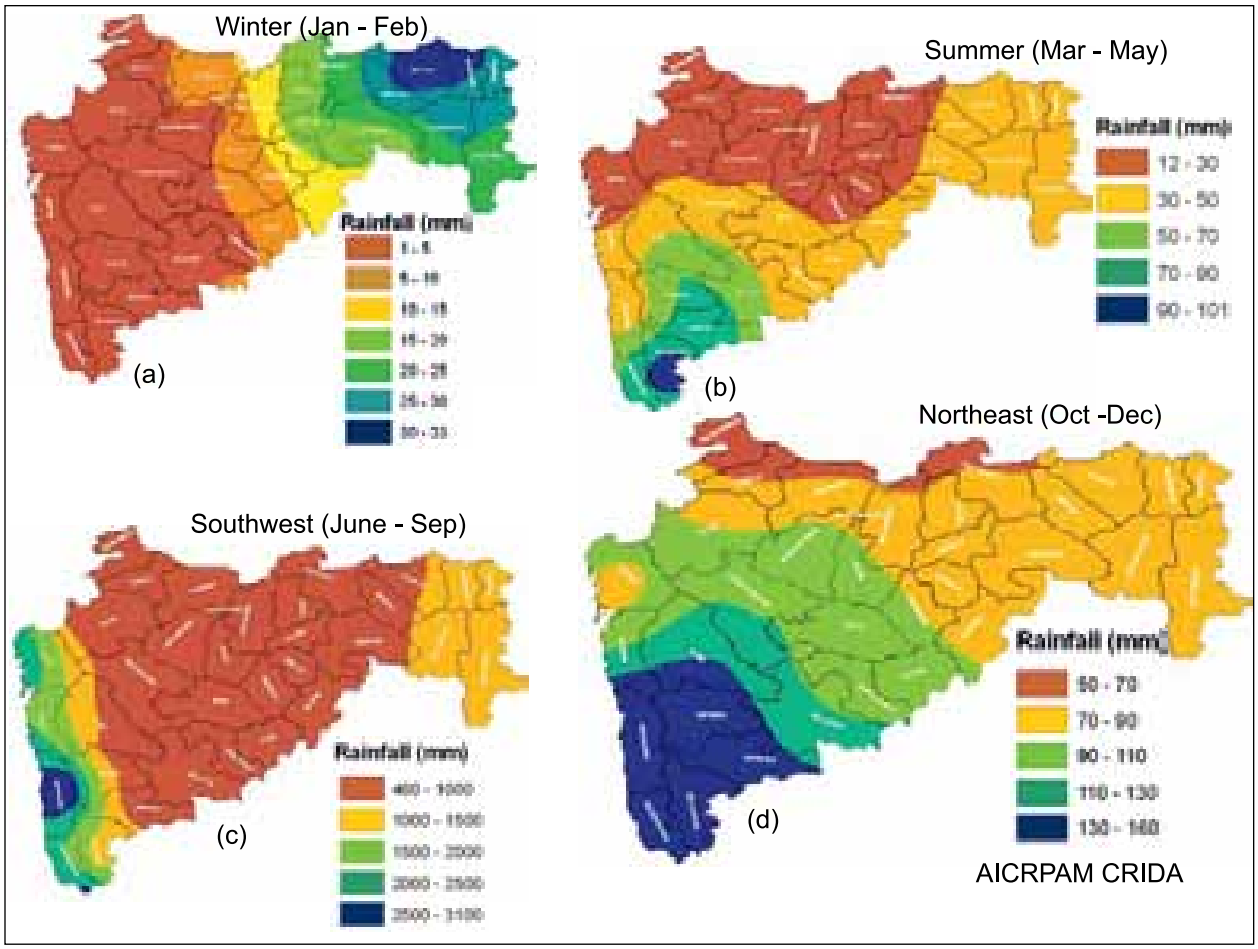


Figure 16. Mean seasonal rainfall distribution in Maharashtra.

32°C in all districts of the state. The highest temperature is observed during summer, (>40°C) in the whole of the Vidharbha region and parts of Marathawada in the month of May. The temperature is less by 4-6°C towards Madhya Maharashtra and the coastal regions. With the onset of the monsoon season the temperature dropped during the month of July, and it varies from 30°C in coastal and Madhya Maharashtra regions to 34°C in Vidharbha. During the month of October, maximum temperature is around 32-34°C in major parts of the state and is around 30-32°C in the southwest region of Maharashtra.

In the case of minimum temperatures, a low of ≤ 10°C is noticed in Jalagaon, Aurangabad, Ahmednagar, Nagpur and parts of Pune districts during January (Figure 18). However, in most parts of the state minimum temperature is about 13-16°C and the coastal districts experience 16-19°C. The minimum temperature rises between 22 to 28°C in the month of May. During the southwest monsoon season, minimum temperature varies between 22 and 26°C in different districts of the state. In October the minimum temperature is around 19-22°C in major portions of the state except in parts of the coastal region, where the minimum temperatures range from 22-25°C. However, the temperature is around 16-19°C in some parts of Pune, Satara and Ahmednagar, Solapur, Latur and Osmanabad districts.

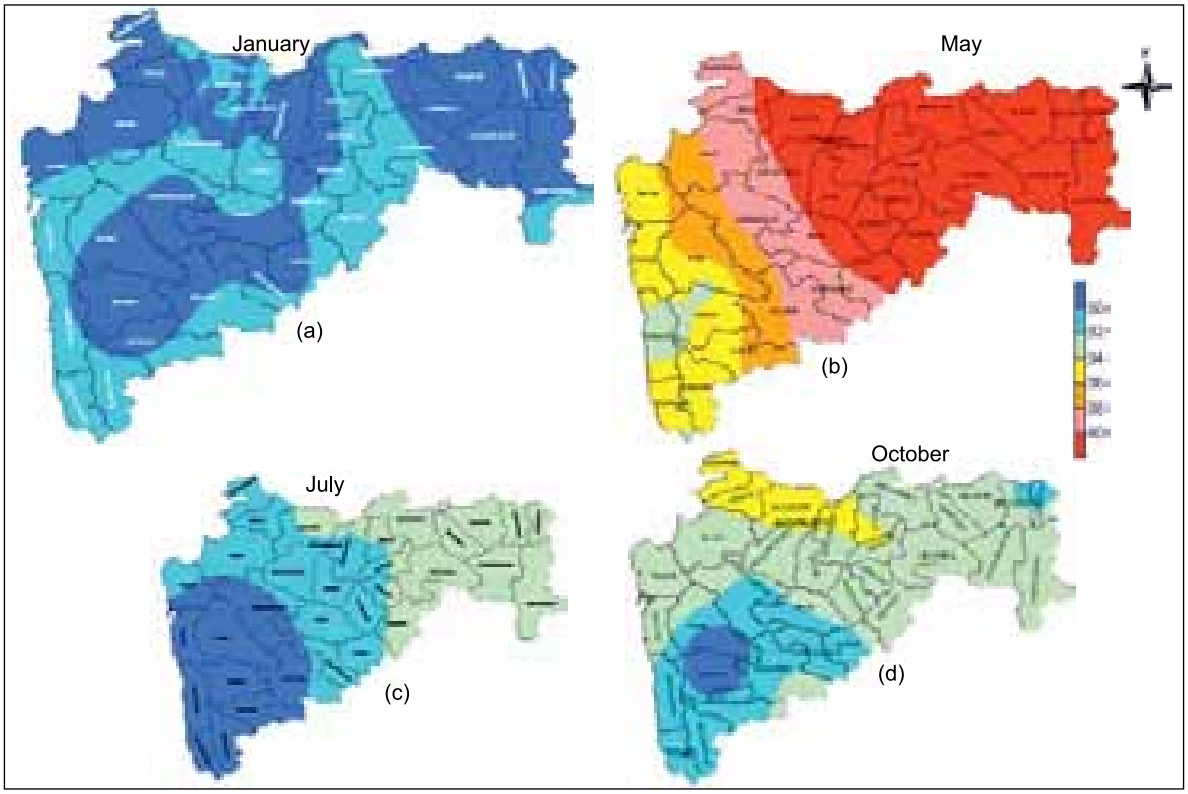


Figure 17. Mean monthly maximum temperature distribution in Maharashtra.

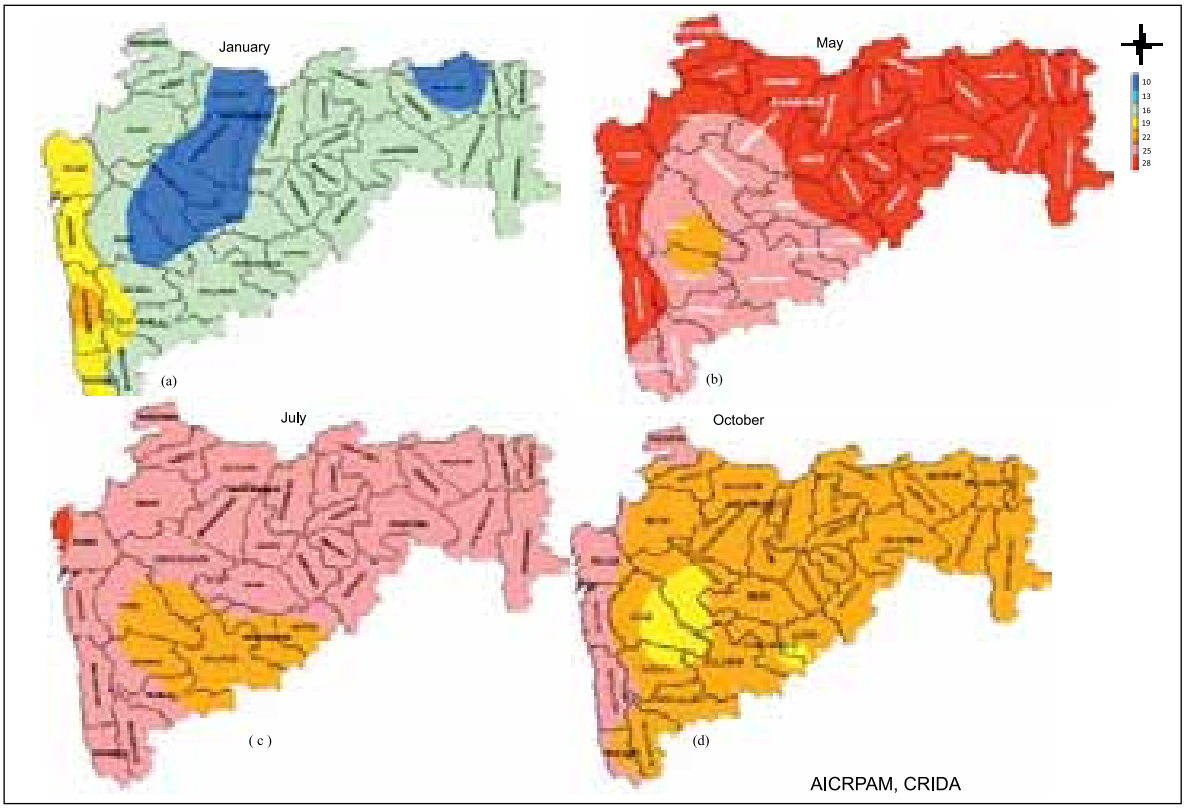


Figure 18. Mean monthly minimum temperature distribution in Maharashtra.

6. Climatic trends and variability in study region

6.1 Anantapur

6.1.1. Temperature and Rainfall

Geographically Anantapur in Andhra Pradesh is located in the southern arid region of the country at latitude of 14.68°N and longitude of 77.6°E. Climatic conditions are not favorable for practicing economic agriculture as it falls in the rain shadow region and is often subjected to severe drought conditions. The monthly averages of temperatures (maximum and minimum) and rainfall are given below (Figure 19). The normal annual rainfall of the district is 546.8 mm received from both SW and NE monsoons. About 61% of the total annual rainfall received by the district is from the SW monsoon rains, while 27% of it is received from NE monsoon rains. Winter season rainfall is nil but during summer a slight amount of rainfall is received. The highest rainfall is received during September and October (Figure 19).

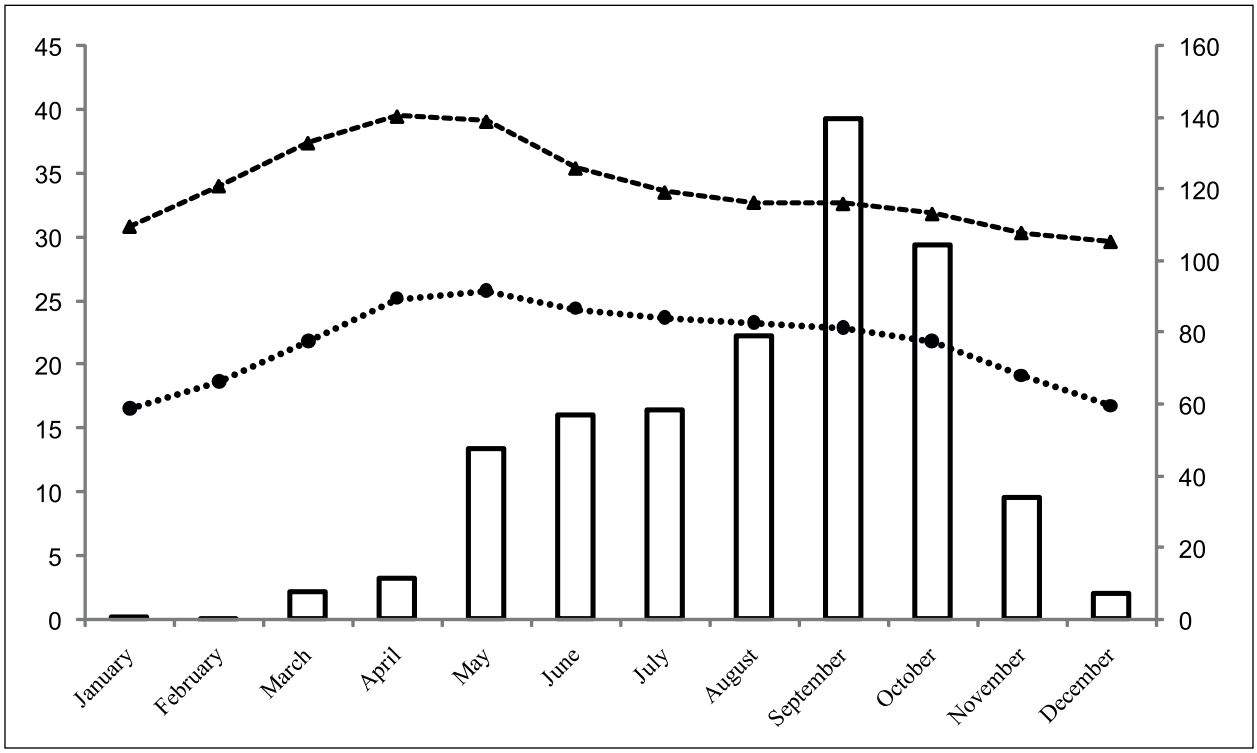


Figure 19. Monthly normal temperature and rainfall of Anantapur district.

The mean annual and season-wise maximum and minimum temperature at Anantapur for the years 1971 to 2009 are plotted and shown in Figure 20. An increased trend in maximum temperature over the years in all the seasons is observed. However, a negative trend in minimum temperature has been noted during the SWM and NEM periods. Though the temperature trends are not significant, yet the rate of increase in maximum temperature is found to be greater in winter season compared to other seasons. The mean annual maximum temperature is about 33.9˚C and mean minimum temperature is 21.7˚C at Anantapur. The SD and CV of maximum and minimum temperatures were 0.7, 2.1% and 0.7 and 3.2 % respectively (Figure 24). The variability (CV%) of maximum and minimum temperatures over its mean is high during the northeast and winter season compared to the SW monsoon period. This shows that crops grown during NEM and winter were subjected to higher temperature fluctuations. The five year moving averages of different seasonal rainfall was plotted (Figure 21) and it also exhibited cyclical variation. The period from 2003 onwards showed an increasing trend in rainfall. Rainfall anomaly index and cumulative departure index were also plotted and there exists a huge variation among years in rainfall received during the last forty years. Even though precipitation received by the district is low compared to other districts of Andhra Pradesh, groundnut is cultivated over a large area of this region, and therefore information on rainfall distribution during the season and the chances of occurrence of dry and wet spells are important for efficient crop planning. For this reason, the weekly probability analysis for experiencing wet (W) and dry (D) weeks were computed for different rainfall limits of 10, 20, 30, 40 and 50 mm, and the results are presented in Appendix 1.

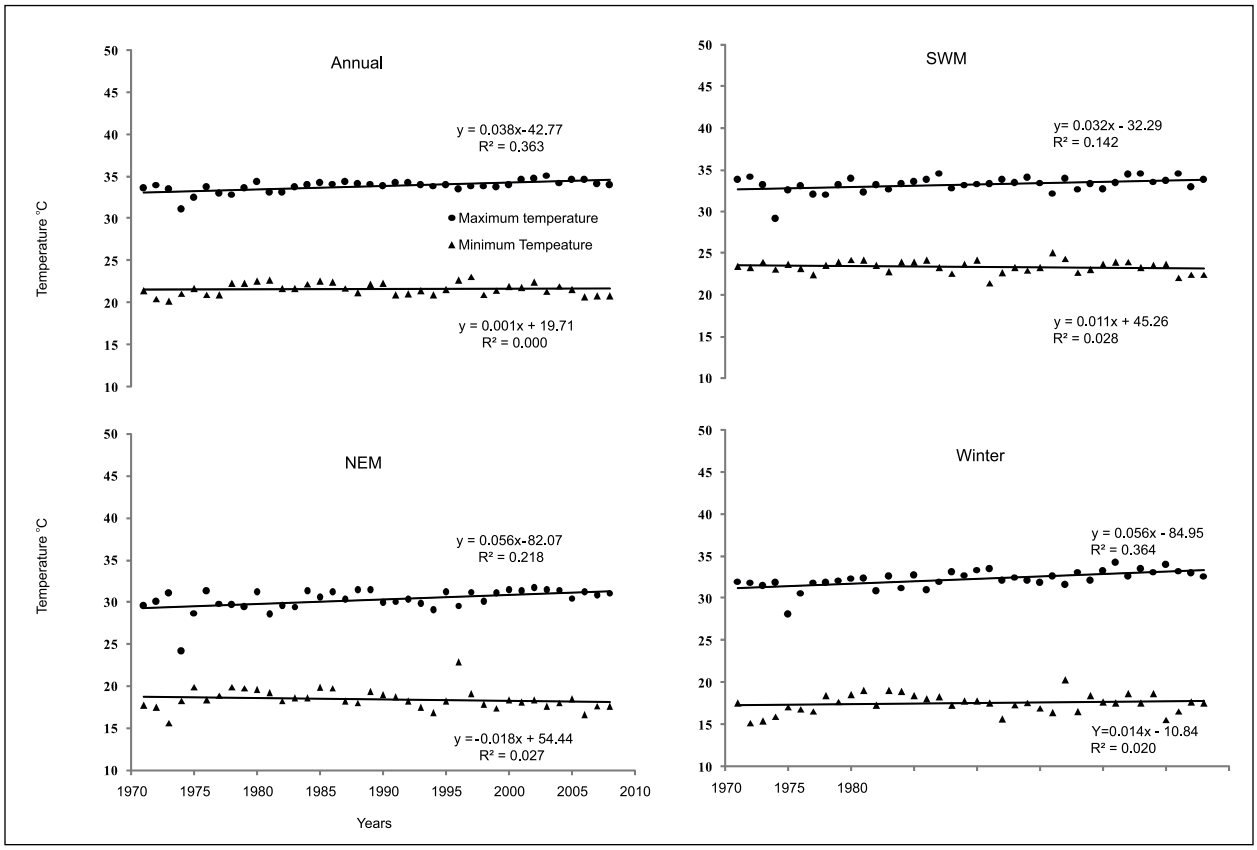
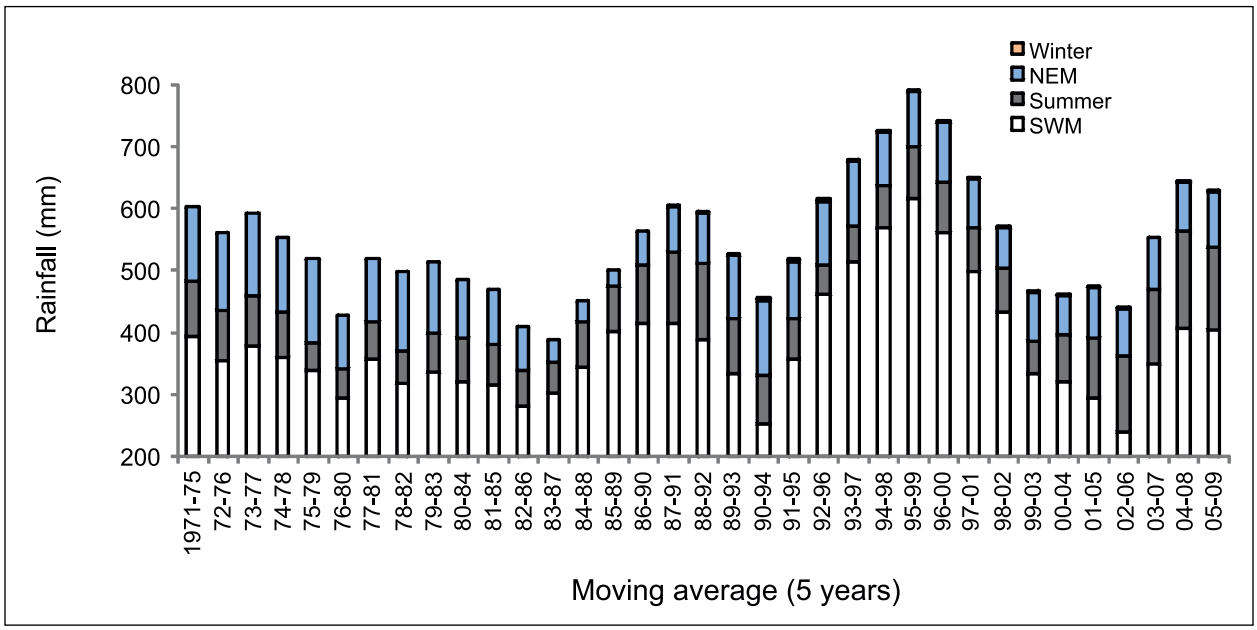
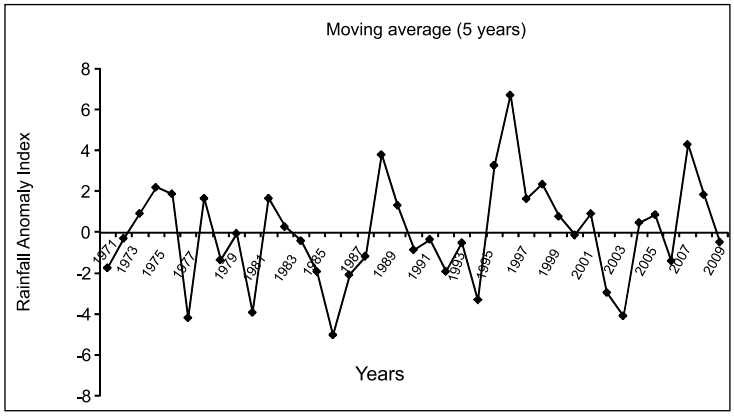


Figure 20. Long term (1971-2009) annual and seasonal trends in average maximum and minimum temperature in Anantapur district of Andhra Pradesh; SWM – southwest monsoon; NEM-northeast monsoon.





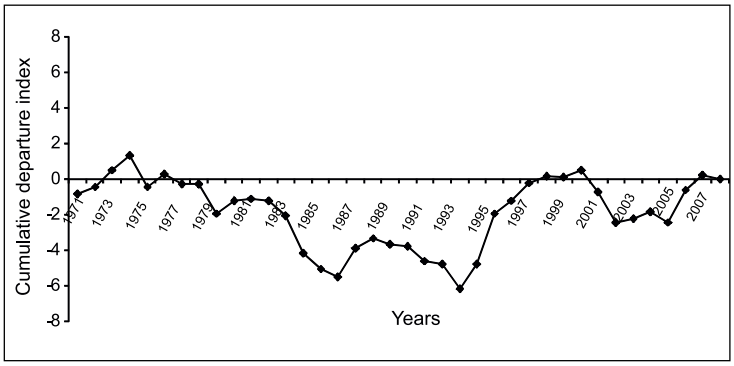


Figure 21. Annual and seasonal rainfall variation and trends of Anantapur district. (a) Seasonal rainfall averages (5 year moving); (b) Mean, Coefficient of variation (CV), Standard deviation (SD); (c) rainfall anomaly index and cumulative departure index.

	Max Temp.(°C)	Min Temp.(°C)	RF (mm)
Annual	-	-	-
Mean	33.9	21.7	546.8
SD	0.7	0.7	192.3
CV	2.1	3.2	35.2
Southwest			
Mean	33.6	23.6	334
SD	1	0.7	168.6
CV	2.8	3.1	50.5
Northeast			
Mean	30.6	19.2	145.8
SD	1.3	1.1	88.6
CV	4.3	5.9	60.8
Winter			
Mean	32.3	17.5	0.9
SD	1.1	1.1	2.8
CV	3.4	6.4	295.5
Summer			
Mean	38.6	24.3	66.1
SD	0.7	1	55.5
CV	1.8	4.2	84

The probability of receiving 10 mm rain per week is quiet low (< 15%) till the 19th week and it increases as the SWM season approaches. Even during the peak season, the probability reaches the maximum value of 67% around weeks 38 to 40 (end of September) and decreases towards the start of the NEM season. The probability of rainfall decreases with increased rainfall. Conditional probabilities of rainfall in Anantapur district is also computed for having wet/wet, dry/wet, dry/dry and wet/dry weeks during the years. Initially probability to have wet/wet weeks are almost nil during the first 11-17th weeks. It then increases and peaks during the SWM. Probability of dry/wet is higher than wet/dry during the different seasons. This emphasizes the likely events of weeks with more probability of dry weeks followed by wet weeks. During the season the rainy days are erratic with high frequency of occurrence of weeks without rainfall. The probabilities of consecutive wet and dry weeks are also computed at various limits and are given in Appendix 2.

6.1.2. Rainy days

Anantapur's annual rainfall is received in 33 rainy days with SD of 7.5 and CV of 22% (Table 2). Seasonally, there are variations in rainy days within and among the different seasons. The mean number of rainy days is 19 during the southwest monsoon season, is 9 during the northeast monsoon, and 4 during summer. The rainy days are almost nil during winter. Month-wise, the highest number of rainy days is observed in September and the lowest number is in February.

Table 2. Mean, SD and CV of annual, seasonal and monthly rainy days from 1971-2009 in Anantapur.

	Winter	Summer	Southwest	Northeast	Annual	
Mean	0.15	4.36	18.87	9.44	32.82	
SD	0.43	3.01	5.88	3.97	59	
CV	280.51	69.12	31.14	42.1	4.61	
	January	February	March	April	May	June
Mean	0.13	0.03	0.54	0.87	2.95	3.46
SD	0.41	0.16	1.47	1.08	2.19	2.34
CV	319.08	624.50	272.30	123.93	74.20	67.54
	July	August	September	October	November	December
Mean	3.46	5.21	6.74	6.21	2.69	0.54
SD	2.46	2.96	3.28	3.40	2.28	0.91
CV	71.03	56.82	48.68	54.74	84.85	169.60

6.1.3. Droughts

Droughts are common in the SAT and Anantapur is subjected to a high frequency of droughts as it is located in the arid region. Anantapur district experienced 5 years of mild drought, 5 years of moderate drought, 4 years of severe drought and 24 years without drought over the past 38 years (1971-2008). On an average, it experienced a minimum of 4 droughts for each 10-year period. One severe drought was experienced during early part of last decade, but with the improved rainfall, droughts were less frequent in later years. Of the detailed year-wise analysis of drought years, annual rainfall and deviation (%) from the normal is given in Table 3. Agricultural drought periods

in Anantapur district are also given in the same table. A close glance at the table shows that the frequency of agricultural droughts are more in July and in August coinciding with vegetative and pegging stage of the groundnut crop. A no-rainfall period extending up to >20 days during the crucial crop growth period will affect the crop productivity. The periods of no rainfall during the crop season have been seen more during the recent years (2000-2008) as this period witnessed 3 drought years of significant intensity.

6.1.4. Extreme events (Rainfall and Temperature)

The frequencies of extreme rain events for the amounts 25-50, 50-75, 75-100 and above 100 mm were analyzed for the 38 year period (1971-2008) and are given in Appendix 3. Also, similar analysis was done for the various seasons, SWM, NEM and summer season in appendixes 4, 5 and 6. There is no set pattern for the extreme rainfall events of >50 mm/day over the study period. Similarly, the frequencies of maximum temperature >40°C during the summer period is shown in Appendix 7. It is observed that frequencies of temperatures above 40°C have increased in the recent past compared to earlier years. This is in conformity with the increased number of warmest years globally and in the country.

Table 3. Meteorological (a) and agricultural (b) drought experienced at Anantapur district during the past 38 years.

a) Meteorological drought

Year	Annual Condition RF(mm)	Deviation (%)	Drought	Year	Annual Condition RF(mm)	Deviation (%)	Drought
1971	414.8	-24.1	Mild	1991	522.4	-4.5	No drought
1972	526.2	-3.8	No drought	1992	400.9	-26.7	Moderate
1973	620.3	13.4	No drought	1993	509.9	-6.7	No drought
1974	719.1	31.5	No drought	1994	294.3	-46.2	Moderate
1975	694.8	27.1	No drought	1995	802.8	46.8	No drought
1976	226.1	-58.6	Severe	1996	1068.6	95.4	No drought
1977	677.4	23.9	No drought	1997	676.2	23.7	No drought
1978	444.3	-18.7	Mild	1998	731.2	33.7	No drought
1979	545.2	-0.3	No drought	1999	609.3	11.4	No drought
1980	245.9	-55.0	Severe	2000	539.2	-1.4	No drought
1981	677.5	23.9	No drought	2001	620.0	13.4	No drought
1982	570.5	4.3	No drought	2002	321.6	-41.2	Moderate
1983	517.3	-5.4	No drought	2003	233.4	-57.3	Severe
1984	401.2	-26.6	Moderate	2004	586.4	7.2	No drought
1985	161.2	-70.5	Severe	2005	616.0	12.7	No drought
1986	388.4	-28.9	Moderate	2006	440.8	-19.4	Mild

Continued

Table 3. Meteorological (a) and agricultural (b) drought experienced at Anantapur district during the past 38 years *continued*.

a) Meteorological drought

Year	Annual Condition RF(mm)	Deviation (%)	Drought	Year	Annual Condition RF(mm)	Deviation (%)	Drought
1987	458.7	-16.1	Mild	2007	881.4	61.2	No drought
1988	842.8	54.1	No drought	2008	691.8	26.5	No drought
1989	651.6	19.2	No drought				
1990	483.3	-11.6	Mild				

b) Agricultural drought

Years	Weeks	Years	Weeks	Years	Weeks	-	-
1972	28-31	1983	27-30	1994	22-25	-	-
	32-35		39-42		28-31	-	-
1974	26-29	1984	22-25		35-38	-	-
	31-34		32-35	1995	22-25	-	-
1975	22-25	1985	22-25		26-29	-	-
	27-30		32-35	1997	25-28	-	-
1976	26-29		37-40		38-41	-	-
	35-38	1986	28-31	2000	35-38	-	-
1977	34-37	1987	27-30	2001	27-30	-	-
1979	26-29		34-37	2002	22-25	-	-
1980	25-28	1988	24-27		26-29	-	-
1981	26-29	1989	22-25		33-36	-	-
1982	31-34	1990	34-37	2003	22-25	-	-
		1991	32-35		26-29	-	-
		1992	36-39		33-36	-	-
		1993	25-28	2004	23-26	-	-
					31-34	-	-

6.2. Mahbubnagar

6.2.1. Temperature and Rainfall

Mahbubnagar district is located in the central part of peninsular India at a latitude of 16.5° N and longitude of 78.25° E. The district receives the most rainfall during the SWM (June–September) and the NEM (October–December). The air temperature can reach more than 40°C (maximum) and 25°C (minimum) during summer (March–May), Figure 22. The months when major rainfall is received are June–October and average rainfall of the district is 786 mm/year.

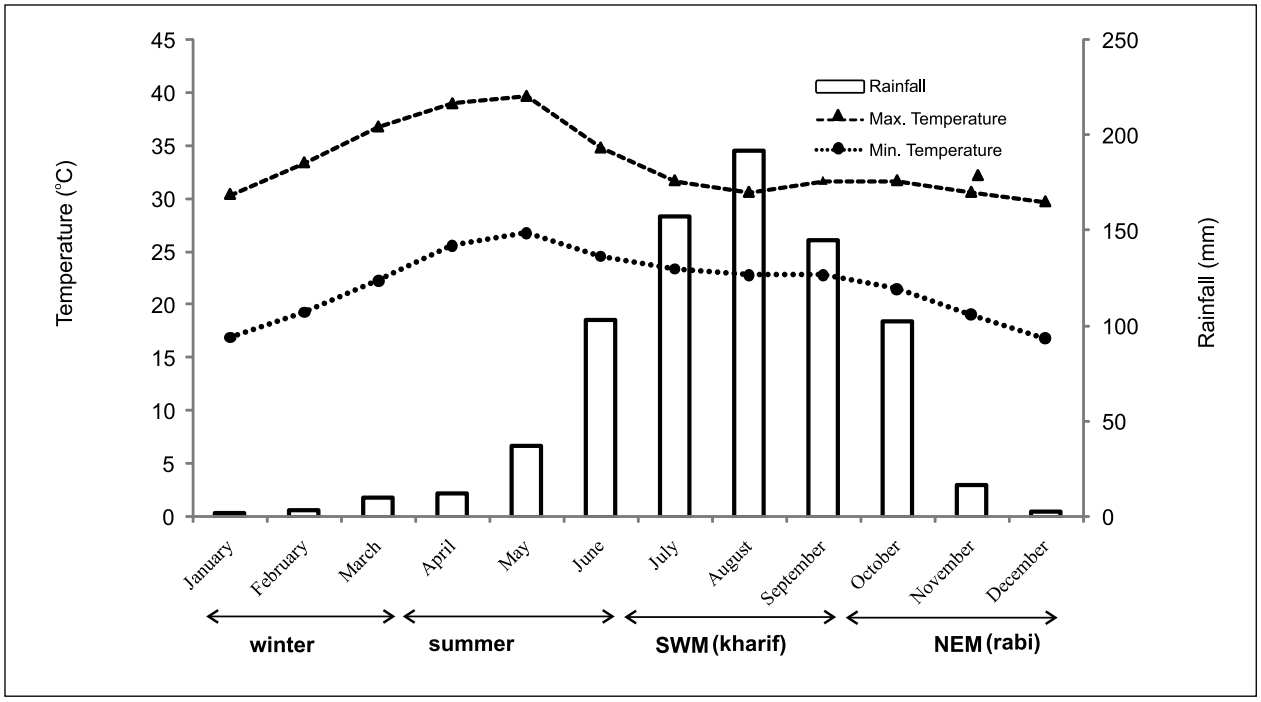


Figure 22. Monthly normal temperature and rainfall of Mahbubnagar District.

Trend analysis of climatic parameters viz., annual maximum and minimum temperatures and rainfall from climatic data sets showed that temperatures for different seasons indicated a positive trend from the past for all the seasons except that of minimum temperature during NEM (Figure 23). However, the increase in temperature is not significant. It is observed that in the recent decade (2000-2010), a slight increase in maximum temperature and decrease in minimum temperature was noticed during SWM. Comparison of seasonal variations of maximum and minimum temperatures in different seasons (Fig.23) indicated that temperature fluctuations over its mean were comparatively less during the SWM period against other seasons. However, the difference in CV values is not significant among seasons, which indicates that temperature remained stable over the study period at Mahbubnagar.

Of the total annual rainfall of 786 mm received in the district, about 70-75% is received during the SWM period and 13-17% is contributed by NEM rainfall. The contributions from winter and summer rainfall are scanty. Five year moving averages of rainfall of different seasons showed that cyclical variations in rainfall are in conformity with the findings of the Network Project on Climate Change. In the past 40 years, there were two major troughs in rainfall, during 1980-90 and 1991-2001. However the total rainfall had improved during 2000-2010. Annual rainfall indices, rainfall anomaly index and cumulative departure index were also computed and are presented in Figure 24. For agricultural planning, the distribution of weekly rainfall and its probability of being a wet or dry week is important. Hence, the initial probability of wet (W) and dry (D) weeks and conditional probability of W/W, D/W, D/D and W/D are computed for various rainfall limits - 10, 20, 30, 40, 50 mm. As expected, the probabilities of receiving dry weeks are >80% during the first 1-22 weeks of the year, and this decreases with the onset of monsoon to about < 25% from week 24 to 40 onwards.

