AN ANALYSIS OF ANANTAPUR CLIMATE

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DROUGHT RESEARCH SEMINAR FORUM

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
Patancheru, A.P. 502 324, India

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AGRICULTURAL RESEARCH STATION

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PREFACE

The yields of rainfed crops in the semi-arid tropics have remained low and unstable because of several environmental constraints among which soil and climatic factors are the foremost. Success or failure of rainfed crops depends upon the pattern and amounts of rainfall. However, other factors like temperature, photoperiod and wind also significantly influence crop growth and yield. The analysis of climate plays a key role in planning better farming systems to improve and stabilize yields, and to design appropriate crop breeding strategies.

The main objective of this report is to demonstrate the extensive use of climatic data for improving crop production by assessing the extent and intensity of climatic risks. We have chosen to study the climate of Anantapur which is in a dry tract with degraded soil. The International Crop Research Institute for the Semi-arid Tropics (ICRISAT) and the Andhra Pradesh Agricultural University (APAU) use this location for conducting drought research. Therefore, assessment and interpretation of the natural resources of this region in agronomically relevant terms (particularly those related to water), assume a special significance.

This is not a formal publication endorsed either by ICRISAT or APAU. Its purpose is mainly to stimulate discussion among professional colleagues, and therefore should not be cited. Comments are most welcome. We hope that similar exercise will be carried out for other benchmark stations in the arid and semi-arid tropics.

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1. INTRODUCTION

Quantitative analyses of environmental characteristics deserve high priority in defining agroclimate, and in determining the crop production potential of a region. Rainfall and soil characteristics are the two primary factors limiting the agricultural production in dryland areas. These two factors largely determine the land use potential and common cropping patterns. In this report, we have attempted to analyze the climate of Anantapur, a dry and resource-poor tract.

The Anantapur district (Figure 1) is located in the Rayalaseema region in the southern part of Andhra Pradesh, India. There is an Agricultural Research Station administered by the Andhra Pradesh Agricultural University at Rekulakuntala village, which is 11 km East of Anantapur town on the Anantapur-Narpala road. The station is located at 14° 41' N latitude, 77° 44' E longitude at an elevation of 348 m above the mean sea level. It receives rains during the South-West monsoon from June to September, and during the North-East monsoons from May to November. However, being far from the coastal belt, Anantapur receives meager rainfall. The high Western Ghats also reduce the rainfall from South-West monsoon. The rainfall during the later part of the North-East monsoon season is erratic in this tract, as it is much influenced by the depressions in the Bay of Bengal. Eventhough the total rainfall may appear adequate, its poor distribution results in partial or complete failure of crops during many years. Based on the pattern of monsoon rainfall, the pre-rainy, rainy and postrainy season periods are recognized. Pre-rainy season is 18 weeks long [(std. wks.) standard weeks: 19-36] and the rainy season is very short (5 weeks; std. wks. 37-41). Postrainy season is 11 weeks long (std. wks. 42-52).

In the tropics, rainfall is the major climatic element that affects crop growth and development, particularly where rainfed farming practised widely. Data on long-term rainfall, in contrast to those on other climatic parameters, are easily available. An understanding of rainfall distribution in relation to the growth stages of the crop cultivars and soil condition is essential for successful crop planning and management. The discussion that follows is therefore confined largely to the methods of analysis of rainfall patterns as related to crop planning. Simple criteria related to sequential phenomena such as dry and wet spells can be used to obtain specific information needed for crop planning. The computation of probabilities of rainfall and drought, and water balance is discussed in detail.

At Anantapur, the soils are primarily red sandy loams (alfisols). They are shallow (0.1-0.3 m deep), and have a compact sub-soil layer that could restrict the root growth. The stored-soil moisture is about 100-115 mm m^{-1} depth. The soils are neutral in reaction, low in organic matter, deficient in nitrogen, phosphorus, zinc, and low to medium in potassium.

Groundnut is the major crop grown throughout the district. On a limited scale, groundnut is intercropped with long duration redgram (pigeonpea). Sorghum, pearl millet and foxtail millet (*Setaria*) are also grown, but during recent years these cereals are increasingly replaced by the more remunerative groundnut.

SOURCE OF DATA AND COMPUTATION PROCEDURES

Data were assembled from several sources. Daily rainfall for the early period of 1911-1965 were obtained from the District Collector's Office at Anantapur. For 1965-1989, data on rainfall, relative humidity, maximum and minimum air temperatures were collected from the Agricultural Research Station, Anantapur. The data on wind velocity, wind direction, sunshine hours, and evaporation were available since 1976. Climatic water balance was calculated using Keig and Mc Alpine's procedure (1974). Initial and conditional probability analysis was carried out using Markov chain first order probability analysis (Gabriel and Neuman, 1962). The probability of receiving different amounts of rainfall was carried out using gamma distribution (de Arruda and Pinto 1980). The computation procedures for the initial and conditional probability analysis, and gamma distributions are shown in appendices. Daily photoperiod including civil twilight (Jones and Kiniry 1986) and heat units (Ong et al. 1986, and Alagarsamy and Ritchie 1991) were calculated. The data were computed using SAS (1985), or FORTRAN and BASIC programs specially written for climatic analyses.

2. RAINFALL

Temporal variation in rainfall is high at Anantapur. We studied variation in rainfall on annual, monthly, decadal (10-day period), weekly and daily basis. Using the daily rainfall data for 1911-1989, we also analyzed following important characteristics of rainfall distribution:

(i) Means for the specified periods

(ii) Extremes (maximum and minimum) for the specified periods

(iii) Standard deviation (sd), and coefficient of variation (CV; %), and

(iv) Probability of receiving specified amount of rainfall during a year.

2.1. ANNUAL RAINFALL

At Anantapur, the mean annual rainfall over the 79 year period (1911-1989) was only 565 mm with a CV of 30% (**Table 1**). The annual rainfall is low and highly erratic, and ranged from 176 mm (1984) to 976 mm (1919; **Figure 2**).

Rainfall exceeded 900 mm only thrice during the study period: in 1917 (945 mm), 1919 (976 mm) and in 1988 (915 mm; **Table 1**). The recent drought during 1984 was unique in its persistence: only 176 mm of rainfall was received during that year, which was the lowest annual rainfall during 1911-1989 at Anantapur.

Rainfall deviations of 20% from the long-term mean were quite common (**Figure 3**). The number of years receiving $\leq$ 20% of long-term mean rainfall were 21 (out of 79), and that above 20%, was 22. Similarly, in 9 years (out of 79) the rainfall was below 40% of the mean, and in 7 years it was 40% above the mean. Generally, the variation in rainfall across years was less during the recent past than during 1911-1960. The rainfall was normal ($\pm$ 19% of mean) in 38 years, and above normal in 21 years out of 79 years.

The five-years moving average of annual rainfall indicates that there was a frequent and conspicuous trend of decrease in annual rainfall between 1940-1950 resulting in drought. Similar trend was repeated again between 1980-1990 (**Figure 4**).

2.1.1. Frequency of rainfall distribution

We used the definition of the Planning Commission, Government of India (1973), to calculate the frequency of occurrence of drought. According to the Commission, the years receiving <75% of the long-term mean rainfall are drought years. The number of such drought years during 1911 to 1989 at this station was 12 (i.e., approximately 1 in 6-7 years).

The distribution of years receiving specified amounts of annual rainfall is given in **Table 2**. Only in 1984, the rainfall was <200 mm. Altogether, 82% (65 out of 79) of the years received >400 mm of rainfall, while only 38% of the years received >600 mm (30 out of 79 years). The probability of receiving 800 mm or more of rainfall is only 7.6% (6 out of 79 years).

2.1.2. Frequency of drought occurrence during calendar years:

We examined the scope for predicting drought as per the definition of the Planning Commission (see above section: 2.1.1). The objective was to find out how and when to decide whether a year is a drought year or a normal one, based on simpler calculations. This analysis is significant for initiating prompt drought relief operations by the public agencies during a drought year. **Table 3** shows the frequency of years with specified percentage of excess or deficit rainfall up to specified calendar dates. On July 1, a drought year can be assumed once in 3, or twice in 7 years (30 out of 100). If the same exercise is done earlier on June 1, one out of two years can be considered as drought year (45 out of 100). For August 1, the chance is once in three years (32 out of 100). However, based on rainfall till December, it is once in five years (19 out of 100). Thus, the chances of a year being classified as normal increases considerably during the season. The North-East monsoon rains, especially those caused by depression in the Bay of Bengal during September-October period considerably influence the outcome of above exercise at Anantapur.

2.1.3. Dependable annual precipitation

Hargreaves (1977) defined dependable precipitation (*DP*) as the amount of rainfall received at 75% probability (*P*). For agricultural purposes, 70 or 75 % *P* is generally accepted as a reasonable risk level. For drought-sensitive or high value crops, or during critical crop growth stages, a higher *P* may be more appropriate. Conversely, for drought hardy crops, or during a relatively less sensitive growth stage, a lower *P* may be acceptable.

At Anantapur, the dependable *annual* precipitation (DP_a) is 436 mm. That is, in 3 out of 4 years the annual rainfall is ≥436 mm (=77% of the mean annual rainfall). At a lower *P* of 50%, DP_a is 547 mm (= 97% of long-term mean; please refer to section 2.3.1. for more details).

2.2 SEASONAL RAINFALL

Based on the rainfall distribution, there are four seasons at Anantapur:

1. South-West monsoon season: June to September.
2. North-East monsoon season : October to December.
3. Winter season : January to February.
4. Summer season : March to May.

The data on seasonal distribution of rainfall (**Table 4**) reveal that 332 mm (58.8%) of the annual rainfall is received during South-West monsoon, and 153.2 mm (27.1%) during North-East monsoon. The Winter season contributes only 6.7 mm (1.2%), and summer season 75 mm (12.9%).