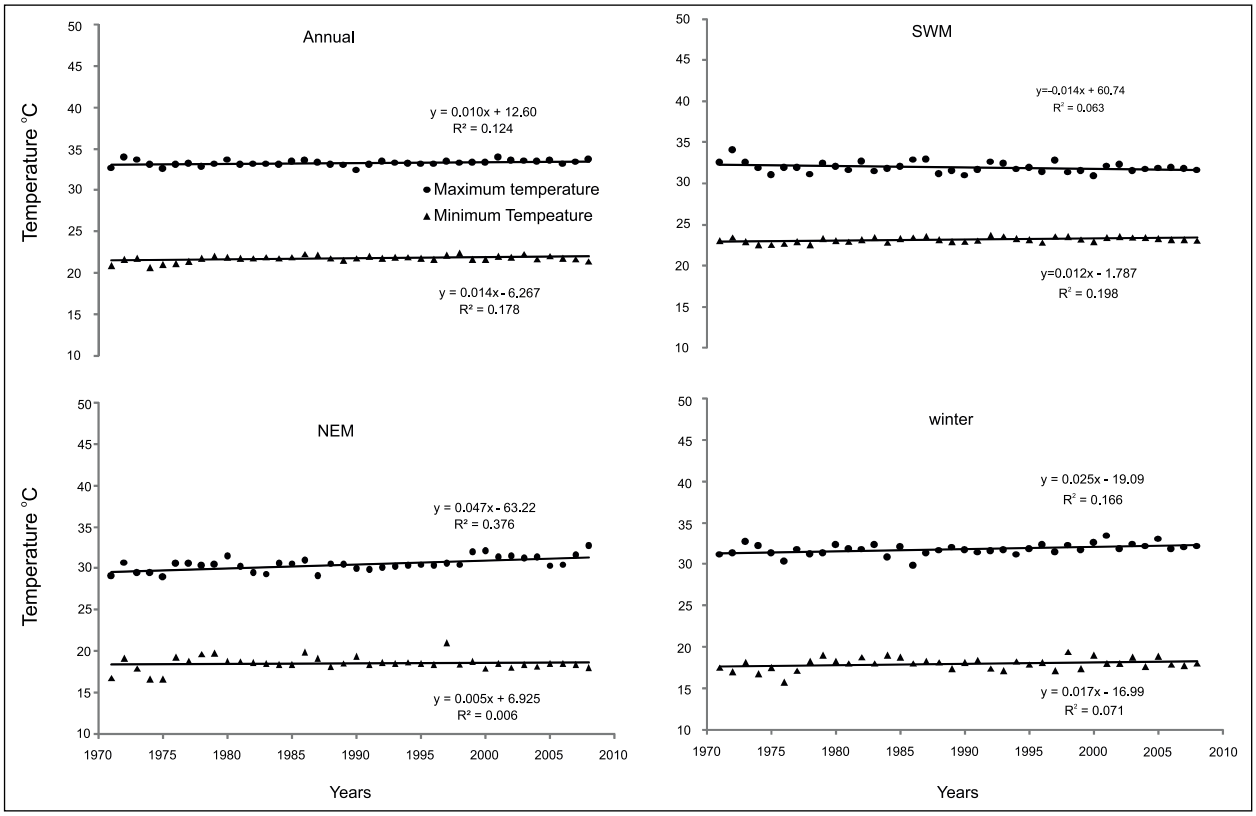


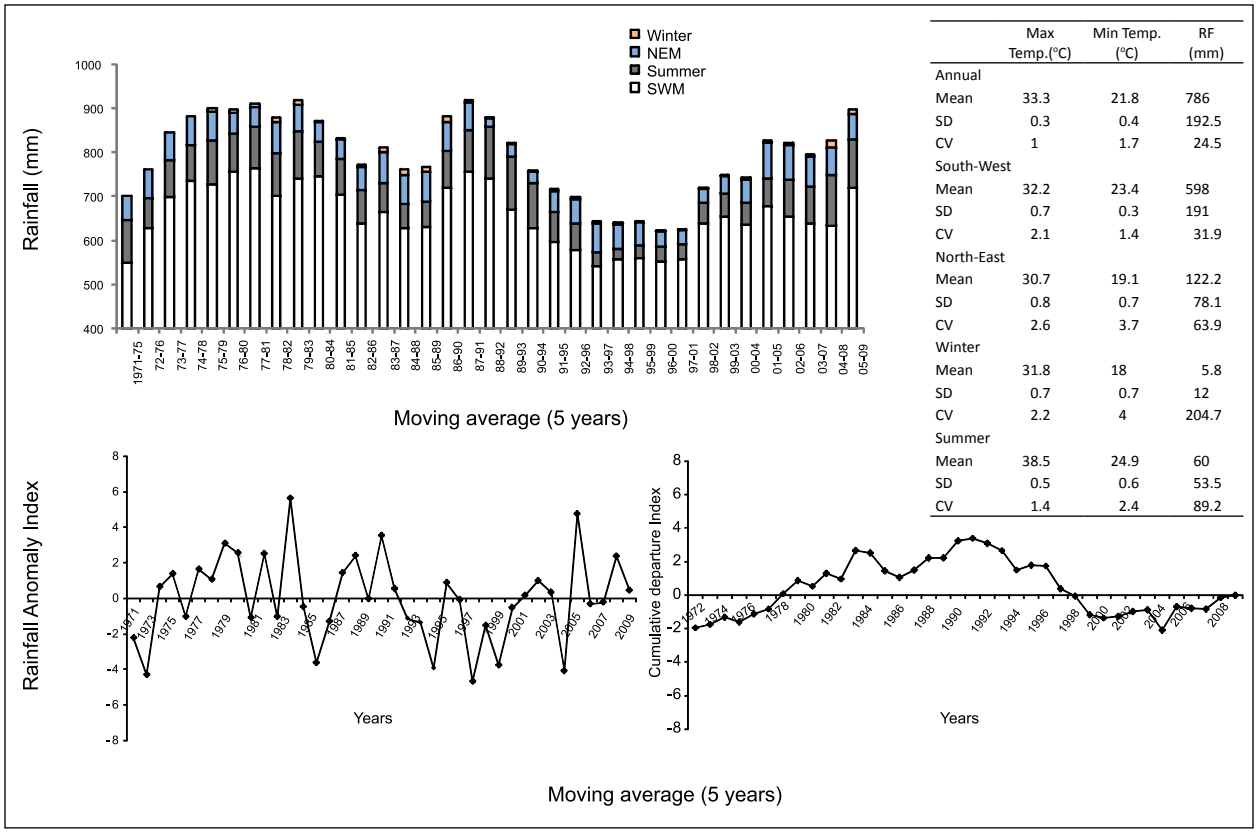
Figure 23. Long term (1971-2009) annual and seasonal trends in average maximum and minimum temperature in Mahbubnagar district of Andhra Pradesh; SWM – southwest monsoon; NEM - northeast monsoon.

	Max Temp.(°C)	Min Temp.(°C)	RF(mm)
Annual			
Mean	33.3	21.8	786
SD	0.3	0.4	192.5
CV	1	1.7	24.5
Southwest			
Mean	32.2	23.4	598
SD	0.7	0.3	191
CV	2.1	1.4	31.9
Northeast			
Mean	30.7	19.1	122.2
SD	0.8	0.7	78.1
CV	2.6	3.7	63.9
Winter			
Mean	31.8	18	5.8
SD	0.7	0.7	12
CV	2.2	4	204.7
Summer			
Mean	38.5	24.9	60
SD	0.5	0.6	53.5
CV	1.4	2.4	89.2

The conditional probabilities of having W/W, which is about 70-80%, indicates favorable moisture conditions for crop growth during the rainy season. This declines from week 41 to the end of December. The probabilities of wet week followed by dry week (W/D), and Dry week followed by Wet week (D/W) indicating the duration of wet and dry periods, are given in Appendix 8. The probabilities of consecutive wet and dry weeks are also computed at various limits and are given in Appendix 9.

6.2.2. Rainy days

Rainy day is defined as the day in which the total rainfall is 2.5 mm and above. The significance of occurrence of number of rainy days during a cropping season influences the crop growth and ultimately its yield. Any variation in number of rainy days significantly affects crop production. Hence analyses were done to compute the annual, seasonal and monthly rainy days for Mahbubnagar. The results (see Table 4) show that Mahbubnagar has on an average 52 rainy days with an SD of 16 and CV of 3.34%. The mean number of rainy days are more in SWM (41) followed by NEM (7). The number of rainy days are insignificant in the rest of the season as very meager rainfall is expected in winter and summer seasons. The monthly distribution of number of rainy days shows that July and August receive highest number of rainy days with CV values lower than 45%.



	Max Temp.(°C)	Min Temp. (°C)	RF (mm)
Annual			
Mean	33.3	21.8	786
SD	0.3	0.4	192.5
CV	1	1.7	24.5
South-West			
Mean	32.2	23.4	598
SD	0.7	0.3	191
CV	2.1	1.4	31.9
North-East			
Mean	30.7	19.1	122.2
SD	0.8	0.7	78.1
CV	2.6	3.7	63.9
Winter			
Mean	31.8	18	5.8
SD	0.7	0.7	12
CV	2.2	4	204.7
Summer			
Mean	38.5	24.9	60
SD	0.5	0.6	53.5
CV	1.4	2.4	89.2

Figure 24. Annual and seasonal rainfall variation and trends of Mahbubnagar district.(a) Seasonal rainfall averages (5 year moving); (b) Mean, CV and SD; (c) rainfall anomaly index and cumulative departure index.

Table 4. Mean, SD and CV of annual, seasonal and monthly rainy days from 1971-2009 in Mahbubnagar.

Parameter	Winter	Summer	SouthWest	NorthEast	Annual	
Mean	0.37	3.84	40.53	7.34	52.08	
SD	0.75	2.76	14.41	3.91	66	
CV	203.72	71.73	35.56	53.2	3.34	
	January	February	March	April	May	June
Mean	0.2	0.2	0.5	0.9	2.4	7.6
SD	0.4	0.7	1.0	1.0	2.4	3.3
CV	276.5	315.4	206.6	106.5	98.1	43.6
	July	August	September	October	November	December
Mean	11.4	12.1	9.4	6.1	1.1	0.2
SD	5.2	5.2	5.5	4.0	1.6	0.5
CV	45.3	42.7	58.7	65.3	148.3	278.1

6.2.3. Droughts

Droughts are caused due to insufficient rainfall over time. It is one of the serious problems of the SAT region that affect crop production. Droughts are classified broadly as meteorological, hydrological and agricultural droughts. The meteorological and agricultural droughts as defined by the National Commission on Agriculture (1976) are computed and given in Table 5. The table shows that out of 38 years (1971-2008) Mahbubnagar experienced 23 normal years, 9 mild and 7 moderate meteorological droughts (Table 5). Severe droughts were never experienced during the study period. The frequency of experiencing moderate and mild drought is high during the last decades compared to previous decades. The agricultural drought during the SWM season was computed for the study period. It is seen that agricultural droughts were noticed on 16 occasions over the study period and a close look indicated that of 16 drought periods, about 8 occurred during August (31-35 week) coinciding with the grand growth period, and 5 droughts were during September (36-39 weeks) coinciding with the reproductive and maturity phase of crops, and 3 droughts were during the initial stages in July (27-30 weeks).

6.2.4. Extreme events (Rainfall and Temperature)

The increased frequency of extreme weather events such as heavy rainfall, and high and low temperatures are indicators for climate change processes over a region. Though predicting these events can be extremely difficult, understanding vulnerabilities to such changes is a critical part of developing future climate change policies and strategies. Generally, in an agriculture related ecosystem, unseasonal rainfall, high intensity storms, high winds and the like have greater significance on farming due to water logging, lodging of matured crop and physical damage that result in large economic loss. Therefore, the frequencies of different amounts of rainfall viz., 25-50, 50-75, 75-100 mm and greater than 100 mm have been computed for the last 39 years and the data is presented in Appendix 10. It is seen that there is no increased high rainfall (>100 mm) activity over the years at Mahbubnagar. However, the recent decade witnessed increased rainfall events in the range 20-50 and 50-75 mm compared to the preceding decade (1991-2000). Similar results are noticed for different seasons (Appendix 11, 12 and 13). Mahbubnagar district normally records atmospheric temperature of >40°C during the summer season. Similar to rainfall extremes, the extreme temperature events during summer (April-May) were analysed with respect to

temperatures 40-44°C and above and are given in Appendix 14. It is observed that the frequencies of extreme temperature above 40°C are more in the decade 2000-2008. This is in conformity with the increased number of warmest years in the recent decade.

Table 5. Meteorological (a) and agricultural (b) drought experienced in Mahbubnagar district during the past 38 years.

a) Meteorological drought

Year	Annual RF (mm)	Deviation (%)	Drought
1971	612.5	-22.1	Mild
1972	451.4	-42.6	Moderate
1973	836.3	6.4	No drought
1974	892.9	13.6	No drought
1975	705.6	-10.2	No drought
1976	912.6	16.1	No drought
1977	868.1	10.4	No drought
1978	1025.3	30.4	No drought
1979	983.3	25.1	No drought
1980	700.9	-10.8	Mild
1981	980.3	24.7	No drought
1982	704.8	-10.3	No drought
1983	1222.4	55.5	No drought
1984	748.2	-4.8	No drought
1985	503.6	-35.9	Moderate
1986	684.32	-12.9	Mild
1987	896.4	14.0	No drought
1988	971.6	23.6	No drought
1989	782.9	-0.4	No drought
1990	1059.2	34.8	No drought
1991	827.4	5.3	No drought
1992	697.5	-11.3	Mild
1993	678.4	-13.7	Mild
1994	480.3	-38.9	Moderate
1995	854	8.6	No drought
1996	778.52	-1.0	No drought
1997	422.5	-46.3	Moderate
1998	666.6	-15.2	Mild
1999	493.2	-37.3	Moderate
2000	744.1	-5.3	No drought
2001	798.3	1.6	No drought
2002	861.7	9.6	No drought
2003	810.9	3.2	No drought
2004	467.9	-40.5	Moderate
2005	1154.1	46.8	No drought
2006	854	8.6	No drought
2007	768.6	-2.2	No drought
2008	969.2	23.3	No drought

b) Agricultural drought

Kharif season

Year	Drought Period
1972	30-33
	38-41
1973	28-31
	34-37
1975	27-30
1976	38-41
1979	32-35
1982	34-37
1984	32-35
1991	33-36
	39-42
1994	36-39
1997	28-31
	39-42
1999	31-34
2004	32-35

Note: A drought year is defined as when the annual rainfall is less than the 25% of the long term mean annual rainfall. Its intensity is termed as moderate if the rainfall is less than 26-50% and severe if more than 50% of normal. AICRPAM, CRIDA further defined drought as mild if the annual rainfall is less than 11 to 25% of normal value.

6.3 Akola

6.3.1. Temperature and Rainfall

Akola is located in the north-central region of Maharashtra state at latitude 20.5°N and longitude 77.166°E. Rain-fed dependent agriculture predominates in this region. The main crops grown are sorghum, green gram, black gram and cotton. The monthly distribution of temperature and rainfall of Akola is given in Figure 25. The rainfall distribution of the district showed that July and August receive peak rainfall. Both maximum and minimum temperatures decreased during the monsoon season. However, the maximum temperature increases with the cessation of the rainy season and the minimum continues to fall. The annual average precipitation of the district is 723.5 mm and maximum and minimum temperatures are 33.1 and 23.6°C respectively. Seasonally major precipitation of about 86% is received during the SWM and 10% during the NEM. The remaining rainfall is received during the summer and winter seasons. The trends for maximum and minimum temperatures on an annual basis and for other seasons are shown in Figure 26. A slight decreasing trend has been observed on annual and seasonal maximum temperatures. However, minimum temperature has shown an increasing trend in all the seasons. The variability in minimum temperature during the SWM period is less compared to NEM and winter season. Since the trends are not significant, the impact of temperatures on agricultural production may not be reflected. However the impacts can be studied on an annual basis as fluctuations in temperature are large in NEM and in winter season.

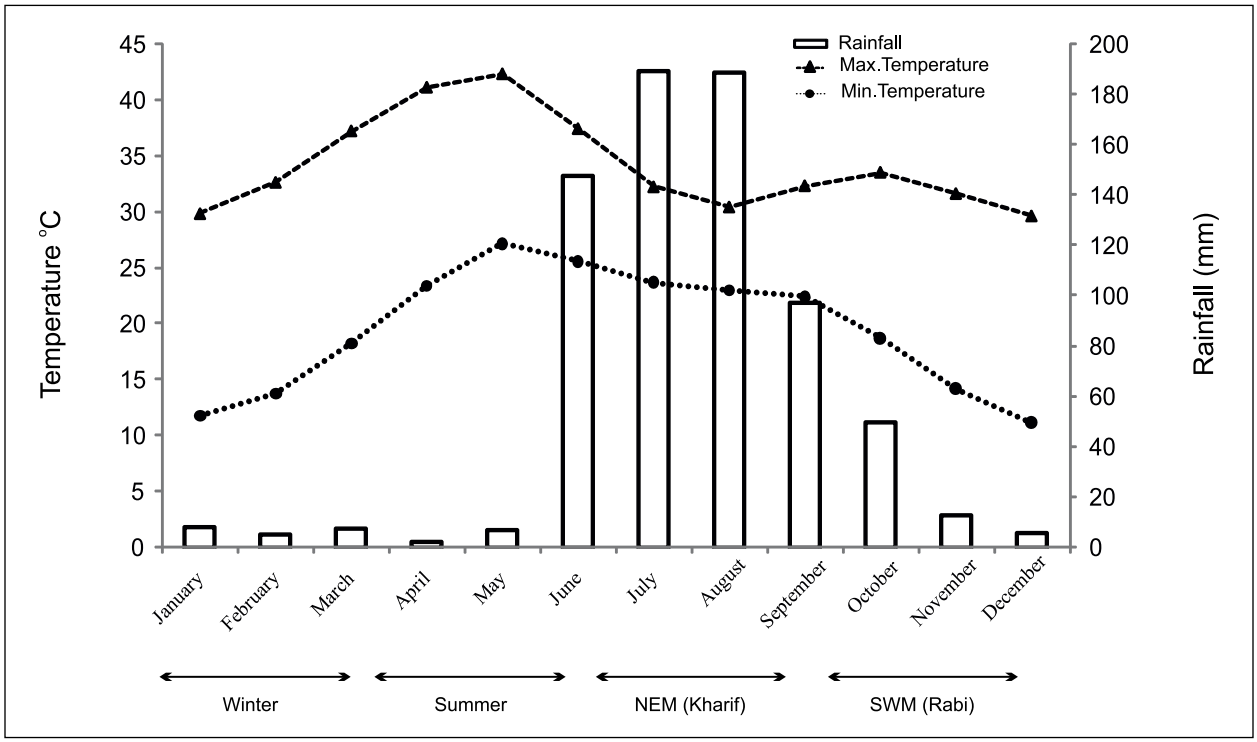


Figure 25. Monthly normal temperature and rainfall of Akola district.

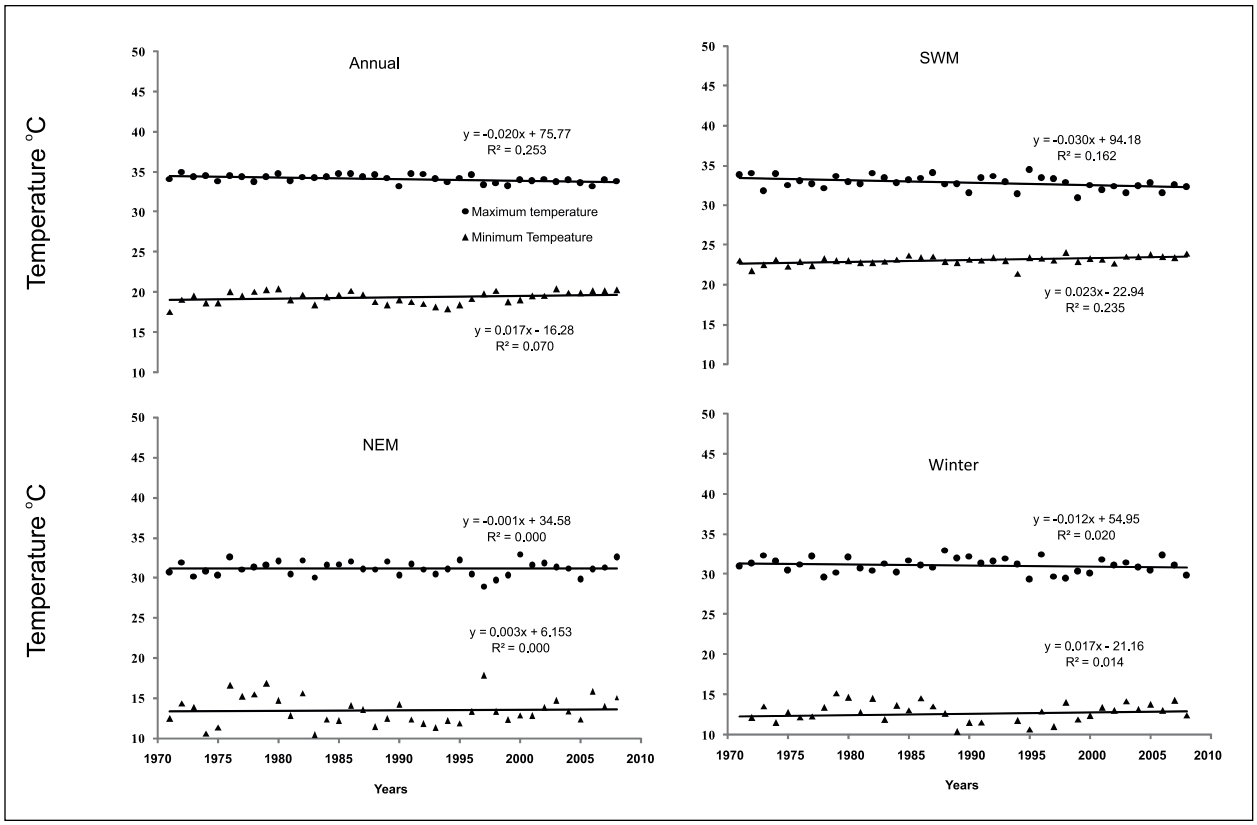
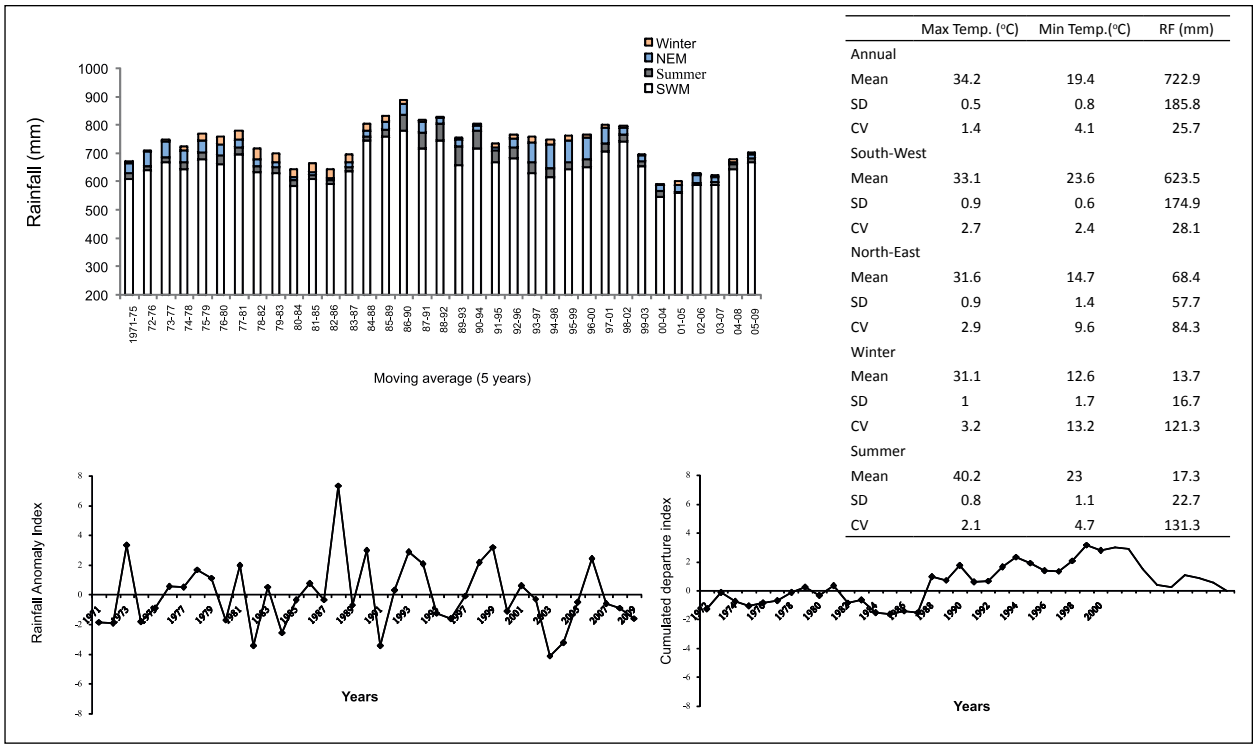


Figure 26. Long term (1971-2009) annual and seasonal trends in average maximum and minimum temperature in Akola district of Maharashtra; SWM – southwest monsoon; NEM – northeast monsoon.

The rainfall characteristics of Akola station (Figure 27) revealed that about 722.9 mm of rainfall is received in a year and 86% (623.5 mm) of it is received through SWM rains. As CV is around 25%, which shows rainfall is less variable in Akola compared to other districts that are analyzed. Only 9% of total rainfall is received through NEM rains annually. The contribution of rainfall from winter and summer periods is negligible. The five year moving average of rainfall during different seasons indicated cyclical variations, which are in conformity with the findings of the NPCC project of ICAR. Rainfall indices computed showed that from 1988 onwards there was an increase in rainfall above the normal, which decreased from 2002 onwards (Figure 27).

Weekly rainfall distribution and their probabilities are essential for agricultural planning. Hence, the initial probability of annual wet (W) and dry (D) weeks and conditional probability of W/W, D/W, D/D and W/D at different rainfall limits of 10, 20, 30, 40 and 50 mm are computed and given in Appendix 15. As expected. the probabilities of receiving dry weeks are of >70% from weeks 1-22 and the value decreases to about <25 % with the onset of the monsoon at week 24. This trend continues up to week 40, after which it increases till the end of December. The initial probability of receiving rain of at least 10 mm/week is above 50% from week 24 to 36, which is sufficient for short duration crops like pulses under rainfed conditions. Conditional probabilities of having W/W of above 10 mm are 50% for weeks 23 to 39, showing favorable conditions for better crop production at this time. The probabilities of D/W, D/D and W/D at different limits, which are essential for crop



	Max Temp. (°C)	Min Temp.(°C)	RF (mm)
Annual			
Mean	34.2	19.4	722.9
SD	0.5	0.8	185.8
CV	1.4	4.1	25.7
South-West			
Mean	33.1	23.6	623.5
SD	0.9	0.6	174.9
CV	2.7	2.4	28.1
North-East			
Mean	31.6	14.7	68.4
SD	0.9	1.4	57.7
CV	2.9	9.6	84.3
Winter			
Mean	31.1	12.6	13.7
SD	1	1.7	16.7
CV	3.2	13.2	121.3
Summer			
Mean	40.2	23	17.3
SD	0.8	1.1	22.7
CV	2.1	4.7	131.3

Figure 27. Annual and seasonal rainfall variation and trends of Akola district. (a) Seasonal rainfall averages (5 year moving); (b) Mean, CV and SD; (c) Rainfall anomaly index and cumulative departure index.

planning, were also computed and appended. Similarly probabilities of consecutive wet and dry weeks were also computed at various limits and are given in Appendix 16.

6.3.2. Rainy Days

The number of rainy days and amount of rainfall per day are important climatic parameters that influence rainfed agriculture significantly. Hence, analyses were done for Akola to compute the number of rainy days in different seasons, as detailed in Table 6. The values in the table indicated that Akola receives its annual rainfall in about 40 rainy days with a standard deviation of 52 and coefficient of variation of 3.4%. The number of rainy days is 33 in the SWM and 4 in the NEM period. The highest number of rainy days is recorded in July and August, followed by June and September.

Table 6. Mean SD and CV of annual, seasonal and monthly rainy days from 1971-2009 in Akola.

	Winter	Summer	SWM	NEM	Annual	
Mean	1.21	1.77	32.82	4.05	39.85	
SD	1.4	1.99	6.94	3.05	52	
CV	116.08	112.64	21.13	75.33	3.35	
	January	February	March	April	May	June
Mean	0.7	0.5	0.8	0.3	0.7	7.1
SD	1.1	0.7	1.5	0.6	1.2	2.7
CV	64.1	71.1	52.7	43.1	62.7	262.2
	July	August	September	October	November	December
Mean	10.2	9.6	6.0	2.6	0.9	0.6
SD	3.4	2.8	4.0	2.5	1.7	0.9
CV	295.4	336.2	152.5	103.4	52.1	66.2

6.3.3. Droughts

Annual rainfall departures from its mean value for the years 1971-2009 are given in Table 7. The data shows that during the past 39 years Akola experienced 24 normal years, 10 mild and 5 moderate droughts. The frequency of moderate and mild droughts is more in the last decade compared to other decades. Akola never experienced a severe drought situation during the study period. However, a high intensity of moderate drought (-46.3%) very near to severe drought conditions was experienced during 2003. Perhaps a long term series of data (of about 100 years) might catch a year with severe drought conditions at Akola. The agricultural droughts during the *kharif* season were computed for the period 1972-2000 and are given in Table 7. A close look at the table shows that there were a total of 33 occasions when the crops were subjected to a water deficit (agricultural droughts) period of at least 4 weeks duration. In some years, the crop suffered drought conditions twice within the season. On analyzing the periods of occurrence it was found that mostly agricultural droughts occurred during the reproductive stage (September), the next in frequency was during the vegetative stage in August.

Table 7. Meteorological (a) and agricultural (b) drought experienced in Akola district during the past 39 years.

a) Meteorological drought

Year	Annual Rainfall (mm)	Deviation (%)	Drought	Year	Annual Rainfall (mm)	Deviation (%)	Drought
1971	572.3	-20.8	Mild	1991	443.8	-38.6	Moderate
1972	566.6	-21.6	Mild	1992	747.0	3.3	No drought
1973	993.9	37.5	No drought	1993	956.9	32.4	No drought
1974	575.7	-20.4	Mild	1994	890.0	23.1	No drought
1975	649.2	-10.2	No drought	1995	616.8	-14.7	Mild
1976	768.0	6.2	No drought	1996	597.3	-17.4	Mild
1977	761.9	5.4	No drought	1997	716.3	-0.9	No drought
1978	860.0	19.0	No drought	1998	898.0	24.2	No drought
1979	814.4	12.7	No drought	1999	982.7	35.9	No drought
1980	585.0	-19.1	Mild	2000	631.8	-12.6	Mild
1981	881.8	22.0	No drought	2001	772.0	6.8	No drought
1982	442.5	-38.8	Moderate	2002	699.2	-3.3	No drought
1983	765.3	5.9	No drought	2003	388.1	-46.3	Moderate
1984	514.6	-28.8	Moderate	2004	460.4	-36.3	Moderate
1985	692.5	-4.2	No drought	2005	682.5	-5.6	No drought
1986	784.3	8.5	No drought	2006	918.3	27.0	No drought
1987	696.0	-3.7	No drought	2007	672.6	-7.0	No drought
1988	1318.6	82.4	No drought	2008	650.7	-10.0	No drought
1989	667.0	-7.7	No drought	2009	593.7	-17.9	Mild
1990	965.2	33.5	No drought				

b) Agricultural drought	
Year	Weeks
1971	26-29
	30-33
1972	38-41
1974	22-25
	33-36
1976	38-41
1978	36-39
1979	33-36
1980	34-37
	38-41
1982	23-26
	39-42
1985	33-36
1986	34-37
	38-41
1987	29-32
1989	28-31
1990	36-39
1991	34-37
	38-41
1994	37-40
1995	22-25
	31-34
	38-41
1996	22-25
	31-34
2000	30-33
	38-41
2001	35-38
2005	22-25
2008	39-42
2009	22-25

6.3.4. Extreme events (Rainfall and Temperature)

Unpredictable climatic extreme events can cause devastation to agriculture (crop and livestock), which form the backbone of rural income. Though prediction of these events is difficult, understanding vulnerabilities to such changes is essential for managing the climate risks effectively. Therefore, rainfall was analysed to compute the frequencies of different rainfall events viz., 25-50, 50-75, 75-100 and >100 mm per day during the last 40 years, as detailed in Appendix 17. The same analysis was done for different seasons and is furnished in Appendixes 18, 19 and 20. On an average, 4-5 days of extreme precipitation events of above 100 mm took place during the last 4 decades. There is no evidence that frequency of extreme rainfall is increasing in the last decade. Similarly, the extreme maximum temperature above 40-44°C during summer was analysed and is given in Appendix 21. The data revealed that occurrence of high temperature events during summer have actually decreased over the past 40 years. To substantiate this, more information about extreme events from weather data of nearby places in the state is required.

6.4. Solapur

6.4.1. Temperature and Rainfall

Solapur district is situated in the southeastern region of Maharashtra bordering northern Karnataka. It is located in the semi-arid tract of the Indian subcontinent at latitude 18.32°N and longitude 76.15°E. Sorghum, pigeonpea, cotton, groundnut, wheat and chickpea are grown in this district in two crop seasons, *kharif* and *rabi*. The district receives an average rainfall of 725.8 mm and an average temperature of 34°C (max) and 20°C (min). The maximum amount of rainfall (about 17 mm) is received in September followed by rainfall during the receding period of SWM and commencement of NEM (Figure 28).

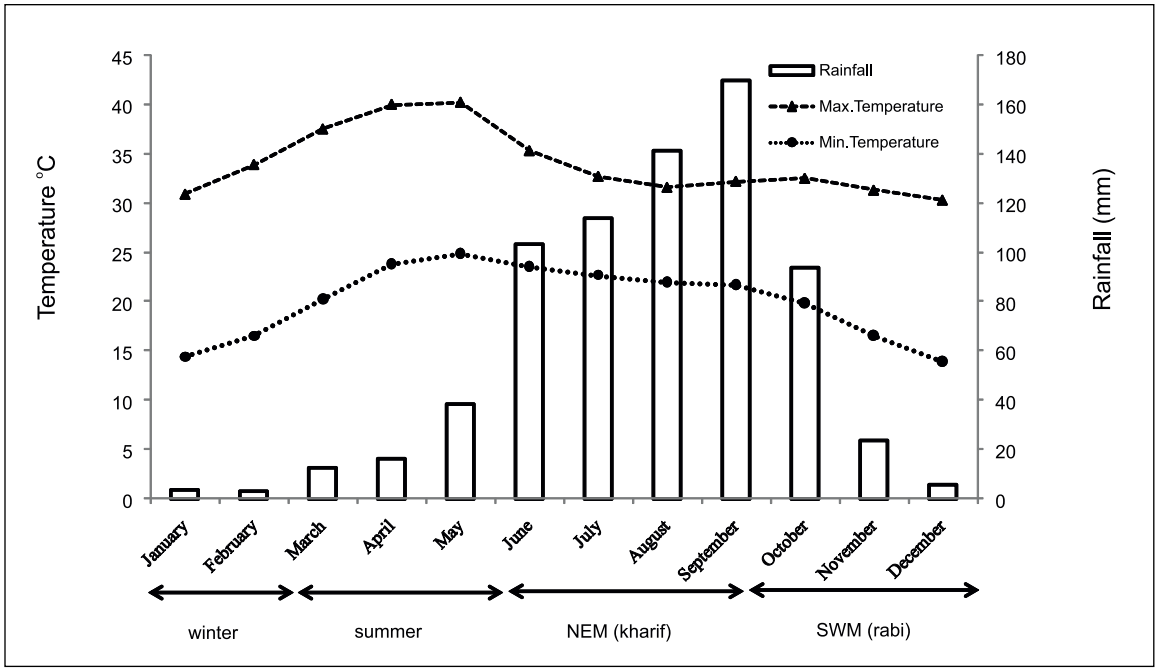


Figure 28. Monthly normal temperature and rainfall of Solapur district.

Mean annual and seasonal temperature trends for the period 1971-2009 have been worked out and are presented in Figure 29. It is observed that a slight increasing trend in both maximum and minimum temperatures has been noticed with a small fall in temperature in the recent period. Among the seasons, both NEM and winter temperatures have shown a positive trend while SWM temperature values did not exhibit any trend. As observed in Akola, the variability in minimum temperature was higher in NEM and winter seasons. The five year moving average of annual precipitation showed short term fluctuations. Its variation is more during the 1990-2008 period compared to previous years. The rainfall distribution in different seasons shows that about 73% of annual rainfall is received during the SWM and 17% during the NEM period. The computed indices, ie, rainfall anomaly index and cumulative departure index, showed that there is increase in quantum of rainfall from 1987 onwards, which declined from 1997 onwards (Figure 30). The initial probability of annual wet (W) and dry (D) weeks and conditional probability of W/W, D/W, D/D and W/D at different rainfall limits of 10, 20, 30, 40 and 50 mm are computed and given in Appendix 22. As expected, the probabilities of receiving dry weeks are >70% during weeks 1-22, the probability decreases to about <25% during weeks 24 to 42, then increases till the end of December. Probabilities of receiving at least 10 mm at 50% during the monsoon period is observed during weeks 23-40. With increased rainfall limits, the period at 50% probability decreases. Conditional probabilities of having a wet week followed by wet week is very low in Solapur and is about 60-80% during weeks 25-42, indicating assured rainfall periods for rainfed crops. Conditional probabilities of D/W, D/D and W/D have also been given in Appendix 22. These are also useful in evaluating suitable cropping sequences that require intermittent dry and wet weeks. Also the probabilities of consecutive wet and dry weeks of 2, 3 and 4 weeks duration are also computed at various limits and are given in Appendix 23.

6.4.2. Rainy days

The number of rainy days, along with SD and CV for different seasons are given in Table 8. The total annual rainfall at Solapur is received in about 44 days. The SWM period had an average of 31 rainy days, NEM had 7 days, and average number of days during summer was 5. There was hardly any rain during winter. The months of August and September had the highest number of rainy days, followed by July, June and October.

Table 8. Mean, SD and CV of annual, seasonal and monthly rainy days of Solapur from 1971–2009.

	Winter	Summer	SWM	NEM	Annual	
Mean	0.64	4.97	31.15	6.79	43.56	
SD	1.09	2.94	8.76	3.93	5.5	
CV	169.71	59.15	28.11	57.91	32.4	
	January	February	March	April	May	June
Mean	0.33	0.31	0.79	1.28	2.90	6.26
SD	0.74	0.69	1.44	1.41	2.26	2.60
CV	221.24	225.58	180.66	110.23	77.90	41.60
	July	August	September	October	November	December
Mean	7.18	8.87	8.85	4.92	1.56	0.31
SD	3.71	4.01	4.20	3.83	1.98	0.66
CV	51.61	45.25	47.43	77.89	126.85	212.91

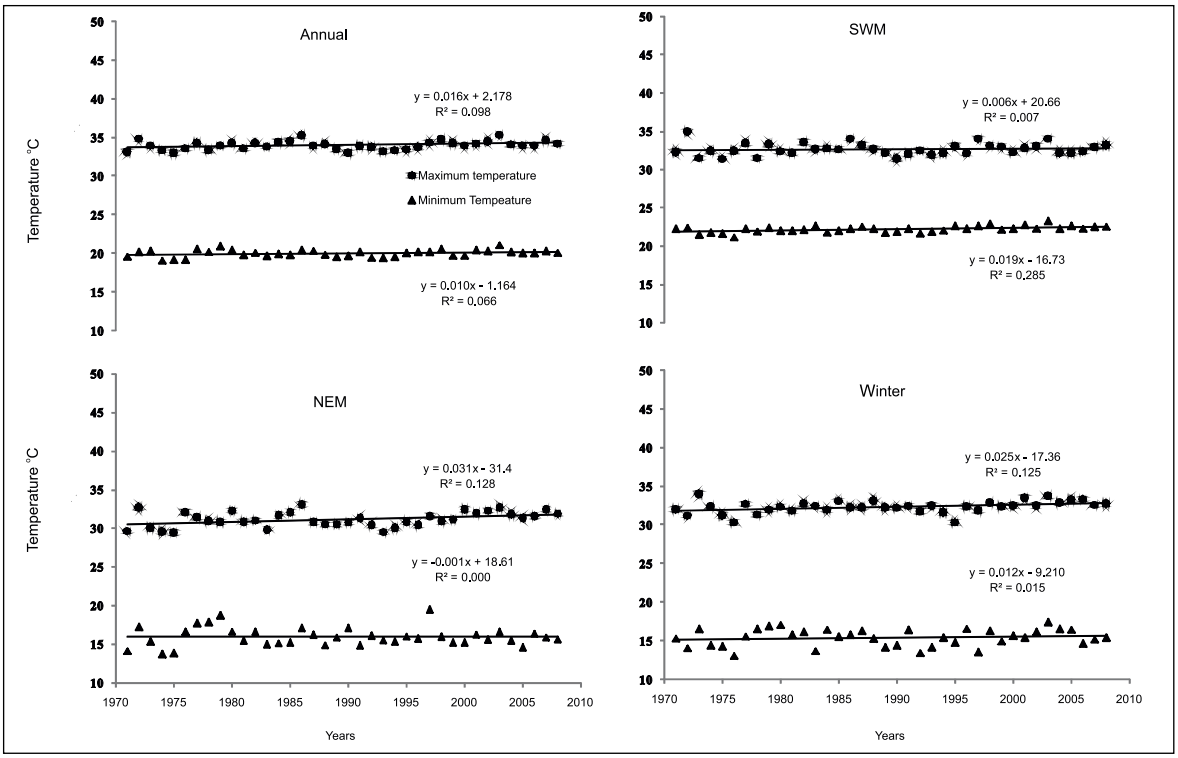
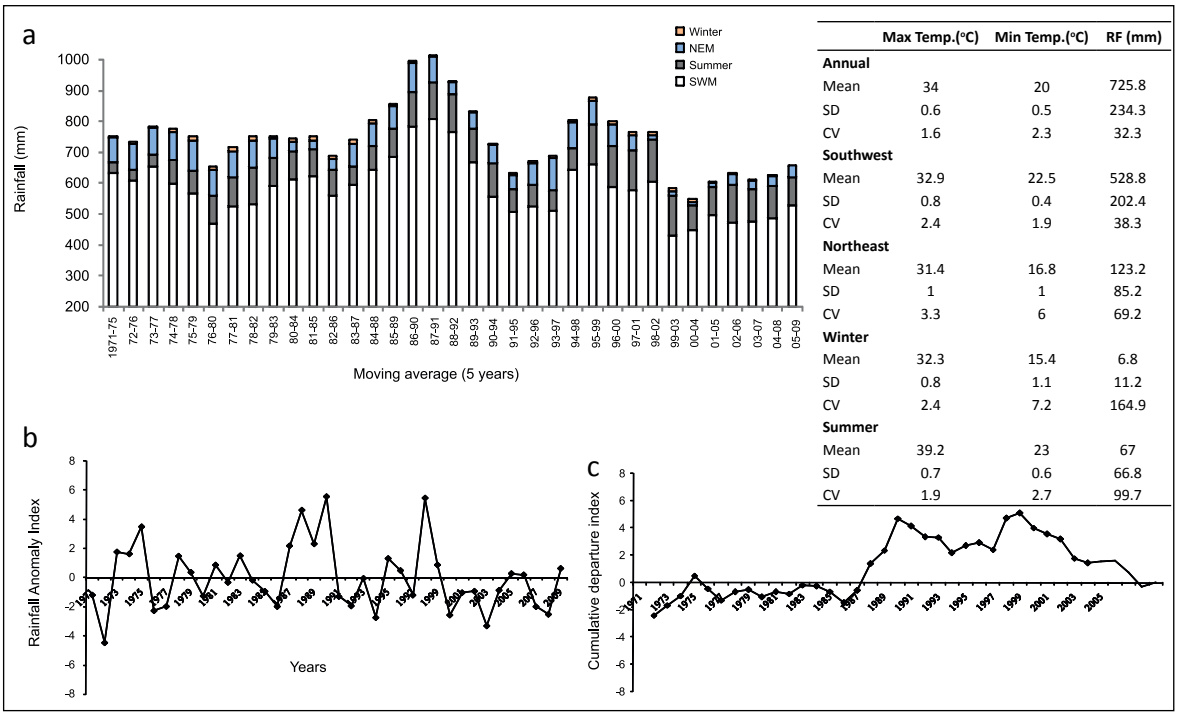


Figure 29. Long term (1971-2009) annual and seasonal trends in average maximum and minimum temperature in Solapur district of Maharashtra.



	Max Temp.(°C)	Min Temp.(°C)	RF (mm)
Annual			
Mean	34	20	725.8
SD	0.6	0.5	234.3
CV	1.6	2.3	32.3
Southwest			
Mean	32.9	22.5	528.8
SD	0.8	0.4	202.4
CV	2.4	1.9	38.3
Northeast			
Mean	31.4	16.8	123.2
SD	1	1	85.2
CV	3.3	6	69.2
Winter			
Mean	32.3	15.4	6.8
SD	0.8	1.1	11.2
CV	2.4	7.2	164.9
Summer			
Mean	39.2	23	67
SD	0.7	0.6	66.8
CV	1.9	2.7	99.7

Figure 30. Annual and seasonal rainfall variation and trends of Solapur district. (a) Seasonal rainfall averages (5 year moving); (b) Mean, CV and SD; (c) rainfall anomaly index and cumulative departure index.

6.4.3. Droughts

Drought of different intensities have been computed from rainfall departure for the period 1971-2009 and are given in Table 9. It is observed that Solapur recorded 8 mild, 9 moderate and 1 severe meteorological droughts in this period. The frequency of occurrence of moderate and mild drought is more in the last decade (2000-2009) compared to other years. 1972 witnessed severe drought, and a moderate drought of high intensity (-46.5%) was recorded in 2003. Table 9 shows that there were 27 agricultural drought periods during the last 40 years in which crops were subjected to water stress. In some years crops were subjected to water stress twice during the season. For example, in 1972, no crop was sown due to total failure of rains. A close look at the table shows that the month of September coincides with crop maturity, and is found to have more chances of experiencing agricultural drought.

6.4.4. Extreme events (Rainfall and Temperature)

The frequencies of occurrence of extreme rainfall events in a year for the amounts 25-50, 50-75, 75-100 and >100 mm for the period 1971 to 2009 were computed and are given in Appendix 24. Seasonal analyses for these amounts have also been worked out and are given in Appendixes 25, 26 and 27. It is seen that occurrence of high rainfall events of above 75 and 100 mm are less in the recent decades due to reduced rainfall activity. Solapur district normally records an atmospheric temperature of >40°C during summer. Computation of the frequency of occurrence of days that recorded temperatures above 40°C-44°C are given in Appendix 28. The data revealed a sharp increase in the frequency of occurrence of temperature events above 44°C during 2000-2009.

Table 9. Meteorological (a) and agricultural (b) drought experienced by Solapur district from 1971–2009.

a) Meteorological drought

Year	Annual Rainfall (mm)	Deviation (%)	Drought	Year	Annual Rainfall (mm)	Deviation (%)	Drought
1971	604.1	-16.8	Mild	1991	593.6	-18.2	Mild
1972	270.3	-62.8	Severe	1992	528.2	-27.2	Moderate
1973	905.6	24.8	No drought	1993	720.8	-0.7	No drought
1974	891.9	22.9	No drought	1994	446.1	-38.5	Moderate
1975	1081.6	49.0	No drought	1995	859.8	18.5	No drought
1976	494.7	-31.8	Moderate	1996	776.0	6.9	No drought
1977	524.3	-27.8	Moderate	1997	603.4	-16.9	Mild
1978	875.9	20.7	No drought	1998	1282.5	76.7	No drought
1979	762.8	5.1	No drought	1999	814.5	12.2	No drought
1980	597.4	-17.7	Mild	2000	464.2	-36.0	Moderate
1981	814.2	12.2	No drought	2001	621.2	-14.4	Mild
1982	692.4	-4.6	No drought	2002	631.0	-13.1	Mild
1983	879.0	21.1	No drought	2003	388.5	-46.5	Moderate
1984	708.1	-2.4	No drought	2004	637.6	-12.2	Mild
1985	630.0	-13.2	Mild	2005	754.7	4.0	No drought
1986	523.9	-27.8	Moderate	2006	745.6	2.7	No drought
1987	948.1	30.6	No drought	2007	523.0	-27.9	Moderate
1988	1198.0	65.1	No drought	2008	469.2	-35.4	Moderate
1989	962.0	32.5	No drought	2009	790.2	8.9	No drought
1990	1292.4	78.1	No drought				

b) Agricultural drought

Year	Week No	Year	Week No
1972	27-30	1986	26-29
	31-34		39-42
	39-42	1987	22-25
1973	34-37	1991	33-36
1976	36-39	1992	37-40
1977	35-38	1994	35-38
1980	25-28	1996	28-31
	37-40	1997	28-31
1981	26-29		32-35
1982	33-36	2001	25-28
1984	24-27	2002	37-40
	33-36	2004	39-42
		2008	24-27
		2009	26-29
			30-33

7. Micro regional analysis

7.1. Sub-district rainfall trend analysis at Anantapur and Mahbubnagar in Andhra Pradesh, and Akola and Solapur in Maharashtra

In India, studies by several researchers have shown that there is an increasing trend in surface temperature (Kothawale and Rupa Kumar 2005; Mall et al. 2006) and no significant increasing / decreasing trend in rainfall (Mall et al. 2006). The variability study of climate over the region was carried out largely using single station data due to the limited number of observational points. As there is greater variability, especially in rainfall pattern, within the district, it is advisable to conduct micro-regional analysis wherever the data is available at sub-district level. In India, recording of sub-district level rainfall started some time during the 1980-90 period at many locations. Hence, efforts have been made to find the rainfall trend at mandal / tehsil level both during the southwest monsoon period and on annual basis, and temperature trends at station-level. For this purpose, mandal / tehsil (sub-districts) level daily rainfall data of Anantapur and Mahbubnagar in Andhra Pradesh state, and Akola and Solapur in Maharashtra state was used.

Annual and southwest monsoon rainfall trends in respect of sub-district (Mandals) in Anantapur and Mahbubnagar were computed and the statistical significance was obtained using the Mann-Kendall test (Figure 31 and Figure 32). The mandal map of Anantapur and Mahbubnagar districts is given in Appendix 29. It is seen that there is more variability among the mandals with respect to annual rainfall compared with the southwest monsoon rainfall. Most of the mandals in the district do not show any trend, but an increasing trend is seen for annual rainfall in 12 mandals. The mandals are Bommanahal and Atmakur mandals (1% significant level), Guntakal, Rayadurgam, Roddam, Amarapuram, Gorantala and Chilamathur (5% level), Uravakonda, Bukkapatnam, Penukonda and Nallamada (10%) in Anantapur district (Figure 31). No decreasing trend in annual as well as southwest monsoon rainfall is observed at any mandal. This is in conformity with the earlier findings

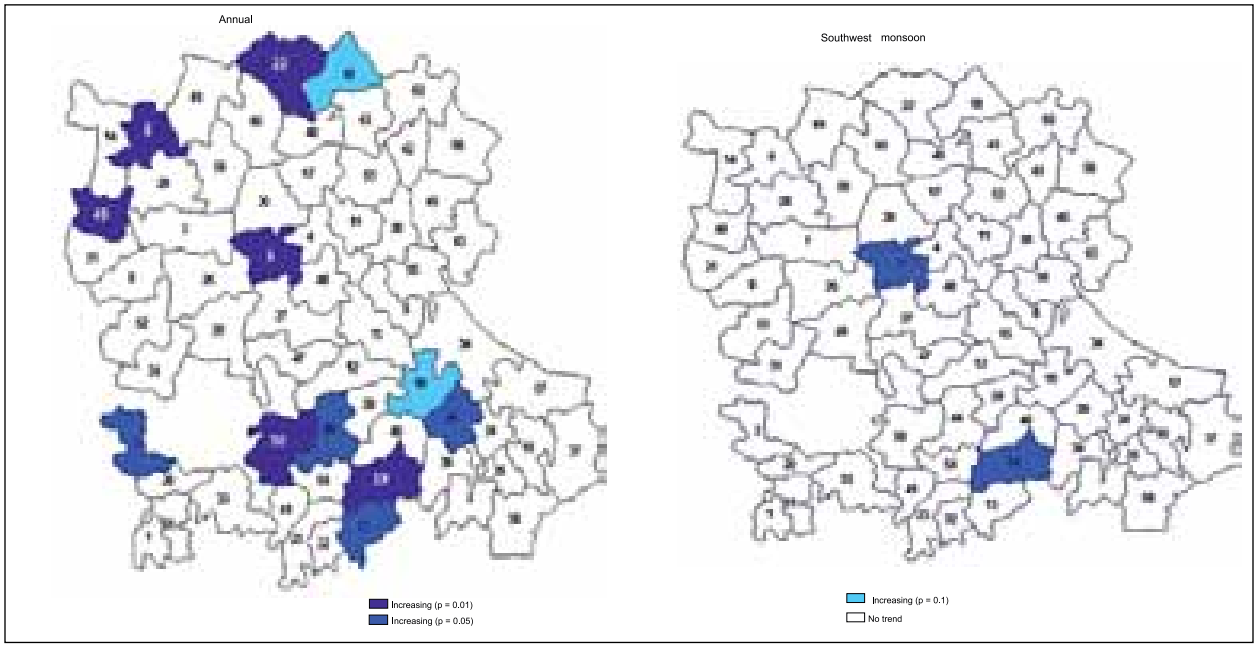


Figure 31. Annual and southwest monsoon rainfall trend at Anantapur.

that the total rainfall of the districts shows an increasing trend in the recent decades. During the southwest monsoon period, only two mandals, ie, Atmakur and Gorantala, showed an increasing trend at 5% and 10% level, respectively. No significant increasing / decreasing trend was observed in the rest of the mandals of Anantapur district.

Similarly for Mahbubnagar, of 64 mandals, most did not show any significant trend. An increasing trend in annual rainfall is noticed at six mandals - Monabad at 5% significant level and 10% significant level in Aiza, Bomraspeta, Dhanwada, Kondurg and Veldanda mandals. Annual rainfall showed a declining trend at three mandals - Gopalpeta, Koilkonda and Veepangandla mandals (5% significant level). In the case of southwest monsoon rainfall, only two mandals, Koilkonda and Veepangandla, showed a declining tendency at 1% significant level (Figure 32). No increasing/ decreasing trend is noticed in the remaining mandals of Mahbubnagar district.

Annual and southwest monsoon seasonal rainfall in respect of tehsils in Akola and Solapur districts of Maharashtra state are given in Table 10.

Table 10. Trend in annual and southwest monsoon rainfall at Akola and Solapur.

Akola tehsils	Annual	Southwest monsoon	Solapur tehsils	Annual	Southwest monsoon
Akola city	NS	NS	Akkalkot	DT (5%)	NS
Akot	NS	NS	Barshi	NS	NS
Balapur	NS	NS	Karamal	DT (5%)	DT (10%)
Barshitakli	NS	NS	Madha	NS	NS
Murtijapur	NS	NS	Malshiras	NS	NS
Patur	NS	NS	Mangalwedha	NS	NS
Telhara	NS	NS	Mohol	NS	NS
			Pandhapur	NS	NS
			Sangola	NS	NS
			Solapur	NS	NS

DT – Decreasing trend

NS - Non–significant

The trend analysis revealed that in Akola district no tehsils showed a significant increasing or decreasing trend. However, in Solapur district, a decreasing trend is noticed in annual rainfall in Akkalkot tehsil at 5% significant level (Table 10). At Karamal tehsil both annual and southwest monsoon rainfall showed a decreasing tendency and no trend is observed in other tehsils.

From the results it can be concluded that no significant increasing/decreasing trend is noticed in most of the mandals/tehsils of the four selected districts. However, Anantapur has the greater number of mandals showing an increasing trend in annual rainfall than Mahbubnagar district. But in Akola and Solapur districts only a decreasing or no trend is noticed.

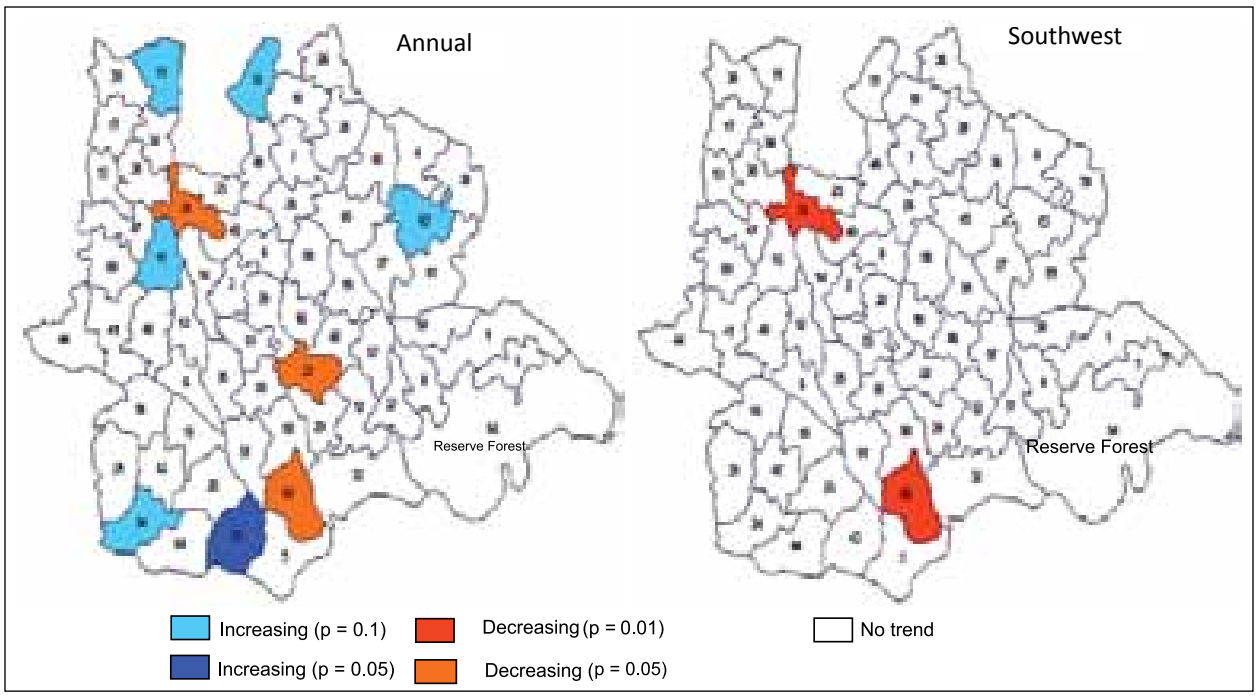


Figure 32. Annual and southwest monsoon rainfall trend at Mahbubnagar.

7.2. Heavy rainfall analysis

Frequency of heavy rainfall events in the order of 75–100 mm and more than 100 mm per day during the southwest monsoon period was calculated using mandal/tehsil-wise data of Anantapur, Mahbubnagar, Akola and Solapur districts. The results revealed that Uravakonda mandal in Anantapur district showed a decreasing trend at 10% significant level under the 75-100 mm category. Though a significant increase in annual rainfall is recorded, the increase is perhaps the result of a number of small-intensity storms that contributed to increased rainfall at this mandal. There is no signficant increasing or decreasing trend in heavy rainfall events at Mahbubnagar district. In Akola, a decreasing trend at 5% significant level was noticed in Akola tehsil, and in Barshi of Solapur district, at 1% significant level. However, an increasing trend was observed in Malsiras tehsil of Solapur district at 10% significant level. Under the more than 100 mm category, no increasing/decreasing trend was noticed in any of the four districts.

7.3. Trend analysis of maximum and minimum temperature

Temperature data is not available at sub-district level at any of the districts under study. Therefore, the station data at Anantapur and Mahbubnagar in Andhra Pradesh, and Akola and Solapur in Maharashtra was analyzed. In addition to the fitting of data sets for linear trends, the data was subjected to a Mann-Kendall test for its significance, and results are given in Table 11. Maximum and minimum temperature trend analysis indicated that an increasing trend in maximum temperature is seen in all seasons and also on an annual basis at Anantapur. However, a significant increase in minimum temperature is noticed only in the summer season at this station. Improved rainfall at many mandals might have reduced the impact of increased temperature on crops. In Mahbubnagar, an increasing trend is observed in both annual maximum temperature and minimum temperature at 1% and 5% respectively. Similarly, an increasing trend in maximum temperature was noted during

the post-monsoon and winter seasons, and the minimum temperature showed an increasing trend during the southwest monsoon and summer seasons (Table 11). These significant changes over the past 40 years are in conformity with the findings of increased rate of temperature in the recent decades. There was no change in rainfall in most of the mandals, and together with the increased temperatures, this might have affected the crop performance in the district.

Table 11. Temperature trend at selected stations.

	Southwest Monsoon (June – Sep)		Post-Monsoon (Oct – Dec)		Winter (Jan – Feb)		Summer (Mar – May)		Annual	
Station	MaxT	MinT	MaxT	MinT	MaxT	MinT	MaxT	MinT	MaxT	MinT
Anantapur	IT (5%)	NS	IT (1%)	NS	IT (1%)	NS	IT (10%)	IT (10%)	IT (1%)	NS
Mahbubnagar	NS	IT (1%)	IT (1%)	NS	IT (1%)	NS	NS	IT (5%)	IT (1%)	IT (5%)
Akola	NS	IT (1%)	NS	NS	NS	NS	DT (10%)	IT (5%)	DT (5%)	IT (5%)
Solapur	NS	IT (1%)	IT (10%)	IT (10%)	IT (1%)	NS	IT (5%)	NS	IT (1%)	IT (5%)

IT – Increasing trend; DT – Decreasing trend; NS – Non significant

At Akola, annual and summer season maximum temperatures showed a declining trend. At the same time, an increasing trend is seen in annual, southwest and summer season minimum temperatures. Increased temperature during the southwest monsoon period coupled with no change in rainfall might have affected the crop performance. In Solapur, maximum temperature is increasing annually and in all seasons except during the southwest monsoon period. In the case of minimum temperature, an increasing tendency is observed in annual, southwest and post-monsoon seasons. The increasing temperature coupled with no changes in rainfall might have affected the crop yields.

7. 4. Extreme temperature analysis

Frequency of extreme temperature events for both maximum (above 40°C) during summer (March to June) and minimum in the range of 7–10°C during winter (November to February) for all the four stations have been calculated, and the trends of such extreme events have also been computed and their statistical significance have also been worked out. The analysis of extreme maximum temperature revealed that frequency of above 40°C days during the month of March showed an increasing trend at 5% significant level at Anantapur, whereas no significant trend was observed at Mahbubnagar. At Akola, the number of days with temperature above 42°C in the month of May was in a decreasing trend at 1% significant level. On the other hand, at Solapur, an increasing trend was noticed for above 41 and 42°C in the month of April and above 43°C in May at 5% significant level (Table 12).

Table 12. Trend in extreme maximum temperature.

Station	Above 40°C				Above 41°C				Above 42°C				Above 43°C			
	Mar	Apr	May	June	Mar	Apr	May	June	Mar	Apr	May	June	Mar	Apr	May	June
Anantapur	IT (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	-	NS	-	-
Mahbubnagar	NS	NS	NS	NS	-	NS	NS	NS	-	NS	NS	NS	-	-	NS	NS
Akola	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	DT (1%)	NS	NS	NS	NS	NS
Solapur	NS	NS	NS	NS	NS	IT (5%)	NS	NS	NS	IT (5%)	NS	NS	NS	NS	IT (5%)	NS

IT – Increasing trend; DT – Decreasing trend

Table 13. Trend in extreme minimum temperature.

Station	7–10°C			
	Nov	Dec	Jan	Feb
Anantapur	NS	NS	NS	-
Mahbubnagar	NS	NS	NS	NS
Akola	NS	NS	NS	NS
Solapur	NS	NS	DT (5%)	NS

DT – Decreasing trend

In the case of minimum temperature, frequency of days with 7–10°C in the month of January showed a decreasing trend only at Solapur (Table 13). No significant trend was noticed for the other three stations. A significant increasing trend in high maximum temperatures during summer and a decreasing trend in minimum temperature during peak winter (January) shows a warming trend at Solapur only.

7.5. Meteorological drought analysis

To capture the spatial variability of probability of occurrence of droughts within the district, the rainfall data at mandal and tehsil level was subjected to drought analysis. Meteorological drought is defined as the negative departure of annual rainfall from the long term average rainfall of the location. If the departure is from 11-25% it is considered as a mild drought, 26-50% a moderate drought, and if it is >50 % it is defined as a severe drought year. Accordingly, the percentage probability of these droughts for different mandals/tehsils of Anantapur and Mahbubnagar districts, and Akola and Solapur districts have been computed and are furnished in Figures 3 to 6.

In Anantapur district (Figure 33) 10 of the 63 mandals have a very low probability of mild drought occurrence. However, the majority of mandals may experience mild droughts at 11 to 30 %. Only 3 mandals have the highest probability (>30%) of mild drought. The probability of getting 2 to 3

drought years in a decade is seen in 25 of the mandals, and highest being Pamidi (33%) followed by Atmakur (31%), and Rolla and Yellanur (30%). In the case of severe drought conditions the probability of experiencing one severe drought in a decade is noticed in six mandals (Figure 33).

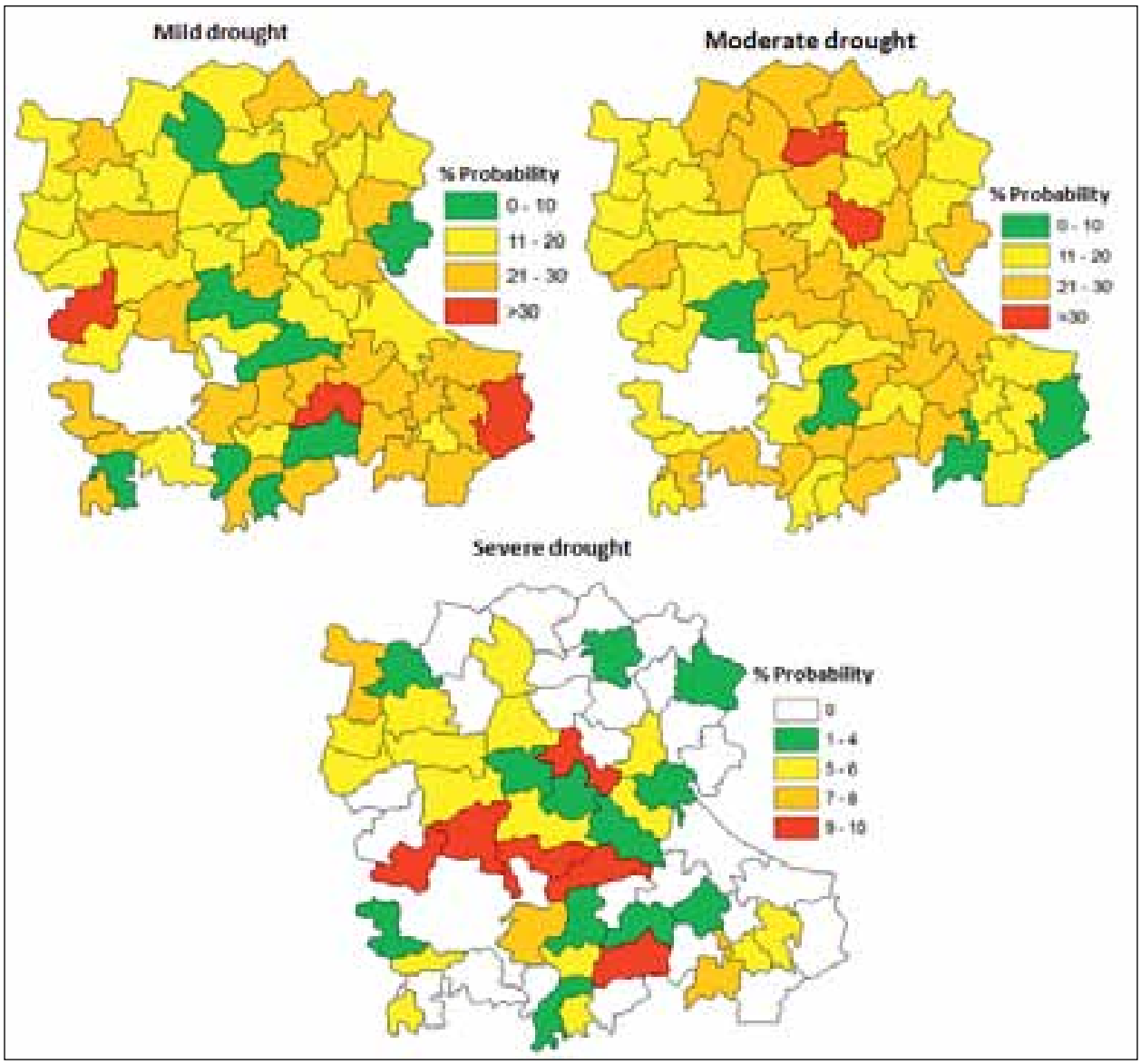


Figure 33. Percent probability of meteorological droughts at Anantapur district.

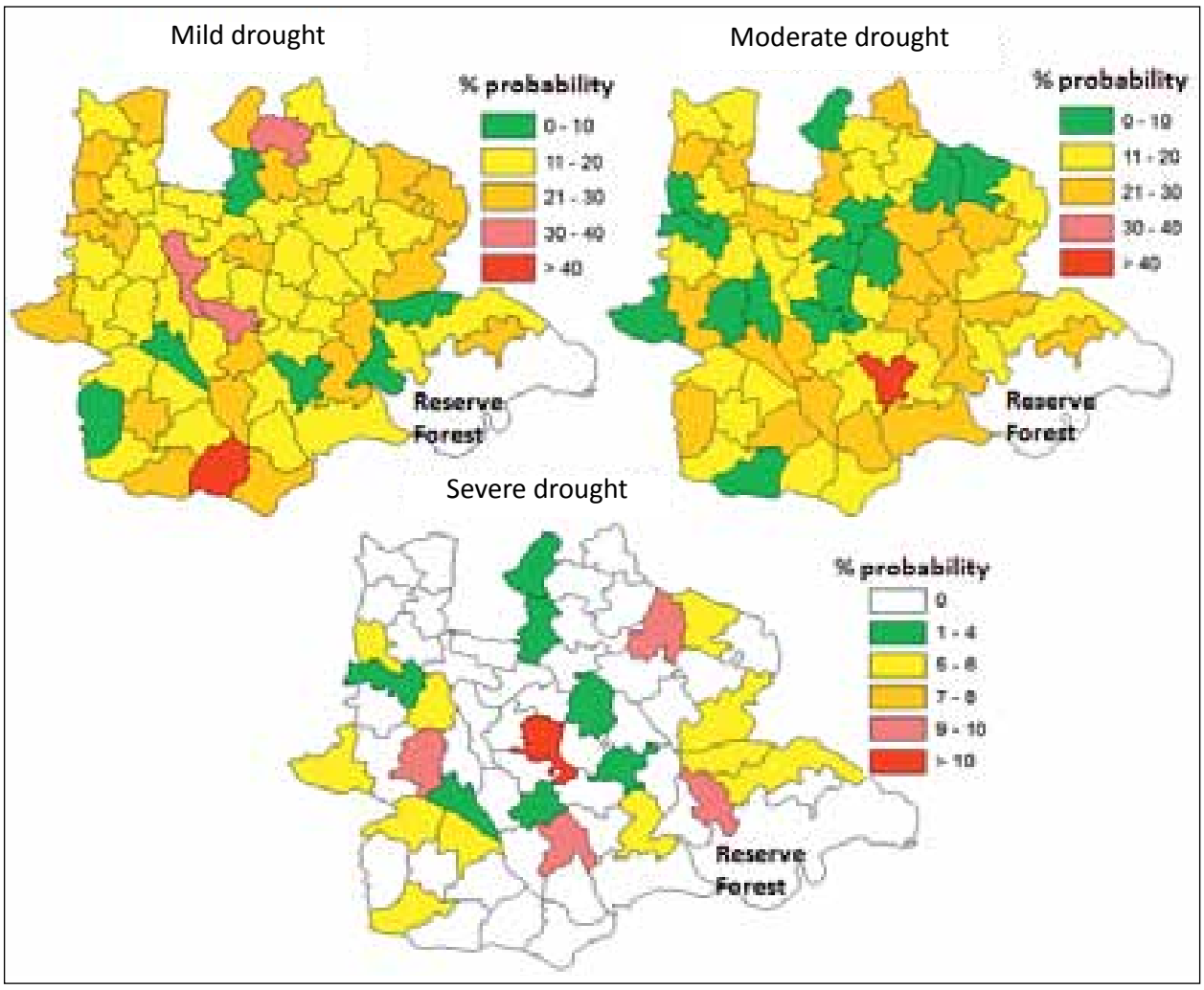


Figure 34. Percent probability of meteorological droughts at Mahbubnagar district.

The probability of occurrence of mild drought at 10-20% is noticed in 41 mandals and 20-40% in 22 mandals of 64 mandals in the district. There is only one mandal that experiences mild drought above 40%. In Mahbubnagar district, the probability of occurrence of moderate drought at less than 20% is observed in 41 mandals and 21 to 40% in 22 mandals. The highest probability, >40%, is observed in only Kodair mandal. The probability of occurrence of approximately one severe drought in a decade is noticed in 5 mandals, Narva, Ghanpur, Tallakondapalle, Pangal and Belmur (Figure 34).

In Akola district, the probability of mild drought, and approximately two drought years in a decade, is noticed in 5 of the 7 tehsils. Occurrence of moderate drought in two years in a ten year period is noticed in three tehsils, Telhara, Akot and Murthijapur, whereas, the probability of occurrence of one moderate drought in a ten year period is observed in Akola, Balapur, Patur and Barsitakli tehsils. No tehsil is likely to be subjected to severe drought in the district as the probabilities are very low (Figure 35).

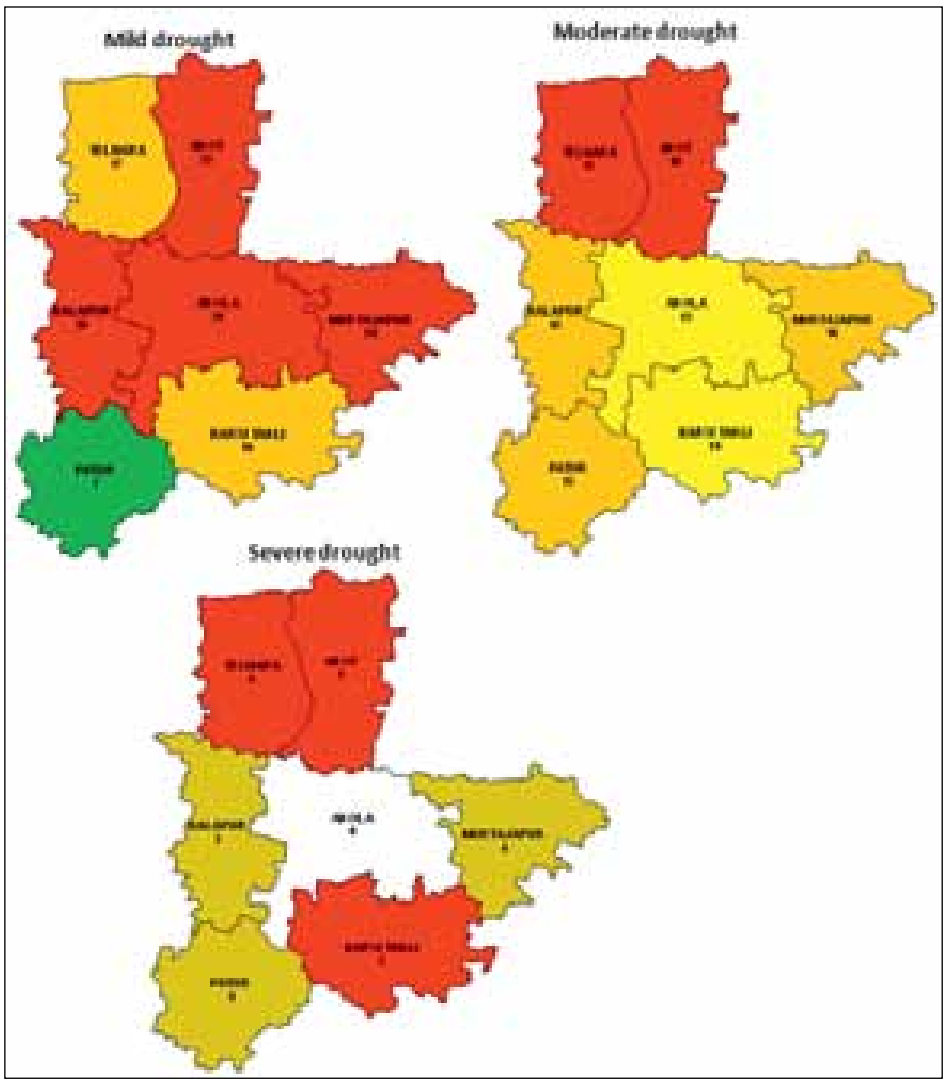


Figure 35. Percent probability of meteorological droughts at Akola district.

Since Solapur is located in the rainfall scarcity zone of Maharashtra, the probability of one mild drought year in a decade is observed in four tehsils, whereas approximately two mild years in a decade is seen in the remaining tehsils. The probability of occurrence of a moderate drought (20-30%) is observed in Sangole (29%), North and South Solapur (24%), Malsiras (23%) and Mangalweda (20%) tehsils (Figure 6). The probability of occurrence of one severe drought in a ten-year period was observed in Karmal Malsiras, Pandharpur and Mangalwedha tehsils.