2.3. MONTHLY RAINFALL

The monthly rainfall statistics for the 79 years are summarized in **Table 4**. September (145 mm), followed by October (102 mm) are the wettest months. Together, they account for 44% of the annual precipitation. Monthly rainfall during May through August, and November varies between 43 to 74 mm (8 to 13% of the annual total rainfall).

The rainfall within a month over the years varied widely between nil and 489.0 mm. Even the wettest month of September may go dry without any rain in certain years. The monthly highest rainfall of 489 mm fell during August 1938 (66% of the total rainfall during that year; **Table 1**). Rainfall during most months of the year (especially those between November and February) is relatively low.

The variability in the monthly rainfall is even greater than the variability of annual rainfall. While the CV for annual mean rainfall is only 30%, the CV's for rainfall during different months are between 63-525% (**Table 4**). The CV is 63% even for the wettest months of September.

2.3.1. Dependable monthly precipitation

We computed the dependable monthly precipitation (DP_m) at 90, 75, 50, 25 and 10% P (**Table 5**). The DP_m at 75% P during the early months was low. It is only 4 mm during April and 22 mm during May. Even with the start of the South-West monsoon, it is low (June: 27 mm;

July: 16 mm; August: 18 mm). DP_m is highest during September [62 mm, which forms 14% of the annual DP_a (annual DP) at 75% P], followed by October (35 mm; 8% of DP_a). It declines from November (7 mm) and continues to remain low until March (1.0 mm).

2.4. ANALYSES OF WEEKLY RAINFALL

The information on annual, and even monthly rainfall is often grossly inadequate for making agricultural decisions. Therefore, we need to analyze rainfall for a period shorter than a month. Weekly analyses are more appropriate to interpret and use than the decadal rainfall. We calculated probabilities of rainfall both on weekly and decade basis for comparison.

2.4.1. Total number of rainy weeks

We calculated the total number of weeks at different threshold levels of rainfall for certain minimum amounts of rainfall (including drizzle: all recorded rainfall events): $\geq$2.5, $\geq$10, $\geq$20 and $\geq$30 mm week^{-1}. The results are plotted in **Figure 5**. On an average, there are 22 weeks in a year that receive rains (including a drizzle); the highest was 29 weeks in 1915, and the lowest was 9 weeks in 1946 (**Figure 5A**). At $\geq$2.5 mm threshold value, the mean was 18 weeks year^{-1}; the highest was 26 weeks year^{-1} in 1930, and the lowest was 7 in 1946 (not shown in the figure). At $\geq$10 mm the mean was 12 weeks year^{-1}; the highest was 19 (1977) and the lowest was 6 in 1976 (**Figure 5B**). At $\geq$20 mm, the mean was 8 weeks year^{-1}, the highest was 14 (1916, 1917 and 1919) while the lowest was 3 (1923, 1934 and 1984; **Figure 5C**). For $\geq$30 mm, the mean was 6 rainy weeks year^{-1}; the highest was 12 (1977 and 1988), and the lowest was 1.0 in 1934, 1980 and 1984 (**Figure 5D**).

2.4.2. Total amount of rainfall

The total amount of rainfall received during a year with $\geq$2.5 mm threshold value per day was 560 mm (range 172-969 mm). This did not differ much from the total rains in a year (565 mm; range: 176-974 mm; **Table 6**). For other threshold levels the mean during the year were as follows: rains $\geq$10 mm: 525 mm (range: 137-934 mm), rains $\geq$20 mm: 471 mm (range: 92-903 mm); and rains $\geq$30 mm: 419 mm (range: 43-813 mm). Such data are useful in planning land treatments and water harvesting.

2.4.2. Probability estimates of weekly rainfall

Using the daily rainfall data, we characterized weekly rainfall in the following two ways:

- Constant rainfall analysis (CRA).
- Constant probability analysis (CPA).

These are the two crucial parameters useful for planning farm operations like timely land preparation, sowing and crop harvest.

2.4.2.1. Constant rainfall analysis

Constant rainfall analysis (CRA) deals with the *probability of occurrence of a specified minimum amount of rainfall.* This analysis was carried out by using Markov chain first order probability analysis (Gabriel and Neuman, 1962).

By analyzing constant rainfall on weekly basis, we can test the degree of certainty of rainfall to meet the weekly demand at different crop growth stages. The threshold values of rainfall vary depending upon the nature of farm operations during the week. We examined the probability of each standard week receiving $\geq$10, $\geq$20, $\geq$30, $\geq$40, and $\geq$50 mm of rainfall during the year (**Table 7**). Details of the calculations are presented in **Appendix A**.

The weekly rainfall probabilities can be studied in three ways

(i) The initial probability of a wet week $P(W_w)$.
(ii) Conditional probability of a wet week preceded by a wet week $P(W/W_w)$, and
(iii) Conditional probability of a dry week preceded by a wet week $P(W/D_w)$.

$P(W_w)$, indicates the probability of receiving certain amounts of rainfall during a given week. $P(W/W_w)$ lets us examine the probability of rain during the next week following rain during the current week. $P(W/D_w)$ does the opposite; it deals with the probability of next week being dry following a current wet week (Virmani et al. 1982).

At Anantapur, even at $\geq$10 mm rain week^{-1}, $P(W_w)$ is not more than 46% in any one of the weeks during the 'pre-rainy season'. These early rains are not at all dependable as frequently they are only light showers. $P(W_w)$ does not exceed 70% during any part of the year (**Figure 6A**).

The $P(W/W_w)$ also follows a fairly similar pattern as $P(W_w)$ (**Figure 6B**). Only during the standard week 37, $P(W/W_w)$ exceeds 70%.

The $P(W/D_w)$ is high (>50%) only in standard week 37 (**Figure 6C**).

These show the low and undependable rainfall pattern at Anantapur. This point is further illustrated, by comparing the Initial and Conditional probabilities of Hyderabad and Anantapur **Appendix A**.

2.4.2.2. Constant probability analysis

Constant probability analysis (CPA), *represents the amount of rainfall expected at a given level of probability*. We used the incomplete gamma distribution to find the probability of receiving different amounts of rainfall in each week (de Arruda and Pinto, 1980). Details of the calculations are presented in **Appendix B**. Results of expected rainfall at 90, 75, 50, 25 and 10 per cent probability levels are presented in **Table 8**.

At 90% *P*, on an average there are only 2 weeks that receive at least 1.0 mm of rainfall (std. wks. 38 and 39), the maximum amount being only 1.9 mm. Even at a lower level of 75% probability, none of the weeks received $\geq$10 mm rain. The highest amount of rainfall received at 75% *P* is 8.5 mm during week 38 (Sep 17-23).

2.5. DECADAL RAINFALL

The Food and Agricultural organization (FAO) has chosen the decade as the standard time scale for generating the weather data for crop planning and monitoring (Frere, 1986). Therefore, we also carried out the analysis on decadal basis (**Table 9**). As expected, the decadal and weekly analyses agree with each other.

2.5.1. Constant rainfall analysis

For rainfall $\geq$10 mm decade^{-1}, only for three decades (26-28) the $P(W_d)$ is greater than 40%, $P(W_d)$ increases from 19% (decade 25) to 46% (decade 28). The $P(W/W_d)$ for the period after decade 18 reveals that following early events, rains persist until decade 29 (*P*= 24%). The maximum $P(W/D_d)$ at 10 mm week^{-1} is 54% (for decade 26). The relative probabilities of rainfall reduce considerably with an increase in the threshold amounts of rainfall.

2.5.2. Constant probability analysis

The expected amounts of decadal rainfall at 90, 75, 50, 25 and 10% *P* levels were calculated using an incomplete gamma distribution (**Table 10**). At 90% *P*, rainfall was *nil* for all the decades except decade 27 (1.0 mm). At 75% *P*, rainfall was *nil* up to decade 14 followed by 3.0 mm and 2.0 mm during the subsequent two consecutive decades. Again, there was no rain during the decades 17, 19, 20, 22 and 24. Further, rainfall was highest during the decade 27 (Sep 27 - Oct 8; 11 mm), and no rain was recorded from decade 29 to decade 14 of the next year. There were only four consecutive decades (25 to 28: Sep 1 to Oct 10) during a year that received some rainfall at 75% *P*. At 50% *P*, 11 consecutive decades received ≥5.0 mm of rainfall (decade 18-28). The highest amount of rainfall was received during decade 27.

2.6. TOTAL NUMBER OF RAINY DAYS

We calculated the total number of rainy days in a year, and during the growing season (Growing season is characterized in section 2.8). The following threshold rainfall amounts were considered: all rains, ≥2.5, ≥10, ≥20, ≥30 mm.

2.6.1. Total number of rainy days in a year

The mean total number of days in a year for different threshold amounts of rain varied as follows: all rains: 49 (range: 78-22); ≥2.5 mm: 33 (range 13-52); ≥10 mm: 16 (range: 6-28); ≥20 mm: 9 (range: 1-18) and ≥30 mm: 5 (range: 0-11; **Table 11**). The mean maximum and minimum number of days for different threshold levels of rain are shown in **Table 12A** with the list of years showing extreme values.

2.6.2. Total number of rainy days during the growing season

The mean total number of days during the growing season for different threshold amounts of rainfall varied as follows: all rains: 28 (range: 6-55); ≥2.5 mm: 20 (range: 5-40); ≥10 mm: 10 (range: 2-24); ≥20 mm: 6 (range: 1-13) and ≥30 mm: 4 (range: 0-9; **Table 11**). These figures (days with rain), constituted 57-80% of the corresponding rainy days during the year. The maximum and minimum number of rainy days during the growing season is shown in **Table 12B** with the list of years showing extreme values.

2.7. DRY SPELLS BETWEEN RAINY DAYS

We calculated the length of dry spells (mean duration of rain-free days) between two consecutive rainy days both in a year, and during a growing season. The following threshold rainfall amounts were considered for the computation of dry spells: all rains: ≥2.5, ≥10, ≥20, ≥30 mm.

2.7.1. Dry spells between rainy days in a year

During a year, on an average, there is a dry spell of 8 days (range: 5-16 days) between rains, when all rains are considered (**Table 13**). For rains ≥2.5 mm the average dry spell was 12 days in its duration (range: 7-26), for rains ≥10 mm it was 25 days (range: 13-52), for rains ≥20 mm it was 44 days (range: 19-182), and for rains ≥30 mm it was 72 days (range: 30-365). The maximum dry spell for rainfall amount ≥30 mm was 365 days during 1984 (lowest annual rainfall), and the corresponding minimum was 30 days (during 1917). The mean maximum and minimum number of dry spells for different threshold levels are shown in **Table 14A** with the list of years showing the extreme values.

2.7.2. Dry spells between rainy days during the growing season

The mean duration of dry spells between consecutive rains for all rains was 4 days (range: 2-8); for rains ≥2.5 mm: 6 days (range: 2-19); for rains ≥10 mm: 11 days (range: 3-32); for rains ≥20 mm: 17 days (range: 5-48), and for rains ≥30 mm: 28 days (range: 6-91; **Table 13**). The maximum dry spell of 91 days at ≥30 mm threshold rainfall was again in 1984; there was not even a single rainy day with ≥30 mm of rainfall during that year, and the length of the growing season was only 92 days.

The mean maximum and minimum number of dry spells for different threshold levels are shown in **Table 14B** along with the list of years showing the extreme values. The number of dry spells during the growing season for all rains, and for ≥2.5 mm threshold levels is exactly half that during a year (8 and 12 days during a year, and 4 and 6 days during the growing season). For the remaining threshold rainfall levels, as expected, the dry spell is usually more than double of the dry spell during the growing season.

2.8. DAILY RAINFALL

As expected, the daily rainfall is highly variable at Anantapur. **Figure 7** shows the variation in daily rainfall for the 6 consecutive years of 1984-1989. Lowest rainfall of 176 mm was received during 1984. The subsequent three years received below normal rainfall (1985: 392 mm; 1986: 436 mm, and 1987: 502 mm). During 1988, highest rainfall of 915 mm was received followed by 1989 (821 mm), which received above normal rainfall.

2.8.1. Number of rainy days in a month

2.8.1.1. Mean

The month-wise analysis of the number of rainy days with all rains, and those $\geq$2.5 mm are given in **Table 15**. The maximum numbers of rainy days are in September (9.1 days for all rains, i.e., 19% of the total rainy days, and 6.6 days for $\geq$2.5 mm rains, i.e., 14% of the total rainy days). It is followed by October (7.6 days for all rains, and 5.4 days for $\geq$2.5 mm). During August, September and October together there are 23.9 rainy days; this accounts for 49% of the total rainy days in a year (all rains considered). For threshold values of $\geq$2.5 mm during these three months (Aug-Oct) there are only 16.5 rainy days (51% of the total rainy days in a year).

2.8.1.2. Range

Although the total number of mean rainy days is higher in September, the highest numbers of rainy days ever recorded was in August (all rains: 20 and $\geq$2.5 mm: 17; **Table 15**) followed by October (all rains: 19 and $\geq$2.5 mm: 16) and September (all rains: 18 and $\geq$2.5 mm: 16).

During all the months except July, there were at least few years without any rains for all the threshold amounts of rainfall. Out of the 79 years, only during four years (1942, 1965, 1976 and 1987), there was no effective rainfall of $\geq$2.5 mm during July. Therefore, July can be considered as the most assured month during which crops can be planted at Anantapur.

2.8.1.3. Extremes

We analyzed the highest and lowest amount of rainfall that was received during a single day in each month (**Table 15**). The highest amount of 180.0 mm of rainfall during the 79 year period was received on July 17, 1988. This rain was followed by next two high-rainfall events of 145.2 mm on October 10, 1937, and 130.2 mm on September 28, 1974. The lowest amount of recorded rainfall during a single rainy day in a month was lower than 0.3 mm for all the months except February (1.0 mm: February 7, 1929, and February 2, 1956).

2.8.3. Dry spell between rains within a month.

We calculated the mean duration of dry spells within a month (**Table 15**). During the season, the dry spell is lowest during September (9 days) followed by October (11 days), July (12 days) and August (13 days). The dry spell increases from November to January. The mean dry spells were highest in January (30 days) followed by March, February and December (28 days).

The extremes of dry spell are shown in the parenthesis in **Table 15**. These figures shows that the shortest dry spell is two days for all the months, while the longest dry spells were equal to the number of days in a month.

2.9. RAINY SEASON LENGTH.

2.9.1. Start and end of rainy season.

We defined the **beginning of rains** (X) as the first day between June 1 and October 1 when (i) at least a total of 20 mm of rain is received in five days (not necessary consecutive days), and (ii) at least there is one rainy day with $\geq$2.5 mm rainfall in the next 10 days. The **end of rains** (Y) is defined as the last day of the first dry spell of 10 days ending between October 1 and November 30. The difference (days) between the beginning and end of rain is the **length of rainy season** (Y-X).

The average date of beginning of rains at Anantapur is July 11 (sd= $\pm$32 days: June 9 to August 12; **Table 16**). The average date of ending of rains is October 15 (sd= $\pm$11 days: October 4 to October 26). Therefore, the average growing season length is 97 days (sd= $\pm$31 days: 66 to 128 days).

2.9.2. Length of the rainy season

As mentioned above, the length of the rainy season varied six folds (**Table 16**). During the year 1961, the length of the rainy season was longest (151 days; total seasonal rainfall was 288 mm). During 1972, the length of the rainy period was very short (26 days), but the amount of rainfall during the growing season (280 mm) was almost equal to the rainfall (288 mm) during the long rainy season of 1961 (151 days). Thus the length of the rainy season is not related to the seasonal rainfall.

The amounts of rainfall that is received before, during, and after the rainy season also varied widely (**Table 16**). The mean rainfall received during the season is 380 mm, the same before the start of season is 115 mm, and after the season, 70 mm.

We also calculated the amount of rainfall that was received during the growing season as the percentage of the total annual rainfall for each year. The mean seasonal rainfall is 66% of the annual total rainfall. It is the highest (93%) during 1965, and lowest (24%) during 1982. The number of years that received rainfall lower than the mean (66%) was 33 years; among them it was less than even 50% of the mean during three years.

During 4 years (1911, 1922, 1980 and 1982) more rainfall was received before the growing season than during the growing season itself. In 1951, almost equal amount of rainfall was received during (265 mm) and before (260 mm) the growing season. During 1928, 1935, 1944, 1946, 1953 and 1970, no rains were received after the growing season. During 1922 (162 mm), 1948 (163 mm), 1982 (284 mm), higher amount of rainfall was received after the growing season than during the growing season.

2.9.3. Probable date of sowing of crops, and the probability of dry spells

Morris and Zandra (1978) suggested that the rainfed crops can be sown when the rainfall accumulates to 75 mm at 75% P in the beginning of the rainy season, and the date of cessation of the rainy season can be determined by backward accumulation of 20 mm at 75% P of rainfall from the end of the rainy season. Accordingly, a program was developed to calculate the probable week receiving 75 mm rainfall for forward accumulation and 20 mm rainfall for backward accumulation along with their probability percentage. The standard weeks along with their probability percentage were ranked and shown in **Table 17** (also see in the next page).

The probabilities of occurrence of 2 consecutive, and 3 consecutive dry weeks were also calculated, using the Markov chain Model suggested by Robertson (1976). We assumed a standard week as dry when the rainfall was less than 20 mm (approximately equal to half the potential evapotranpiration). These probabilities indicates the risk of drought to the rainfed crops during a growing season. The probability of dry spells during the growing season ranged between 5-38% for 2 consecutive dry weeks and 1-17% for 3 consecutive dry weeks (**Table 18**; also see below).

Using the data in **Table 17** and **Table 18** a graph has been plotted see **Figure 8**. Sowing of rainfed crops in Anantapur region is possible by second week of July (std. wk. 28) in 3 out of 4 years, and the rainy season practically ends by the last week of October (std. wk. 43; probability >75%). Thus a crop of 15 weeks might succeed in this alfisols- dominated tract.

After sowing the crop by the second week of July (**Figure 8**), a dry spell of 2 consecutive weeks could be expected to begin in standard week 31 (July 30) at 38% **P**. Later the **P** falls down to 31%. Besides, a dry spells of 2 consecutive weeks could also be expected from the standard week 33 to 35 in 1 out of 5 years. Even during the cessation of rains the dry spell of 2 consecutive weeks touch as high as 42% **P** (std. wk. 45).

The dry spell of 3 consecutive standard weeks could be expected to begin with standard weeks. 30-31. Yogeshwara Rao et al. (1988) analyzed the probable decade of sowing of groundnut, and its effect on yield at Anantapur. They reported that the bunch type groundnut of 110 days duration is extensively grown in Anantapur region and subjected to dry spell during the first flush of flowering (18-28 DAS), thus adversely affecting the pod yield.

3. AIR TEMPERATURE

Anantapur is somewhat warm throughout the year. However, this warm environment is modified seasonally by changes in water regimes and surface (land) conditions. Monthly air temperatures, and probabilities of the temperatures exceeding specified threshold values using daily data for the period 1911-1989 are presented in **Table 19** (maximum temperature) and **Table 20** (minimum temperature)

3.1. MAXIMUM AIR TEMPERATURE

Mean monthly maximum air temperatures exceed the annual mean maximum temperature of 33.7°C from March through July (**Table 19**); during this period, mean monthly air temperatures exceed 35°C during all years except July (P = 100%). The CVs range between 1.0 and 3.1%. The probabilities of maximum temperatures exceeding 40°C but below 45°C is 3.0% in May, and only 1.0% in April. Throughout the crop growing season (Jul-Oct) the mean maximum temperature is always ≥30°C except during September (*P*=97%).