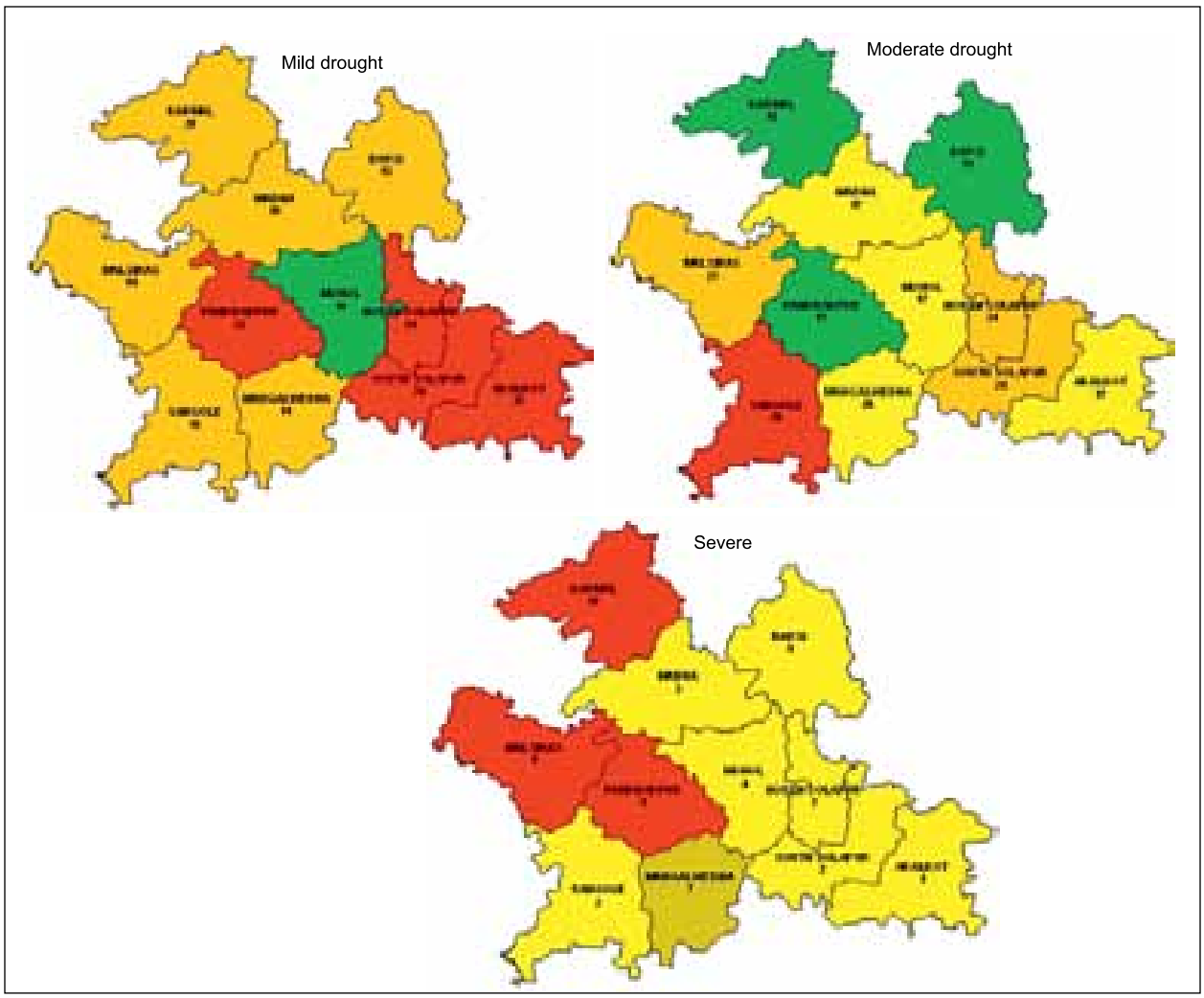


Figure 36. Percent probability of meteorological droughts at Solapur district.

7.6. Climatic types variations – Moisture regime

Fluctuations in climate over a region provide a valuable input to study the changes that affected crop productivity in different agro-climatic regions. Therefore, from climatic water balance of Thornthwaite and Mather (1955), the annual march of Moisture Index (Im) values, which is the difference between humidity (Ih) and aridity index (Ia), serves as a useful index to study the variability in climate over the years. These values are useful to study the effects of climatic variability and change on the hydroclimate of a region (Feddema and Mather 1992). From the weekly climatic water balance analysis for Anantapur, Mahbubnagar, Akola and Solapur for the years 1971–2009, the yearly climatic shifts were studied by computing the annual Moisture Index (Ih–Ia) values, shown plotted in Figure 37.

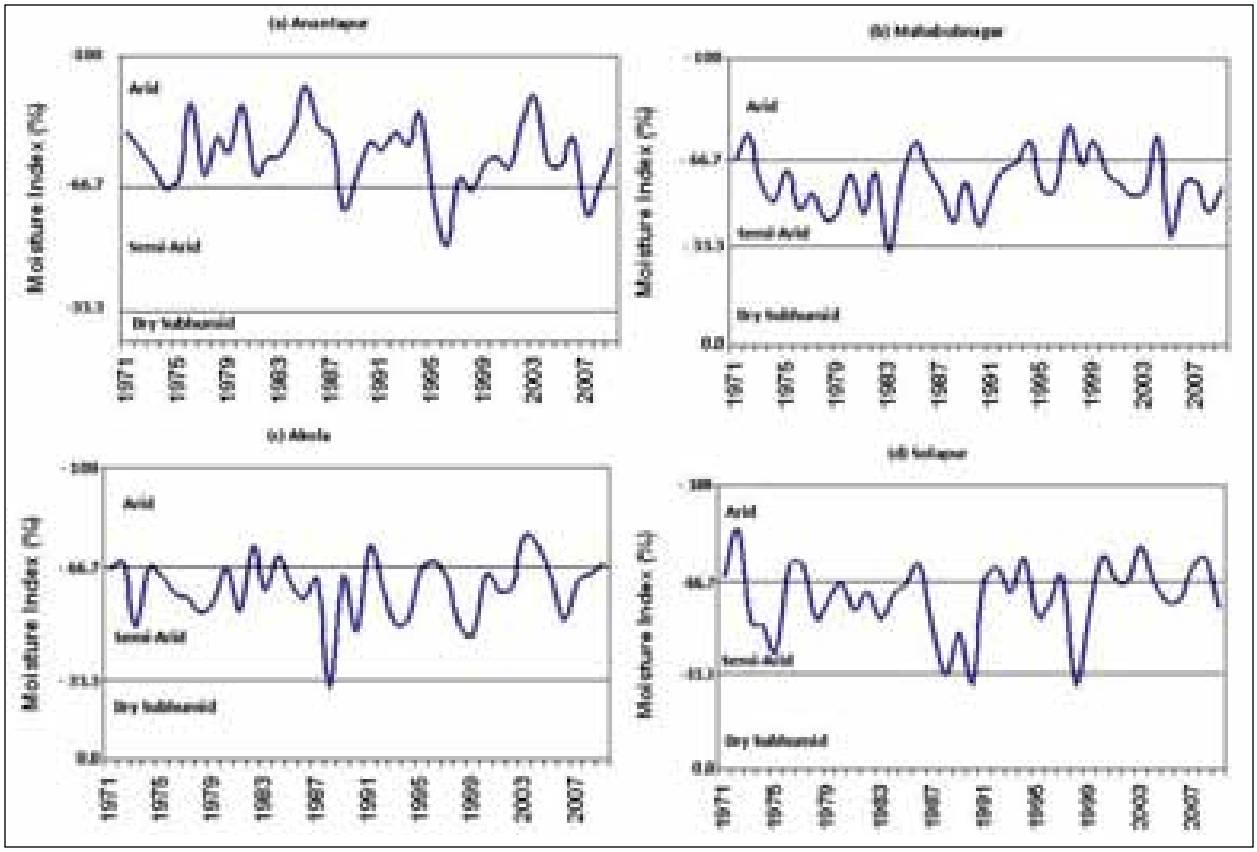


Figure 37. Variability in climatic types in selected stations.

Depending upon the moisture index (Im) value, the climates, ie, arid type (>-66.7) and semi-arid (-66.6 to - 33.3), are determined. It is observed that in majority of the cases all the stations, Akola, Solapur, Mahbubnagar and Anantapur, remained well within their climate types. At Akola, Solapur and Mahbubnagar, which are climatically defined as semi-arid, the number of years that moved towards arid are 6, 8 and 9 out of 39 years, respectively. The number of years that shifted towards the semi-arid type at Anantapur was 4 out of 39 years (Figure 7). At Solapur too, favorable climates towards dry sub-humid was noticed in 3 years - 1988, 1990 and 1998. At Mahbubnagar, favorable climate towards dry sub-humid was noticed in 1983 and 2005, when rainfall was above 1000 mm.

7.7. Crop water requirements (for important crops)–Baseline, 2020 and 2050

Water is crucial for crop production and the best use of available water must be made for efficient crop production and high yields. The relationships between crop, climate, water and soil are complex and many biological, physiological, physical and chemical processes are involved. Knowledge on reliable estimates of water required by different crops in a given set of climatological conditions of a region is of great help in rational utilization of irrigation water for irrigation scheduling, planning of irrigation schemes and effective design of water saving and management systems. A warming climate is observed over the past several decades and is consistently associated with changes in a number of components of the hydrological cycle and hydrological systems. The investigation by McCabe and Wolock (1992), based on an irrigation model, concluded that the

increase in mean annual water use is strongly associated with the increase in temperature. On the other hand, the natural resource base of agriculture is shrinking and degrading, and also adversely affecting the production capacity of the ecosystem. However, demand for agriculture is rising rapidly with rise in population and per capita income, and the increasing demand from the industry sector. Monsoon being the most important climatic phenomenon, occurrence of deficit or failure of the southwest monsoon puts tremendous pressure on the water resources and food basket of the country. The impact of variability of the monsoon rainfall on food grain production has remained large throughout the last century, despite the Green Revolution over the Indian region (Abrol 1996; Gadgil et al. 1999).

The crop water requirements (CWR) of groundnut (Anantapur) and sorghum (Mahbubnagar) for three dates of sowing (normal, early (one week before) and late (one week after) date of sowing) were calculated using CROPWAT 4 Windows v 4.3 (Smith 1992; Smith 1993). This program uses the FAO Penman-Monteith method (Allen et al. 1998) for calculating reference evapotranspiration (ETo). The crop coefficient (Kc) values were taken from the CROPWAT software. These coefficients present the relationship between references (ETo) and crop evapotranspiration (ETcrop) or ET crop = Kc * ETo. Value of Kc varies with the crop, stage of growth, growing season and the prevailing weather conditions. The required weather input files (normal monthly weather data) were collected from the FAO database software New_LocClimV1.1 (FAO 2005) for the Anantapur and Mahbubnagar stations. To generate weather data files for 2020 and 2050, HadCM3 GCM (Global Circulation Model) output was used, and by using these weather data files, crop water requirements for 2020 and 2050 were estimated.

Table 14. Crop water requirement (mm) and reference crop evapotranspiration (mm) for groundnut during 1990, 2020 and 2050 at Anantapur.

Date of sowing	1990		2020		2050	
	CWR	ETo	CWR	ETo	CWR	ETo
08 July	533.0	634.6	595.9 (11.8)	712.4 (12.3)	660.7 (24.0)	778.9 (22.7)
15 July	521.9	620.6	579.4 (11.0)	692.8 (11.6)	650.9 (24.7)	767.1 (23.6)
22 July	511.8	607.7	563.9 (10.2)	674.4 (11.0)	641.9 (25.4)	756.1 (24.4)

(Figures in parenthesis are percentage increase in crop water requirement and reference evapotranspiration over 1990 values).

The crop water requirement for groundnut in Anantapur in 1990 was in the 512-533 mm range, and the reference crop evapotranspiration was between 608 and 635 mm. The percentage increase in crop water requirement varied from 10.2 to 11.8 during 2020 and it is 24 to 25.4% in 2050 when compared to baseline year 1990 data (Table 14).

Table 15. Crop water requirement (mm) and reference crop evapotranspiration (mm) for sorghum during 1990, 2020 and 2050 at Mahbubnagar.

	1990		2020		2050	
Date of sowing	CWR	ETo	CWR	ETo	CWR	ETo
25 June	398.8	573.2	409.6 (2.7)	588.8 (2.7)	424.6 (6.5)	609.0 (6.2)
02 July	383.4	552.4	393.7 (2.7)	567.3 (2.7)	409.1 (6.7)	587.9 (6.4)
09 July	368.6	532.0	378.4 (2.7)	546.3 (2.7)	394.0 (6.9)	564.2 (6.0)

(Figures in parenthesis are percentage increase in crop water requirement and reference evapotranspiration over 1990 values)

Similarly, the crop water requirement for sorghum at Mahbubnagar in 1990 was between 369 and 399 mm, and reference crop evapotranspiration was between 532 and 573 mm. The percentage increase in crop water requirement and reference evapotranspiration is around 2.7 during 2020 and it is 6.5 to 6.9 in 2050 when compared to baseline year 1990 data (Table 15).

The results of the study clearly indicate that the impact of climate change could increase crop water requirement and negatively influence yield levels unless their need is fulfilled through other resources. It is a big challenge in the coming decades to increase the food production with less water, particularly when the major river basins will have limited water resources and groundwater availability will have reduced. Improved water management practices that increase the productivity of irrigation water use may provide a significant adaptation strategy for all land production systems under future climate change. Micro-irrigation and resource conservation technologies for economizing on water utilization need to be looked at in a big way. Some adaptation strategies include (i) Development of varieties with increased resistance to high temperature and drought; (ii) Modification of irrigation management techniques, including amount, timing or technology; (iii) Improved water management practices to prevent water logging, erosion and leaching; (iv) Adoption of efficient technologies to 'harvest' water; (v) Conservation of soil moisture (eg, crop residue retention), and reduction of siltation; (vi) Modification of crop calendars, ie, timing or location of cropping activities (Bates et al. 2008). However, given the potential adverse impacts on water resources that could be brought about by climate change, it is worthwhile to conduct more in-depth studies and analyses to gauge the extent of problems that the country may face. Climate change is posing a challenge to scientists concerned with water resources, policy makers and most importantly, farmers.

8. Future projection of rainfall and temperature

Realizing future climate is important to re-orient research, development and policy for agricultural and rural development activities, and cater accordingly. IPCC, the authoritative body for global climate projections, have also projected for India from the global climate model (GCM). The climate change research group from India also projected using the regional climate model (RCM) and this is highlighted in the National Communication (NATCOM 2009).

8.1. Andhra Pradesh and Maharashtra States

According to the projections given by NATCOM (2009) the annual rainfall is expected to increase in the future in both the states on an average of 10-20% over the baseline period of 1961-1990. The rainfall increase is distributed among the 4 different seasons including the southwest monsoon period, the major cropping season. However, a projected decrease in rainfall during 2071-2100 during southwest monsoon in Andhra Pradesh and during northeast monsoon and winter rainfall in 2021-2050 in Maharashtra is seen. In case of atmospheric temperatures, both maximum and minimum temperatures are expected to increase over the years in the future (Table 16). The annual average maximum temperature will rise by 1.7°C in 2021-2050 and 3.6°C in 2071-2100 in Andhra Pradesh, and 1.8°C and 3.4°C in Maharashtra, respectively. Minimum temperature values are 2.1°C and 4.5°C in Andhra Pradesh, and 2.2 °C and 4.5°C in Maharashtra. Similarly, future climatic projections for our study districts are given in Table 17.

Table 16. Percent deviation of rainfall and difference in maximum and minimum temperature (°C) from baseline data (1961-1990) during 2021-2050 and 2071-2100 in Andhra Pradesh and Maharashtra States (Source: NATCOM 2009).

	Andhra Pradesh		Maharashtra	
Parameter	2021-2050	2071-2100	2021-2050	2071-2100
Rainfall (% deviation)				
Annual	8.0	9.8	10.7	18.9
Southwest monsoon	5.9	-6.2	12.3	13.4
Northeast monsoon	-1.8	43.6	-5.0	55.8
Summer	35.8	60.6	16.8	75.3
Winter	14.6	46.2	-25.5	21.4
Maximum temperature (°C)				
Annual	1.7	3.6	1.8	3.4
Southwest monsoon	1.5	3.8	1.4	3.2
Northeast monsoon	1.9	3.5	2.1	3.5
Summer	1.6	3.5	1.8	3.5
Winter	1.9	3.3	2.1	3.3
Minimum temperature (°C)				
Annual	2.1	4.5	2.2	4.5
Southwest monsoon	1.7	3.8	1.5	3.4
Northeast monsoon	2.3	4.9	2.8	5.4
Summer	2.2	4.8	2.3	4.7
Winter	2.3	4.7	2.4	4.9

Table 17. Percent deviation of rainfall and difference in maximum and minimum temperature (°C) from baseline data (1961-1990) during 2021-2050 and 2071-2100 in selected districts of Andhra Pradesh and Maharashtra.

	Andhra Pradesh				Maharashtra			
	Anantapur		Mahbubnagar		Akola		Solapur	
Parameter	2021-2050	2071-2100	2021-2050	2071-2100	2021-2050	2071-2100	2021-2050	2071-2100
Rainfall (% deviation)								
Annual	-2	5	-3	-1	-1	0	19	33
Southwest monsoon	-2	-18	-2	-19	-1	-15	24	27
Northeast monsoon	-6	38	-22	47	7	79	-7	55
Summer	1	16	14	44	5	47	32	99
Winter	-4	85	-2	65	-46	-1	-33	18
Maximum temperature (°C)								
Annual	1.9	3.8	2.0	3.8	2.0	3.6	1.8	3.5
Southwest monsoon	1.9	4.4	1.8	4.3	1.7	3.9	1.2	3.2
Northeast monsoon	2.0	3.5	2.2	3.6	2.3	3.5	2.0	3.6
Summer	1.9	3.7	1.8	3.6	1.9	3.6	2.0	3.8
Winter	2.1	3.6	2.2	3.5	2.2	3.6	2.4	3.1
Minimum temperature (°C)								
Annual	1.7	4.4	1.7	4.3	2.3	4.6	2.3	4.6
Southwest monsoon	1.8	4.4	1.8	4.3	1.7	4.6	1.6	4.6
Northeast monsoon	0.9	4.2	0.6	4.2	2.9	5.4	2.9	5.5
Summer	2.1	4.9	2.2	4.8	2.2	4.6	2.4	5.0
Winter	2.5	5.0	2.5	4.8	2.5	5.1	2.7	5.1

Source: NATCOM 2009

9. Conclusion

Agriculture primarily depends on rainfall, and the socioeconomic condition and livelihoods of the rural population depend on agriculture. Climate change can hasten the variability and trend of various macro- and micro-climatic parameters crucial for crop development, growth and productivity. This stresses the importance of analyzing various climatic parameters within a span of 40 years.

The climatic analysis of long-term time series data for the two representative semi-arid Indian states of Andhra Pradesh and Maharashtra are highlighted below. The temperatures (maximum and minimum) and rainfall are analyzed for 2 study districts in each state. The key results are:

- In the entire district, temperature analysis showed a positive trend @ 0.01^{o}C year^{-1} annually.
- Seasonal variation in rate of increase is varied among different districts.
- Significant variability in annual, seasonal and monthly rainfall was evident in the entire study district.
- District with lowest rainfall is Anantpur followed by Akola, Solapur and Mahbubnagar.
- Standard deviation is high in Solapur >Mahbubnagar>Anantpur>Akola.
- The districts experienced mild to severe drought during last 20-25 years.
- Initial and conditional probability of rainfall during different seasons varied among districts.
- Variation in total rainy days, meteorological and agricultural intra-seasonal droughts are also significant during main cropping season (*kharif*).

Among all the weather parameters, rainfall is shown to be highly variable. Climatic characteristics of a region, namely a district or a block, using single station data may not truly represent the climate of the region. The rainfall analysis of this project has clearly brought out the variability among the blocks within the district. To arrive at a clear picture on the spatial variability of rainfall and to plan strategies to cope with the climatic risk at the micro-level, it is advisable to expand the present setup of a rain gauge network by covering all the villages. Perhaps a simple and ordinary rain gauge setup installed in village schools or panchayat offices with a responsibility to record observations regularly at a nominal honorarium, can solve the deficiency of availability of data at the micro-level.

The availability of micro-level data will become an input to the weather forecasting models and enhance its accuracy of forecasts. Thus, the quality of weather-based agro-advisories will be improved and increased farm income is envisaged. The existing mobile communication technology can play a greater role in helping the farmers to readily access information.

The micro-level data set would also help in benefiting the farmers of villages affected by extreme rainfall events by way of paying compensation under the weather insurance program. Many times non-availability of village level data deprives actual sufferers of extreme events, as one single station data is used to represent large regions.

To further strengthen the measures to be adopted to manage climatic risks, there is a need to identify the types of risks experienced in sub-regions even within the sub-districts. Based on their exposure to various risks, contingency plans, even at this level, can be worked out as a measure for effective management of climate.

As the occurrence of extreme weather events and crop damages cannot be avoided, the rural economy of the farming community can be stabilized to a greater extent by creating new avenues of income generation by diversifying traditional cropping activities with other occupations such as practicing farming systems approach including crop and livestock management, backyard poultry and vegetable/horticulture production. For example, under different drought intensities, availability of seed is a major constraint. Perhaps, self-sustaining village seed banks could be established by training women/youth in seed production to address the seed constraint to a greater extent.

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11. Appendixes

Appendix 1. Initial and conditional probabilities of rainfall - Anantapur

Initial and conditional probabilities of rainfall

(Markov chain probability) Limit =10 mm

	Initial probabilities		Conditional probabilities			
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.00	1.00	0.00	1.00	1.00	0.00
2	0.00	1.00	0.00	0.00	1.00	0.00
3	0.03	0.97	0.00	0.00	0.97	0.03
4	0.00	1.00	0.00	1.00	1.00	0.00
5	0.00	1.00	0.00	0.00	1.00	0.00
6	0.00	1.00	0.00	0.00	1.00	0.00
7	0.00	1.00	0.00	0.00	1.00	0.00
8	0.00	1.00	0.00	0.00	1.00	0.00
9	0.00	1.00	0.00	0.00	1.00	0.00
10	0.05	0.95	0.00	0.00	0.95	0.05
11	0.05	0.95	0.00	1.00	0.95	0.05
12	0.08	0.92	0.50	0.50	0.95	0.05
13	0.03	0.97	0.00	1.00	0.97	0.03
14	0.03	0.97	0.00	1.00	0.97	0.03
15	0.08	0.92	0.00	1.00	0.92	0.08
16	0.05	0.95	0.33	0.67	0.97	0.03
17	0.15	0.85	0.00	1.00	0.84	0.16
18	0.15	0.85	0.33	0.67	0.88	0.12
19	0.26	0.74	0.50	0.50	0.79	0.21
20	0.36	0.64	0.40	0.60	0.66	0.34
21	0.36	0.64	0.43	0.57	0.68	0.32
22	0.38	0.62	0.50	0.50	0.68	0.32
23	0.41	0.59	0.53	0.47	0.67	0.33
24	0.38	0.62	0.44	0.56	0.65	0.35
25	0.21	0.79	0.07	0.93	0.71	0.29
26	0.15	0.85	0.25	0.75	0.87	0.13
27	0.28	0.72	0.17	0.83	0.70	0.30
28	0.31	0.69	0.55	0.45	0.79	0.21
29	0.23	0.77	0.42	0.58	0.85	0.15

Continued

Continued

(Markov chain probability) Limit = 10 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
30	0.33	0.67	0.56	0.44	0.73	0.27
31	0.33	0.67	0.15	0.85	0.58	0.42
32	0.41	0.59	0.15	0.85	0.46	0.54
33	0.31	0.69	0.44	0.56	0.78	0.22
34	0.38	0.62	0.42	0.58	0.63	0.37
35	0.41	0.59	0.60	0.40	0.71	0.29
36	0.49	0.51	0.69	0.31	0.65	0.35
37	0.59	0.41	0.58	0.42	0.40	0.60
38	0.67	0.33	0.78	0.22	0.50	0.50
39	0.59	0.41	0.58	0.42	0.38	0.62
40	0.67	0.33	0.74	0.26	0.44	0.56
41	0.49	0.51	0.50	0.50	0.54	0.46
42	0.49	0.51	0.58	0.42	0.60	0.40
43	0.46	0.54	0.58	0.42	0.65	0.35
44	0.28	0.72	0.22	0.78	0.67	0.33
45	0.21	0.79	0.18	0.82	0.79	0.21
46	0.26	0.74	0.38	0.63	0.77	0.23
47	0.18	0.82	0.20	0.80	0.83	0.17
48	0.13	0.87	0.14	0.86	0.88	0.13
49	0.08	0.92	0.00	1.00	0.91	0.09
50	0.10	0.90	0.33	0.67	0.92	0.08
51	0.03	0.97	0.00	1.00	0.97	0.03
52	0.05	0.95	0.00	1.00	0.95	0.05
(Markov chain probability) Limit = 20 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.00	1.00	0.00	1.00	1.00	0.00
2	0.00	1.00	0.00	0.00	1.00	0.00
3	0.00	1.00	0.00	0.00	1.00	0.00
4	0.00	1.00	0.00	0.00	1.00	0.00
5	0.00	1.00	0.00	0.00	1.00	0.00
6	0.00	1.00	0.00	0.00	1.00	0.00
7	0.00	1.00	0.00	0.00	1.00	0.00
8	0.00	1.00	0.00	0.00	1.00	0.00
9	0.00	1.00	0.00	0.00	1.00	0.00

Continued

Continued

(Markov chain probability) Limit = 20 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
10	0.05	0.95	0.00	0.00	0.95	0.05
11	0.03	0.97	0.00	1.00	0.97	0.03
12	0.08	0.92	1.00	0.00	0.95	0.05
13	0.00	1.00	0.00	1.00	1.00	0.00
14	0.03	0.97	0.00	0.00	0.97	0.03
15	0.03	0.97	0.00	1.00	0.97	0.03
16	0.05	0.95	1.00	0.00	0.97	0.03
17	0.10	0.90	0.00	1.00	0.89	0.11
18	0.08	0.92	0.25	0.75	0.94	0.06
19	0.15	0.85	0.33	0.67	0.86	0.14
20	0.18	0.82	0.33	0.67	0.85	0.15
21	0.18	0.82	0.71	0.29	0.94	0.06
22	0.23	0.77	0.29	0.71	0.78	0.22
23	0.28	0.72	0.22	0.78	0.70	0.30
24	0.21	0.79	0.36	0.64	0.86	0.14
25	0.05	0.95	0.00	1.00	0.94	0.06
26	0.08	0.92	0.00	1.00	0.92	0.08
27	0.08	0.92	0.33	0.67	0.94	0.06
28	0.23	0.77	0.33	0.67	0.78	0.22
29	0.23	0.77	0.44	0.56	0.83	0.17
30	0.15	0.85	0.11	0.89	0.83	0.17
31	0.15	0.85	0.17	0.83	0.85	0.15
32	0.31	0.69	0.17	0.83	0.67	0.33
33	0.13	0.87	0.33	0.67	0.96	0.04
34	0.31	0.69	0.60	0.40	0.74	0.26
35	0.36	0.64	0.58	0.42	0.74	0.26
36	0.36	0.64	0.50	0.50	0.72	0.28
37	0.49	0.51	0.64	0.36	0.60	0.40
38	0.54	0.46	0.68	0.32	0.60	0.40
39	0.51	0.49	0.48	0.52	0.44	0.56
40	0.59	0.41	0.70	0.30	0.53	0.47
41	0.28	0.72	0.26	0.74	0.69	0.31
42	0.38	0.62	0.55	0.45	0.68	0.32
43	0.28	0.72	0.40	0.60	0.79	0.21

Continued

Continued

(Markov chain probability) Limit = 20 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
44	0.23	0.77	0.27	0.73	0.79	0.21
45	0.13	0.87	0.00	1.00	0.83	0.17
46	0.13	0.87	0.20	0.80	0.88	0.12
47	0.10	0.90	0.20	0.80	0.91	0.09
48	0.05	0.95	0.00	1.00	0.94	0.06
49	0.05	0.95	0.00	1.00	0.95	0.05
50	0.05	0.95	0.50	0.50	0.97	0.03
51	0.03	0.97	0.00	1.00	0.97	0.03
52	0.03	0.97	0.00	1.00	0.97	0.03
(Markov chain probability) Limit = 30 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.00	1.00	0.00	0.00	1.00	0.00
2	0.00	1.00	0.00	0.00	1.00	0.00
3	0.00	1.00	0.00	0.00	1.00	0.00
4	0.00	1.00	0.00	0.00	1.00	0.00
5	0.00	1.00	0.00	0.00	1.00	0.00
6	0.00	1.00	0.00	0.00	1.00	0.00
7	0.00	1.00	0.00	0.00	1.00	0.00
8	0.00	1.00	0.00	0.00	1.00	0.00
9	0.00	1.00	0.00	0.00	1.00	0.00
10	0.05	0.95	0.00	0.00	0.95	0.05
11	0.00	1.00	0.00	1.00	1.00	0.00
12	0.03	0.97	0.00	0.00	0.97	0.03
13	0.00	1.00	0.00	1.00	1.00	0.00
14	0.03	0.97	0.00	0.00	0.97	0.03
15	0.03	0.97	0.00	1.00	0.97	0.03
16	0.03	0.97	0.00	1.00	0.97	0.03
17	0.05	0.95	0.00	1.00	0.95	0.05
18	0.08	0.92	0.00	1.00	0.92	0.08
19	0.08	0.92	0.00	1.00	0.92	0.08
20	0.15	0.85	0.33	0.67	0.86	0.14
21	0.13	0.87	0.50	0.50	0.94	0.06
22	0.15	0.85	0.20	0.80	0.85	0.15
23	0.28	0.72	0.17	0.83	0.70	0.30
24	0.21	0.79	0.36	0.64	0.86	0.14

Continued

Continued

(Markov chain probability) Limit = 30 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
25	0.05	0.95	0.00	1.00	0.94	0.06
26	0.08	0.92	0.00	1.00	0.92	0.08
27	0.05	0.95	0.33	0.67	0.97	0.03
28	0.23	0.77	0.50	0.50	0.78	0.22
29	0.23	0.77	0.44	0.56	0.83	0.17
30	0.13	0.87	0.00	1.00	0.83	0.17
31	0.10	0.90	0.00	1.00	0.88	0.12
32	0.23	0.77	0.25	0.75	0.77	0.23
33	0.10	0.90	0.11	0.89	0.90	0.10
34	0.28	0.72	0.75	0.25	0.77	0.23
35	0.31	0.69	0.64	0.36	0.82	0.18
36	0.31	0.69	0.58	0.42	0.81	0.19
37	0.38	0.62	0.67	0.33	0.74	0.26
38	0.46	0.54	0.47	0.53	0.54	0.46
39	0.38	0.62	0.28	0.72	0.52	0.48
40	0.49	0.51	0.67	0.33	0.63	0.38
41	0.18	0.82	0.26	0.74	0.90	0.10
42	0.26	0.74	0.43	0.57	0.78	0.22
43	0.26	0.74	0.40	0.60	0.79	0.21
44	0.18	0.82	0.20	0.80	0.83	0.17
45	0.10	0.90	0.00	1.00	0.88	0.13
46	0.08	0.92	0.00	1.00	0.91	0.09
47	0.03	0.97	0.33	0.67	1.00	0.00
48	0.03	0.97	0.00	1.00	0.97	0.03
49	0.03	0.97	0.00	1.00	0.97	0.03
50	0.00	1.00	0.00	1.00	1.00	0.00
51	0.00	1.00	0.00	0.00	1.00	0.00
52	0.00	1.00	0.00	0.00	1.00	0.00

(Markov chain probability) Limit = 40 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.00	1.00	0.00	0.00	1.00	0.00
2	0.00	1.00	0.00	0.00	1.00	0.00
3	0.00	1.00	0.00	0.00	1.00	0.00
4	0.00	1.00	0.00	0.00	1.00	0.00
5	0.00	1.00	0.00	0.00	1.00	0.00
6	0.00	1.00	0.00	0.00	1.00	0.00
7	0.00	1.00	0.00	0.00	1.00	0.00
8	0.00	1.00	0.00	0.00	1.00	0.00
9	0.00	1.00	0.00	0.00	1.00	0.00
10	0.05	0.95	0.00	0.00	0.95	0.05
11	0.00	1.00	0.00	1.00	1.00	0.00
12	0.03	0.97	0.00	0.00	0.97	0.03
13	0.00	1.00	0.00	1.00	1.00	0.00
14	0.00	1.00	0.00	0.00	1.00	0.00
15	0.00	1.00	0.00	0.00	1.00	0.00
16	0.03	0.97	0.00	0.00	0.97	0.03
17	0.03	0.97	0.00	1.00	0.97	0.03
18	0.03	0.97	0.00	1.00	0.97	0.03
19	0.03	0.97	0.00	1.00	0.97	0.03
20	0.08	0.92	0.00	1.00	0.92	0.08
21	0.13	0.87	0.33	0.67	0.89	0.11
22	0.13	0.87	0.20	0.80	0.88	0.12
23	0.23	0.77	0.20	0.80	0.76	0.24
24	0.18	0.82	0.44	0.56	0.90	0.10
25	0.03	0.97	0.00	1.00	0.97	0.03
26	0.08	0.92	0.00	1.00	0.92	0.08
27	0.05	0.95	0.33	0.67	0.97	0.03
28	0.21	0.79	0.50	0.50	0.81	0.19
29	0.21	0.79	0.38	0.63	0.84	0.16
30	0.08	0.92	0.00	1.00	0.90	0.10
31	0.03	0.97	0.00	1.00	0.97	0.03
32	0.08	0.92	1.00	0.00	0.95	0.05
33	0.05	0.95	0.00	1.00	0.94	0.06
34	0.26	0.74	0.50	0.50	0.76	0.24
35	0.28	0.72	0.50	0.50	0.79	0.21

Continued

Continued

(Markov chain probability) Limit = 40 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
36	0.26	0.74	0.45	0.55	0.82	0.18
37	0.31	0.69	0.50	0.50	0.76	0.24
38	0.38	0.62	0.50	0.50	0.67	0.33
39	0.33	0.67	0.33	0.67	0.67	0.33
40	0.38	0.62	0.46	0.54	0.65	0.35
41	0.13	0.87	0.13	0.87	0.88	0.13
42	0.18	0.82	0.20	0.80	0.82	0.18
43	0.18	0.82	0.29	0.71	0.84	0.16
44	0.15	0.85	0.00	1.00	0.81	0.19
45	0.08	0.92	0.00	1.00	0.91	0.09
46	0.05	0.95	0.00	1.00	0.94	0.06
47	0.03	0.97	0.00	1.00	0.97	0.03
48	0.03	0.97	0.00	1.00	0.97	0.03
49	0.03	0.97	0.00	1.00	0.97	0.03
50	0.00	1.00	0.00	1.00	1.00	0.00
51	0.00	1.00	0.00	0.00	1.00	0.00
52	0.00	1.00	0.00	0.00	1.00	0.00
(Markov chain probability) Limit = 50 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.0	1.0	0.0	0.0	1.0	0.0
2	0.0	1.0	0.0	0.0	1.0	0.0
3	0.0	1.0	0.0	0.0	1.0	0.0
4	0.0	1.0	0.0	0.0	1.0	0.0
5	0.0	1.0	0.0	0.0	1.0	0.0
6	0.0	1.0	0.0	0.0	1.0	0.0
7	0.0	1.0	0.0	0.0	1.0	0.0
8	0.0	1.0	0.0	0.0	1.0	0.0
9	0.0	1.0	0.0	0.0	1.0	0.0
10	0.0	1.0	0.0	0.0	1.0	0.0
11	0.0	1.0	0.0	0.0	1.0	0.0
12	0.0	1.0	0.0	0.0	1.0	0.0
13	0.0	1.0	0.0	1.0	1.0	0.0
14	0.0	1.0	0.0	0.0	1.0	0.0
15	0.0	1.0	0.0	0.0	1.0	0.0
16	0.0	1.0	0.0	0.0	1.0	0.0

Continued

Continued

(Markov chain probability) Limit = 50 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
17	0.0	1.0	0.0	0.0	1.0	0.0
18	0.0	1.0	0.0	0.0	1.0	0.0
19	0.0	1.0	0.0	1.0	1.0	0.0
20	0.1	0.9	0.0	0.0	0.9	0.1
21	0.1	0.9	0.0	1.0	0.9	0.1
22	0.1	0.9	0.0	1.0	0.9	0.1
23	0.2	0.8	0.3	0.7	0.8	0.2
24	0.2	0.8	0.4	0.6	0.9	0.1
25	0.0	1.0	0.0	1.0	1.0	0.0
26	0.1	0.9	0.0	1.0	0.9	0.1
27	0.1	0.9	0.3	0.7	1.0	0.0
28	0.2	0.8	0.5	0.5	0.8	0.2
29	0.2	0.8	0.3	0.7	0.9	0.1
30	0.1	0.9	0.0	1.0	0.9	0.1
31	0.0	1.0	0.0	1.0	1.0	0.0
32	0.1	0.9	0.0	0.0	0.9	0.1
33	0.1	0.9	0.0	1.0	0.9	0.1
34	0.3	0.7	0.5	0.5	0.8	0.2
35	0.2	0.8	0.2	0.8	0.8	0.2
36	0.2	0.8	0.4	0.6	0.8	0.2
37	0.3	0.7	0.4	0.6	0.8	0.2
38	0.3	0.7	0.4	0.6	0.7	0.3
39	0.3	0.7	0.2	0.8	0.7	0.3
40	0.2	0.8	0.3	0.7	0.8	0.2
41	0.1	0.9	0.1	0.9	0.9	0.1
42	0.1	0.9	0.2	0.8	0.9	0.1
43	0.1	0.9	0.0	1.0	0.9	0.1
44	0.1	0.9	0.0	1.0	0.9	0.1
45	0.1	0.9	0.0	1.0	0.9	0.1
46	0.1	0.9	0.0	1.0	0.9	0.1
47	0.0	1.0	0.0	1.0	1.0	0.0
48	0.0	1.0	0.0	0.0	1.0	0.0
49	0.0	1.0	0.0	0.0	1.0	0.0
50	0.0	1.0	0.0	1.0	1.0	0.0
51	0.0	1.0	0.0	0.0	1.0	0.0
52	0.0	1.0	0.0	0.0	1.0	0.0