3.2. MINIMUM AIR TEMPERATURE

Mean monthly minimum temperatures also show little variation as indicated by the low CV (**Table 20**). Their CVs for minimum temperature are higher than those for the maximum air temperatures. Mean monthly minimum temperatures during November through February are below the annual mean of 22.0°C. It never reaches above 20°C at Anantapur. During all other months, it is >20°C. In May, during most years the mean minimum temperature exceeds 25°C, but is below 30°C (P = 95%); this is rarely so during April (P = 9%). During the growing season, the mean minimum temperature vary between 23.8°C (July) to 22.0°C (October).

3.3. HEAT UNITS

The mean heat units accumulated during a month have been calculated from the maximum and minimum temperatures using the equation of Alagarswamy and Ritchie (1991). This equation is given in the next page.

Heat units for groundnut have been calculated by modifying the equation given by Ong et al. (1986); we have considered an upper limit of 34°C and lower limit of 6°C with a base temperature of 10°C. When a base temperature of 8°C is considered instead of 10°C, the correspondin values increased by 2°C.

HU = {(Maximum temperature + Minimum temperature)/2 - BT},

Where Maximum temperature = ≤34° C

Minimum temperature = ≥6° C

BT (Base temperature) = 8° C for Sorghum

10° C for Groundnut

The mean heat unit during a year is 16.6 d^{-1}. The range in heat units is not large: it varied between 13.1 in December to 19.2 in May.

We analyzed the highest and lowest heat units that accumulated during a single day in each month (**Table 21**). The highest heat unit of 19.6 was in May, and the lowest heat unit of 10.0 was in March, May, July and August. The lowest was not during 'winter' season.

4. WIND SPEED, HUMIDITY, AND EVAPORATION

4.1. WIND SPEED AND DIRECTION

The wind speed, and its direction recorded at 3 m height are given in **Table 22**. The annual wind speed is 11.0 km h^{-1}. High winds prevail during June to August, with the monthly average exceeding 18 km h^{-1}. During this period the wind speeds in the afternoons touch even 50-60 km h^{-1} (Yogeshwara Rao et al. 1985). This coincides with the beginning of the crop season which is a special feature of Anantapur climate.

4.2. RELATIVE HUMIDITY, MEAN ATMOSPHERIC PRESSURE AND VAPOR PRESSURE

4.2.1. Relative humidity

Statistics on relative humidity (RH) in the morning (0720 hr) and afternoons (1420 hr) are presented in **Table** 23. During summer months of March, April and May, the RH is low (55-64% in the morning, and 25-31% in the afternoon). During rest of the year it exceeded 65% in the morning, and 32% in the afternoon.

4.2.2. Mean atmospheric pressure and Vapor pressure

The annual mean atmospheric pressure is 967 mb (**Table** 23). The range is 965 (during May-Aug) to 974 (during Dec).

The mean vapor pressure deficit for Anantapur is 19.6 mb. Vapor pressure deficit is low during November to April (lowest in March, 13.4 mb; **Table** 23). It then increases with the onset of rains. Maximum vapor pressure is recorded during August (23.5 mb). Throughout the period of June through October, it remains above 23.0 mb. Variation in the mean vapor pressure deficit is also narrow during the crop season.

4.3. EVAPORATION, MOISTURE AVAILABILITY INDEX AND CLIMATIC WATER BALANCE.

4.3.1. Daily pan evaporation and potential evapotranspiration

We obtained daily pan evaporation (PE) from the U.S. Open pan evaporimeter (**Table** 24). The daily mean PE is 7.6 mm d^{-1}. During March, April and May the PE equalled or exceeded 10.0 mm d^{-1} as the solar radiation is high during the same period (23 MJ $month^{-1}$ also **see section 5.2**). During the crop growing season the PE value varied between 8.2 mm (July) and 5.2 mm day^{-1} (October).

We multiplied the mean monthly PE values with a factor 0.75 to get the Potential evapotranspiration (PET). The daily mean PET is 5.8 mm d^{-1}. During April and May, it exceeds 8.0 mm d^{-1}. It continuously declines from May (8.2 mm d^{-1}) to November (3.8 mm d^{-1}). It is >200 mm $month^{-1}$ during the beginning of the rainy season (May & June) but, declines to about 120-130 mm $month^{-1}$ during later part of the season.

Due to high winds that prevail during the crop growing season specially during June through September, the PET values are relatively high (7.1 - 4.4 mm d^{-1}), compared to most locations in the state of Andhra Pradesh. For example, at Hyderabad the PET values range between 6.5 to 4.0 mm during the same period.

4.3.2. Moisture availability index

We computed monthly moisture availability index (MAI) using Hargreaves (1975) formula. Only during September, MAI is moderately deficient (0.47), while during the rest of the year it is low (**Table 25**). A month is too long a period to study crop weather relationship; therefore, we analyzed MAI on a weekly basis (**Table 26**).

From the available crop water use data, it follows that at most stages of crop growth, the ratio of actual evaporation to potential evapotranspiration (AE/PET) had to be at least 0.50 to meet the crop water demand (Yogeshwara Rao et al. 1985). There are only 9 consecutive weeks (std. wks. 37-45) that have sufficient soil moisture (>20.0 mm) for crop growth at Anantapur (**Table 26**).

4.3.3. Climatic water balance

Keig and Mc Alphine (1974) water balance model was used to estimate the weekly available soil moisture storage. This model is based on two assumptions. First, a maximum soil moisture-storage capacity has to be known or at least assumed. Second, run-off or deep drainage losses of rainfall occurs only after the maximum soil water storage capacity has been reached. Soil water-storage at the end of a particular week was calculated by subtracting the soil water loss due to evapotranspiration during the week from the sum of the soil water storage at the end of a previous week and the amount of rainfall received during the week. Soil water loss through the week was estimated by the ratio of actual evapotranspiration (AE) to potential evapotranspiration (PET) multiplied by PE. The ratio of AE/PET is taken as 1.0 as the soil water storage decreases from 100% to a minimum value, x%; and it decreases linearly from 1.0 to 0.0 as the storage decreases from x% to 0%. The value of x varies with the maximum soil water-storage capacity. PET values for the last 13 years (1977-1989) were used in the water-balance computations. Using the above procedure, weekly available soil moisture was estimated (**Table 26**). Maximum soil water-storage capacity for Anantapur is taken as 74 mm (Bulk density is 1.58 Field capacity is 14%, permanent wilting point is 4% meter^{-1} depth of soil.) The mean annual rainfall is 565 mm and the mean PET is 2094 mm. Average monthly PET varied between 115 (Dec) and 254 (May). The total annual run-off is 79.5 mm with peak during the standard week 40 (14.6 mm). There are only five consecutive weeks retaining soil moisture $\geq$30 mm (standard week 38-42).

Cocheme and Franquin (1967) proposed a graphical approach for climatic water balance. It is based on the computation of periods at which average rainfall (R) equals to 1/10, 1/2, and 1.0 of PET at the beginning, middle and end of the rainy season. The point where R equals to 1/10 of PET defines the beginning of the preparatory cultivation period, which in turn ends with the beginning of the first intermediate period (R = 1/2 PET). The humid period begins when R $\geq$ PET. The intermediate period, during which R is more than half the PET but does not exceed it, occur before and after the humid period. The moist period is the sum of the humid and the two adjoining sub-humid and per-humid periods.

Figure 9 depicts the climatic water balance at Anantapur. According to Cocheme and Franquin (1967), the preparatory cultivation period could be used for preparation of the soil. The preparatory cultivation period lasts for 81 days (April 25 to July 15). The beginning of the moist period is the best period for sowing. The moist period is 115 days (July 16 to Nov. 8) while the humid period is 39 days (Sep 5 to Oct 14). The above calculation does not consider soil moisture reserves in the profile that could be used by the crops after the rains end. Length of the rainy season discussed in the **section 2.9** gives weightage to the profile water reserve by computing the end of the season as the last day of first dry spell of 10 days ending between
Oct 1 - Nov 30.

5. OTHER CLIMATIC FACTORS

The monthly data on cloudiness, sunshine and solar radiation are presented in **Table 27.**

5.1. CLOUDINESS

The sky is generally clear throughout the year at Anantapur. During the two high rainfall months of September and October, the cloud covers are only 6 Oktas compared to 7 Oktas during July and August. From November onwards the sky is relatively clear; it further clears up in January.

5.2. SUNSHINE

The annual mean daily sunshine is 7 h 45 m d^{-1}. Sunshine hours range from 8.0 (during Oct - Dec) to 10.0 h day^{-1} (Mar - May). During the crop growth period (Jul - Sep), the sunshine hours are low, with July recording the lowest (5.0 h d^{-1}).

5.3. DAYLENGTH

The daylength (including twilight) was computed using equations as shown in **Appendix** C. The variation at Anantapur (14^0 41' N) is not much. Daylength varied from a low value of 12.0 h in December to a maximum of 13 h 13 m in June. It is $\geq$13.0 h d^{-1} during the growing season except September (12 h 12 m day^{-1}). The average annual mean was 13 h 02 m d^{-1}. Except during the few summer months, the temperature is also moderate; therefore, the phenological response to daylength may not vary much across planting dates without drought stress.

5.4. SOLAR RADIATION

Solar radiation was computed by using a FORTRAN program with the following input data: daily rainfall, temperature maximum, temperature minimum, sunshine hours, latitude and longitude of a station. The average of daily solar radiation is 20.0 MJ d^{-1}. Solar radiation is above average during January to May (20.2 to 23.0 MJ d^{-1}), and below the average during the rest of the year. Solar radiation is lowest during July (16.2 MJ d^{-1}). It increases continuously from August to April (23.8 MJ d^{-1}), and remains high during May and June.

6. SIGNIFICANCE OF CLIMATIC FEATURE ON AGRICULTURAL PRODUCTION AT ANANTAPUR

The amount of rainfall and duration of rainy-season does not provide a good index of productivity. The potential evapotranspiration, water loss, water-holding capacity of soil dictates the amount of available water for crop growth. More important than the quantity of rainfall in a given season is the question of its persistency over a short interval (for instance, during one week or fortnight). For red sandy soil of Anantapur, information on rainfall probabilities is important for agricultural planning. Alfisols, because of their poor structural stability at the surface are susceptible to erosion. Besides, the high winds of >18 km hr^{1} prevailing during cropping season take away the beneficial effect of a rain in no time. Inspite of this observation, rainfall intensities are seldom measured.

The farming system at Anantapur is characterized by small farms, fragmented holdings, limited capital, use of mainly animal or human labor, severe unemployment, limited biological resources, lack of credit facilities and labor shortage at peak times. Improved productivity on this type of soils should consider the period available for crop growth. The beginning and end of the growing period show a wide fluctuation, by that reflecting the need to consider different management strategies. Once the extractable water-holding capacity is determined, water-budgeting techniques can be used to find the pattern of changes in the profile moisture during the crop-growing season. Above factors assume greater importance if the modem technologies, including the new genotypes, is popularized, and moderate amounts of purchased inputs are applied.

The growing season at Anantapur is only 15 weeks long; therefore, a crop that can complete its life cycle within 105 days must be deployed. But, we need to consider the possibility of postponement of flowering time by droughts at pre-flowering stage; in such cases allowances should be made for the time to recover from early season drought.

Climatic and soil characteristics of Anantapur make this place ideal for conducting drought research.

7. SUMMARY

The climate of Anantapur is classified as tropical arid. The rainfall is variable between seasons. The rainfall is erratic, and shallow sandy loam soils have low infiltration capacity with the high evapotranspiration at this location, droughts are very common and so successful farming is difficult in the region.

Rainfall

Anantapur receives a mean annual rainfall of only 565 mm with a CV of 30%. According to the Planning Commission's definition, drought prevails once in three, or twice in 7 years. The data on seasonal distribution of rainfall reveals that 58.8% of annual rainfall is received during South-West monsoon and 27.1% during North-East monsoon. The dependable annual precipitation at 75% probability is 436 mm. September and October are the wettest months, together accounting for 44% of the annual precipitation. The variability in rainfall within the month is so high that even the wettest month goes dry without rain.

During any part of the year, the Initial probability of wet week, $P(W_w)$ does not exceed 70%. The conditional probability of wet week followed by wet week, $P(W/W_w)$ follows a similar pattern as $P(W_w)$ except during the standard week 37. During none of the weeks the conditional probability of $P(W/D_w)$ exceeds 59%. Constant probability analysis for rainfall $\geq$10 mm reveals that the highest amount of rainfall at 75% probability is 8.5 mm. At 75% probability there are only three consecutive decades (24-26) during the year receiving a minimum rainfall of 30 mm.

On an average, there are 49 days in a year with at least some rainfall. During the rainy season there are 28 rainy days. There is a dry spell of 8 days duration between rains when all rains are considered during a year. The mean dry spell during the growing season is 4 days only, but it can range from 2 to 8 days. The maximum number of rainy days is in September (mean: 9.1; range: 0-18).

The mean date of onset of South-West monsoon at Anantapur is July 11(sd: $\pm$32 days). The mean date of cessation of North-East monsoon is October 15 (sd $\pm$11 days). Therefore, the length of the rainy season is 97 days (sd: $\pm$31 days); it range from 26 - 151 days, thus shows the risks faced by the local farmers.

The probable date of sowing crops at Anantapur is around standard week 28 in 3 out of 4 years. The rainy season practically ceased by standard week 43. Thus, a crop of 15 weeks might succeed in this alfisols-dominated tract.

After sowing the crop by second week of July, a dry spell of 2 consecutive weeks are highly probable, which begin with the standard week 31 (38% probability). The probability of 3 consecutive std. wks. could be expected beginning with standard week 30-31.

Temperature and heat units

The annual mean maximum temperature is 33.7°C. The annual mean minimum temperature is 22.0°C. During crop growing season (July-Oct), the variation in maximum (32-33°C) and minimum (22.0 to 23.8°C) temperatures is low. The annual mean heat unit is 19.2 d^{-1}. During the growing season the heat units range between 19.0 to 20.4 d^{-1}. Given the growing season length of 15 weeks, a crop that require about 2500 heat units can mature in Anantapur.

Wind speed and relative humidity

The annual wind speed is 11.0 km h^{-1}. The wind speeds during the afternoons are high touching 50-60 km h^{-1}. This coincides with the beginning of the crop season, a special feature of Anantapur. During summer months of March, April and May, the relative humidity is low (55-64% in the mornings, and 25-31% in the afternoons), while during rest of the year it exceeds 65% in the morning and 32% in the afternoons.

Atmospheric pressure and vapor pressure

The annual mean atmospheric pressure is 967 mb. The mean vapor pressure deficit is 19.6 mb. Maximum vapor pressure deficit of 23.5 mb is recorded during August. The change in the mean vapor pressure deficit is also narrow during the crop season.

Potential evaporation and water balance

The monthly mean PET is 174.5 mm (5.8 mm day^{-1}). It exceeds $\geq$200 mm $month^{-1}$ during the beginning of the season, but declines to about 120-130 mm $month^{-1}$ during later part of the season. There is sufficient soil moisture for crop growth only during std. wks. 29-46.

A graphical approach of climatic water balance showed that the preparatory period lasts for 81 days (April 25-July 15), the moist period for 115 days (July 16 - Nov 8) and the humid period is only for 39 days (Sep 5- Oct 14).

Cloudiness, sunshine and daylength

The sky is generally overcast from May to October with a peak overcast between July and August. The annual mean daily sunshine is 7 h 45 m d^{-1}. During the crop growth period (Jul-Sep), the number of sunshine hours is low, with July recording the lowest (5.0 h d^{-1}). The annual mean daylength including twilight is 13 h 02 m d^{-1}. During the growing season the daylength is

13.0 h d^{-1} except in September (12 h 12 m d^{-1}).

Implementation of above analysis on different strategies for crop production and research at Anatapur are discussed.

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8. APPENDICES

A. Initial and Conditional probability analysis

1. Initial probability of a given week having rain in excess of a specific amount, P(W).

$$P(W) = \frac{\text{No. of years which have rain more than 10 mm}}{\text{No. of years of data}}$$

At any given week, we implement the following formulae

$$P(wi) = \frac{N(wi)}{N} \quad \text{and}$$

$$P(Di) = \frac{N(Di)}{N}$$

where N(Wi) = No. of occurrences of a wet week in the i'th period.
N(Di) = No. of occurrences of a dry week in the i'th period.
N = Total No. of years [N(Wi) + N(Di)]

2. Conditional probability of a given wet week to be followed by a wet week, P(W/W).

$$P(Wj/Wi) = \frac{N(Wj, Wi)}{N(Wi)}$$

Where N(Wj, Wi) = No. of occurrences of a wet week in i'th and j'th period.
N(Wi) = No. of occurrences of a wet week in i'th period.

3. Conditional probability of a given dry week following a wet week, P(W/D).

$$P(Wj/Di) = \frac{N(Wj,Di)}{N(Di)}$$

Where N(Wj,Di) = No. of occurrences of a dry week in i'th period and a wet week in j'th period.

From the **Table 28**, we could get the following results,

$$P\,(Wet) = 14/79 = 0.18 = 18\%$$

$$P\,(Wet/Wet) = \frac{2/79}{14/79} = 2/14 = 0.14 = 14\%$$

$$P\,(Wet/\,Dry) = \frac{28/79}{(79\text{-}14)} = 28/65 = 0.42 = 42\%$$

Similarly, the calculation process for any given amount of rainfall can be achieved. A more complete description of the conditional probability analysis is given by Robertson (1976), cited in Virmani (1982).

Comparison of analyses of Initial and conditional probability at Hyderabad and Anantapur

According to the Troll's method of classification, Anantapur and Hyderabad are classified as dry semi-arid [2-$4^1/_2$ humid months where *R* (rainfall) $\geq$ *PE* (potential evapotranspiration)]. According to other classifications, the climate at Anantapur is arid. It actually falls under semi-arid bordering the arid climate. According to Hargreaves method of classification (1971), both Hyderabad and Anantapur are in the climate class semi-arid (3-4 consecutive months of R/PE $\geq$0.34).

The initial and conditional probability analysis shown in **Figure 10** reveals the following:

The rainfall distribution at Anantapur is bimodal. Not even a single estimate of weekly initial probability of *P(W)* exceeds the 70% threshold (**Figure 10a**). The conditional probability of wet period followed by wet period *P(W/W)* also follows a fairly similar pattern as *P(W)*. Only during the standard week 37, *P(W/W)* exceeds 70% (**Figure 10b**). The conditional probability of wet followed by dry period *P(W/D)* is not more than 59% in any of the week (**Figure 10c**). In comparison, rainfall distribution for Hyderabad is unimodal. A dependable rainfall (602 mm) distributed between June 18 to the end of July and from about mid-August to mid-September. Monsoon rainfall during rainy season (Jun -Sep) at Anantapur is highly erratic and therefore undependable. It is the major environmental factor that has led to low agricultural production; other factors are red sandy soils (Alfisols) which are well drained but possess low water holding-storage capacity, and traditional methods of rainfed farming. The soils are both unproductive and prone to excessive run-off and erosion. Hyderabad seems to have much more favorable season for crop production during rainy season as the soils are vertisols or medium or deep Alfisols with high water holding-storage capacity.

Thus from the study of rainfall, moisture index and the length of the growing season **Table 30**, it is closely seen that the two areas are quite different with each other. Further, following observations can be made:

1. At Hyderabad the length of the growing season is long (130 days) and reliable especially on vertisols. Dry seeding can be adopted for Hyderabad region as the start of the season is reliable. At Anantapur same is impossible as the start of the season is variable, short (97 days) and the soils are Alfisols (shallow and sandy soils) and prone to crusting.