Appendix 2. Consecutive wet and dry spell probability - Anantapur

(Markov chain probability) Limit = 10 mm

	Consecutive dry probabilities			Consecutive wet probabilities		
WEEK	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	1.00	0.97	0.97	0.00	0.00	0.00
2	0.97	0.97	0.97	0.00	0.00	0.00
3	0.97	0.97	0.97	0.00	0.00	0.00
4	1.00	1.00	1.00	0.00	0.00	0.00
5	1.00	1.00	1.00	0.00	0.00	0.00
6	1.00	1.00	1.00	0.00	0.00	0.00
7	1.00	1.00	0.95	0.00	0.00	0.00
8	1.00	0.95	0.90	0.00	0.00	0.00
9	0.95	0.90	0.85	0.00	0.00	0.00
10	0.90	0.85	0.83	0.00	0.00	0.00
11	0.90	0.87	0.85	0.03	0.00	0.00
12	0.90	0.87	0.80	0.00	0.00	0.00
13	0.95	0.87	0.85	0.00	0.00	0.00
14	0.90	0.87	0.73	0.00	0.00	0.00
15	0.90	0.75	0.66	0.03	0.00	0.00
16	0.79	0.70	0.55	0.00	0.00	0.00
17	0.74	0.59	0.38	0.05	0.03	0.01
18	0.67	0.44	0.30	0.08	0.03	0.01
19	0.49	0.33	0.23	0.10	0.04	0.02
20	0.44	0.30	0.20	0.15	0.08	0.04
21	0.44	0.29	0.19	0.18	0.10	0.04
22	0.41	0.27	0.19	0.21	0.09	0.01
23	0.38	0.27	0.24	0.18	0.01	0.00
24	0.44	0.38	0.26	0.03	0.01	0.00
25	0.69	0.48	0.38	0.05	0.01	0.00
26	0.59	0.46	0.39	0.03	0.01	0.01
27	0.56	0.48	0.35	0.15	0.06	0.04
28	0.59	0.43	0.25	0.13	0.07	0.01
29	0.56	0.33	0.15	0.13	0.02	0.00
30	0.38	0.18	0.14	0.05	0.01	0.00
31	0.31	0.24	0.15	0.05	0.02	0.01
32	0.46	0.29	0.21	0.18	0.07	0.04
33	0.44	0.31	0.20	0.13	0.08	0.05

Continued

Continued

(Markov chain probability) Limit = 10 mm						
	Consecutive dry probabilities			Consecutive wet probabilities		
WEEK	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
34	0.44	0.28	0.11	0.23	0.16	0.09
35	0.38	0.15	0.08	0.28	0.16	0.13
36	0.21	0.10	0.04	0.28	0.22	0.13
37	0.21	0.08	0.03	0.46	0.27	0.20
38	0.13	0.06	0.03	0.38	0.28	0.14
39	0.18	0.10	0.06	0.44	0.22	0.13
40	0.18	0.11	0.07	0.33	0.19	0.11
41	0.31	0.20	0.13	0.28	0.16	0.04
42	0.33	0.22	0.17	0.28	0.06	0.01
43	0.36	0.28	0.22	0.10	0.02	0.01
44	0.56	0.44	0.36	0.05	0.02	0.00
45	0.62	0.51	0.45	0.08	0.02	0.00
46	0.62	0.54	0.49	0.05	0.01	0.00
47	0.72	0.65	0.60	0.03	0.00	0.00
48	0.79	0.73	0.71	0.00	0.00	0.00
49	0.85	0.82	0.78	0.03	0.00	0.00
50	0.87	0.83	0.00	0.00	0.00	0.00
51	0.92	0.00	0.00	0.00	0.00	0.00
(Markov chain probability) Limit = 20 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	1.00	1.00	1.00	0.00	0.00	0.00
2	1.00	1.00	1.00	0.00	0.00	0.00
3	1.00	1.00	1.00	0.00	0.00	0.00
4	1.00	1.00	1.00	0.00	0.00	0.00
5	1.00	1.00	1.00	0.00	0.00	0.00
6	1.00	1.00	1.00	0.00	0.00	0.00
7	1.00	1.00	0.95	0.00	0.00	0.00
8	1.00	0.95	0.92	0.00	0.00	0.00
9	0.95	0.92	0.87	0.00	0.00	0.00
10	0.92	0.87	0.87	0.00	0.00	0.00
11	0.92	0.92	0.90	0.03	0.00	0.00
12	0.92	0.90	0.88	0.00	0.00	0.00
13	0.97	0.95	0.92	0.00	0.00	0.00
14	0.95	0.92	0.82	0.00	0.00	0.00
15	0.95	0.85	0.80	0.03	0.00	0.00

Continued

Continued

(Markov chain probability) Limit = 20 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
16	0.85	0.80	0.69	0.00	0.00	0.00
17	0.85	0.73	0.62	0.03	0.01	0.00
18	0.79	0.67	0.63	0.03	0.01	0.01
19	0.72	0.67	0.53	0.05	0.04	0.01
20	0.77	0.60	0.42	0.13	0.04	0.01
21	0.64	0.45	0.38	0.05	0.01	0.00
22	0.54	0.46	0.43	0.05	0.02	0.00
23	0.62	0.58	0.53	0.10	0.00	0.00
24	0.74	0.68	0.65	0.00	0.00	0.00
25	0.87	0.82	0.64	0.00	0.00	0.00
26	0.87	0.68	0.57	0.03	0.01	0.00
27	0.72	0.60	0.50	0.03	0.01	0.00
28	0.64	0.53	0.45	0.10	0.01	0.00
29	0.64	0.54	0.36	0.03	0.00	0.00
30	0.72	0.48	0.46	0.03	0.00	0.00
31	0.56	0.54	0.40	0.03	0.01	0.01
32	0.67	0.49	0.36	0.10	0.06	0.04
33	0.64	0.47	0.34	0.08	0.04	0.02
34	0.51	0.37	0.22	0.18	0.09	0.06
35	0.46	0.28	0.17	0.18	0.12	0.08
36	0.38	0.23	0.10	0.23	0.16	0.08
37	0.31	0.14	0.07	0.33	0.16	0.11
38	0.21	0.11	0.07	0.26	0.18	0.05
39	0.26	0.18	0.12	0.36	0.09	0.05
40	0.28	0.19	0.15	0.15	0.08	0.03
41	0.49	0.39	0.30	0.15	0.06	0.02
42	0.49	0.38	0.32	0.15	0.04	0.00
43	0.56	0.47	0.41	0.08	0.00	0.00
44	0.64	0.57	0.52	0.00	0.00	0.00
45	0.77	0.70	0.66	0.03	0.01	0.00
46	0.79	0.75	0.71	0.03	0.00	0.00
47	0.85	0.80	0.78	0.00	0.00	0.00
48	0.90	0.87	0.85	0.00	0.00	0.00
49	0.92	0.90	0.87	0.03	0.00	0.00
50	0.92	0.90	0.00	0.00	0.00	0.00
51	0.95	0.00	0.00	0.00	0.00	0.00

(Markov chain probability) Limit = 30 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	1.00	1.00	1.00	0.00	0.00	0.00
2	1.00	1.00	1.00	0.00	0.00	0.00
3	1.00	1.00	1.00	0.00	0.00	0.00
4	1.00	1.00	1.00	0.00	0.00	0.00
5	1.00	1.00	1.00	0.00	0.00	0.00
6	1.00	1.00	1.00	0.00	0.00	0.00
7	1.00	1.00	0.95	0.00	0.00	0.00
8	1.00	0.95	0.95	0.00	0.00	0.00
9	0.95	0.95	0.92	0.00	0.00	0.00
10	0.95	0.92	0.92	0.00	0.00	0.00
11	0.97	0.97	0.95	0.00	0.00	0.00
12	0.97	0.95	0.92	0.00	0.00	0.00
13	0.97	0.95	0.92	0.00	0.00	0.00
14	0.95	0.92	0.88	0.00	0.00	0.00
15	0.95	0.90	0.83	0.00	0.00	0.00
16	0.92	0.85	0.78	0.00	0.00	0.00
17	0.87	0.80	0.69	0.00	0.00	0.00
18	0.85	0.73	0.68	0.00	0.00	0.00
19	0.79	0.75	0.64	0.03	0.01	0.00
20	0.79	0.68	0.47	0.08	0.02	0.00
21	0.74	0.52	0.44	0.03	0.00	0.00
22	0.59	0.51	0.47	0.03	0.01	0.00
23	0.62	0.58	0.53	0.10	0.00	0.00
24	0.74	0.68	0.66	0.00	0.00	0.00
25	0.87	0.85	0.66	0.00	0.00	0.00
26	0.90	0.70	0.59	0.03	0.01	0.01
27	0.74	0.62	0.52	0.03	0.01	0.00
28	0.64	0.53	0.47	0.10	0.00	0.00
29	0.64	0.57	0.44	0.00	0.00	0.00
30	0.77	0.59	0.53	0.00	0.00	0.00
31	0.69	0.62	0.48	0.03	0.00	0.00
32	0.69	0.53	0.44	0.03	0.02	0.01
33	0.69	0.57	0.46	0.08	0.05	0.03
34	0.59	0.48	0.36	0.18	0.10	0.07
35	0.56	0.42	0.23	0.18	0.12	0.06

Continued

Continued

(Markov chain probability) Limit = 30 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
36	0.51	0.28	0.15	0.21	0.10	0.03
37	0.33	0.17	0.11	0.18	0.05	0.03
38	0.28	0.18	0.16	0.13	0.09	0.02
39	0.38	0.35	0.27	0.26	0.07	0.03
40	0.46	0.36	0.29	0.13	0.05	0.02
41	0.64	0.51	0.42	0.08	0.03	0.01
42	0.59	0.49	0.43	0.10	0.02	0.00
43	0.62	0.54	0.49	0.05	0.00	0.00
44	0.72	0.66	0.66	0.00	0.00	0.00
45	0.82	0.82	0.80	0.00	0.00	0.00
46	0.92	0.90	0.88	0.03	0.00	0.00
47	0.95	0.92	0.92	0.00	0.00	0.00
48	0.95	0.95	0.95	0.00	0.00	0.00
49	0.97	0.97	0.97	0.00	0.00	0.00
50	1.00	1.00	0.00	0.00	0.00	0.00
51	1.00	0.00	0.00	0.00	0.00	0.00
(Markov chain probability) Limit = 40 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	1.00	1.00	1.00	0.00	0.00	0.00
2	1.00	1.00	1.00	0.00	0.00	0.00
3	1.00	1.00	1.00	0.00	0.00	0.00
4	1.00	1.00	1.00	0.00	0.00	0.00
5	1.00	1.00	1.00	0.00	0.00	0.00
6	1.00	1.00	1.00	0.00	0.00	0.00
7	1.00	1.00	0.95	0.00	0.00	0.00
8	1.00	0.95	0.95	0.00	0.00	0.00
9	0.95	0.95	0.92	0.00	0.00	0.00
10	0.95	0.92	0.92	0.00	0.00	0.00
11	0.97	0.97	0.97	0.00	0.00	0.00
12	0.97	0.97	0.97	0.00	0.00	0.00
13	1.00	1.00	0.97	0.00	0.00	0.00
14	1.00	0.97	0.95	0.00	0.00	0.00
15	0.97	0.95	0.92	0.00	0.00	0.00
16	0.95	0.92	0.90	0.00	0.00	0.00
17	0.95	0.92	0.85	0.00	0.00	0.00

Continued

Continued

(Markov chain probability) Limit = 40 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
18	0.95	0.87	0.78	0.00	0.00	0.00
19	0.90	0.80	0.70	0.00	0.00	0.00
20	0.82	0.72	0.55	0.03	0.01	0.00
21	0.77	0.59	0.53	0.03	0.01	0.00
22	0.67	0.60	0.58	0.03	0.01	0.00
23	0.69	0.67	0.62	0.10	0.00	0.00
24	0.79	0.73	0.71	0.00	0.00	0.00
25	0.90	0.87	0.71	0.00	0.00	0.00
26	0.90	0.73	0.61	0.03	0.01	0.00
27	0.77	0.65	0.58	0.03	0.01	0.00
28	0.67	0.60	0.59	0.08	0.00	0.00
29	0.72	0.70	0.66	0.00	0.00	0.00
30	0.90	0.85	0.80	0.00	0.00	0.00
31	0.92	0.87	0.66	0.03	0.00	0.00
32	0.87	0.66	0.52	0.00	0.00	0.00
33	0.72	0.57	0.47	0.03	0.01	0.01
34	0.59	0.48	0.37	0.13	0.06	0.03
35	0.59	0.45	0.30	0.13	0.06	0.03
36	0.56	0.38	0.25	0.13	0.06	0.02
37	0.46	0.31	0.20	0.15	0.05	0.02
38	0.41	0.27	0.23	0.13	0.06	0.01
39	0.44	0.38	0.31	0.15	0.02	0.00
40	0.54	0.44	0.37	0.05	0.01	0.00
41	0.72	0.61	0.49	0.03	0.01	0.00
42	0.69	0.56	0.51	0.05	0.00	0.00
43	0.67	0.61	0.57	0.00	0.00	0.00
44	0.77	0.73	0.71	0.00	0.00	0.00
45	0.87	0.85	0.83	0.00	0.00	0.00
46	0.92	0.90	0.88	0.00	0.00	0.00
47	0.95	0.92	0.92	0.00	0.00	0.00
48	0.95	0.95	0.95	0.00	0.00	0.00
49	0.97	0.97	0.97	0.00	0.00	0.00
50	1.00	1.00	0.00	0.00	0.00	0.00
51	1.00	0.00	0.00	0.00	0.00	0.00

(Markov chain probability) Limit = 50 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	1.00	1.00	1.00	0.00	0.00	0.00
2	1.00	1.00	1.00	0.00	0.00	0.00
3	1.00	1.00	1.00	0.00	0.00	0.00
4	1.00	1.00	1.00	0.00	0.00	0.00
5	1.00	1.00	1.00	0.00	0.00	0.00
6	1.00	1.00	1.00	0.00	0.00	0.00
7	1.00	1.00	1.00	0.00	0.00	0.00
8	1.00	1.00	1.00	0.00	0.00	0.00
9	1.00	1.00	0.97	0.00	0.00	0.00
10	1.00	0.97	0.97	0.00	0.00	0.00
11	0.97	0.97	0.97	0.00	0.00	0.00
12	0.97	0.97	0.97	0.00	0.00	0.00
13	1.00	1.00	1.00	0.00	0.00	0.00
14	1.00	1.00	1.00	0.00	0.00	0.00
15	1.00	1.00	0.97	0.00	0.00	0.00
16	1.00	0.97	0.97	0.00	0.00	0.00
17	0.97	0.97	0.90	0.00	0.00	0.00
18	0.97	0.90	0.80	0.00	0.00	0.00
19	0.92	0.82	0.75	0.00	0.00	0.00
20	0.82	0.75	0.60	0.00	0.00	0.00
21	0.82	0.66	0.60	0.00	0.00	0.00
22	0.74	0.67	0.65	0.03	0.01	0.00
23	0.72	0.70	0.64	0.08	0.00	0.00
24	0.82	0.76	0.73	0.00	0.00	0.00
25	0.90	0.87	0.73	0.00	0.00	0.00
26	0.90	0.75	0.66	0.03	0.01	0.00
27	0.79	0.70	0.65	0.03	0.01	0.00
28	0.72	0.67	0.67	0.05	0.00	0.00
29	0.79	0.79	0.75	0.00	0.00	0.00
30	0.95	0.90	0.85	0.00	0.00	0.00
31	0.95	0.90	0.68	0.00	0.00	0.00
32	0.90	0.68	0.54	0.00	0.00	0.00
33	0.72	0.57	0.48	0.03	0.01	0.00
34	0.59	0.49	0.38	0.05	0.02	0.01
35	0.67	0.52	0.36	0.08	0.03	0.01
36	0.62	0.42	0.29	0.08	0.03	0.01

Continued

Continued

(Markov chain probability) Limit = 50 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
37	0.51	0.36	0.28	0.10	0.02	0.01
38	0.46	0.36	0.31	0.08	0.02	0.00
39	0.56	0.49	0.45	0.08	0.01	0.00
40	0.67	0.61	0.56	0.03	0.01	0.00
41	0.79	0.73	0.65	0.03	0.00	0.00
42	0.82	0.73	0.69	0.00	0.00	0.00
43	0.82	0.77	0.73	0.00	0.00	0.00
44	0.85	0.80	0.80	0.00	0.00	0.00
45	0.90	0.90	0.90	0.00	0.00	0.00
46	0.95	0.95	0.92	0.00	0.00	0.00
47	1.00	0.97	0.97	0.00	0.00	0.00
48	0.97	0.97	0.97	0.00	0.00	0.00
49	0.97	0.97	0.97	0.00	0.00	0.00
50	1.00	1.00	0.00	0.00	0.00	0.00
51	1.00	0.00	0.00	0.00	0.00	0.00

Appendix 3. Frequency of occurrence of heavy rain events at different intensities in Anantapur district (annual basis).

	25 to 50 mm/day		51 to 75 mm/day		76 to 100 mm/day		More than 100 mm/day	
Year	Days	Sum	Days	Sum	Days	Sum	Days	Sum
1971	1	31.9	0	0	1	77.1	0	0
1972	6	238.6	1	51.8	0	0	0	0
1973	5	173.5	2	117.1	1	90.2	0	0
1974	1	41.3	3	172.3	0	0	1	167.7
1975	4	133.6	3	157.8	0	0	1	159.4
1976	1	30	0	0	0	0	0	0
1977	6	184.9	3	189.5	0	0	0	0
1978	2	67	1	73.6	0	0	0	0
1979	8	291.2	0	0	0	0	0	0
1980	2	60	0	0	0	0	0	0
1981	4	142	4	246.2	0	0	0	0
1982	5	208.7	1	62.4	1	80	0	0
1983	8	272.2	0	0	0	0	0	0
1984	2	53.8	1	50.4	1	77.6	0	0
1985	1	42.8	0	0	0	0	0	0
1986	5	194.2	1	65	0	0	0	0
1987	1	28.4	1	56.8	2	166	0	0
1988	9	329.4	2	121.2	1	90.2	0	0
1989	4	142	3	178.8	2	168.6	0	0
1990	6	218.1	0	0	0	0	0	0
1991	4	140.6	2	130.2	1	98	0	0
1992	4	135.5	0	0	0	0	0	0
1993	3	117.6	0	0	1	98.5	0	0
1994	3	89	0	0	0	0	0	0
1995	4	145	4	227	3	257	0	0
1996	13	444.6	5	307.2	1	86	0	0
1997	5	184	1	53.6	0	0	1	201.6
1998	7	250.6	1	51.4	0	0	1	110.4
1999	3	96.2	1	71	1	77.4	0	0
2000	6	202.4	1	57.6	0	0	0	0
2001	3	101.2	1	68.6	1	76.2	0	0
2002	5	171.6	0	0	0	0	0	0
2003	3	93.4	0	0	0	0	0	0
2004	6	202.8	2	117.4	0	0	0	0
2005	8	274.2	1	55.4	0	0	0	0
2006	4	137.8	0	0	0	0	0	0
2007	5	171.4	4	241.6	1	84	1	124.2
2008	8	274.2	0	0	1	77	0	0

Appendix 4. Frequency of occurrence of heavy rain events at different intensities in Anantapur district (Southwest monsoon).

	25 to 50 mm/day		51 to 75 mm/day		76 to 100 mm/day		More than 100 mm/day	
Year	Days	Sum	Days	Sum	Days	Sum	Days	Sum
1971	0	0	0	0	0	0	0	0
1972	5	205.5	0	0	0	0	0	0
1973	1	40.1	2	117.1	0	0	0	0
1974	1	41.3	1	51.8	0	0	1	167.7
1975	1	33.2	2	104.6	0	0	0	0
1976	1	30	0	0	0	0	0	0
1977	3	94.1	2	125	0	0	0	0
1978	1	33.8	1	73.6	0	0	0	0
1979	5	178.6	0	0	0	0	0	0
1980	1	34.2	0	0	0	0	0	0
1981	2	55.8	3	176.2	0	0	0	0
1982	2	84	0	0	1	80	0	0
1983	7	242.8	0	0	0	0	0	0
1984	2	53.8	1	50.4	1	77.6	0	0
1985	1	42.8	0	0	0	0	0	0
1986	3	130.8	1	65	0	0	0	0
1987	1	28.4	0	0	2	166	0	0
1988	6	214.4	1	51.8	1	90.2	0	0
1989	3	102	3	178.8	2	168.6	0	0
1990	3	102.9	0	0	0	0	0	0
1991	1	29	2	130.2	0	0	0	0
1992	3	92.5	0	0	0	0	0	0
1993	2	72.6	0	0	0	0	0	0
1994	1	35.4	0	0	0	0	0	0
1995	3	101	4	227	3	257	0	0
1996	8	281.6	5	307.2	0	0	0	0
1997	3	119.6	1	53.6	0	0	1	201.6
1998	5	186.8	1	51.4	0	0	1	110.4
1999	3	96.2	0	0	1	77.4	0	0
2000	4	137.4	0	0	0	0	0	0
2001	3	101.2	0	0	0	0	0	0
2002	1	46.6	0	0	0	0	0	0
2003	1	37.4	0	0	0	0	0	0
2004	3	94	1	60.2	0	0	0	0
2005	5	163.2	1	55.4	0	0	0	0
2006	2	70	0	0	0	0	0	0
2007	3	105	4	241.6	1	84	1	124.2
2008	6	204.4	0	0	1	77	0	0

Appendix 5. Frequency of occurrence of heavy rain events at different intensities in Anantapur district (Northeast monsoon).

	25 to 50 mm/day		51 to 75 mm/day		76 to 100 mm/day		More than 100 mm/day	
Year	Days	Sum	Days	Sum	Days	Sum	Days	Sum
1971	1	31.9	0	0	1	77.1	0	0
1972	1	33.1	0	0	0	0	0	0
1973	4	133.4	0	0	1	90.2	0	0
1974	0	0	0	0	0	0	0	0
1975	3	100.4	1	53.2	0	0	1	159.4
1976	0	0	0	0	0	0	0	0
1977	3	90.8	0	0	0	0	0	0
1978	1	33.2	0	0	0	0	0	0
1979	3	112.6	0	0	0	0	0	0
1980	1	25.8	0	0	0	0	0	0
1981	1	45	1	70	0	0	0	0
1982	3	124.7	1	62.4	0	0	0	0
1983	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0
1986	2	63.4	0	0	0	0	0	0
1987	0	0	1	56.8	0	0	0	0
1988	1	32.2	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0
1990	2	66.2	0	0	0	0	0	0
1991	2	76.6	0	0	1	98	0	0
1992	1	43	0	0	0	0	0	0
1993	1	45	0	0	1	98.5	0	0
1994	2	53.6	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0
1996	4	134.4	0	0	1	86	0	0
1997	1	36	0	0	0	0	0	0
1998	1	33.4	0	0	0	0	0	0
1999	0	0	1	71	0	0	0	0
2000	2	65	1	57.6	0	0	0	0
2001	0	0	1	68.6	1	76.2	0	0
2002	2	66.4	0	0	0	0	0	0
2003	2	56	0	0	0	0	0	0
2004	1	30.8	0	0	0	0	0	0
2005	2	72.6	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0
2007	1	36.2	0	0	0	0	0	0
2008	1	26.8	0	0	0	0	0	0

Appendix 6. Frequency of occurrence of heavy rain events at different intensities in Anantapur district (Summer).

	25 to 50 mm/day		51 to 75 mm/day		76 to 100 mm/day		More than 100 mm/day	
Year	Days	Sum	Days	Sum	Days	Sum	Days	Sum
1971	0	0	0	0	0	0	0	0
1972	0	0	1	51.8	0	0	0	0
1973	0	0	0	0	0	0	0	0
1974	0	0	2	120.5	0	0	0	0
1975	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0
1977	0	0	1	64.5	0	0	0	0
1978	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0
1981	1	41.2	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0
1983	1	29.4	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0
1988	2	82.8	1	69.4	0	0	0	0
1989	1	40	0	0	0	0	0	0
1990	1	49	0	0	0	0	0	0
1991	1	35	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0
1995	1	44	0	0	0	0	0	0
1996	1	28.6	0	0	0	0	0	0
1997	1	28.4	0	0	0	0	0	0
1998	1	30.4	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0
2002	2	58.6	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0
2004	2	78	1	57.2	0	0	0	0
2005	1	38.4	0	0	0	0	0	0
2006	2	67.8	0	0	0	0	0	0
2007	1	30.2	0	0	0	0	0	0
2008	1	43	0	0	0	0	0	0

Appendix 7. Frequency of days with maximum temperature – Anantapur district.

Year	>=40°C	>=41°C	>=42°C	>=43°C	>=44°C
1971	17	2	1	0	0
1972	26	8	0	0	0
1973	43	30	4	0	0
1974	54	35	8	1	0
1975	40	10	0	0	0
1976	33	8	3	0	0
1977	16	7	5	1	1
1978	15	3	0	0	0
1979	34	6	0	0	0
1980	36	16	6	0	0
1981	27	14	0	0	0
1982	1	0	0	0	0
1983	43	18	5	0	0
1984	34	22	4	0	0
1985	34	14	3	1	0
1986	52	13	0	0	0
1987	36	17	4	0	0
1988	20	12	3	2	0
1989	28	12	2	0	0
1990	23	12	1	0	0
1991	34	12	2	0	0
1992	44	15	0	0	0
1993	33	19	12	5	0
1994	27	11	3	0	0
1995	25	11	1	0	0
1996	35	20	4	0	0
1997	7	1	0	0	0
1998	39	16	6	1	0
1999	12	2	0	0	0
2000	19	11	5	1	0
2001	44	25	9	0	0
2002	32	15	3	0	0
2003	54	34	12	1	0
2004	20	10	3	0	0
2005	47	32	13	6	1
2006	36	19	4	0	0
2007	31	11	0	0	0
2008	16	5	0	0	0

Appendix 8. Initial and conditional probabilities of rainfall - Mahbubnagar

Initial and conditional probabilities of rainfall

(Markov chain probability) Limit =10 mm

	Initial probabilities		Conditional probabilities			
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.00	1.00	0.00	1.00	1.00	0.00
2	0.03	0.97	0.00	0.00	0.97	0.03
3	0.05	0.95	0.00	1.00	0.95	0.05
4	0.00	1.00	0.00	1.00	1.00	0.00
5	0.03	0.97	0.00	0.00	0.97	0.03
6	0.05	0.95	0.00	1.00	0.95	0.05
7	0.05	0.95	0.50	0.50	0.97	0.03
8	0.03	0.97	0.00	1.00	0.97	0.03
9	0.00	1.00	0.00	1.00	1.00	0.00
10	0.11	0.89	0.00	0.00	0.89	0.11
11	0.05	0.95	0.25	0.75	0.97	0.03
12	0.05	0.95	0.00	1.00	0.94	0.06
13	0.05	0.95	0.00	1.00	0.94	0.06
14	0.13	0.87	0.00	1.00	0.86	0.14
15	0.08	0.92	0.20	0.80	0.94	0.06
16	0.11	0.89	0.33	0.67	0.91	0.09
17	0.21	0.79	0.00	1.00	0.76	0.24
18	0.16	0.84	0.00	1.00	0.80	0.20
19	0.21	0.79	0.17	0.83	0.78	0.22
20	0.34	0.66	0.63	0.38	0.73	0.27
21	0.24	0.76	0.31	0.69	0.80	0.20
22	0.29	0.71	0.22	0.78	0.69	0.31
23	0.58	0.42	0.45	0.55	0.37	0.63
24	0.63	0.37	0.68	0.32	0.44	0.56
25	0.61	0.39	0.46	0.54	0.14	0.86
26	0.76	0.24	0.78	0.22	0.27	0.73
27	0.71	0.29	0.72	0.28	0.33	0.67
28	0.61	0.39	0.59	0.41	0.36	0.64
29	0.68	0.32	0.65	0.35	0.27	0.73
30	0.74	0.26	0.88	0.12	0.58	0.42
31	0.82	0.18	0.86	0.14	0.30	0.70
32	0.84	0.16	0.84	0.16	0.14	0.86
33	0.66	0.34	0.72	0.28	0.67	0.33
34	0.61	0.39	0.60	0.40	0.38	0.62

Continued

Continued

(Markov chain probability) Limit = 10 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
35	0.63	0.37	0.70	0.30	0.47	0.53
36	0.66	0.34	0.67	0.33	0.36	0.64
37	0.58	0.42	0.56	0.44	0.38	0.62
38	0.79	0.21	0.82	0.18	0.25	0.75
39	0.68	0.32	0.70	0.30	0.38	0.63
40	0.61	0.39	0.54	0.46	0.25	0.75
41	0.53	0.47	0.61	0.39	0.60	0.40
42	0.42	0.58	0.55	0.45	0.72	0.28
43	0.34	0.66	0.44	0.56	0.73	0.27
44	0.24	0.76	0.23	0.77	0.76	0.24
45	0.08	0.92	0.00	1.00	0.90	0.10
46	0.16	0.84	0.33	0.67	0.86	0.14
47	0.00	1.00	0.00	1.00	1.00	0.00
48	0.08	0.92	0.00	0.00	0.92	0.08
49	0.05	0.95	0.33	0.67	0.97	0.03
50	0.00	1.00	0.00	1.00	1.00	0.00
51	0.00	1.00	0.00	0.00	1.00	0.00
52	0.03	0.97	0.00	0.00	0.97	0.03
(Markov chain probability) Limit = 20 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.00	1.00	0.00	1.00	1.00	0.00
2	0.03	0.97	0.00	0.00	0.97	0.03
3	0.00	1.00	0.00	1.00	1.00	0.00
4	0.00	1.00	0.00	0.00	1.00	0.00
5	0.00	1.00	0.00	0.00	1.00	0.00
6	0.00	1.00	0.00	0.00	1.00	0.00
7	0.03	0.97	0.00	0.00	0.97	0.03
8	0.03	0.97	0.00	1.00	0.97	0.03
9	0.00	1.00	0.00	1.00	1.00	0.00
10	0.03	0.97	0.00	0.00	0.97	0.03
11	0.05	0.95	0.00	1.00	0.95	0.05
12	0.03	0.97	0.00	1.00	0.97	0.03
13	0.05	0.95	0.00	1.00	0.95	0.05
14	0.08	0.92	0.00	1.00	0.92	0.08
15	0.05	0.95	0.00	1.00	0.94	0.06
16	0.03	0.97	0.00	1.00	0.97	0.03

Continued

Continued

(Markov chain probability) Limit = 20 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
17	0.08	0.92	0.00	1.00	0.92	0.08
18	0.08	0.92	0.00	1.00	0.91	0.09
19	0.16	0.84	0.00	1.00	0.83	0.17
20	0.13	0.87	0.67	0.33	0.97	0.03
21	0.13	0.87	0.20	0.80	0.88	0.12
22	0.16	0.84	0.20	0.80	0.85	0.15
23	0.39	0.61	0.17	0.83	0.56	0.44
24	0.45	0.55	0.67	0.33	0.70	0.30
25	0.45	0.55	0.29	0.71	0.43	0.57
26	0.66	0.34	0.71	0.29	0.38	0.62
27	0.42	0.58	0.52	0.48	0.77	0.23
28	0.39	0.61	0.56	0.44	0.73	0.27
29	0.58	0.42	0.60	0.40	0.43	0.57
30	0.68	0.32	0.86	0.14	0.56	0.44
31	0.66	0.34	0.73	0.27	0.50	0.50
32	0.63	0.37	0.64	0.36	0.38	0.62
33	0.66	0.34	0.83	0.17	0.64	0.36
34	0.53	0.47	0.52	0.48	0.46	0.54
35	0.53	0.47	0.65	0.35	0.61	0.39
36	0.45	0.55	0.55	0.45	0.67	0.33
37	0.47	0.53	0.47	0.53	0.52	0.48
38	0.74	0.26	0.78	0.22	0.30	0.70
39	0.58	0.42	0.61	0.39	0.50	0.50
40	0.53	0.47	0.45	0.55	0.38	0.63
41	0.47	0.53	0.55	0.45	0.61	0.39
42	0.42	0.58	0.61	0.39	0.75	0.25
43	0.18	0.82	0.31	0.69	0.91	0.09
44	0.16	0.84	0.00	1.00	0.81	0.19
45	0.05	0.95	0.00	1.00	0.94	0.06
46	0.08	0.92	0.00	1.00	0.92	0.08
47	0.00	1.00	0.00	1.00	1.00	0.00
48	0.03	0.97	0.00	0.00	0.97	0.03
49	0.03	0.97	0.00	1.00	0.97	0.03
50	0.00	1.00	0.00	1.00	1.00	0.00
51	0.00	1.00	0.00	0.00	1.00	0.00
52	0.03	0.97	0.00	0.00	0.97	0.03

(Markov chain probability) Limit = 30 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.00	1.00	0.00	0.00	1.00	0.00
2	0.00	1.00	0.00	0.00	1.00	0.00
3	0.00	1.00	0.00	0.00	1.00	0.00
4	0.00	1.00	0.00	0.00	1.00	0.00
5	0.00	1.00	0.00	0.00	1.00	0.00
6	0.00	1.00	0.00	0.00	1.00	0.00
7	0.03	0.97	0.00	0.00	0.97	0.03
8	0.03	0.97	0.00	1.00	0.97	0.03
9	0.00	1.00	0.00	1.00	1.00	0.00
10	0.00	1.00	0.00	0.00	1.00	0.00
11	0.05	0.95	0.00	0.00	0.95	0.05
12	0.03	0.97	0.00	1.00	0.97	0.03
13	0.03	0.97	0.00	1.00	0.97	0.03
14	0.03	0.97	0.00	1.00	0.97	0.03
15	0.00	1.00	0.00	1.00	1.00	0.00
16	0.03	0.97	0.00	0.00	0.97	0.03
17	0.03	0.97	0.00	1.00	0.97	0.03
18	0.08	0.92	0.00	1.00	0.92	0.08
19	0.13	0.87	0.00	1.00	0.86	0.14
20	0.05	0.95	0.40	0.60	1.00	0.00
21	0.05	0.95	0.00	1.00	0.94	0.06
22	0.11	0.89	0.00	1.00	0.89	0.11
23	0.26	0.74	0.00	1.00	0.71	0.29
24	0.21	0.79	0.30	0.70	0.82	0.18
25	0.26	0.74	0.13	0.88	0.70	0.30
26	0.47	0.53	0.50	0.50	0.54	0.46
27	0.37	0.63	0.50	0.50	0.75	0.25
28	0.37	0.63	0.43	0.57	0.67	0.33
29	0.47	0.53	0.57	0.43	0.58	0.42
30	0.63	0.37	0.78	0.22	0.50	0.50
31	0.58	0.42	0.63	0.38	0.50	0.50
32	0.50	0.50	0.45	0.55	0.44	0.56
33	0.53	0.47	0.79	0.21	0.74	0.26
34	0.39	0.61	0.40	0.60	0.61	0.39
35	0.47	0.53	0.60	0.40	0.61	0.39
36	0.29	0.71	0.33	0.67	0.75	0.25
37	0.42	0.58	0.27	0.73	0.52	0.48

Continued

Continued

(Markov chain probability) Limit = 30 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
38	0.50	0.50	0.63	0.38	0.59	0.41
39	0.47	0.53	0.53	0.47	0.58	0.42
40	0.47	0.53	0.50	0.50	0.55	0.45
41	0.37	0.63	0.50	0.50	0.75	0.25
42	0.26	0.74	0.50	0.50	0.88	0.13
43	0.11	0.89	0.30	0.70	0.96	0.04
44	0.11	0.89	0.00	1.00	0.88	0.12
45	0.03	0.97	0.00	1.00	0.97	0.03
46	0.08	0.92	0.00	1.00	0.92	0.08
47	0.00	1.00	0.00	1.00	1.00	0.00
48	0.03	0.97	0.00	0.00	0.97	0.03
49	0.00	1.00	0.00	1.00	1.00	0.00
50	0.00	1.00	0.00	0.00	1.00	0.00
51	0.00	1.00	0.00	0.00	1.00	0.00
52	0.00	1.00	0.00	0.00	1.00	0.00
(Markov chain probability) Limit = 40 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.00	1.00	0.00	0.00	1.00	0.00
2	0.00	1.00	0.00	0.00	1.00	0.00
3	0.00	1.00	0.00	0.00	1.00	0.00
4	0.00	1.00	0.00	0.00	1.00	0.00
5	0.00	1.00	0.00	0.00	1.00	0.00
6	0.00	1.00	0.00	0.00	1.00	0.00
7	0.03	0.97	0.00	0.00	0.97	0.03
8	0.00	1.00	0.00	1.00	1.00	0.00
9	0.00	1.00	0.00	0.00	1.00	0.00
10	0.00	1.00	0.00	0.00	1.00	0.00
11	0.05	0.95	0.00	0.00	0.95	0.05
12	0.03	0.97	0.00	1.00	0.97	0.03
13	0.00	1.00	0.00	1.00	1.00	0.00
14	0.00	1.00	0.00	0.00	1.00	0.00
15	0.00	1.00	0.00	0.00	1.00	0.00
16	0.00	1.00	0.00	0.00	1.00	0.00
17	0.00	1.00	0.00	0.00	1.00	0.00
18	0.05	0.95	0.00	0.00	0.95	0.05
19	0.08	0.92	0.00	1.00	0.92	0.08
20	0.03	0.97	0.33	0.67	1.00	0.00

Continued

Continued

(Markov chain probability) Limit = 40 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
21	0.03	0.97	0.00	1.00	0.97	0.03
22	0.08	0.92	0.00	1.00	0.92	0.08
23	0.18	0.82	0.00	1.00	0.80	0.20
24	0.13	0.87	0.00	1.00	0.84	0.16
25	0.18	0.82	0.00	1.00	0.79	0.21
26	0.32	0.68	0.43	0.57	0.71	0.29
27	0.24	0.76	0.42	0.58	0.85	0.15
28	0.32	0.68	0.44	0.56	0.72	0.28
29	0.39	0.61	0.58	0.42	0.69	0.31
30	0.53	0.47	0.60	0.40	0.52	0.48
31	0.53	0.47	0.60	0.40	0.56	0.44
32	0.42	0.58	0.40	0.60	0.56	0.44
33	0.37	0.63	0.50	0.50	0.73	0.27
34	0.26	0.74	0.36	0.64	0.79	0.21
35	0.32	0.68	0.40	0.60	0.71	0.29
36	0.18	0.82	0.17	0.83	0.81	0.19
37	0.34	0.66	0.14	0.86	0.61	0.39
38	0.39	0.61	0.38	0.62	0.60	0.40
39	0.34	0.66	0.33	0.67	0.65	0.35
40	0.42	0.58	0.38	0.62	0.56	0.44
41	0.32	0.68	0.44	0.56	0.77	0.23
42	0.26	0.74	0.50	0.50	0.85	0.15
43	0.08	0.92	0.30	0.70	1.00	0.00
44	0.11	0.89	0.00	1.00	0.89	0.11
45	0.00	1.00	0.00	1.00	1.00	0.00
46	0.05	0.95	0.00	0.00	0.95	0.05
47	0.00	1.00	0.00	1.00	1.00	0.00
48	0.00	1.00	0.00	0.00	1.00	0.00
49	0.00	1.00	0.00	0.00	1.00	0.00
50	0.00	1.00	0.00	0.00	1.00	0.00
51	0.00	1.00	0.00	0.00	1.00	0.00
52	0.00	1.00	0.00	0.00	1.00	0.00

(Markov chain probability) Limit = 50 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.00	1.00	0.00	0.00	1.00	0.00
2	0.00	1.00	0.00	0.00	1.00	0.00
3	0.00	1.00	0.00	0.00	1.00	0.00
4	0.00	1.00	0.00	0.00	1.00	0.00
5	0.00	1.00	0.00	0.00	1.00	0.00
6	0.00	1.00	0.00	0.00	1.00	0.00
7	0.00	1.00	0.00	0.00	1.00	0.00
8	0.00	1.00	0.00	0.00	1.00	0.00
9	0.00	1.00	0.00	0.00	1.00	0.00
10	0.00	1.00	0.00	0.00	1.00	0.00
11	0.00	1.00	0.00	0.00	1.00	0.00
12	0.03	0.97	0.00	0.00	0.97	0.03
13	0.00	1.00	0.00	1.00	1.00	0.00
14	0.00	1.00	0.00	0.00	1.00	0.00
15	0.00	1.00	0.00	0.00	1.00	0.00
16	0.00	1.00	0.00	0.00	1.00	0.00
17	0.00	1.00	0.00	0.00	1.00	0.00
18	0.00	1.00	0.00	0.00	1.00	0.00
19	0.05	0.95	0.00	0.00	0.95	0.05
20	0.03	0.97	0.50	0.50	1.00	0.00
21	0.03	0.97	0.00	1.00	0.97	0.03
22	0.03	0.97	0.00	1.00	0.97	0.03
23	0.16	0.84	0.00	1.00	0.84	0.16
24	0.08	0.92	0.00	1.00	0.91	0.09
25	0.13	0.87	0.00	1.00	0.86	0.14
26	0.24	0.76	0.20	0.80	0.76	0.24
27	0.18	0.82	0.33	0.67	0.86	0.14
28	0.26	0.74	0.43	0.57	0.77	0.23
29	0.32	0.68	0.40	0.60	0.71	0.29
30	0.39	0.61	0.67	0.33	0.73	0.27
31	0.34	0.66	0.40	0.60	0.70	0.30
32	0.37	0.63	0.31	0.69	0.60	0.40
33	0.29	0.71	0.43	0.57	0.79	0.21
34	0.24	0.76	0.36	0.64	0.81	0.19
35	0.18	0.82	0.22	0.78	0.83	0.17
36	0.13	0.87	0.14	0.86	0.87	0.13
37	0.32	0.68	0.20	0.80	0.67	0.33

Continued

Continued

(Markov chain probability) Limit = 50 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
38	0.29	0.71	0.33	0.67	0.73	0.27
39	0.34	0.66	0.36	0.64	0.67	0.33
40	0.32	0.68	0.31	0.69	0.68	0.32
41	0.24	0.76	0.17	0.83	0.73	0.27
42	0.16	0.84	0.33	0.67	0.90	0.10
43	0.08	0.92	0.00	1.00	0.91	0.09
44	0.05	0.95	0.00	1.00	0.94	0.06
45	0.00	1.00	0.00	1.00	1.00	0.00
46	0.00	1.00	0.00	0.00	1.00	0.00
47	0.00	1.00	0.00	0.00	1.00	0.00
48	0.00	1.00	0.00	0.00	1.00	0.00
49	0.00	1.00	0.00	0.00	1.00	0.00
50	0.00	1.00	0.00	0.00	1.00	0.00
51	0.00	1.00	0.00	0.00	1.00	0.00
52	0.00	1.00	0.00	0.00	1.00	0.00

Appendix 9. Consecutive wet and dry spell probability – Mahbubnagar.

(Markov chain probability) Limit = 10 mm

	Consecutive dry probabilities			Consecutive wet probabilities		
WEEK	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	0.97	0.92	0.92	0.00	0.00	0.00
2	0.92	0.92	0.90	0.00	0.00	0.00
3	0.95	0.92	0.87	0.00	0.00	0.00
4	0.97	0.92	0.90	0.00	0.00	0.00
5	0.92	0.90	0.87	0.00	0.00	0.00
6	0.92	0.90	0.90	0.03	0.00	0.00
7	0.92	0.92	0.82	0.00	0.00	0.00
8	0.97	0.87	0.85	0.00	0.00	0.00
9	0.89	0.87	0.82	0.00	0.00	0.00
10	0.87	0.82	0.77	0.03	0.00	0.00
11	0.89	0.85	0.73	0.00	0.00	0.00
12	0.89	0.77	0.72	0.00	0.00	0.00
13	0.82	0.77	0.70	0.00	0.00	0.00
14	0.82	0.75	0.57	0.03	0.01	0.00
15	0.84	0.64	0.52	0.03	0.00	0.00
16	0.68	0.55	0.43	0.00	0.00	0.00
17	0.63	0.49	0.36	0.00	0.00	0.00
18	0.66	0.48	0.39	0.03	0.02	0.01
19	0.58	0.46	0.32	0.13	0.04	0.01
20	0.53	0.36	0.13	0.11	0.02	0.01
21	0.53	0.19	0.09	0.05	0.02	0.02
22	0.26	0.12	0.02	0.13	0.09	0.04
23	0.18	0.03	0.01	0.39	0.18	0.14
24	0.05	0.01	0.00	0.29	0.23	0.16
25	0.11	0.04	0.01	0.47	0.34	0.20
26	0.08	0.03	0.01	0.55	0.33	0.21
27	0.11	0.03	0.02	0.42	0.27	0.24
28	0.11	0.06	0.02	0.39	0.35	0.30
29	0.18	0.06	0.01	0.61	0.52	0.44
30	0.08	0.01	0.01	0.63	0.53	0.38
31	0.03	0.02	0.01	0.68	0.49	0.30
32	0.11	0.04	0.02	0.61	0.36	0.25
33	0.13	0.06	0.02	0.39	0.27	0.18
34	0.18	0.07	0.03	0.42	0.28	0.16
35	0.13	0.05	0.01	0.42	0.24	0.19

Continued

Continued

(Markov chain probability) Limit = 10 mm						
WEEK	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
36	0.13	0.03	0.01	0.37	0.30	0.21
37	0.11	0.04	0.01	0.47	0.33	0.18
38	0.08	0.02	0.01	0.55	0.30	0.18
39	0.08	0.05	0.03	0.37	0.22	0.12
40	0.24	0.17	0.12	0.37	0.20	0.09
41	0.34	0.25	0.19	0.29	0.13	0.03
42	0.42	0.32	0.29	0.18	0.04	0.00
43	0.50	0.45	0.38	0.08	0.00	0.00
44	0.68	0.59	0.59	0.00	0.00	0.00
45	0.79	0.79	0.73	0.03	0.00	0.00
46	0.84	0.78	0.75	0.00	0.00	0.00
47	0.92	0.89	0.89	0.00	0.00	0.00
48	0.89	0.89	0.89	0.03	0.00	0.00
49	0.95	0.95	0.92	0.00	0.00	0.00
50	1.00	0.97	0.00	0.00	0.00	0.00
51	0.97	0.00	0.00	0.00	0.00	0.00
(Markov chain probability) Limit = 20 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.97	0.97	0.97	0.00	0.00	0.00
2	0.97	0.97	0.97	0.00	0.00	0.00
3	1.00	1.00	1.00	0.00	0.00	0.00
4	1.00	1.00	0.97	0.00	0.00	0.00
5	1.00	0.97	0.95	0.00	0.00	0.00
6	0.97	0.95	0.95	0.00	0.00	0.00
7	0.95	0.95	0.92	0.00	0.00	0.00
8	0.97	0.95	0.90	0.00	0.00	0.00
9	0.97	0.92	0.90	0.00	0.00	0.00
10	0.92	0.90	0.85	0.00	0.00	0.00
11	0.92	0.87	0.80	0.00	0.00	0.00
12	0.92	0.84	0.80	0.00	0.00	0.00
13	0.87	0.82	0.80	0.00	0.00	0.00
14	0.87	0.84	0.78	0.00	0.00	0.00
15	0.92	0.85	0.77	0.00	0.00	0.00
16	0.89	0.82	0.68	0.00	0.00	0.00
17	0.84	0.70	0.68	0.00	0.00	0.00
18	0.76	0.74	0.65	0.00	0.00	0.00

Continued

Continued

(Markov chain probability) Limit = 20 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
19	0.82	0.72	0.61	0.11	0.02	0.00
20	0.76	0.65	0.36	0.03	0.01	0.00
21	0.74	0.41	0.29	0.03	0.00	0.00
22	0.47	0.33	0.14	0.03	0.02	0.01
23	0.42	0.18	0.07	0.26	0.08	0.05
24	0.24	0.09	0.07	0.13	0.09	0.05
25	0.21	0.16	0.12	0.32	0.16	0.09
26	0.26	0.19	0.08	0.34	0.19	0.12
27	0.42	0.18	0.10	0.24	0.14	0.12
28	0.26	0.15	0.07	0.24	0.20	0.15
29	0.24	0.12	0.05	0.50	0.37	0.23
30	0.16	0.06	0.04	0.50	0.32	0.27
31	0.13	0.08	0.04	0.42	0.35	0.18
32	0.24	0.11	0.07	0.53	0.27	0.18
33	0.16	0.10	0.06	0.34	0.22	0.12
34	0.29	0.19	0.10	0.34	0.19	0.09
35	0.32	0.17	0.05	0.29	0.14	0.11
36	0.29	0.09	0.04	0.21	0.16	0.10
37	0.16	0.08	0.03	0.37	0.22	0.10
38	0.13	0.05	0.03	0.45	0.20	0.11
39	0.16	0.10	0.07	0.26	0.14	0.09
40	0.29	0.22	0.20	0.29	0.18	0.06
41	0.39	0.36	0.29	0.29	0.09	0.00
42	0.53	0.42	0.40	0.13	0.00	0.00
43	0.66	0.62	0.57	0.00	0.00	0.00
44	0.79	0.72	0.72	0.00	0.00	0.00
45	0.87	0.87	0.85	0.00	0.00	0.00
46	0.92	0.90	0.87	0.00	0.00	0.00
47	0.97	0.95	0.95	0.00	0.00	0.00
48	0.95	0.95	0.95	0.00	0.00	0.00
49	0.97	0.97	0.95	0.00	0.00	0.00
50	1.00	0.97	0.00	0.00	0.00	0.00
51	0.97	0.00	0.00	0.00	0.00	0.00

(Markov chain probability) Limit = 30 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	1.00	1.00	1.00	0.00	0.00	0.00
2	1.00	1.00	1.00	0.00	0.00	0.00
3	1.00	1.00	1.00	0.00	0.00	0.00
4	1.00	1.00	0.97	0.00	0.00	0.00
5	1.00	0.97	0.95	0.00	0.00	0.00
6	0.97	0.95	0.95	0.00	0.00	0.00
7	0.95	0.95	0.95	0.00	0.00	0.00
8	0.97	0.97	0.92	0.00	0.00	0.00
9	1.00	0.95	0.92	0.00	0.00	0.00
10	0.95	0.92	0.90	0.00	0.00	0.00
11	0.92	0.90	0.87	0.00	0.00	0.00
12	0.95	0.92	0.92	0.00	0.00	0.00
13	0.95	0.95	0.92	0.00	0.00	0.00
14	0.97	0.95	0.92	0.00	0.00	0.00
15	0.97	0.95	0.87	0.00	0.00	0.00
16	0.95	0.87	0.75	0.00	0.00	0.00
17	0.89	0.77	0.77	0.00	0.00	0.00
18	0.79	0.79	0.75	0.00	0.00	0.00
19	0.87	0.82	0.73	0.05	0.00	0.00
20	0.89	0.80	0.56	0.00	0.00	0.00
21	0.84	0.59	0.49	0.00	0.00	0.00
22	0.63	0.52	0.36	0.00	0.00	0.00
23	0.61	0.42	0.23	0.08	0.01	0.00
24	0.55	0.30	0.22	0.03	0.01	0.01
25	0.39	0.30	0.20	0.13	0.07	0.03
26	0.39	0.26	0.15	0.24	0.10	0.06
27	0.42	0.25	0.12	0.16	0.09	0.07
28	0.37	0.18	0.09	0.21	0.16	0.10
29	0.26	0.13	0.06	0.37	0.23	0.10
30	0.18	0.08	0.06	0.39	0.18	0.14
31	0.18	0.14	0.08	0.26	0.21	0.08
32	0.37	0.23	0.14	0.39	0.16	0.09
33	0.29	0.18	0.13	0.21	0.13	0.04
34	0.37	0.28	0.14	0.24	0.08	0.02
35	0.39	0.20	0.12	0.16	0.04	0.03
36	0.37	0.22	0.13	0.08	0.05	0.03
37	0.34	0.20	0.11	0.26	0.14	0.07

Continued

Continued

(Markov chain probability) Limit = 30 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
38	0.29	0.16	0.12	0.26	0.13	0.07
39	0.29	0.22	0.19	0.24	0.12	0.06
40	0.39	0.35	0.33	0.24	0.12	0.04
41	0.55	0.53	0.47	0.18	0.06	0.00
42	0.71	0.63	0.61	0.08	0.00	0.00
43	0.79	0.77	0.70	0.00	0.00	0.00
44	0.87	0.80	0.80	0.00	0.00	0.00
45	0.89	0.89	0.87	0.00	0.00	0.00
46	0.92	0.90	0.90	0.00	0.00	0.00
47	0.97	0.97	0.97	0.00	0.00	0.00
48	0.97	0.97	0.97	0.00	0.00	0.00
49	1.00	1.00	1.00	0.00	0.00	0.00
50	1.00	1.00	0.00	0.00	0.00	0.00
51	1.00	0.00	0.00	0.00	0.00	0.00
(Markov chain probability) Limit = 40 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	1.00	1.00	1.00	0.00	0.00	0.00
2	1.00	1.00	1.00	0.00	0.00	0.00
3	1.00	1.00	1.00	0.00	0.00	0.00
4	1.00	1.00	0.97	0.00	0.00	0.00
5	1.00	0.97	0.97	0.00	0.00	0.00
6	0.97	0.97	0.97	0.00	0.00	0.00
7	0.97	0.97	0.97	0.00	0.00	0.00
8	1.00	1.00	0.95	0.00	0.00	0.00
9	1.00	0.95	0.92	0.00	0.00	0.00
10	0.95	0.92	0.92	0.00	0.00	0.00
11	0.92	0.92	0.92	0.00	0.00	0.00
12	0.97	0.97	0.97	0.00	0.00	0.00
13	1.00	1.00	1.00	0.00	0.00	0.00
14	1.00	1.00	1.00	0.00	0.00	0.00
15	1.00	1.00	0.95	0.00	0.00	0.00
16	1.00	0.95	0.87	0.00	0.00	0.00
17	0.95	0.87	0.87	0.00	0.00	0.00
18	0.87	0.87	0.85	0.00	0.00	0.00
19	0.92	0.90	0.82	0.03	0.00	0.00
20	0.95	0.87	0.70	0.00	0.00	0.00
21	0.89	0.72	0.60	0.00	0.00	0.00

Continued

Continued

(Markov chain probability) Limit = 40 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
22	0.74	0.62	0.49	0.00	0.00	0.00
23	0.68	0.54	0.38	0.00	0.00	0.00
24	0.68	0.49	0.41	0.00	0.00	0.00
25	0.58	0.49	0.35	0.08	0.03	0.01
26	0.58	0.42	0.29	0.13	0.06	0.03
27	0.55	0.38	0.20	0.11	0.06	0.04
28	0.47	0.25	0.14	0.18	0.11	0.07
29	0.32	0.18	0.10	0.24	0.14	0.06
30	0.26	0.15	0.11	0.32	0.13	0.06
31	0.26	0.19	0.15	0.21	0.11	0.04
32	0.42	0.33	0.24	0.21	0.08	0.03
33	0.50	0.36	0.29	0.13	0.05	0.01
34	0.53	0.43	0.26	0.11	0.02	0.00
35	0.55	0.34	0.20	0.05	0.01	0.00
36	0.50	0.30	0.20	0.03	0.01	0.00
37	0.39	0.26	0.14	0.13	0.04	0.02
38	0.39	0.22	0.17	0.13	0.05	0.02
39	0.37	0.28	0.24	0.13	0.06	0.03
40	0.45	0.38	0.38	0.18	0.09	0.03
41	0.58	0.58	0.51	0.16	0.05	0.00
42	0.74	0.65	0.65	0.08	0.00	0.00
43	0.82	0.82	0.77	0.00	0.00	0.00
44	0.89	0.85	0.85	0.00	0.00	0.00
45	0.95	0.95	0.95	0.00	0.00	0.00
46	0.95	0.95	0.95	0.00	0.00	0.00
47	1.00	1.00	1.00	0.00	0.00	0.00
48	1.00	1.00	1.00	0.00	0.00	0.00
49	1.00	1.00	1.00	0.00	0.00	0.00
50	1.00	1.00	0.00	0.00	0.00	0.00
51	1.00	0.00	0.00	0.00	0.00	0.00

(Markov chain probability) Limit = 50 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	1.00	1.00	1.00	0.00	0.00	0.00
2	1.00	1.00	1.00	0.00	0.00	0.00
3	1.00	1.00	1.00	0.00	0.00	0.00
4	1.00	1.00	1.00	0.00	0.00	0.00
5	1.00	1.00	1.00	0.00	0.00	0.00
6	1.00	1.00	1.00	0.00	0.00	0.00
7	1.00	1.00	1.00	0.00	0.00	0.00
8	1.00	1.00	1.00	0.00	0.00	0.00
9	1.00	1.00	0.97	0.00	0.00	0.00
10	1.00	0.97	0.97	0.00	0.00	0.00
11	0.97	0.97	0.97	0.00	0.00	0.00
12	0.97	0.97	0.97	0.00	0.00	0.00
13	1.00	1.00	1.00	0.00	0.00	0.00
14	1.00	1.00	1.00	0.00	0.00	0.00
15	1.00	1.00	1.00	0.00	0.00	0.00
16	1.00	1.00	0.95	0.00	0.00	0.00
17	1.00	0.95	0.95	0.00	0.00	0.00
18	0.95	0.95	0.92	0.00	0.00	0.00
19	0.95	0.92	0.90	0.03	0.00	0.00
20	0.95	0.92	0.77	0.00	0.00	0.00
21	0.95	0.79	0.72	0.00	0.00	0.00
22	0.82	0.74	0.63	0.00	0.00	0.00
23	0.76	0.65	0.50	0.00	0.00	0.00
24	0.79	0.60	0.52	0.00	0.00	0.00
25	0.66	0.57	0.44	0.03	0.01	0.00
26	0.66	0.51	0.36	0.08	0.03	0.01
27	0.63	0.45	0.33	0.08	0.03	0.02
28	0.53	0.38	0.27	0.11	0.07	0.03
29	0.50	0.35	0.21	0.21	0.08	0.03
30	0.42	0.25	0.20	0.16	0.05	0.02
31	0.39	0.31	0.25	0.11	0.05	0.02
32	0.50	0.41	0.34	0.16	0.06	0.01
33	0.58	0.48	0.42	0.11	0.02	0.00
34	0.63	0.55	0.37	0.05	0.01	0.00
35	0.71	0.47	0.35	0.03	0.01	0.00
36	0.58	0.42	0.28	0.03	0.01	0.00
37	0.50	0.33	0.23	0.11	0.04	0.01

Continued

Continued

(Markov chain probability) Limit = 50 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
38	0.47	0.32	0.24	0.11	0.03	0.01
39	0.45	0.33	0.29	0.11	0.02	0.01
40	0.50	0.45	0.41	0.05	0.02	0.00
41	0.68	0.62	0.58	0.08	0.00	0.00
42	0.76	0.72	0.72	0.00	0.00	0.00
43	0.87	0.87	0.87	0.00	0.00	0.00
44	0.95	0.95	0.95	0.00	0.00	0.00
45	1.00	1.00	1.00	0.00	0.00	0.00
46	1.00	1.00	1.00	0.00	0.00	0.00
47	1.00	1.00	1.00	0.00	0.00	0.00
48	1.00	1.00	1.00	0.00	0.00	0.00
49	1.00	1.00	1.00	0.00	0.00	0.00
50	1.00	1.00	0.00	0.00	0.00	0.00
51	1.00	0.00	0.00	0.00	0.00	0.00

Appendix 10. Frequency of occurrence of heavy rain events at different intensities in Mahbubnagar district (annual basis).

	25 to 50 mm/day		51 to 75 mm/day		76 to 100 mm/day		More than 100 mm/day	
Year	Days	Sum	Days	Sum	Days	Sum	Days	Sum
1971	6	208.5	1	61	0	0	0	0
1972	2	60.9	1	51.6	0	0	0	0
1973	5	176.5	3	163.8	1	97.8	1	109.2
1974	7	250.6	1	66.8	0	0	1	113.8
1975	2	53.8	1	55.4	0	0	0	0
1976	9	329.3	2	117.9	1	95	0	0
1977	7	227.1	1	67.3	0	0	1	140.7
1978	5	171.5	3	198.3	0	0	1	170.4
1979	5	174.8	3	176.1	0	0	2	283.2
1980	7	260.9	2	127.3	0	0	0	0
1981	8	265.1	2	105.7	1	76.1	1	124.2
1982	7	234.9	0	0	0	0	0	0
1983	11	366.2	3	158.2	2	162.8	0	0
1984	9	319.8	2	112.6	0	0	0	0
1985	3	89.8	1	52.2	0	0	0	0
1986	4	138	0	0	0	0	0	0
1987	7	225	1	63.2	0	0	1	144.4
1988	10	341.9	2	111.2	0	0	0	0
1989	5	161	3	190.8	0	0	0	0
1990	8	279.8	5	283.6	0	0	0	0
1991	5	160.2	4	248.7	1	87	0	0
1992	5	166.2	0	0	1	83.4	0	0
1993	5	152.2	0	0	1	98.6	0	0
1994	1	36.2	0	0	1	91.6	0	0
1995	7	250.3	1	65	1	95	0	0
1996	0	0	0	0	0	0	0	0
1997	6	196.8	0	0	0	0	0	0
1998	4	124.6	1	63	0	0	1	117
1999	4	138.7	1	54.1	0	0	0	0
2000	5	185	1	54.4	0	0	1	108.6
2001	8	276.7	0	0	1	82	0	0
2002	12	398.6	3	185.6	0	0	0	0
2003	5	185	3	193.2	0	0	0	0
2004	5	162.8	1	54	0	0	0	0
2005	9	276.6	4	249.4	0	0	1	106.8
2006	7	250.3	1	65	1	95	0	0
2007	9	294.6	0	0	0	0	0	0
2008	11	353.2	1	58	2	167.2	0	0

Appendix 11. Frequency of occurrence of heavy rain events at different intensities in Mahbubnagar district (Southwest monsoon).

	25 to 50 mm/day		51 to 75 mm/day		76 to 100 mm/day		More than 100 mm/day	
	Days	Sum	Days	Sum	Days	Sum	Days	Sum
1971	4	150.4	1	61	0	0	0	0
1972	2	60.9	1	51.6	0	0	0	0
1973	3	110	2	113	1	97.8	1	109.2
1974	3	106.5	0	0	0	0	1	113.8
1975	1	27.8	1	55.4	0	0	0	0
1976	9	329.3	2	117.9	1	95	0	0
1977	5	162.5	1	67.3	0	0	0	0
1978	4	139.9	2	131	0	0	1	170.4
1979	3	111	2	116	0	0	1	111.8
1980	7	260.9	2	127.3	0	0	0	0
1981	6	211.9	2	105.7	1	76.1	1	124.2
1982	4	145.2	0	0	0	0	0	0
1983	10	337.8	3	158.2	2	162.8	0	0
1984	7	253.6	1	58	0	0	0	0
1985	3	89.8	1	52.2	0	0	0	0
1986	3	94	0	0	0	0	0	0
1987	3	86.4	1	63.2	0	0	0	0
1988	10	341.9	2	111.2	0	0	0	0
1989	4	134.6	3	190.8	0	0	0	0
1990	6	203.2	5	283.6	0	0	0	0
1991	3	108	4	248.7	1	87	0	0
1992	5	166.2	0	0	0	0	0	0
1993	3	93.8	0	0	0	0	0	0
1994	1	36.2	0	0	0	0	0	0
1995	4	138.7	1	65	1	95	0	0
1996	0	0	0	0	0	0	0	0
1997	4	121.6	0	0	0	0	0	0
1998	4	124.6	1	63	0	0	1	117
1999	2	69.4	1	54.1	0	0	0	0
2000	5	185	1	54.4	0	0	1	108.6
2001	5	159.5	0	0	1	82	0	0
2002	10	333.2	2	112.6	0	0	0	0
2003	5	185	3	193.2	0	0	0	0
2004	3	87.2	0	0	0	0	0	0
2005	7	205.2	2	126.6	0	0	1	106.8
2006	4	138.7	1	65	1	95	0	0
2007	8	266.6	0	0	0	0	0	0
2008	8	253	0	0	1	84.2	0	0

Appendix 12. Frequency of occurrence of heavy rain events at different intensities in Mahbubnagar district (Northeast monsoon).

	25 to 50 mm/day		51 to 75 mm/day		76 to 100 mm/day		More than 100 mm/day	
	Days	Sum	Days	Sum	Days	Sum	Days	Sum
1971	1	33	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0
1973	2	66.5	1	50.8	0	0	0	0
1974	2	70.4	1	66.8	0	0	0	0
1975	1	26	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0
1977	2	64.6	0	0	0	0	1	140.7
1978	1	31.6	1	67.3	0	0	0	0
1979	1	32.6	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0
1982	2	63.2	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0
1984	0	0	1	54.6	0	0	0	0
1985	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0
1987	3	110.4	0	0	0	0	1	144.4
1988	0	0	0	0	0	0	0	0
1989	1	26.4	0	0	0	0	0	0
1990	1	42	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0
1993	2	58.4	0	0	1	98.6	0	0
1994	0	0	0	0	1	91.6	0	0
1995	3	111.6	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0
1997	2	75.2	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0
1999	1	26	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0
2001	3	117.2	0	0	0	0	0	0
2002	2	65.4	1	73	0	0	0	0
2003	0	0	0	0	0	0	0	0
2004	2	75.6	1	54	0	0	0	0
2005	0	0	2	122.8	0	0	0	0
2006	3	111.6	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0
2008	0	0	1	58	0	0	0	0

Appendix 13. Frequency of occurrence of heavy rain events at different intensities in Mahbubnagar district (Summer).

	25 to 50 mm/day		51 to 75 mm/day		76 to 100 mm/day		More than 100 mm/day	
	Days	Sum	Days	Sum	Days	Sum	Days	Sum
1971	1	25.1	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0
1974	2	73.7	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0
1979	0	0	1	60.1	0	0	1	171.4
1980	0	0	0	0	0	0	0	0
1981	2	53.2	0	0	0	0	0	0
1982	1	26.5	0	0	0	0	0	0
1983	1	28.4	0	0	0	0	0	0
1984	2	66.2	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0
1986	1	44	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0
1990	1	34.6	0	0	0	0	0	0
1991	2	52.2	0	0	0	0	0	0
1992	0	0	0	0	1	83.4	0	0
1993	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0
1999	1	43.3	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0
2005	2	71.4	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0
2007	1	28	0	0	0	0	0	0
2008	2	56	0	0	1	83	0	0

Appendix 14. Frequency of occurrence of days with maximum temperature in Mahbubnagar.

Year	>=40°C	>=41°C	>=42°C	>=43°C	>=44°C
1971	11	7	2	0	0
1972	33	13	8	3	0
1973	48	35	23	14	4
1974	16	9	3	0	0
1975	33	17	2	0	0
1976	27	17	10	0	0
1977	18	5	1	0	0
1978	27	6	2	1	0
1979	33	17	9	1	0
1980	41	28	19	6	0
1981	27	20	16	9	1
1982	24	8	2	0	0
1983	45	23	12	3	0
1984	36	23	12	9	5
1985	36	20	6	4	0
1986	37	23	6	3	0
1987	37	13	1	0	0
1988	28	21	16	14	4
1989	30	18	10	2	1
1990	13	6	4	0	0
1991	34	10	3	0	0
1992	15	2	1	0	0
1993	32	23	10	2	0
1994	24	6	0	0	0
1995	8	0	0	0	0
1996	41	29	15	5	0
1997	22	11	6	2	0
1998	27	18	12	6	1
1999	23	16	7	2	0
2000	22	15	10	7	0
2001	28	17	13	5	1
2002	28	13	2	0	0
2003	44	34	23	11	4
2004	30	14	5	2	0
2005	27	21	14	6	4
2006	8	0	0	0	0
2007	14	3	1	0	0
2008	24	13	2	1	0

Appendix 15. Initial and conditional probabilities of rainfall - Akola

Initial and conditional probabilities of rainfall

(Markov chain probability) Limit = 10 mm

	Initial probabilities		Conditional probabilities			
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.08	0.92	0.00	1.00	0.91	0.09
2	0.10	0.90	0.33	0.67	0.92	0.08
3	0.05	0.95	0.00	1.00	0.94	0.06
4	0.03	0.97	0.50	0.50	1.00	0.00
5	0.05	0.95	0.00	1.00	0.95	0.05
6	0.10	0.90	0.00	1.00	0.89	0.11
7	0.00	1.00	0.00	1.00	1.00	0.00
8	0.10	0.90	0.00	0.00	0.90	0.10
9	0.05	0.95	0.00	1.00	0.94	0.06
10	0.08	0.92	0.50	0.50	0.95	0.05
11	0.05	0.95	0.00	1.00	0.94	0.06
12	0.03	0.97	0.00	1.00	0.97	0.03
13	0.08	0.92	0.00	1.00	0.92	0.08
14	0.03	0.97	0.00	1.00	0.97	0.03
15	0.00	1.00	0.00	1.00	1.00	0.00
16	0.00	1.00	0.00	0.00	1.00	0.00
17	0.00	1.00	0.00	0.00	1.00	0.00
18	0.03	0.97	0.00	0.00	0.97	0.03
19	0.03	0.97	0.00	1.00	0.97	0.03
20	0.03	0.97	0.00	1.00	0.97	0.03
21	0.08	0.92	0.00	1.00	0.92	0.08
22	0.18	0.82	0.33	0.67	0.83	0.17
23	0.44	0.56	0.71	0.29	0.63	0.38
24	0.59	0.41	0.76	0.24	0.55	0.45
25	0.64	0.36	0.61	0.39	0.31	0.69
26	0.74	0.26	0.68	0.32	0.14	0.86
27	0.67	0.33	0.69	0.31	0.40	0.60
28	0.62	0.38	0.62	0.38	0.38	0.62
29	0.79	0.21	0.75	0.25	0.13	0.87
30	0.69	0.31	0.77	0.23	0.63	0.38
31	0.64	0.36	0.67	0.33	0.42	0.58
32	0.77	0.23	0.84	0.16	0.36	0.64
33	0.62	0.38	0.63	0.37	0.44	0.56
34	0.56	0.44	0.58	0.42	0.47	0.53

Continued

Continued

(Markov chain probability) Limit = 10 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
35	0.64	0.36	0.77	0.23	0.53	0.47
36	0.49	0.51	0.48	0.52	0.50	0.50
37	0.38	0.62	0.58	0.42	0.80	0.20
38	0.46	0.54	0.53	0.47	0.58	0.42
39	0.44	0.56	0.56	0.44	0.67	0.33
40	0.38	0.62	0.41	0.59	0.64	0.36
41	0.26	0.74	0.40	0.60	0.83	0.17
42	0.15	0.85	0.10	0.90	0.83	0.17
43	0.10	0.90	0.00	1.00	0.88	0.12
44	0.10	0.90	0.25	0.75	0.91	0.09
45	0.05	0.95	0.25	0.75	0.97	0.03
46	0.05	0.95	0.00	1.00	0.95	0.05
47	0.10	0.90	0.50	0.50	0.92	0.08
48	0.08	0.92	0.50	0.50	0.97	0.03
49	0.05	0.95	0.33	0.67	0.97	0.03
50	0.03	0.97	0.00	1.00	0.97	0.03
51	0.03	0.97	0.00	1.00	0.97	0.03
52	0.08	0.92	0.00	1.00	0.92	0.08
(Markov chain probability) Limit = 20 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.03	0.97	0.00	1.00	0.97	0.03
2	0.05	0.95	0.00	1.00	0.95	0.05
3	0.00	1.00	0.00	1.00	1.00	0.00
4	0.00	1.00	0.00	0.00	1.00	0.00
5	0.05	0.95	0.00	0.00	0.95	0.05
6	0.05	0.95	0.00	1.00	0.95	0.05
7	0.00	1.00	0.00	1.00	1.00	0.00
8	0.00	1.00	0.00	0.00	1.00	0.00
9	0.03	0.97	0.00	0.00	0.97	0.03
10	0.03	0.97	0.00	1.00	0.97	0.03
11	0.05	0.95	0.00	1.00	0.95	0.05
12	0.03	0.97	0.00	1.00	0.97	0.03
13	0.08	0.92	0.00	1.00	0.92	0.08
14	0.00	1.00	0.00	1.00	1.00	0.00
15	0.00	1.00	0.00	0.00	1.00	0.00
16	0.00	1.00	0.00	0.00	1.00	0.00

Continued

Continued

(Markov chain probability) Limit = 20 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
17	0.00	1.00	0.00	0.00	1.00	0.00
18	0.00	1.00	0.00	0.00	1.00	0.00
19	0.03	0.97	0.00	0.00	0.97	0.03
20	0.00	1.00	0.00	1.00	1.00	0.00
21	0.03	0.97	0.00	0.00	0.97	0.03
22	0.10	0.90	0.00	1.00	0.89	0.11
23	0.26	0.74	0.50	0.50	0.77	0.23
24	0.46	0.54	0.70	0.30	0.62	0.38
25	0.54	0.46	0.44	0.56	0.38	0.62
26	0.64	0.36	0.57	0.43	0.28	0.72
27	0.56	0.44	0.60	0.40	0.50	0.50
28	0.59	0.41	0.64	0.36	0.47	0.53
29	0.62	0.38	0.61	0.39	0.38	0.63
30	0.56	0.44	0.63	0.38	0.53	0.47
31	0.54	0.46	0.45	0.55	0.35	0.65
32	0.64	0.36	0.81	0.19	0.56	0.44
33	0.54	0.46	0.52	0.48	0.43	0.57
34	0.51	0.49	0.52	0.48	0.50	0.50
35	0.46	0.54	0.60	0.40	0.68	0.32
36	0.49	0.51	0.56	0.44	0.57	0.43
37	0.26	0.74	0.42	0.58	0.90	0.10
38	0.33	0.67	0.50	0.50	0.72	0.28
39	0.31	0.69	0.46	0.54	0.77	0.23
40	0.31	0.69	0.17	0.83	0.63	0.37
41	0.18	0.82	0.17	0.83	0.81	0.19
42	0.10	0.90	0.00	1.00	0.88	0.13
43	0.08	0.92	0.00	1.00	0.91	0.09
44	0.03	0.97	0.00	1.00	0.97	0.03
45	0.03	0.97	0.00	1.00	0.97	0.03
46	0.03	0.97	0.00	1.00	0.97	0.03
47	0.10	0.90	0.00	1.00	0.89	0.11
48	0.05	0.95	0.50	0.50	1.00	0.00
49	0.00	1.00	0.00	1.00	1.00	0.00
50	0.00	1.00	0.00	0.00	1.00	0.00
51	0.03	0.97	0.00	0.00	0.97	0.03
52	0.03	0.97	0.00	1.00	0.97	0.03

(Markov chain probability) Limit = 30 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.00	1.00	0.00	1.00	1.00	0.00
2	0.03	0.97	0.00	0.00	0.97	0.03
3	0.00	1.00	0.00	1.00	1.00	0.00
4	0.00	1.00	0.00	0.00	1.00	0.00
5	0.05	0.95	0.00	0.00	0.95	0.05
6	0.03	0.97	0.00	1.00	0.97	0.03
7	0.00	1.00	0.00	1.00	1.00	0.00
8	0.00	1.00	0.00	0.00	1.00	0.00
9	0.03	0.97	0.00	0.00	0.97	0.03
10	0.00	1.00	0.00	1.00	1.00	0.00
11	0.03	0.97	0.00	0.00	0.97	0.03
12	0.00	1.00	0.00	1.00	1.00	0.00
13	0.03	0.97	0.00	0.00	0.97	0.03
14	0.00	1.00	0.00	1.00	1.00	0.00
15	0.00	1.00	0.00	0.00	1.00	0.00
16	0.00	1.00	0.00	0.00	1.00	0.00
17	0.00	1.00	0.00	0.00	1.00	0.00
18	0.00	1.00	0.00	0.00	1.00	0.00
19	0.00	1.00	0.00	0.00	1.00	0.00
20	0.00	1.00	0.00	0.00	1.00	0.00
21	0.03	0.97	0.00	0.00	0.97	0.03
22	0.08	0.92	0.00	1.00	0.92	0.08
23	0.21	0.79	0.67	0.33	0.83	0.17
24	0.38	0.62	0.38	0.63	0.61	0.39
25	0.41	0.59	0.40	0.60	0.58	0.42
26	0.41	0.59	0.38	0.63	0.57	0.43
27	0.44	0.56	0.38	0.63	0.52	0.48
28	0.51	0.49	0.59	0.41	0.55	0.45
29	0.54	0.46	0.60	0.40	0.53	0.47
30	0.49	0.51	0.52	0.48	0.56	0.44
31	0.49	0.51	0.42	0.58	0.45	0.55
32	0.49	0.51	0.53	0.47	0.55	0.45
33	0.44	0.56	0.47	0.53	0.60	0.40
34	0.44	0.56	0.41	0.59	0.55	0.45
35	0.36	0.64	0.47	0.53	0.73	0.27
36	0.46	0.54	0.50	0.50	0.56	0.44
37	0.15	0.85	0.33	0.67	1.00	0.00