2. At Hyderabad, as evidenced from the rainfall probability analysis (Fig. 9) mid-season breaks in the continuity of rainfall are likely to occur once in 4 to 6 years in a 10-year period. Generally, one would not select a crop cultivar whose growth is sensitive to moisture stress during this period. Therefore, either a sole short-duration crop (which completes most of its life cycle before cessation of rainfall) or a long duration base crop with a short duration intercrop would be best suited for the Hyderabad under dryland conditions (Virmani et al 1980). At Anantapur, sole cropping of groundnut or sorghum is possible as the rainfall is received for a short period of 13-14 weeks, with an intermittent drought. Therefore, crop cultivars which can withstand stress during the early stages of crop growth are preferred. The possibilities for intercrop at Anantapur are low, and double cropping it is not feasible.

3. The potential benefit for recycling of run-off water would be much more favorable in Anantapur region than at Hyderabad. The run-off is more at Anantapur (102 mm year^{-1}) since the

soils are Alfisols with inherent characteristic, such as low water-holding capacity, high errodability, and a potential for excessive run-off, that are constraints in crop production under rainfed conditions compared to vertisols which are high water-holding capacity and high cation exchange capacity because of physico chemical nature of the soils.

B. Gamma distribution.

A number of models have been proposed for the patterns of rainfall over a period of time either daily, weekly, or monthly. Gamma distribution is one of the most appropriate models for interpreting rainfall data. The gamma distribution function is expressed by

$$g(x) = \frac{1}{\beta^{\gamma}\Gamma(\gamma)} x^{\gamma-1} e^{-x/\beta}$$

Where B is a scale parameter, γ is a shape parameter and $\Gamma(\gamma)$ is the ordinary gamma function of . However, this formula gives a poor estimate of the parameters. Adequate estimates are approximated by

$$\hat{\gamma} = \frac{1}{4A} (1 + 1 + 4A/3)$$

and $\hat{\beta} = \frac{\hat{X}}{\hat{\gamma}}$

where A is given by

$$A = \ln \bar{X} - \frac{\Sigma \ln x}{n} \text{ or } \Sigma \ln xi - \ln x$$

The distribution function from which probabilities may be obtained is

$$G(x) = \int_{0}^{x} g(t)dt$$

Gamma distribution for week # 25 has been calculated (Table 29). From the example we get an average rainfall of 6.32 mm and ln x = 1.84372. The total of ln x = 78.05. Therefore, A= $\ln \bar{x} - \Sigma \ln x/n$ = 1.84372 - 0.99000 = 0.85372.

Thus, $= \frac{1 + 1 + 4\ (0.85372)\ /\ 3}{4\ (0.85372)} = 2.75$

$\beta = 6.32\ /\ 2.75 = 2.30$

To determine the amount of rainfall at any given probability, it must be put in the standard form t (F) = X/β.From the gamma distribution table, we can get the amount of rainfall.

C. Equation for calculating daylength including civic twilight

Photoperiod in hours (HRLT) is calculated from the day of the year (JDATE) with a series of three equations:

1. DEC= 0.4093 * SIN [0.0172 * (JDATE-82.2)]

2. DLV= (-S_1 * SIN (DEC) - 0.1047) / [C_1 * COS (DEC)]

3. HRLT= 7.639 * ACOS (DLV)

Where,

DEC is solar declination angle (radians).
S_1 = SIN (LAT * 0.01745)
C_1 = COS (LAT * 0.01745)

TABLES

ıble 1. Monthly and annual rainfall (mm) data for Anantapur (database: 1911-1989; section: 2.1).

'EAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL RAINFALL
911	0	0	1	32	60	73	16	26	126	69	23	38	464
912	0	3	0	16	18	45	52	138	250	105	93	0	721
913	0	0	0	0	64	38	59	16	282	119	0	4	583
914	0	0	0	0	26	62	30	153	117	9	27	0	424
915	4	0	26	0	98	33	92	32	331	45	109	0	771
916	0	0	0	4	13	51	316	83	118	152	26	0	764
917	0	132	1	8	102	86	44	168	168	113	122	0	945
918	3	0	29	5	66	26	21	9	198	0	140	0	498
919	0	0	4	33	88	123	54	2	424	76	162	10	976
920	26	0	0	8	64	14	17	47	148	62	8	0	394
921	5	0	0	36	5	53	66	50	79	347	76	0	715
922	130	0	0	2	46	31	9	13	10	105	151	1	497
923	0	6	5	4	27	62	27	8	106	1	0	0	246
924	0	0	0	34	82	12	71	60	356	44	74	0	734
925	0	0	0	10	96	28	2	67	136	79	46	72	537
926	10	0	0	30	12	138	41	2	201	87	10	0	530
927	0	2	0	1	37	61	138	30	231	37	195	0	733
928	0	22	0	17	67	54	98	63	119	86	0	0	526
929	3	19	0	3	31	24	18	14	247	73	80	1	512
930	4	0	15	5	61	45	74	47	90	269	55	18	685
931	0	0	0	4	42	71	9	0	151	27	63	2	371
932	0	21	0	0	18	141	24	220	102	103	100	3	733
933	0	3	0	24	119	6	72	311	14	114	23	40	728
934	0	0	0	13	21	24	120	5	4	38	8	1	234
935	0	0	0	32	18	83	17	269	44	78	0	0	540
936	0	0	3	20	74	33	14	20	158	39	83	0	443
937	0	19	0	99	43	98	41	23	151	285	12	3	774
938	0	0	6	2	48	16	36	489	146	5	2	0	.750
939	0	0	26	37	5	83	16	123	98	116	35	0	539
940	0	0	0	16	107	24	6	33	100	337	85	0	709
941	20	0	0	0	24	26	52	65	195	94	13	42	530
942	0	0	0	1	43	126	4	49	46	20	10	1	300
943	0	0	0	18	119	21	13	21	130	144	.56	0	522
944	0	7	19	0	19	116	41	0	89	225	0	0	517
945	0	0	0	41	60	3	112	54	96	22	28	0	416
946	0	0	0	30	46	26	30	151	0	0	0	0	282
947	8	11	0	16	17	28	27	185	236	43	29	14	615
948	0	0	5	12	26	2	23	56	86	18	163	0	391
949	0	0	0	2	101	30	32	109	149	78	12	0	512
950	0	9	0	0	80	33	41	50	89	123	31	0	457

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(Table 1. Continued from the previous page)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
1951	0	0	50	19	176	42	28	7	123	80	3	0	528
1952	0	0	0	0	81	20	38	26	52	95	0	38	351
1953	0	0	0	39	4	60	154	39	238	324	0	0	858
1954	0	0	0	8	33	0	84	60	23	88	0	39	335
1955	0	0	0	0	129	63	26	88	168	95	30	1	599
1956	0	1	0	70	85	47	109	15	138	237	146	7	854
1957	0	0	0	4	55	177	32	76	92	102	10	0	548
1958	0	2	1	22	55	78	33	96	152	78	16	7	540
1959	0	8	0	29	21	139	66	49	207	51	0	17	587
1960	0	0	0	2	27	19	119	3	284	60	42	0	555
1961	0	7	0	0	122	103	36	44	2	103	20	0	437
1962	0	0	0	24	63	54	80	71	77	142	22	85	619
1963	0	0	0	58	53	22	60	175	64	74	0	2	510
1964	0	0	0	7	5	78	193	39	260	43	30	1	655
1965	0	0	0	16	9	54	6	109	106	0	0	62	36[illegible]
1966	2	0	0	0	48	124	92	112	97	72	61	14	623
1967	0	0	10	18	36	27	151	10	143	174	5	3	578
1968	0	10	30	8	15	64	27	0	267	44	52	34	552
1969	0	0	0	4	93	67	35	130	13	199	1	10	55[illegible]
1970	0	0	0	12	120	15	122	68	182	144	0	0	66[illegible]
1971	0	0	16	2	63	25	58	130	22	260	3	2	582
1972	0	0	0	9	83	48	10	6	215	137	33	17	55[illegible]
1973	0	0	0	6	2	83	45	30	200	306	49	0	721
1974	0	0	0	0	90	68	19	11	359	67	1	0	615
1975	0	0	4	0	39	19	51	102	107	323	55	0	69[illegible]
1976	0	0	0	5	11	11	4	190	41	23	23	0	30[illegible]
1977	0	0	4	52	149	67	58	108	70	173	83	0	765
1978	0	3	2	28	13	24	79	19	228	47	51	19	51[illegible]
1979	0	20	0	2	25	20	36	52	281	53	137	0	627
1980	0	0	0	10	38	20	10	35	52	41	18	0	22[illegible]
1981	1	0	15	5	17	6	100	45	213	84	24	18	528
1982	0	0	0	2	106	85	45	2	100	58	226	0	625
1983	0	0	0	0	140	116	24	143	239	30	1	33	725
1984	0	0	13	4	8	0	72	6	40	19	0	14	176
1985	0	0	15	22	0	30	88	33	34	147	20	5	392
1986	9	3	0	0	7	105	8	40	163	68	31	2	436
1987	0	0	0	0	14	87	1	90	120	155	20	14	502
1988	0	0	33	33	112	5	124	343	225	31	0	9	91[illegible]
1989	0	0	26	6	37	58	454	12	201	22	3	2	821
Mean	3	4	5	14	54	53	60	74	145	102	43	9	56[illegible]
Sd±	15	15	10	18	41	39	67	85	91	86	51	17	17[illegible]
CV(%)	525	396	214	124	75	74	112	114	63	84	120	190	3[illegible]

Table 2. Probability of receiving a specified amounts of annual rainfall at Anantapur (database: 1911-1989; section: 2.1.1).

Annual rainfall (mm)	Probability (%)
< 200	1.3 (1)
200 - 400	16.5 (13)
400 - 600	44.0 (35)
600 - 800	30.4 (24)
> 800	7.6 (6)

Figures in parenthesis represents the number of years out of total (79) years.