Continued

Continued

(Markov chain probability) Limit = 30 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
38	0.31	0.69	0.67	0.33	0.76	0.24
39	0.23	0.77	0.42	0.58	0.85	0.15
40	0.23	0.77	0.11	0.89	0.73	0.27
41	0.13	0.87	0.11	0.89	0.87	0.13
42	0.08	0.92	0.00	1.00	0.91	0.09
43	0.05	0.95	0.00	1.00	0.94	0.06
44	0.00	1.00	0.00	1.00	1.00	0.00
45	0.03	0.97	0.00	0.00	0.97	0.03
46	0.00	1.00	0.00	1.00	1.00	0.00
47	0.08	0.92	0.00	0.00	0.92	0.08
48	0.03	0.97	0.33	0.67	1.00	0.00
49	0.00	1.00	0.00	1.00	1.00	0.00
50	0.00	1.00	0.00	0.00	1.00	0.00
51	0.00	1.00	0.00	0.00	1.00	0.00
52	0.03	0.97	0.00	0.00	0.97	0.03
(Markov chain probability) Limit = 40 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.00	1.00	0.00	1.00	1.00	0.00
2	0.00	1.00	0.00	0.00	1.00	0.00
3	0.00	1.00	0.00	0.00	1.00	0.00
4	0.00	1.00	0.00	0.00	1.00	0.00
5	0.03	0.97	0.00	0.00	0.97	0.03
6	0.00	1.00	0.00	1.00	1.00	0.00
7	0.00	1.00	0.00	0.00	1.00	0.00
8	0.00	1.00	0.00	0.00	1.00	0.00
9	0.03	0.97	0.00	0.00	0.97	0.03
10	0.00	1.00	0.00	1.00	1.00	0.00
11	0.00	1.00	0.00	0.00	1.00	0.00
12	0.00	1.00	0.00	0.00	1.00	0.00
13	0.03	0.97	0.00	0.00	0.97	0.03
14	0.00	1.00	0.00	1.00	1.00	0.00
15	0.00	1.00	0.00	0.00	1.00	0.00
16	0.00	1.00	0.00	0.00	1.00	0.00
17	0.00	1.00	0.00	0.00	1.00	0.00
18	0.00	1.00	0.00	0.00	1.00	0.00
19	0.00	1.00	0.00	0.00	1.00	0.00
20	0.00	1.00	0.00	0.00	1.00	0.00

Continued

Continued

(Markov chain probability) Limit = 40 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
21	0.03	0.97	0.00	0.00	0.97	0.03
22	0.05	0.95	0.00	1.00	0.95	0.05
23	0.18	0.82	0.50	0.50	0.84	0.16
24	0.38	0.62	0.43	0.57	0.63	0.38
25	0.36	0.64	0.33	0.67	0.63	0.38
26	0.33	0.67	0.29	0.71	0.64	0.36
27	0.33	0.67	0.38	0.62	0.69	0.31
28	0.38	0.62	0.54	0.46	0.69	0.31
29	0.38	0.62	0.67	0.33	0.79	0.21
30	0.33	0.67	0.33	0.67	0.67	0.33
31	0.44	0.56	0.46	0.54	0.58	0.42
32	0.44	0.56	0.53	0.47	0.64	0.36
33	0.36	0.64	0.47	0.53	0.73	0.27
34	0.36	0.64	0.29	0.71	0.60	0.40
35	0.36	0.64	0.50	0.50	0.72	0.28
36	0.41	0.59	0.50	0.50	0.64	0.36
37	0.10	0.90	0.19	0.81	0.96	0.04
38	0.26	0.74	0.25	0.75	0.74	0.26
39	0.21	0.79	0.30	0.70	0.83	0.17
40	0.18	0.82	0.13	0.88	0.81	0.19
41	0.10	0.90	0.14	0.86	0.91	0.09
42	0.08	0.92	0.00	1.00	0.91	0.09
43	0.05	0.95	0.00	1.00	0.94	0.06
44	0.00	1.00	0.00	1.00	1.00	0.00
45	0.03	0.97	0.00	0.00	0.97	0.03
46	0.00	1.00	0.00	1.00	1.00	0.00
47	0.05	0.95	0.00	0.00	0.95	0.05
48	0.03	0.97	0.50	0.50	1.00	0.00
49	0.00	1.00	0.00	1.00	1.00	0.00
50	0.00	1.00	0.00	0.00	1.00	0.00
51	0.00	1.00	0.00	0.00	1.00	0.00
52	0.03	0.97	0.00	0.00	0.97	0.03

(Markov chain probability) Limit = 50 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.00	1.00	0.00	0.00	1.00	0.00
2	0.00	1.00	0.00	0.00	1.00	0.00
3	0.00	1.00	0.00	0.00	1.00	0.00
4	0.00	1.00	0.00	0.00	1.00	0.00
5	0.00	1.00	0.00	0.00	1.00	0.00
6	0.00	1.00	0.00	0.00	1.00	0.00
7	0.00	1.00	0.00	0.00	1.00	0.00
8	0.00	1.00	0.00	0.00	1.00	0.00
9	0.03	0.97	0.00	0.00	0.97	0.03
10	0.00	1.00	0.00	1.00	1.00	0.00
11	0.00	1.00	0.00	0.00	1.00	0.00
12	0.00	1.00	0.00	0.00	1.00	0.00
13	0.00	1.00	0.00	0.00	1.00	0.00
14	0.00	1.00	0.00	0.00	1.00	0.00
15	0.00	1.00	0.00	0.00	1.00	0.00
16	0.00	1.00	0.00	0.00	1.00	0.00
17	0.00	1.00	0.00	0.00	1.00	0.00
18	0.00	1.00	0.00	0.00	1.00	0.00
19	0.00	1.00	0.00	0.00	1.00	0.00
20	0.00	1.00	0.00	0.00	1.00	0.00
21	0.03	0.97	0.00	0.00	0.97	0.03
22	0.03	0.97	0.00	1.00	0.97	0.03
23	0.15	0.85	1.00	0.00	0.87	0.13
24	0.33	0.67	0.50	0.50	0.70	0.30
25	0.31	0.69	0.31	0.69	0.69	0.31
26	0.28	0.72	0.25	0.75	0.70	0.30
27	0.31	0.69	0.27	0.73	0.68	0.32
28	0.31	0.69	0.42	0.58	0.74	0.26
29	0.33	0.67	0.67	0.33	0.81	0.19
30	0.31	0.69	0.31	0.69	0.69	0.31
31	0.36	0.64	0.42	0.58	0.67	0.33
32	0.41	0.59	0.64	0.36	0.72	0.28
33	0.26	0.74	0.25	0.75	0.74	0.26
34	0.36	0.64	0.30	0.70	0.62	0.38
35	0.28	0.72	0.36	0.64	0.76	0.24
36	0.31	0.69	0.36	0.64	0.71	0.29
37	0.08	0.92	0.17	0.83	0.96	0.04

Continued

Continued

(Markov chain probability) Limit = 50 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
38	0.15	0.85	0.33	0.67	0.86	0.14
39	0.13	0.87	0.33	0.67	0.91	0.09
40	0.15	0.85	0.20	0.80	0.85	0.15
41	0.08	0.92	0.17	0.83	0.94	0.06
42	0.08	0.92	0.00	1.00	0.92	0.08
43	0.05	0.95	0.00	1.00	0.94	0.06
44	0.00	1.00	0.00	1.00	1.00	0.00
45	0.00	1.00	0.00	0.00	1.00	0.00
46	0.00	1.00	0.00	0.00	1.00	0.00
47	0.05	0.95	0.00	0.00	0.95	0.05
48	0.03	0.97	0.50	0.50	1.00	0.00
49	0.00	1.00	0.00	1.00	1.00	0.00
50	0.00	1.00	0.00	0.00	1.00	0.00
51	0.00	1.00	0.00	0.00	1.00	0.00
52	0.00	1.00	0.00	0.00	1.00	0.00

Appendix 16. Consecutive wet and dry spell probability - Akola

(Markov chain probability) Limit = 10 mm

	Consecutive dry probabilities			Consecutive wet probabilities		
WEEK	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	0.84	0.79	0.79	0.03	0.00	0.00
2	0.84	0.84	0.80	0.00	0.00	0.00
3	0.95	0.90	0.80	0.03	0.00	0.00
4	0.92	0.82	0.82	0.00	0.00	0.00
5	0.84	0.84	0.75	0.00	0.00	0.00
6	0.89	0.80	0.75	0.00	0.00	0.00
7	0.89	0.84	0.80	0.00	0.00	0.00
8	0.84	0.80	0.75	0.00	0.00	0.00
9	0.89	0.84	0.82	0.03	0.00	0.00
10	0.87	0.84	0.78	0.00	0.00	0.00
11	0.92	0.85	0.82	0.00	0.00	0.00
12	0.89	0.87	0.87	0.00	0.00	0.00
13	0.89	0.89	0.89	0.00	0.00	0.00
14	0.97	0.97	0.97	0.00	0.00	0.00
15	1.00	1.00	0.97	0.00	0.00	0.00
16	1.00	0.97	0.95	0.00	0.00	0.00
17	0.97	0.95	0.92	0.00	0.00	0.00
18	0.95	0.92	0.85	0.00	0.00	0.00
19	0.95	0.87	0.72	0.00	0.00	0.00
20	0.89	0.74	0.45	0.00	0.00	0.00
21	0.76	0.47	0.25	0.03	0.02	0.01
22	0.50	0.26	0.07	0.13	0.10	0.06
23	0.29	0.08	0.01	0.34	0.21	0.14
24	0.11	0.02	0.01	0.37	0.25	0.17
25	0.05	0.02	0.01	0.45	0.30	0.18
26	0.11	0.04	0.01	0.50	0.30	0.22
27	0.13	0.02	0.01	0.39	0.29	0.22
28	0.05	0.03	0.01	0.45	0.34	0.24
29	0.13	0.05	0.02	0.61	0.42	0.35
30	0.13	0.04	0.02	0.47	0.40	0.25
31	0.11	0.04	0.02	0.55	0.35	0.20
32	0.08	0.04	0.02	0.50	0.29	0.24
33	0.18	0.10	0.05	0.37	0.30	0.14
34	0.24	0.13	0.10	0.45	0.21	0.13
35	0.18	0.15	0.08	0.32	0.19	0.10

Continued

Continued

(Markov chain probability) Limit = 10 mm						
WEEK	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
36	0.42	0.24	0.17	0.29	0.15	0.09
37	0.34	0.24	0.15	0.21	0.12	0.04
38	0.37	0.23	0.20	0.26	0.10	0.04
39	0.37	0.31	0.25	0.16	0.07	0.01
40	0.53	0.43	0.38	0.16	0.02	0.00
41	0.61	0.53	0.48	0.03	0.00	0.00
42	0.74	0.67	0.65	0.00	0.00	0.00
43	0.82	0.79	0.77	0.03	0.01	0.00
44	0.87	0.84	0.78	0.03	0.00	0.00
45	0.92	0.85	0.82	0.00	0.00	0.00
46	0.89	0.87	0.84	0.03	0.01	0.00
47	0.87	0.84	0.82	0.05	0.02	0.00
48	0.89	0.87	0.85	0.03	0.00	0.00
49	0.92	0.90	0.82	0.00	0.00	0.00
50	0.95	0.87	0.00	0.00	0.00	0.00
51	0.89	0.00	0.00	0.00	0.00	0.00
(Markov chain probability) Limit = 20 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.92	0.92	0.92	0.00	0.00	0.00
2	0.95	0.95	0.90	0.00	0.00	0.00
3	1.00	0.95	0.89	0.00	0.00	0.00
4	0.95	0.89	0.89	0.00	0.00	0.00
5	0.89	0.89	0.89	0.00	0.00	0.00
6	0.95	0.95	0.92	0.00	0.00	0.00
7	1.00	0.97	0.95	0.00	0.00	0.00
8	0.97	0.95	0.90	0.00	0.00	0.00
9	0.95	0.90	0.87	0.00	0.00	0.00
10	0.92	0.90	0.82	0.00	0.00	0.00
11	0.92	0.85	0.85	0.00	0.00	0.00
12	0.89	0.89	0.89	0.00	0.00	0.00
13	0.92	0.92	0.92	0.00	0.00	0.00
14	1.00	1.00	1.00	0.00	0.00	0.00
15	1.00	1.00	1.00	0.00	0.00	0.00
16	1.00	1.00	0.97	0.00	0.00	0.00
17	1.00	0.97	0.97	0.00	0.00	0.00
18	0.97	0.97	0.95	0.00	0.00	0.00

Continued

Continued

(Markov chain probability) Limit = 20 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
19	0.97	0.95	0.85	0.00	0.00	0.00
20	0.97	0.87	0.66	0.00	0.00	0.00
21	0.87	0.66	0.40	0.00	0.00	0.00
22	0.68	0.42	0.15	0.05	0.04	0.02
23	0.45	0.16	0.05	0.18	0.08	0.05
24	0.18	0.05	0.03	0.21	0.12	0.07
25	0.13	0.07	0.03	0.32	0.18	0.11
26	0.18	0.09	0.03	0.37	0.23	0.13
27	0.21	0.08	0.04	0.34	0.20	0.12
28	0.16	0.08	0.03	0.34	0.21	0.10
29	0.21	0.07	0.04	0.37	0.18	0.14
30	0.16	0.08	0.03	0.26	0.21	0.11
31	0.24	0.09	0.05	0.45	0.23	0.12
32	0.13	0.07	0.05	0.34	0.18	0.11
33	0.24	0.16	0.10	0.29	0.18	0.10
34	0.34	0.21	0.18	0.32	0.18	0.08
35	0.32	0.28	0.20	0.26	0.12	0.06
36	0.47	0.34	0.26	0.21	0.11	0.05
37	0.53	0.40	0.26	0.13	0.06	0.01
38	0.50	0.33	0.27	0.16	0.03	0.00
39	0.45	0.36	0.32	0.05	0.01	0.00
40	0.58	0.50	0.46	0.05	0.00	0.00
41	0.71	0.65	0.63	0.00	0.00	0.00
42	0.82	0.79	0.77	0.00	0.00	0.00
43	0.89	0.87	0.87	0.00	0.00	0.00
44	0.95	0.95	0.85	0.00	0.00	0.00
45	0.97	0.87	0.87	0.00	0.00	0.00
46	0.89	0.89	0.89	0.00	0.00	0.00
47	0.89	0.89	0.89	0.05	0.00	0.00
48	0.95	0.95	0.92	0.00	0.00	0.00
49	1.00	0.97	0.95	0.00	0.00	0.00
50	0.97	0.95	0.00	0.00	0.00	0.00
51	0.95	0.00	0.00	0.00	0.00	0.00

(Markov chain probability) Limit = 30 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.97	0.97	0.97	0.00	0.00	0.00
2	0.97	0.97	0.92	0.00	0.00	0.00
3	1.00	0.95	0.92	0.00	0.00	0.00
4	0.95	0.92	0.92	0.00	0.00	0.00
5	0.92	0.92	0.92	0.00	0.00	0.00
6	0.97	0.97	0.95	0.00	0.00	0.00
7	1.00	0.97	0.97	0.00	0.00	0.00
8	0.97	0.97	0.95	0.00	0.00	0.00
9	0.97	0.95	0.95	0.00	0.00	0.00
10	0.97	0.97	0.95	0.00	0.00	0.00
11	0.97	0.95	0.95	0.00	0.00	0.00
12	0.97	0.97	0.97	0.00	0.00	0.00
13	0.97	0.97	0.97	0.00	0.00	0.00
14	1.00	1.00	1.00	0.00	0.00	0.00
15	1.00	1.00	1.00	0.00	0.00	0.00
16	1.00	1.00	1.00	0.00	0.00	0.00
17	1.00	1.00	1.00	0.00	0.00	0.00
18	1.00	1.00	0.97	0.00	0.00	0.00
19	1.00	0.97	0.89	0.00	0.00	0.00
20	0.97	0.89	0.74	0.00	0.00	0.00
21	0.89	0.74	0.44	0.00	0.00	0.00
22	0.76	0.46	0.26	0.05	0.02	0.01
23	0.47	0.27	0.16	0.08	0.03	0.01
24	0.34	0.20	0.11	0.16	0.06	0.02
25	0.34	0.18	0.10	0.16	0.05	0.03
26	0.32	0.17	0.09	0.13	0.07	0.04
27	0.32	0.17	0.09	0.24	0.14	0.07
28	0.26	0.15	0.07	0.29	0.14	0.06
29	0.26	0.12	0.06	0.26	0.12	0.06
30	0.24	0.12	0.07	0.21	0.11	0.05
31	0.26	0.15	0.09	0.26	0.12	0.05
32	0.29	0.17	0.12	0.24	0.10	0.05
33	0.32	0.23	0.12	0.18	0.09	0.05
34	0.42	0.23	0.23	0.21	0.11	0.04
35	0.34	0.34	0.26	0.18	0.06	0.04
36	0.53	0.39	0.33	0.16	0.11	0.04
37	0.63	0.53	0.41	0.11	0.04	0.00

Continued

Continued

(Markov chain probability) Limit = 30 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
38	0.58	0.44	0.38	0.13	0.01	0.00
39	0.58	0.50	0.46	0.03	0.00	0.00
40	0.68	0.62	0.59	0.03	0.00	0.00
41	0.79	0.74	0.74	0.00	0.00	0.00
42	0.87	0.87	0.85	0.00	0.00	0.00
43	0.95	0.92	0.92	0.00	0.00	0.00
44	0.97	0.97	0.90	0.00	0.00	0.00
45	0.97	0.90	0.90	0.00	0.00	0.00
46	0.92	0.92	0.92	0.00	0.00	0.00
47	0.92	0.92	0.92	0.03	0.00	0.00
48	0.97	0.97	0.97	0.00	0.00	0.00
49	1.00	1.00	0.97	0.00	0.00	0.00
50	1.00	0.97	0.00	0.00	0.00	0.00
51	0.97	0.00	0.00	0.00	0.00	0.00
(Markov chain probability) Limit = 40 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	1.00	1.00	1.00	0.00	0.00	0.00
2	1.00	1.00	0.97	0.00	0.00	0.00
3	1.00	0.97	0.97	0.00	0.00	0.00
4	0.97	0.97	0.97	0.00	0.00	0.00
5	0.97	0.97	0.97	0.00	0.00	0.00
6	1.00	1.00	0.97	0.00	0.00	0.00
7	1.00	0.97	0.97	0.00	0.00	0.00
8	0.97	0.97	0.97	0.00	0.00	0.00
9	0.97	0.97	0.97	0.00	0.00	0.00
10	1.00	1.00	0.97	0.00	0.00	0.00
11	1.00	0.97	0.97	0.00	0.00	0.00
12	0.97	0.97	0.97	0.00	0.00	0.00
13	0.97	0.97	0.97	0.00	0.00	0.00
14	1.00	1.00	1.00	0.00	0.00	0.00
15	1.00	1.00	1.00	0.00	0.00	0.00
16	1.00	1.00	1.00	0.00	0.00	0.00
17	1.00	1.00	1.00	0.00	0.00	0.00
18	1.00	1.00	0.97	0.00	0.00	0.00
19	1.00	0.97	0.92	0.00	0.00	0.00
20	0.97	0.92	0.77	0.00	0.00	0.00
21	0.92	0.77	0.47	0.00	0.00	0.00

Continued

Continued

(Markov chain probability) Limit = 40 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
22	0.79	0.48	0.29	0.03	0.01	0.00
23	0.50	0.30	0.20	0.08	0.03	0.01
24	0.37	0.25	0.17	0.13	0.04	0.01
25	0.42	0.29	0.20	0.11	0.04	0.02
26	0.47	0.33	0.26	0.11	0.05	0.03
27	0.47	0.38	0.25	0.16	0.10	0.04
28	0.50	0.33	0.19	0.24	0.08	0.04
29	0.42	0.24	0.15	0.13	0.06	0.03
30	0.37	0.23	0.16	0.16	0.08	0.04
31	0.34	0.24	0.15	0.24	0.11	0.03
32	0.39	0.25	0.18	0.21	0.06	0.03
33	0.39	0.28	0.18	0.11	0.06	0.03
34	0.47	0.30	0.28	0.18	0.09	0.02
35	0.39	0.38	0.28	0.18	0.03	0.01
36	0.55	0.41	0.33	0.08	0.02	0.01
37	0.66	0.54	0.45	0.03	0.01	0.00
38	0.61	0.50	0.46	0.08	0.01	0.00
39	0.66	0.60	0.54	0.03	0.00	0.00
40	0.76	0.70	0.66	0.03	0.00	0.00
41	0.82	0.77	0.77	0.00	0.00	0.00
42	0.87	0.87	0.85	0.00	0.00	0.00
43	0.95	0.92	0.92	0.00	0.00	0.00
44	0.97	0.97	0.92	0.00	0.00	0.00
45	0.97	0.92	0.92	0.00	0.00	0.00
46	0.95	0.95	0.95	0.00	0.00	0.00
47	0.95	0.95	0.95	0.03	0.00	0.00
48	0.97	0.97	0.97	0.00	0.00	0.00
49	1.00	1.00	0.97	0.00	0.00	0.00
50	1.00	0.97	0.00	0.00	0.00	0.00
51	0.97	0.00	0.00	0.00	0.00	0.00

(Markov chain probability) Limit = 50 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	1.00	1.00	1.00	0.00	0.00	0.00
2	1.00	1.00	1.00	0.00	0.00	0.00
3	1.00	1.00	1.00	0.00	0.00	0.00
4	1.00	1.00	1.00	0.00	0.00	0.00
5	1.00	1.00	1.00	0.00	0.00	0.00
6	1.00	1.00	0.97	0.00	0.00	0.00
7	1.00	0.97	0.97	0.00	0.00	0.00
8	0.97	0.97	0.97	0.00	0.00	0.00
9	0.97	0.97	0.97	0.00	0.00	0.00
10	1.00	1.00	1.00	0.00	0.00	0.00
11	1.00	1.00	1.00	0.00	0.00	0.00
12	1.00	1.00	1.00	0.00	0.00	0.00
13	1.00	1.00	1.00	0.00	0.00	0.00
14	1.00	1.00	1.00	0.00	0.00	0.00
15	1.00	1.00	1.00	0.00	0.00	0.00
16	1.00	1.00	1.00	0.00	0.00	0.00
17	1.00	1.00	1.00	0.00	0.00	0.00
18	1.00	1.00	0.97	0.00	0.00	0.00
19	1.00	0.97	0.95	0.00	0.00	0.00
20	0.97	0.95	0.82	0.00	0.00	0.00
21	0.95	0.82	0.56	0.00	0.00	0.00
22	0.84	0.58	0.39	0.03	0.01	0.00
23	0.58	0.39	0.29	0.08	0.02	0.01
24	0.45	0.33	0.22	0.11	0.03	0.01
25	0.50	0.34	0.25	0.08	0.02	0.01
26	0.50	0.37	0.31	0.05	0.02	0.02
27	0.53	0.45	0.31	0.13	0.09	0.03
28	0.58	0.40	0.26	0.21	0.07	0.03
29	0.47	0.31	0.22	0.11	0.04	0.03
30	0.45	0.32	0.23	0.13	0.08	0.02
31	0.45	0.33	0.21	0.24	0.06	0.02
32	0.42	0.27	0.21	0.11	0.03	0.01
33	0.47	0.36	0.25	0.08	0.03	0.01
34	0.50	0.35	0.34	0.13	0.05	0.01
35	0.50	0.48	0.41	0.11	0.02	0.01
36	0.66	0.56	0.51	0.05	0.02	0.01
37	0.79	0.72	0.63	0.03	0.01	0.00

Continued

Continued

(Markov chain probability) Limit = 50 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
38	0.76	0.67	0.63	0.05	0.01	0.00
39	0.76	0.72	0.66	0.03	0.01	0.00
40	0.82	0.75	0.70	0.03	0.00	0.00
41	0.84	0.79	0.79	0.00	0.00	0.00
42	0.87	0.87	0.87	0.00	0.00	0.00
43	0.95	0.95	0.95	0.00	0.00	0.00
44	1.00	1.00	0.95	0.00	0.00	0.00
45	1.00	0.95	0.95	0.00	0.00	0.00
46	0.95	0.95	0.95	0.00	0.00	0.00
47	0.95	0.95	0.95	0.03	0.00	0.00
48	0.97	0.97	0.97	0.00	0.00	0.00
49	1.00	1.00	1.00	0.00	0.00	0.00
50	1.00	1.00	0.00	0.00	0.00	0.00
51	1.00	0.00	0.00	0.00	0.00	0.00

Appendix 17. Frequency of occurrence of heavy rain events at different intensities in Akola district (annual basis).

	25 to 50 mm/day		51 to 75 mm/day		76 to 100 mm/day		More than 100 mm/day	
Year	Days	Sum	Days	Sum	Days	Sum	Days	Sum
1971	1	41	0	0	3	251.4	0	0
1972	4	122.7	1	59.7	1	83.2	0	0
1973	6	229.5	2	117.4	1	83.7	2	279.4
1974	5	186.7	2	140.9	0	0	0	0
1975	3	91.7	1	68.2	2	169.3	0	0
1976	10	341.4	3	174.5	0	0	0	0
1977	5	173.4	1	57.4	0	0	1	131
1978	7	239.8	1	52.8	2	176.4	0	0
1979	8	311.3	1	55.4	0	0	1	134.6
1980	5	155.8	1	51	1	85.4	0	0
1981	4	144.8	4	247.6	1	98.2	0	0
1982	0	0	3	165.8	0	0	0	0
1983	8	290.9	1	57.2	0	0	0	0
1984	3	107.8	0	0	1	94.3	0	0
1985	5	167.4	1	58.2	1	98.2	1	131
1986	5	175.2	2	128.1	0	0	1	217.2
1987	4	139.1	1	52.6	2	157.8	0	0
1988	10	330.8	3	170.6	1	85.4	2	330
1989	3	109.1	2	116.4	1	81.8	0	0
1990	9	355.8	3	208.8	1	85.8	0	0
1991	6	215.3	1	56.8	0	0	0	0
1992	2	70.8	3	184.3	0	0	1	113.2
1993	9	304.5	2	116.2	2	181.8	0	0
1994	8	301.8	1	61.4	1	99.6	0	0
1995	3	125.4	2	135.6	1	76	0	0
1996	2	66.3	1	68	1	93	0	0
1997	1	29.4	2	116.6	0	0	1	171.2
1998	6	204	1	56	3	261	0	0
1999	9	327.7	2	125	0	0	1	257
2000	6	212	0	0	0	0	1	151
2001	5	168.4	1	64.8	2	173	1	125
2002	9	313.4	0	0	0	0	1	118.5
2003	2	92.3	0	0	0	0	0	0
2004	5	177.3	0	0	0	0	0	0
2005	6	186.6	2	108.8	0	0	0	0
2006	6	190.7	3	179.2	0	0	2	268.8
2007	6	192.8	2	135.7	0	0	0	0
2008	5	172.6	2	115.1	0	0	0	0
2009	7	256.3	1	58.7	0	0	0	0

Appendix 18. Frequency of occurrence of heavy rain events at different intensities in Akola district (Southwest monsoon).

	25 to 50 mm/day		51 to 75 mm/day		76 to 100 mm/day		More than 100 mm/day	
Year	Days	Sum	Days	Sum	Days	Sum	Days	Sum
1971	1	41	0	0	3	251.4	0	0
1972	4	122.7	1	59.7	1	83.2	0	0
1973	5	179.7	1	64.6	1	83.7	2	279.4
1974	4	153.1	1	73.4	0	0	0	0
1975	3	91.7	1	68.2	2	169.3	0	0
1976	9	308.4	2	105.5	0	0	0	0
1977	4	147	1	57.4	0	0	1	131
1978	6	208.6	1	52.8	2	176.4	0	0
1979	8	311.3	1	55.4	0	0	1	134.6
1980	5	155.8	1	51	1	85.4	0	0
1981	4	144.8	4	247.6	1	98.2	0	0
1982	0	0	3	165.8	0	0	0	0
1983	8	290.9	1	57.2	0	0	0	0
1984	2	81.4	0	0	0	0	0	0
1985	5	167.4	1	58.2	1	98.2	1	131
1986	5	175.2	2	128.1	0	0	1	217.2
1987	3	100.9	1	52.6	2	157.8	0	0
1988	10	330.8	3	170.6	1	85.4	1	186.4
1989	2	75.7	2	116.4	1	81.8	0	0
1990	8	316.2	3	208.8	1	85.8	0	0
1991	6	215.3	1	56.8	0	0	0	0
1992	2	70.8	3	184.3	0	0	1	113.2
1993	7	244.9	2	116.2	1	86.6	0	0
1994	8	301.8	1	61.4	1	99.6	0	0
1995	2	87.4	2	135.6	1	76	0	0
1996	2	66.3	0	0	1	93	0	0
1997	1	29.4	1	65.3	0	0	1	171.2
1998	5	175	1	56	3	261	0	0
1999	8	299.7	2	125	0	0	1	257
2000	6	212	0	0	0	0	1	151
2001	4	119	0	0	1	89	1	125
2002	8	265.4	0	0	0	0	1	118.5
2003	1	44.3	0	0	0	0	0	0
2004	5	177.3	0	0	0	0	0	0
2005	5	142.4	2	108.8	0	0	0	0
2006	5	143.7	3	179.2	0	0	2	268.8
2007	6	192.8	2	135.7	0	0	0	0
2008	4	143.6	2	115.1	0	0	0	0
2009	5	197.5	1	58.7	0	0	0	0

Appendix 19. Frequency of occurrence of heavy rain events at different intensities in Akola district (Northeast monsoon).

	25 to 50 mm/day		51 to 75 mm/day		76 to 100 mm/day		More than 100 mm/day	
Year	Days	Sum	Days	Sum	Days	Sum	Days	Sum
1971	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0
1973	1	49.8	1	52.8	0	0	0	0
1974	1	33.6	1	67.5	0	0	0	0
1975	0	0	0	0	0	0	0	0
1976	0	0	1	69	0	0	0	0
1977	1	26.4	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0
1984	0	0	0	0	1	94.3	0	0
1985	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0
1987	1	38.2	0	0	0	0	0	0
1988	0	0	0	0	0	0	1	143.6
1989	1	33.4	0	0	0	0	0	0
1990	1	39.6	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0
1993	1	31	0	0	1	95.2	0	0
1994	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0
1996	0	0	1	68	0	0	0	0
1997	0	0	1	51.3	0	0	0	0
1998	1	29	0	0	0	0	0	0
1999	1	28	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0
2001	1	49.4	1	64.8	1	84	0	0
2002	1	48	0	0	0	0	0	0
2003	1	48	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0
2005	1	44.2	0	0	0	0	0	0
2006	1	47	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0
2009	2	58.8	0	0	0	0	0	0

Appendix 20. Frequency of occurrence of heavy rain events at different intensities in Akola district (Summer).

	25 to 50 mm/day		51 to 75 mm/day		76 to 100 mm/day		More than 100 mm/day	
Year	Days	Sum	Days	Sum	Days	Sum	Days	Sum
1971	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0
1976	1	33	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0
1993	1	28.6	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0
2008	1	29	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0

Appendix 21. Frequency of days with maximum temperature – Akola district					
Year	>=40°C	>=41°C	>=42°C	>=43°C	>=44°C
1971	58	42	25	10	0
1972	90	65	49	22	11
1973	81	72	63	51	36
1974	53	40	27	14	1
1975	69	60	48	33	7
1976	57	44	24	12	1
1977	75	55	28	12	1
1978	56	48	38	23	14
1979	72	66	48	31	19
1980	65	59	54	38	19
1981	72	62	52	28	12
1982	60	40	14	5	0
1983	77	54	43	25	17
1984	71	58	48	35	25
1985	78	49	38	28	21
1986	70	64	49	37	12
1987	57	44	28	14	6
1988	76	66	47	26	18
1989	56	50	39	23	14
1990	39	28	21	9	4
1991	66	58	44	29	17
1992	87	72	54	34	15
1993	62	58	49	41	21
1994	73	55	34	23	15
1995	59	37	25	19	11
1996	81	62	40	27	17
1997	42	26	18	12	2
1998	71	65	50	26	19
1999	54	50	39	23	15
2000	50	37	29	15	4
2001	47	34	24	20	13
2002	66	52	33	19	11
2003	64	48	32	19	11
2004	68	49	22	6	0
2005	67	45	35	20	7
2006	42	29	19	9	3
2007	64	51	26	16	8
2008	56	42	26	13	7
2009	77	63	46	26	11

Appendix 22. Initial and conditional probabilities of rainfall - Solapur

Initial and conditional probabilities of rainfall

(Markov chain probability) Limit = 10 mm

	Initial probabilities		Conditional probabilities			
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.03	0.97	0.00	1.00	0.97	0.03
2	0.03	0.97	0.00	1.00	0.97	0.03
3	0.08	0.92	1.00	0.00	0.95	0.05
4	0.03	0.97	0.00	1.00	0.97	0.03
5	0.03	0.97	0.00	1.00	0.97	0.03
6	0.05	0.95	1.00	0.00	0.97	0.03
7	0.00	1.00	0.00	1.00	1.00	0.00
8	0.05	0.95	0.00	0.00	0.95	0.05
9	0.00	1.00	0.00	1.00	1.00	0.00
10	0.05	0.95	0.00	0.00	0.95	0.05
11	0.03	0.97	0.00	1.00	0.97	0.03
12	0.05	0.95	0.00	1.00	0.95	0.05
13	0.10	0.90	0.50	0.50	0.92	0.08
14	0.18	0.82	0.00	1.00	0.80	0.20
15	0.21	0.79	0.14	0.86	0.78	0.22
16	0.08	0.92	0.00	1.00	0.90	0.10
17	0.05	0.95	0.00	1.00	0.94	0.06
18	0.21	0.79	0.00	1.00	0.78	0.22
19	0.13	0.87	0.25	0.75	0.90	0.10
20	0.28	0.72	0.60	0.40	0.76	0.24
21	0.31	0.69	0.45	0.55	0.75	0.25
22	0.36	0.64	0.42	0.58	0.67	0.33
23	0.62	0.38	0.50	0.50	0.32	0.68
24	0.56	0.44	0.54	0.46	0.40	0.60
25	0.54	0.46	0.68	0.32	0.65	0.35
26	0.56	0.44	0.62	0.38	0.50	0.50
27	0.46	0.54	0.45	0.55	0.53	0.47
28	0.54	0.46	0.67	0.33	0.57	0.43
29	0.41	0.59	0.57	0.43	0.78	0.22
30	0.72	0.28	0.75	0.25	0.30	0.70
31	0.64	0.36	0.82	0.18	0.82	0.18
32	0.74	0.26	0.80	0.20	0.36	0.64
33	0.59	0.41	0.66	0.34	0.60	0.40
34	0.62	0.38	0.70	0.30	0.50	0.50

Continued

Continued

(Markov chain probability) Limit = 10 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
35	0.59	0.41	0.75	0.25	0.67	0.33
36	0.49	0.51	0.57	0.43	0.63	0.38
37	0.59	0.41	0.68	0.32	0.50	0.50
38	0.72	0.28	0.83	0.17	0.44	0.56
39	0.69	0.31	0.68	0.32	0.27	0.73
40	0.62	0.38	0.70	0.30	0.58	0.42
41	0.41	0.59	0.50	0.50	0.73	0.27
42	0.41	0.59	0.69	0.31	0.78	0.22
43	0.23	0.77	0.31	0.69	0.83	0.17
44	0.21	0.79	0.44	0.56	0.87	0.13
45	0.21	0.79	0.38	0.63	0.84	0.16
46	0.18	0.82	0.25	0.75	0.84	0.16
47	0.10	0.90	0.14	0.86	0.91	0.09
48	0.05	0.95	0.25	0.75	0.97	0.03
49	0.05	0.95	0.00	1.00	0.95	0.05
50	0.05	0.95	0.00	1.00	0.95	0.05
51	0.00	1.00	0.00	1.00	1.00	0.00
52	0.08	0.92	0.00	0.00	0.92	0.08
(Markov chain probability) Limit = 20 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.00	1.00	0.00	1.00	1.00	0.00
2	0.00	1.00	0.00	0.00	1.00	0.00
3	0.05	0.95	0.00	0.00	0.95	0.05
4	0.00	1.00	0.00	1.00	1.00	0.00
5	0.00	1.00	0.00	0.00	1.00	0.00
6	0.00	1.00	0.00	0.00	1.00	0.00
7	0.00	1.00	0.00	0.00	1.00	0.00
8	0.00	1.00	0.00	0.00	1.00	0.00
9	0.00	1.00	0.00	0.00	1.00	0.00
10	0.00	1.00	0.00	0.00	1.00	0.00
11	0.00	1.00	0.00	0.00	1.00	0.00
12	0.05	0.95	0.00	0.00	0.95	0.05
13	0.08	0.92	0.50	0.50	0.95	0.05
14	0.10	0.90	0.00	1.00	0.89	0.11
15	0.05	0.95	0.00	1.00	0.94	0.06
16	0.03	0.97	0.00	1.00	0.97	0.03

Continued

Continued

(Markov chain probability) Limit = 20 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
17	0.05	0.95	0.00	1.00	0.95	0.05
18	0.03	0.97	0.00	1.00	0.97	0.03
19	0.10	0.90	0.00	1.00	0.89	0.11
20	0.21	0.79	0.50	0.50	0.83	0.17
21	0.10	0.90	0.13	0.88	0.90	0.10
22	0.31	0.69	0.50	0.50	0.71	0.29
23	0.41	0.59	0.25	0.75	0.52	0.48
24	0.44	0.56	0.44	0.56	0.57	0.43
25	0.38	0.62	0.47	0.53	0.68	0.32
26	0.38	0.62	0.33	0.67	0.58	0.42
27	0.41	0.59	0.53	0.47	0.67	0.33
28	0.38	0.62	0.56	0.44	0.74	0.26
29	0.26	0.74	0.40	0.60	0.83	0.17
30	0.49	0.51	0.70	0.30	0.59	0.41
31	0.49	0.51	0.79	0.21	0.80	0.20
32	0.46	0.54	0.47	0.53	0.55	0.45
33	0.41	0.59	0.44	0.56	0.62	0.38
34	0.44	0.56	0.44	0.56	0.57	0.43
35	0.33	0.67	0.41	0.59	0.73	0.27
36	0.41	0.59	0.62	0.38	0.69	0.31
37	0.54	0.46	0.50	0.50	0.43	0.57
38	0.62	0.38	0.71	0.29	0.50	0.50
39	0.64	0.36	0.67	0.33	0.40	0.60
40	0.54	0.46	0.64	0.36	0.64	0.36
41	0.31	0.69	0.43	0.57	0.83	0.17
42	0.28	0.72	0.58	0.42	0.85	0.15
43	0.21	0.79	0.27	0.73	0.82	0.18
44	0.13	0.87	0.25	0.75	0.90	0.10
45	0.15	0.85	0.20	0.80	0.85	0.15
46	0.08	0.92	0.00	1.00	0.91	0.09
47	0.05	0.95	0.33	0.67	0.97	0.03
48	0.05	0.95	0.50	0.50	0.97	0.03
49	0.03	0.97	0.00	1.00	0.97	0.03
50	0.05	0.95	0.00	1.00	0.95	0.05
51	0.00	1.00	0.00	1.00	1.00	0.00
52	0.05	0.95	0.00	0.00	0.95	0.05