Table 3. Frequency of drought occurrence during a calendar year at Anantapur (database: 1911-1989; calculated based on the definition of Planning Commission see section: 2.1.2)

Percentage of annual rainfall	Number of years (%) in frequency class													
	Jun		Jul		Aug		Sept		Oct		Nov		Dec	
	1	15	1	15	1	15	1	15	1	15	1	15	1	15
A. 25 % Interval														
<25	8	4	3	1	1	0	0	0	0	0	0	0	0	0
25-50	13	10	10	14	6	6	6	5	5	6	6	5	5	5
50-75	24	23	17	15	25	24	28	27	19	14	15	14	14	14
Total	45	37	30	30	32	30	34	32	24	20	21	19	19	19
75-100	10	24	26	27	24	28	19	30	29	29	28	38	38	37
100-125	14	12	20	15	16	22	27	15	27	32	29	19	19	22
125-150	10	11	11	12	15	13	8	13	13	12	15	16	18	16
Total	34	47	57	54	55	63	44	58	69	73	62	73	65	75
150-175	11	6	4	10	8	3	6	2	2	6	5	8	6	6
175-200	4	4	5	5	3	4	1	4	4	1	1	0	0	0
>200	6	6	4	1	1	1	5	4	1	0	0	0	0	0
Total	21	16	13	16	12	8	11	10	7	7	6	8	6	6
B. 12.5 % Interval														
75-87.5	8	10	13	13	17	16	14	13	16	19	13	11	9	8
87.5-100	2	14	13	14	7	12	5	17	13	10	15	27	29	29
100-112.5	6	7	9	11	10	7	16	11	13	18	20	10	11	14
112.5-125	8	5	11	4	6	15	10	4	14	14	9	9	8	8
Long term mean rain fall (mm)*	82	112	133	153	194	218	269	314	416	475	515	545	556	563

* (Upto that particular date)

Table 4. Monthly rainfall statistics for Anantapur (database: 1911 - 1989 section: 2.2 and 2.3).

Month (or) season	Mean rainfall (mm mon^{-1})	Standard Deviation (Sd±)	C.V. (%)	Maximum Rainfall (mm mon^{-1})	Minimum Rainfall (mm mon^{-1})	Max-Min (mm)
Winter season						
January	2.8	15.0	525	130	0.0	130
February	3.9	15.4	396	132	0.0	132
Summer season						
March	4.5	9.7	214	50	0.0	50
April	14.4	17.8	124	99	0.0	99
May	54.1	40.6	75	176	0.0	176
South-West monsoon season						
June	52.9	39.2	74	177	0.0	177
July	60.2	67.2	112	454	1.0	453
August	74.4	84.9	114	489	0.0	489
September	144.5	91.4	63	424	0.0	424
North-East monsoon season						
October	101.7	85.8	84	347	0.0	347
November	42.6	51.3	120	226	0.0	226
December	8.9	17.0	190	85	0.0	85
Annual	565.1	169.9	30	976	176.0	800

Table 5. Dependable monthly rainfall (mm) for given probabilities using gamma distribution (database:1911-1989; section: 2.3.1).

Month	Rainfall (mm) at probability levels (%)					Mean rainfall (mm)
	90	75	50	25	10	
January	0	1	2	5	10	3
February	0	1	3	7	13	4
March	0	1	3	8	14	5
April	1	4	10	21	37	14
May	11	22	43	76	115	54
June	.3	27	53	81	105	53
July	0	16	60	107	148	60
August	0	18	74	133	185	74
September	32	62	117	198	297	145
October	15	35	76	142	225	102
November	2	7	24	59	112	43
December	0	1	5	13	26	9
Annual	350	436	547	675	806	565

Table 6. Total number of rainy weeks, receiving rainfall, and the amount received (mm week^{-1}) during different weeks at Anantapur (database: 1911-1989; section: 2.4.1).

Year	All rains		>2.5 mm		≥10 mm		≥20 mm		≥30 mm	
	No	Amount	No	Amount	No	Amount	No	Amount	No	Amount
1911	27	463	22	458	13	403	9	349	4	232
1912	24	721	20	716	14	696	8	604	8	604
1913	17	583	14	578	10	554	7	516	6	490
1914	20	424	19	422	11	382	7	325	5	276
1915	29	770	23	762	12	695	8	631	5	566
1916	28	763	23	755	16	722	14	608	8	539
1917	23	944	21	941	16	904	14	873	11	796
1918	20	497	16	494	11	.468	9	438	5	331
1919	28	974	24	969	16	934	14	903	10	795
1920	22	394	19	389	11	346	7	291	5	242
1921	18	715	16	711	12	689	9	645	6	572
1922	23	497	20	492	8	438	8	438	5	364
1923	18	246	13	241	6	197	3	149	2	128
1924	21	734	18	732	14	701	9	643	6	577
1925	26	536	21	530	13	491	12	478	6	341
1926	18	530	14	525	8	493	7	483	5	434
1927	24	732	18	725	15	709	9	615	7	570
1928	24	525	20	522	11	466	10	454	7	383
1929	23	511	20	508	12	463	6	369	5	344
1930	26	684	26	684	16	632	12	566	9	493
1931	22	370	15	364	10	338	7	295	6	271
1932	26	732	20	724	15	697	10	617	8	569
1933	26	727	21	722	15	691	12	651	7	531
1934	16	233	12	230	7	202	3	143	1	94
1935	20	539	16	535	13	519	6	405	6	405
1936	23	442	19	437	13	418	8	341	5	267
1937	20	773	19	771	15	750	9	657	7	614
1938	19	749	16	746	10	709	8	684	8	684
1939	23	538	19	535	14	509	10	449	8	395
1940	23	709	19	706	14	671	9	587	6	519
1941	21	529	17	526	13	504	8	429	6	383
1942	18	299	13	294	8	270	5	224	3	178
1943	20	521	17	517	14	499	9	421	6	347
1944	15	517	13	513	7	474	6	454	5	428
1945	18	415	16	413	11	388	8	345	6	297
1946	9	282	7	281	7	281	5	251	2	171
1947	26	614	24	612	13	535	7	442	5	392
1948	21	391	15	384	13	374	5	251	4	230
1949	20	512	16	506	9	453	5	397	5	397
1950	20	456	19	454	13	425	9	379	6	305
1951	26	-528	18	518	14	499	11	447	8	375
1952	22	350	20	348	10	301	6	246	3	177
1953	21	858	17	853	14	832	12	798	10	744
1954	16	334	13	331	8	306	6	274	5	253
1955	26	599	21	594	13	536	11	507	8	441
1956	27	853	22	848	15	822	11	752	9	702
1957	23	547	22	547	11	476	8	434	7	413
1958	28	540	23	534	15	482	8	378	4	282
1959	19	586	17	584	15	567	10	490	6	387
1960	23	554	16	546	10	510	5	437	5	437
1961	21	436	17	429	11	396	8	351	5	276
1962	26	619	23	614	14	555	10	499	8	457
1963	24	509	19	503	14	473	10	413	6	321
1964	27	655	21	647	13	612	10	564	7	490
1965	18	362	13	357	8	329	5	284	5	284
1966	25	622	23	620	16	584	11	510	7	411
1967	19	577	17	575	11	548	7	498	6	475
1968	23	551	20	547	12	480	8	417	6	367
1969	23	552	17	547	8	505	8	505	8	505
1970	18	663	16	661	11	630	9	606	8	582

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(Table 6 Continued from the previous page)

Year	All rains No	All rains Amount	≥2.5 mm No	≥2.5 mm Amount	≥10 mm No	≥10 mm Amount	≥20 mm No	≥20 mm Amount	≥30 mm No	≥30 mm Amount
1971	23	581	17	571	12	550	5	447	5	447
1972	26	557	22	555	12	501	9	462	7	404
1973	18	721	15	715	10	686	8	656	8	656
1974	17	614	14	612	11	601	7	537	6	516
1975	26	698	23	692	14	649	9	577	6	510
1976	15	307	13	304	6	270	4	237	2	190
1977	26	765	23	760	19	737	12	642	12	642
1978	25	513	22	507	14	462	7	359	3	264
1979	28	626	24	621	13	556	9	503	5	415
1980	21	224	13	215	8	175	5	130	1	43
1981	26	528	19	520	13	486	7	395	6	367
1982	20	624	13	614	9	589	9	589	8	564
1983	23	725	20	721	13	675	11	653	10	620
1984	17	176	14	172	7	137	3	92	1	47
1985	19	392	18	390	12	360	6	275	4	234
1986	23	435	18	427	10	389	8	352	7	331
1987	22	501	19	499	9	448	6	407	5	384
1988	26	914	22	910	16	872	13	836	12	813
1989	20	821	17	817	12	787	9	747	8	725
Mean	22	565	18	560	12	525	8	471	6	419
Max	29	974	26	969	19	934	14	903	12	813
Min	9	176	7	172	6	137	3	92	1	43
Sd±	4	171	4	171	3	171	3	172	2	174

Table 7. Weekly initial and conditional probabilities of rainfall (%) for selected amounts, and the mean weekly rainfall at Anantapur (database: 1911-1989; section: 2.4.2.1).