(Markov chain probability) Limit =30 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.00	1.00	0.00	1.00	1.00	0.00
2	0.00	1.00	0.00	0.00	1.00	0.00
3	0.00	1.00	0.00	0.00	1.00	0.00
4	0.00	1.00	0.00	0.00	1.00	0.00
5	0.00	1.00	0.00	0.00	1.00	0.00
6	0.00	1.00	0.00	0.00	1.00	0.00
7	0.00	1.00	0.00	0.00	1.00	0.00
8	0.00	1.00	0.00	0.00	1.00	0.00
9	0.00	1.00	0.00	0.00	1.00	0.00
10	0.00	1.00	0.00	0.00	1.00	0.00
11	0.00	1.00	0.00	0.00	1.00	0.00
12	0.05	0.95	0.00	0.00	0.95	0.05
13	0.05	0.95	0.50	0.50	0.97	0.03
14	0.05	0.95	0.00	1.00	0.95	0.05
15	0.05	0.95	0.00	1.00	0.95	0.05
16	0.03	0.97	0.00	1.00	0.97	0.03
17	0.03	0.97	0.00	1.00	0.97	0.03
18	0.00	1.00	0.00	1.00	1.00	0.00
19	0.00	1.00	0.00	0.00	1.00	0.00
20	0.13	0.87	0.00	0.00	0.87	0.13
21	0.05	0.95	0.00	1.00	0.94	0.06
22	0.23	0.77	0.50	0.50	0.78	0.22
23	0.31	0.69	0.11	0.89	0.63	0.37
24	0.33	0.67	0.33	0.67	0.67	0.33
25	0.23	0.77	0.15	0.85	0.73	0.27
26	0.31	0.69	0.33	0.67	0.70	0.30
27	0.31	0.69	0.50	0.50	0.78	0.22
28	0.28	0.72	0.50	0.50	0.81	0.19
29	0.15	0.85	0.27	0.73	0.89	0.11
30	0.46	0.54	0.50	0.50	0.55	0.45
31	0.44	0.56	0.72	0.28	0.81	0.19
32	0.33	0.67	0.41	0.59	0.73	0.27
33	0.28	0.72	0.46	0.54	0.81	0.19
34	0.33	0.67	0.45	0.55	0.71	0.29
35	0.26	0.74	0.38	0.62	0.81	0.19
36	0.28	0.72	0.60	0.40	0.83	0.17
37	0.51	0.49	0.55	0.45	0.50	0.50

Continued

Continued

(Markov chain probability) Limit =30 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
38	0.51	0.49	0.70	0.30	0.68	0.32
39	0.56	0.44	0.55	0.45	0.42	0.58
40	0.46	0.54	0.55	0.45	0.65	0.35
41	0.31	0.69	0.44	0.56	0.81	0.19
42	0.18	0.82	0.42	0.58	0.93	0.07
43	0.15	0.85	0.14	0.86	0.84	0.16
44	0.10	0.90	0.33	0.67	0.94	0.06
45	0.10	0.90	0.25	0.75	0.91	0.09
46	0.05	0.95	0.00	1.00	0.94	0.06
47	0.05	0.95	0.50	0.50	0.97	0.03
48	0.03	0.97	0.50	0.50	1.00	0.00
49	0.03	0.97	0.00	1.00	0.97	0.03
50	0.00	1.00	0.00	1.00	1.00	0.00
51	0.00	1.00	0.00	0.00	1.00	0.00
52	0.05	0.95	0.00	0.00	0.95	0.05
(Markov chain probability) Limit = 40 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.00	1.00	0.00	1.00	1.00	0.00
2	0.00	1.00	0.00	0.00	1.00	0.00
3	0.00	1.00	0.00	0.00	1.00	0.00
4	0.00	1.00	0.00	0.00	1.00	0.00
5	0.00	1.00	0.00	0.00	1.00	0.00
6	0.00	1.00	0.00	0.00	1.00	0.00
7	0.00	1.00	0.00	0.00	1.00	0.00
8	0.00	1.00	0.00	0.00	1.00	0.00
9	0.00	1.00	0.00	0.00	1.00	0.00
10	0.00	1.00	0.00	0.00	1.00	0.00
11	0.00	1.00	0.00	0.00	1.00	0.00
12	0.00	1.00	0.00	0.00	1.00	0.00
13	0.03	0.97	0.00	0.00	0.97	0.03
14	0.03	0.97	0.00	1.00	0.97	0.03
15	0.03	0.97	0.00	1.00	0.97	0.03
16	0.03	0.97	0.00	1.00	0.97	0.03
17	0.00	1.00	0.00	1.00	1.00	0.00
18	0.00	1.00	0.00	0.00	1.00	0.00
19	0.00	1.00	0.00	0.00	1.00	0.00
20	0.13	0.87	0.00	0.00	0.87	0.13

Continued

Continued

(Markov chain probability) Limit = 40 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
21	0.05	0.95	0.00	1.00	0.94	0.06
22	0.15	0.85	0.00	1.00	0.84	0.16
23	0.23	0.77	0.00	1.00	0.73	0.27
24	0.28	0.72	0.33	0.67	0.73	0.27
25	0.18	0.82	0.09	0.91	0.79	0.21
26	0.23	0.77	0.14	0.86	0.75	0.25
27	0.15	0.85	0.33	0.67	0.90	0.10
28	0.18	0.82	0.17	0.83	0.82	0.18
29	0.13	0.87	0.43	0.57	0.94	0.06
30	0.41	0.59	0.60	0.40	0.62	0.38
31	0.26	0.74	0.44	0.56	0.87	0.13
32	0.26	0.74	0.20	0.80	0.72	0.28
33	0.18	0.82	0.20	0.80	0.83	0.17
34	0.31	0.69	0.29	0.71	0.69	0.31
35	0.21	0.79	0.25	0.75	0.81	0.19
36	0.21	0.79	0.25	0.75	0.81	0.19
37	0.41	0.59	0.63	0.38	0.65	0.35
38	0.46	0.54	0.56	0.44	0.61	0.39
39	0.46	0.54	0.50	0.50	0.57	0.43
40	0.36	0.64	0.44	0.56	0.71	0.29
41	0.26	0.74	0.36	0.64	0.80	0.20
42	0.18	0.82	0.40	0.60	0.90	0.10
43	0.13	0.87	0.14	0.86	0.88	0.13
44	0.03	0.97	0.20	0.80	1.00	0.00
45	0.08	0.92	0.00	1.00	0.92	0.08
46	0.05	0.95	0.00	1.00	0.94	0.06
47	0.03	0.97	0.50	0.50	1.00	0.00
48	0.03	0.97	0.00	1.00	0.97	0.03
49	0.03	0.97	0.00	1.00	0.97	0.03
50	0.00	1.00	0.00	1.00	1.00	0.00
51	0.00	1.00	0.00	0.00	1.00	0.00
52	0.03	0.97	0.00	0.00	0.97	0.03

(Markov chain probability) Limit = 50 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	0.00	1.00	0.00	0.00	1.00	0.00
2	0.00	1.00	0.00	0.00	1.00	0.00
3	0.00	1.00	0.00	0.00	1.00	0.00
4	0.00	1.00	0.00	0.00	1.00	0.00
5	0.00	1.00	0.00	0.00	1.00	0.00
6	0.00	1.00	0.00	0.00	1.00	0.00
7	0.00	1.00	0.00	0.00	1.00	0.00
8	0.00	1.00	0.00	0.00	1.00	0.00
9	0.00	1.00	0.00	0.00	1.00	0.00
10	0.00	1.00	0.00	0.00	1.00	0.00
11	0.00	1.00	0.00	0.00	1.00	0.00
12	0.00	1.00	0.00	0.00	1.00	0.00
13	0.03	0.97	0.00	0.00	0.97	0.03
14	0.00	1.00	0.00	1.00	1.00	0.00
15	0.00	1.00	0.00	0.00	1.00	0.00
16	0.00	1.00	0.00	0.00	1.00	0.00
17	0.00	1.00	0.00	0.00	1.00	0.00
18	0.00	1.00	0.00	0.00	1.00	0.00
19	0.00	1.00	0.00	0.00	1.00	0.00
20	0.08	0.92	0.00	0.00	0.92	0.08
21	0.05	0.95	0.00	1.00	0.94	0.06
22	0.08	0.92	0.00	1.00	0.92	0.08
23	0.13	0.87	0.00	1.00	0.86	0.14
24	0.21	0.79	0.20	0.80	0.79	0.21
25	0.10	0.90	0.13	0.88	0.90	0.10
26	0.15	0.85	0.00	1.00	0.83	0.17
27	0.13	0.87	0.00	1.00	0.85	0.15
28	0.10	0.90	0.20	0.80	0.91	0.09
29	0.08	0.92	0.25	0.75	0.94	0.06
30	0.38	0.62	0.67	0.33	0.64	0.36
31	0.26	0.74	0.47	0.53	0.88	0.13
32	0.21	0.79	0.10	0.90	0.76	0.24
33	0.13	0.87	0.25	0.75	0.90	0.10
34	0.28	0.72	0.40	0.60	0.74	0.26
35	0.21	0.79	0.27	0.73	0.82	0.18
36	0.18	0.82	0.25	0.75	0.84	0.16
37	0.36	0.64	0.57	0.43	0.69	0.31

Continued

Continued

(Markov chain probability) Limit = 50 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
38	0.33	0.67	0.50	0.50	0.76	0.24
39	0.41	0.59	0.54	0.46	0.65	0.35
40	0.31	0.69	0.31	0.69	0.70	0.30
41	0.21	0.79	0.33	0.67	0.85	0.15
42	0.13	0.87	0.25	0.75	0.90	0.10
43	0.13	0.87	0.00	1.00	0.85	0.15
44	0.03	0.97	0.20	0.80	1.00	0.00
45	0.08	0.92	0.00	1.00	0.92	0.08
46	0.00	1.00	0.00	1.00	1.00	0.00
47	0.00	1.00	0.00	0.00	1.00	0.00
48	0.03	0.97	0.00	0.00	0.97	0.03
49	0.03	0.97	0.00	1.00	0.97	0.03
50	0.00	1.00	0.00	1.00	1.00	0.00
51	0.00	1.00	0.00	0.00	1.00	0.00
52	0.00	1.00	0.00	0.00	1.00	0.00

Appendix 23. Consecutive wet and dry spell probability - Solapur

(Markov chain probability) Limit = 10 mm

	Consecutive dry probabilities			Consecutive wet probabilities		
WEEK	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	0.95	0.90	0.87	0.00	0.00	0.00
2	0.92	0.90	0.87	0.03	0.00	0.00
3	0.90	0.87	0.85	0.00	0.00	0.00
4	0.95	0.92	0.92	0.00	0.00	0.00
5	0.95	0.95	0.90	0.03	0.00	0.00
6	0.95	0.90	0.90	0.00	0.00	0.00
7	0.95	0.95	0.90	0.00	0.00	0.00
8	0.95	0.90	0.88	0.00	0.00	0.00
9	0.95	0.92	0.87	0.00	0.00	0.00
10	0.92	0.87	0.80	0.00	0.00	0.00
11	0.92	0.85	0.68	0.00	0.00	0.00
12	0.87	0.70	0.54	0.03	0.00	0.00
13	0.72	0.56	0.51	0.00	0.00	0.00
14	0.64	0.58	0.55	0.03	0.00	0.00
15	0.72	0.68	0.53	0.00	0.00	0.00
16	0.87	0.68	0.62	0.00	0.00	0.00
17	0.74	0.67	0.51	0.00	0.00	0.00
18	0.72	0.55	0.41	0.05	0.03	0.01
19	0.67	0.50	0.33	0.08	0.04	0.01
20	0.54	0.36	0.11	0.13	0.05	0.03
21	0.46	0.15	0.06	0.13	0.06	0.03
22	0.21	0.08	0.05	0.18	0.10	0.07
23	0.15	0.10	0.05	0.33	0.23	0.14
24	0.28	0.14	0.07	0.38	0.24	0.11
25	0.23	0.12	0.07	0.33	0.15	0.10
26	0.23	0.13	0.10	0.26	0.17	0.10
27	0.31	0.24	0.07	0.31	0.18	0.13
28	0.36	0.11	0.09	0.31	0.23	0.19
29	0.18	0.15	0.05	0.31	0.25	0.20
30	0.23	0.08	0.05	0.59	0.47	0.31
31	0.13	0.08	0.04	0.51	0.34	0.23
32	0.15	0.08	0.05	0.49	0.34	0.25
33	0.21	0.14	0.09	0.41	0.31	0.17
34	0.26	0.16	0.08	0.46	0.26	0.18
35	0.26	0.13	0.06	0.33	0.23	0.19

Continued

Continued

(Markov chain probability) Limit = 10 mm						
WEEK	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
36	0.26	0.11	0.03	0.33	0.28	0.19
37	0.18	0.05	0.03	0.49	0.33	0.23
38	0.08	0.04	0.03	0.49	0.34	0.17
39	0.18	0.13	0.10	0.49	0.24	0.17
40	0.28	0.22	0.18	0.31	0.21	0.07
41	0.46	0.38	0.33	0.28	0.09	0.04
42	0.49	0.42	0.35	0.13	0.06	0.02
43	0.67	0.56	0.47	0.10	0.04	0.01
44	0.67	0.56	0.51	0.08	0.02	0.00
45	0.67	0.60	0.59	0.05	0.01	0.00
46	0.74	0.72	0.68	0.03	0.01	0.00
47	0.87	0.82	0.78	0.03	0.00	0.00
48	0.90	0.85	0.85	0.00	0.00	0.00
49	0.90	0.90	0.83	0.00	0.00	0.00
50	0.95	0.88	0.00	0.00	0.00	0.00
51	0.92	0.00	0.00	0.00	0.00	0.00
(Markov chain probability) Limit = 20 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	1.00	0.95	0.95	0.00	0.00	0.00
2	0.95	0.95	0.95	0.00	0.00	0.00
3	0.95	0.95	0.95	0.00	0.00	0.00
4	1.00	1.00	1.00	0.00	0.00	0.00
5	1.00	1.00	1.00	0.00	0.00	0.00
6	1.00	1.00	1.00	0.00	0.00	0.00
7	1.00	1.00	1.00	0.00	0.00	0.00
8	1.00	1.00	1.00	0.00	0.00	0.00
9	1.00	1.00	0.95	0.00	0.00	0.00
10	1.00	0.95	0.90	0.00	0.00	0.00
11	0.95	0.90	0.80	0.00	0.00	0.00
12	0.90	0.80	0.75	0.03	0.00	0.00
13	0.82	0.77	0.75	0.00	0.00	0.00
14	0.85	0.82	0.78	0.00	0.00	0.00
15	0.92	0.87	0.85	0.00	0.00	0.00
16	0.92	0.90	0.80	0.00	0.00	0.00
17	0.92	0.83	0.68	0.00	0.00	0.00
18	0.87	0.72	0.65	0.00	0.00	0.00

Continued

Continued

(Markov chain probability) Limit = 20 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
19	0.74	0.67	0.48	0.05	0.01	0.00
20	0.72	0.51	0.27	0.03	0.01	0.00
21	0.64	0.33	0.19	0.05	0.01	0.01
22	0.36	0.20	0.14	0.08	0.03	0.02
23	0.33	0.23	0.13	0.18	0.08	0.03
24	0.38	0.22	0.15	0.21	0.07	0.04
25	0.36	0.24	0.18	0.13	0.07	0.04
26	0.41	0.30	0.25	0.21	0.12	0.05
27	0.44	0.36	0.21	0.23	0.09	0.06
28	0.51	0.30	0.24	0.15	0.11	0.09
29	0.44	0.35	0.19	0.18	0.14	0.07
30	0.41	0.23	0.14	0.38	0.18	0.08
31	0.28	0.17	0.10	0.23	0.10	0.04
32	0.33	0.19	0.14	0.21	0.09	0.04
33	0.33	0.24	0.17	0.18	0.07	0.05
34	0.41	0.28	0.12	0.18	0.11	0.06
35	0.46	0.20	0.10	0.21	0.10	0.07
36	0.26	0.13	0.05	0.21	0.15	0.10
37	0.23	0.09	0.06	0.38	0.26	0.16
38	0.15	0.10	0.08	0.41	0.26	0.11
39	0.23	0.19	0.16	0.41	0.18	0.10
40	0.38	0.33	0.27	0.23	0.13	0.04
41	0.59	0.48	0.44	0.18	0.05	0.01
42	0.59	0.53	0.45	0.08	0.02	0.00
43	0.72	0.61	0.56	0.05	0.01	0.00
44	0.74	0.68	0.66	0.03	0.00	0.00
45	0.77	0.75	0.73	0.00	0.00	0.00
46	0.90	0.87	0.85	0.03	0.01	0.00
47	0.92	0.90	0.85	0.03	0.00	0.00
48	0.92	0.87	0.87	0.00	0.00	0.00
49	0.92	0.92	0.88	0.00	0.00	0.00
50	0.95	0.90	0.00	0.00	0.00	0.00
51	0.95	0.00	0.00	0.00	0.00	0.00

(Markov chain probability) Limit = 30 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	1.00	1.00	1.00	0.00	0.00	0.00
2	1.00	1.00	1.00	0.00	0.00	0.00
3	1.00	1.00	1.00	0.00	0.00	0.00
4	1.00	1.00	1.00	0.00	0.00	0.00
5	1.00	1.00	1.00	0.00	0.00	0.00
6	1.00	1.00	1.00	0.00	0.00	0.00
7	1.00	1.00	1.00	0.00	0.00	0.00
8	1.00	1.00	1.00	0.00	0.00	0.00
9	1.00	1.00	0.95	0.00	0.00	0.00
10	1.00	0.95	0.92	0.00	0.00	0.00
11	0.95	0.92	0.87	0.00	0.00	0.00
12	0.92	0.87	0.83	0.03	0.00	0.00
13	0.90	0.85	0.83	0.00	0.00	0.00
14	0.90	0.87	0.85	0.00	0.00	0.00
15	0.92	0.90	0.90	0.00	0.00	0.00
16	0.95	0.95	0.95	0.00	0.00	0.00
17	0.97	0.97	0.85	0.00	0.00	0.00
18	1.00	0.87	0.82	0.00	0.00	0.00
19	0.87	0.82	0.64	0.00	0.00	0.00
20	0.82	0.64	0.41	0.00	0.00	0.00
21	0.74	0.47	0.31	0.03	0.00	0.00
22	0.49	0.32	0.24	0.03	0.01	0.00
23	0.46	0.34	0.24	0.10	0.02	0.01
24	0.49	0.34	0.27	0.05	0.02	0.01
25	0.54	0.42	0.34	0.08	0.04	0.02
26	0.54	0.44	0.39	0.15	0.08	0.02
27	0.56	0.50	0.27	0.15	0.04	0.02
28	0.64	0.35	0.28	0.08	0.04	0.03
29	0.46	0.37	0.27	0.08	0.06	0.02
30	0.44	0.32	0.26	0.33	0.14	0.06
31	0.41	0.33	0.24	0.18	0.08	0.04
32	0.54	0.38	0.31	0.15	0.07	0.03
33	0.51	0.41	0.34	0.13	0.05	0.03
34	0.54	0.45	0.22	0.13	0.08	0.04
35	0.62	0.31	0.21	0.15	0.08	0.06
36	0.36	0.25	0.10	0.15	0.11	0.06
37	0.33	0.14	0.09	0.36	0.20	0.11

Continued

Continued

(Markov chain probability) Limit = 30 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
38	0.21	0.13	0.11	0.28	0.15	0.07
39	0.28	0.23	0.21	0.31	0.14	0.06
40	0.44	0.40	0.34	0.21	0.09	0.01
41	0.64	0.54	0.51	0.13	0.02	0.01
42	0.69	0.65	0.59	0.03	0.01	0.00
43	0.79	0.73	0.69	0.05	0.01	0.00
44	0.82	0.77	0.75	0.03	0.00	0.00
45	0.85	0.82	0.82	0.00	0.00	0.00
46	0.92	0.92	0.90	0.03	0.01	0.00
47	0.95	0.92	0.92	0.03	0.00	0.00
48	0.95	0.95	0.95	0.00	0.00	0.00
49	0.97	0.97	0.92	0.00	0.00	0.00
50	1.00	0.95	0.00	0.00	0.00	0.00
51	0.95	0.00	0.00	0.00	0.00	0.00
(Markov chain probability) Limit = 40 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	1.00	1.00	1.00	0.00	0.00	0.00
2	1.00	1.00	1.00	0.00	0.00	0.00
3	1.00	1.00	1.00	0.00	0.00	0.00
4	1.00	1.00	1.00	0.00	0.00	0.00
5	1.00	1.00	1.00	0.00	0.00	0.00
6	1.00	1.00	1.00	0.00	0.00	0.00
7	1.00	1.00	1.00	0.00	0.00	0.00
8	1.00	1.00	1.00	0.00	0.00	0.00
9	1.00	1.00	1.00	0.00	0.00	0.00
10	1.00	1.00	0.97	0.00	0.00	0.00
11	1.00	0.97	0.95	0.00	0.00	0.00
12	0.97	0.95	0.92	0.00	0.00	0.00
13	0.95	0.92	0.90	0.00	0.00	0.00
14	0.95	0.92	0.92	0.00	0.00	0.00
15	0.95	0.95	0.95	0.00	0.00	0.00
16	0.97	0.97	0.97	0.00	0.00	0.00
17	1.00	1.00	0.87	0.00	0.00	0.00
18	1.00	0.87	0.82	0.00	0.00	0.00
19	0.87	0.82	0.69	0.00	0.00	0.00
20	0.82	0.69	0.50	0.00	0.00	0.00
21	0.79	0.58	0.42	0.00	0.00	0.00

Continued

Continued

(Markov chain probability) Limit = 40 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
22	0.62	0.45	0.35	0.00	0.00	0.00
23	0.56	0.44	0.33	0.08	0.01	0.00
24	0.56	0.42	0.38	0.03	0.00	0.00
25	0.62	0.55	0.45	0.03	0.01	0.00
26	0.69	0.57	0.53	0.08	0.01	0.01
27	0.69	0.65	0.40	0.03	0.01	0.01
28	0.77	0.48	0.41	0.08	0.05	0.02
29	0.54	0.47	0.34	0.08	0.03	0.01
30	0.51	0.37	0.31	0.18	0.04	0.01
31	0.54	0.45	0.31	0.05	0.01	0.00
32	0.62	0.42	0.34	0.05	0.01	0.00
33	0.56	0.46	0.37	0.05	0.01	0.00
34	0.56	0.45	0.29	0.08	0.02	0.01
35	0.64	0.41	0.25	0.05	0.03	0.02
36	0.51	0.31	0.18	0.13	0.07	0.04
37	0.36	0.21	0.15	0.23	0.12	0.05
38	0.31	0.22	0.18	0.23	0.10	0.04
39	0.38	0.31	0.28	0.21	0.07	0.03
40	0.51	0.46	0.40	0.13	0.05	0.01
41	0.67	0.58	0.58	0.10	0.01	0.00
42	0.72	0.72	0.66	0.03	0.01	0.00
43	0.87	0.80	0.76	0.03	0.00	0.00
44	0.90	0.85	0.85	0.00	0.00	0.00
45	0.87	0.87	0.85	0.00	0.00	0.00
46	0.95	0.92	0.90	0.03	0.00	0.00
47	0.95	0.92	0.92	0.00	0.00	0.00
48	0.95	0.95	0.95	0.00	0.00	0.00
49	0.97	0.97	0.95	0.00	0.00	0.00
50	1.00	0.97	0.00	0.00	0.00	0.00
51	0.97	0.00	0.00	0.00	0.00	0.00

(Markov chain probability) Limit = 50 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
1	1.00	1.00	1.00	0.00	0.00	0.00
2	1.00	1.00	1.00	0.00	0.00	0.00
3	1.00	1.00	1.00	0.00	0.00	0.00
4	1.00	1.00	1.00	0.00	0.00	0.00
5	1.00	1.00	1.00	0.00	0.00	0.00
6	1.00	1.00	1.00	0.00	0.00	0.00
7	1.00	1.00	1.00	0.00	0.00	0.00
8	1.00	1.00	1.00	0.00	0.00	0.00
9	1.00	1.00	1.00	0.00	0.00	0.00
10	1.00	1.00	0.97	0.00	0.00	0.00
11	1.00	0.97	0.97	0.00	0.00	0.00
12	0.97	0.97	0.97	0.00	0.00	0.00
13	0.97	0.97	0.97	0.00	0.00	0.00
14	1.00	1.00	1.00	0.00	0.00	0.00
15	1.00	1.00	1.00	0.00	0.00	0.00
16	1.00	1.00	1.00	0.00	0.00	0.00
17	1.00	1.00	0.92	0.00	0.00	0.00
18	1.00	0.92	0.87	0.00	0.00	0.00
19	0.92	0.87	0.80	0.00	0.00	0.00
20	0.87	0.80	0.69	0.00	0.00	0.00
21	0.87	0.75	0.60	0.00	0.00	0.00
22	0.79	0.63	0.57	0.00	0.00	0.00
23	0.69	0.63	0.52	0.03	0.00	0.00
24	0.72	0.59	0.50	0.03	0.00	0.00
25	0.74	0.63	0.58	0.00	0.00	0.00
26	0.72	0.65	0.62	0.00	0.00	0.00
27	0.79	0.75	0.48	0.03	0.01	0.00
28	0.85	0.54	0.47	0.03	0.02	0.01
29	0.59	0.52	0.39	0.05	0.02	0.00
30	0.54	0.41	0.37	0.18	0.02	0.00
31	0.56	0.51	0.37	0.03	0.01	0.00
32	0.72	0.53	0.43	0.05	0.02	0.01
33	0.64	0.53	0.44	0.05	0.01	0.00
34	0.59	0.49	0.34	0.08	0.02	0.01
35	0.67	0.46	0.35	0.05	0.03	0.01
36	0.56	0.43	0.28	0.10	0.05	0.03
37	0.49	0.32	0.22	0.18	0.10	0.03

Continued

Continued

(Markov chain probability) Limit = 50 mm						
WEEK	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)
38	0.44	0.30	0.26	0.18	0.06	0.02
39	0.41	0.35	0.32	0.13	0.04	0.01
40	0.59	0.53	0.45	0.10	0.03	0.00
41	0.72	0.61	0.61	0.05	0.00	0.00
42	0.74	0.74	0.68	0.00	0.00	0.00
43	0.87	0.80	0.80	0.03	0.00	0.00
44	0.90	0.90	0.90	0.00	0.00	0.00
45	0.92	0.92	0.90	0.00	0.00	0.00
46	1.00	0.97	0.95	0.00	0.00	0.00
47	0.97	0.95	0.95	0.00	0.00	0.00
48	0.95	0.95	0.95	0.00	0.00	0.00
49	0.97	0.97	0.97	0.00	0.00	0.00
50	1.00	1.00	0.00	0.00	0.00	0.00
51	1.00	0.00	0.00	0.00	0.00	0.00
52	1.00	0.00	0.00	0.00	0.00	0.00

Appendix 24. Frequency of occurrence of heavy rain events at different intensities in Solapur district (annual basis).

	25 to 50 mm/day		51 to 75 mm/day		76 to 100 mm/day		More than 100 mm/day	
Year	Days	Sum	Days	Sum	Days	Sum	Days	Sum
1971	3	92.4	2	111.2	0	0	1	105.9
1972	2	63.7	0	0	0	0	0	0
1973	8	289.1	3	199.9	0	0	0	0
1974	5	177.6	5	306.2	1	80	0	0
1975	11	353.5	3	191.5	1	76.1	0	0
1976	6	191.7	0	0	0	0	0	0
1977	2	56.8	2	134	0	0	0	0
1978	2	77.8	0	0	1	88	2	215.8
1979	5	177.7	1	54.4	1	98	0	0
1980	5	198	1	51	0	0	0	0
1981	9	322.1	1	55.2	0	0	0	0
1982	5	170.2	1	50	1	97.2	0	0
1983	9	323.7	4	229.3	0	0	0	0
1984	4	133.2	2	109	1	76.6	1	150
1985	5	174.2	0	0	1	88.2	0	0
1986	5	166	2	110.8	0	0	0	0
1987	10	338.4	1	63.3	0	0	1	122.2
1988	10	326.9	6	360.9	0	0	1	113
1989	9	314.5	3	174.7	1	85	0	0
1990	5	188.3	7	452.5	1	85	1	100
1991	6	220.8	2	120.4	0	0	0	0
1992	5	158.2	1	63	0	0	0	0
1993	7	258.6	1	55.5	1	76	0	0
1994	2	65	0	0	0	0	0	0
1995	6	248.5	3	164.2	1	75.2	0	0
1996	9	282.9	2	112.2	0	0	0	0
1997	5	161.7	2	140.3	0	0	0	0
1998	6	219.5	6	378.4	1	75.6	0	0
1999	11	424.9	2	118.9	0	0	0	0
2000	4	132.4	0	0	0	0	0	0
2001	5	159.2	3	175.8	0	0	0	0
2002	3	91.9	0	0	0	0	1	108.2
2003	4	143	0	0	0	0	0	0
2004	6	208	1	63.4	0	0	0	0
2005	11	334.1	0	0	1	93	0	0
2006	5	171.8	1	67	1	76.2	0	0
2007	2	76.8	2	119.2	0	0	0	0
2008	3	103	0	0	1	85.6	0	0
2009	9	336.4	4	224.8	0	0	0	0

Appendix 25. Frequency of occurrence of heavy rain events at different intensities in Solapur district (Southwest monsoon).

	25 to 50 mm/day		51 to 75 mm/day		76 to 100 mm/day		More than 100 mm/day	
Year	Days	Sum	Days	Sum	Days	Sum	Days	Sum
1971	2	60.3	2	111.2	0	0	1	105.9
1972	2	63.7	0	0	0	0	0	0
1973	4	170.7	2	126.5	0	0	0	0
1974	2	70.1	4	243.7	1	80	0	0
1975	9	280.1	3	191.5	1	76.1	0	0
1976	6	191.7	0	0	0	0	0	0
1977	2	56.8	1	64.3	0	0	0	0
1978	2	77.8	0	0	1	88	0	0
1979	4	139.5	0	0	1	98	0	0
1980	5	198	1	51	0	0	0	0
1981	7	270	1	55.2	0	0	0	0
1982	4	127.4	1	50	0	0	0	0
1983	7	251.5	4	229.3	0	0	0	0
1984	3	103.4	1	54.2	0	0	1	150
1985	3	102	0	0	1	88.2	0	0
1986	4	123.6	2	110.8	0	0	0	0
1987	5	181.9	0	0	0	0	1	122.2
1988	10	326.9	6	360.9	0	0	1	113
1989	8	281.5	3	174.7	1	85	0	0
1990	3	109.8	5	341.5	1	85	1	100
1991	4	156.4	2	120.4	0	0	0	0
1992	4	119.9	1	63	0	0	0	0
1993	5	185.8	1	55.5	1	76	0	0
1994	1	31.8	0	0	0	0	0	0
1995	3	114.4	2	111.4	1	75.2	0	0
1996	8	249.7	1	58.2	0	0	0	0
1997	4	133.1	1	72.4	0	0	0	0
1998	6	219.5	5	322.7	0	0	0	0
1999	1	33	2	118.9	0	0	0	0
2000	4	132.4	0	0	0	0	0	0
2001	3	90.9	2	118.2	0	0	0	0
2002	2	63	0	0	0	0	1	108.2
2003	3	113.4	0	0	0	0	0	0
2004	5	170.5	0	0	0	0	0	0
2005	7	200.2	0	0	1	93	0	0
2006	4	145	1	67	0	0	0	0
2007	2	76.8	2	119.2	0	0	0	0
2008	2	73.8	0	0	1	85.6	0	0
2009	6	220.2	3	161	0	0	0	0

Appendix 26. Frequency of occurrence of heavy rain events at different intensities in Solapur district (Northeast monsoon)

	25 to 50 mm/day		51 to 75 mm/day		76 to 100 mm/day		More than 100 mm/day	
Year	Days	Sum	Days	Sum	Days	Sum	Days	Sum
1971	1	32.1	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0
1973	4	118.4	1	73.4	0	0	0	0
1974	3	107.5	1	62.5	0	0	0	0
1975	2	73.4	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0
1977	0	0	1	69.7	0	0	0	0
1978	0	0	0	0	0	0	1	106.8
1979	1	38.2	1	54.4	0	0	0	0
1980	0	0	0	0	0	0	0	0
1981	1	25.1	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0
1983	2	72.2	0	0	0	0	0	0
1984	1	29.8	1	54.8	1	76.6	0	0
1985	2	72.2	0	0	0	0	0	0
1986	1	42.4	0	0	0	0	0	0
1987	5	156.5	1	63.3	0	0	0	0
1988	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0
1990	1	36	2	111	0	0	0	0
1991	1	34.4	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0
1993	2	72.8	0	0	0	0	0	0
1994	1	33.2	0	0	0	0	0	0
1995	3	134.1	1	52.8	0	0	0	0
1996	0	0	1	54	0	0	0	0
1997	1	28.6	1	67.9	0	0	0	0
1998	0	0	1	55.7	1	75.6	0	0
1999	1	47.6	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0
2001	2	68.3	1	57.6	0	0	0	0
2002	1	28.9	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0
2005	2	62.7	0	0	0	0	0	0
2006	0	0	0	0	1	76.2	0	0
2007	0	0	0	0	0	0	0	0
2008	1	29.2	0	0	0	0	0	0
2009	2	70.2	1	63.8	0	0	0	0

Appendix 27. Frequency of occurrence of heavy rain events at different intensities in Solapur district (Summer).

	25 to 50 mm/day		51 to 75 mm/day		76 to 100 mm/day		More than 100 mm/day	
Year	Days	Sum	Days	Sum	Days	Sum	Days	Sum
1971	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	1	109
1979	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0
1982	1	42.8	0	0	1	97.2	0	0
1983	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0
1989	1	33	0	0	0	0	0	0
1990	1	42.5	0	0	0	0	0	0
1991	1	30	0	0	0	0	0	0
1992	1	38.3	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0
1996	1	33.2	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0
1999	9	344.3	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0
2003	1	29.6	0	0	0	0	0	0
2004	1	37.5	1	63.4	0	0	0	0
2005	2	71.2	0	0	0	0	0	0
2006	1	26.8	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0
2009	1	46	0	0	0	0	0	0

Appendix 28. Frequency of days with maximum temperature – Solapur district					
Year	>=40°C	>=41°C	>=42°C	>=43°C	>=44°C
1971	12	3	0	0	0
1972	32	12	6	0	0
1973	62	51	35	13	5
1974	31	19	12	0	0
1975	40	17	6	0	0
1976	28	14	2	0	0
1977	26	8	3	0	0
1978	33	18	11	5	1
1979	43	24	16	9	0
1980	48	36	13	0	0
1981	44	26	13	2	0
1982	20	6	0	0	0
1983	59	33	20	3	0
1984	56	35	22	12	1
1985	54	32	14	2	0
1986	62	43	19	5	0
1987	37	23	7	2	0
1988	45	27	16	11	2
1989	34	22	12	11	4
1990	24	13	5	0	0
1991	50	29	12	2	0
1992	42	10	1	0	0
1993	36	17	9	1	0
1994	48	14	9	0	0
1995	25	14	5	3	2
1996	49	29	11	2	0
1997	31	15	10	3	0
1998	73	59	45	29	7
1999	46	35	20	9	0
2000	36	26	20	10	2
2001	27	22	17	6	2
2002	39	29	16	7	3
2003	67	52	37	8	3
2004	44	29	21	5	1
2005	42	28	14	8	3
2006	41	33	17	7	0
2007	53	26	14	6	0
2008	43	14	5	0	0
2009	47	36	17	8	1

Appendix 29. Mandal map of (a) Anantapur and (b) Mahbubnagar districts

List of mandals in Anantapur district

S. No.	Mandal	S. No.	Mandal	S. No.	Mandal	S. No.	Mandal
1	Agali	17	Garladinne	33	Madakasira	49	Rayadurg
2	Amadagur	18	Gooty	34	Mudigubba	50	Roddam
3	Amarapuram	19	Gorantla	35	Nallacheruvu	51	Rolla
4	Anantapur	20	Gudibanda	36	Nallamada	52	Settur
5	Atmakur	21	Gummagatya	37	Nambulipuli Kunta	53	Singanamala
6	Bathalapalli	22	Guntakal	38	Narpala	54	Somandepalli
7	Beluguppa	23	Hindupur	39	Obuladevaracheruvu	55	Tadimarri
8	Bommanahal	24	Kadiri	40	Pamidi	56	Tadpatri
9	Brahmasamudram	25	Kalyandurg	41	Parigi	57	Talupula
10	Bukkapatnam	26	Kambadur	42	Pedda Pappuru	58	Tanakal
11	Bukkarayasamuram	27	Kanaganapalli	43	Peddavadugur	59	Urvakonda
12	Chennakothapalli	28	Kanekal	44	Penukonda	60	Vajrakarur
13	Chilamathuru	29	Kotha Cheruvu	45	Putlur	61	Vidupanakal
14	Dandina Hirehal	30	Kudair	46	Puttaparthi	62	Yadaki
15	Dharmavaram	31	Kundurpi	47	Ramagiri	63	Yellanur
16	Gandlapenta	32	Lepakshi	48	Raptadu		

List of mandals in Mahbubnagar district

S. No.	Mandal	S. No.	Mandal	S. No.	Mandal	S. No.	Mandal
1	Achampet	17	Doulatabad	33	Kondurg	49	Nawabpet
2	Addakal	18	Farooq Nagar	34	Kosgi	50	Pangal
3	Alampur	19	Gadwal	35	Kothakota	51	Pebbair
4	Amangal	20	Ghanpura	36	Kothur	52	Peddakottapally
5	Amrabad	21	Ghatt	37	Lingal	53	Peddamandadi
6	Atmakur	22	Gopalpet	38	Maddur	54	Tadoor
7	Balanagar	23	Hanwada	39	Madugul	55	Talkondapalli
8	Balmoor	24	Ieeja	40	Mahbubnagar	56	Telkapally
9	Bhoothpur	25	Itkyal	41	Makthal	57	Timmajipet
10	Bijinapalli	26	Jadcherla	42	Maldakal	58	Uppununtala
11	Bombaspet	27	Kalwakurthy	43	Manapad	59	Utkoor
12	Chinnachintalakunta	28	Keshampet	44	MangaNo droughtor	60	Vangoor
13	Damargidda	29	Kodair	45	Midjiil	61	Veepangandla
14	Devarkadra	30	Kodangal	46	NagarkurNo droughtol	62	Veldanda
15	Dhanwada	31	Koilkonda	47	Narayanpet	63	Waddapalli
16	Dharur	32	Kollapur	48	Narva	64	Wanaparthy
						65	Reserve Forest

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