Standard Week No	≥10 mm W	≥10 mm W/W	≥10 mm W/D	≥20 mm W	≥20 mm W/W	≥20 mm W/D	≥30 mm W	≥30 mm W/W	≥30 mm W/D	≥40 mm W	≥40 mm W/W	≥40 mm W/D	≥50 mm W	≥50 mm W/W	≥50 mm W/D	Mean (mm)
	<------							Probability (%)							------>	
1	4	33	0	3	50	0	1	100	0	1	100	0	0	0	1	1.3
2	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1.2
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3
4	0	0	4	0	0	3	0	0	1	0	0	1	0	0	1	0.1
5	4	0	1	3	0	0	1	0	0	1	0	0	1	0	0	2.3
6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3
7	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0.1
8	1	0	5	0	0	3	0	0	0	0	0	0	0	0	0	0.8
9	5	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0.9
10	3	0	3	0	0	1	0	0	1	0	0	0	0	0	0	0.5
11	3	0	4	1	0	3	1	0	1	0	0	0	0	0	0	0.6
12	4	0	9	3	0	3	1	0	1	0	0	1	0	0	0	1.2
13	9	14	6	3	0	4	1	0	1	1	0	1	0	0	0	2.5
14	6	20	7	4	0	5	1	0	1	1	0	0	0	0	0	2.2
15	8	17	15	5	0	8	1	0	4	0	0	1	0	0	1	2.6
16	15	0	10	8	0	5	4	0	1	1	0	1	1	0	1	4.7
17	9	43	13	5	25	11	1	100	9	1	100	6	1	100	5	3.1
18	15	17	19	11	22	9	10	13	6	8	0	5	6	0	4	7.3
Pre-rainy (total: 264 mm)																
19	19	33	34	10	25	23	6	0	18	5	0	13	4	0	9	7.0
20	34	44	42	23	17	28	16	0	27	13	0	17	9	0	13	13.7
21	43	47	31	25	35	25	23	11	21	15	0	18	11	0	10	17.9
22	38	57	39	28	45	30	19	20	22	15	17	15	9	14	11	15.4
23	46	17	26	34	11	21	22	12	13	15	8	7	11	0	6	19.5
24	22	24	16	18	14	12	13	10	6	8	0	3	5	0	1	8.6
25	18	14	42	13	20	20	6	20	11	3	0	8	1	0	8	6.3
26	37	34	18	20	25	10	11	22	7	8	0	5	8	0	4	2.9
27	24	32	25	13	30	16	9	29	14	5	25	8	4	33	4	8.4
28	27	57	28	18	29	23	15	25	24	9	43	13	5	75	9	11.0
29	35	43	27	24	37	20	24	37	13	15	25	12	13	20	10	20.3
30	33	46	32	24	26	18	19	27	11	14	18	6	11	22	6	15.5
31	37	34	16	20	25	17	14	9	13	8	17	5	8	17	5	13.0
32	23	44	33	19	40	25	13	30	14	6	20	14	6	20	9	11.1
33	35	57	31	28	45	19	16	54	21	14	45	15	10	50	13	16.9
34	41	31	38	27	29	28	27	29	19	19	33	14	16	38	12	23.2
35	35	46	41	28	32	28	22	24	18	18	21	11	16	15	11	19.4
36	43	59	49	29	57	38	19	53	31	13	60	30	11	44	27	16.3
Rainy season (total: 185 mm)																
37	53	71	59	43	62	51	35	61	49	34	56	42	29	48	43	32.2
38	66	69	44	56	52	46	53	45	35	47	24	36	44	23	20	51.7
39	61	65	48	49	54	38	41	38	30	30	25	31	22	12	24	39.3
40	58	65	42	46	44	33	33	42	26	29	30	21	22	24	18	30.8
41	56	45	31	38	33	31	32	24	19	24	16	15	19	0	13	31.0
Post-rainy (total: 80 mm)																
42	39	45	31	32	36	22	20	38	19	15	25	18	10	25	15	15.7
43	37	45	32	27	29	22	23	28	11	19	27	6	16	8	6	19.9
44	37	48	22	24	37	20	15	33	16	10	13	15	6	20	8	13.6
45	32	32	17	24	16	10	19	7	8	15	8	6	9	14	4	17.3
46	22	18	18	11	11	7	8	0	3	6	0	3	5	0	3	8.0
47	18	21	11	8	17	4	3	0	4	3	0	3	3	0	3	5.3
48	13	20	7	5	0	1	4	0	1	3	0	1	3	0	1	3.8
49	9	29	7	1	0	6	1	0	4	1	0	3	1	0	3	2.6
50	9	0	1	6	0	1	4	0	0	3	0	0	3	0	0	3.5
51	1	0	4	1	0	1	0	0	1	0	0	0	0	0	0	0.5
52	4	0	4	1	0	3	1	0	1	0	0	1	0	0	0	1.0

Table 8. Weekly rainfall (mm) for a given specified probability at Anantapur using gamma distribution (database 1911-1989; section: 2.4.2.2).

Standard week no.	Rainfall (mm) at different probability levels (%) 90	75	50	25	10	Mean (mm)
1	0.2	0.6	1.5	3.3	5.6	1.3
2	0.2	0.6	1.4	3.0	5.2	1.2
3	0.6	0.8	1.2	1.6	2.1	0.3
4	0.8	0.9	1.0	1.2	1.3	0.1
5	0.1	0.5	1.8	4.5	8.4	2.3
6	0.0	0.0	0.3	3.0	4.4	0.3
7	0.0	0.2	0.1	2.1	3.0	0.1
8	0.0	0.0	0.8	3.7	5.5	0.8
9	0.3	0.6	1.4	2.6	4.3	0.9
10	0.4	0.7	1.3	2.1	3.1	0.5
11	0.3	0.7	1.3	2.2	3.4	0.6
12	0.2	0.7	1.5	3.0	4.9	1.2
13	0.2	0.7	2.1	4.8	8.6	2.5
14	0.3	0.8	2.1	4.5	7.7	2.2
15	0.3	0.8	2.3	4.9	8.6	2.6
16	0.2	0.9	3.1	7.7	14.6	4.7
17	0.3	0.9	2.6	5.7	9.9	3.1
18	0.2	1.1	4.1	11.2	21.9	7.3
Pre-rainy						
19	0.3	1.3	4.4	10.9	20.4	7.0
20	0.4	2.1	7.8	19.9	38.2	13.7
21	0.6	2.8	10.0	25.6	49.0	17.9
22	0.7	2.8	9.2	22.4	41.6	15.4
23	0.7	3.1	10.9	27.9	53.1	19.5
24	0.3	1.3	4.9	12.9	25.1	8.6
25	0.4	1.5	4.4	10.1	18.2	6.3
26	0.6	2.3	7.8	19.0	35.4	12.9
27	0.5	1.8	5.6	13.0	23.6	8.4
28	0.4	1.8	6.4	16.3	31.0	11.0
29	0.4	2.3	9.9	28.3	57.4	20.3
30	0.5	2.4	8.8	22.4	42.9	15.5
31	0.4	2.1	7.4	19.0	36.3	13.0
32	0.2	1.4	5.8	16.2	32.4	11.1
33	0.5	2.4	9.1	24.2	47.1	16.9
34	0.4	2.4	10.9	32.0	65.7	23.2
35	0.4	2.2	9.5	27.1	54.9	19.4
36	0.7	2.8	9.6	23.6	44.1	16.3
Rainy season						
37	0.8	4.1	16.4	44.6	87.9	32.2
38	1.9	8.5	29.0	71.9	135.1	51.7
39	1.4	6.3	21.9	54.9	103.6	39.3
40	1.0	4.6	16.7	43.1	82.7	30.8
41	0.5	3.4	14.8	42.5	86.4	31.0
Post-rainy						
42	0.5	2.3	8.7	22.7	43.8	15.7
43	0.3	2.1	9.4	27.6	56.7	19.9
44	0.3	1.7	7.0	19.5	39.2	13.6
45	0.2	1.4	7.3	23.6	50.9	17.3
46	0.2	1.1	4.5	12.1	23.8	8.0
47	0.2	0.9	3.3	8.5	16.3	5.3
48	0.2	0.7	2.6	6.5	12.3	3.8
49	0.2	0.7	2.1	5.0	9.1	2.6
50	0.2	0.7	2.4	6.1	11.6	3.5
51	0.4	0.7	1.2	2.0	3.0	0.5
52	0.3	0.7	1.5	2.8	4.5	1.0
Annual	349.9	435.6	546.5	674.8	806.0	564.6

Table 9. Decadal initial and Conditional probabilities of rainfall (%) for selected amounts, and the mean decadal rainfall at Anantapur (database: 1911-1989; section: 2.5).

Standard decade No	≥10 mm			≥20 mm			≥30 mm			≥40 mm			≥50 mm			Mean rainfall (mm)
	W	W/W	W/D	W	W/W	W/D	W	W/W	W/D	W	W/W	W/D	W	W/W	W/D	
	<----------						Probability (%)								---------->	
1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2.5
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2
3	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0.1
4	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2.6
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8
8	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1.1
9	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2.6
10	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3.9
11	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	4.9
12	3	50	9	0	0	3	0	0	0	0	0	0	0	0	0	5.6
13	10	25	13	3	0	3	0	0	0	0	0	0	0	0	0	10.3
14	14	18	34	3	0	10	0	0	0	0	0	0	0	0	0	16.6
15	32	20	26	10	0	7	0	0	3	0	0	0	0	0	0	27.2
16	24	5	10	6	0	0	3	0	0	0	0	0	0	0	0	25.6
17	9	0	11	0	0	3	0	0	0	0	0	0	0	0	0	11.4
18	10	13	8	3	0	4	0	0	0	0	0	0	0	0	0	15.9
19	9	29	18	4	67	5	0	0	4	0	0	1	0	0	1	12.6
20	19	20	22	8	17	10	4	0	4	1	0	0	1	0	0	23.4
21	22	12	15	10	0	3	4	0	1	0	0	1	0	0	1	24.0
22	14	27	16	3	50	5	1	100	3	1	0	0	1	0	0	16.7
Pre-rainy season (84 mm)																
23	18	36	22	6	20	15	4	0	7	0	0	4	0	0	4	22.2
24	24	11	22	15	8	10	6	0	5	4	0	1	4	0	0	35.4
25	19	40	50	10	13	32	5	0	16	1	0	6	0	0	3	26.6
Rainy season (168 mm)																
26	48	45	54	30	29	31	15	25	13	6	0	8	3	0	6	57.2
27	49	46	45	30	17	22	15	8	13	8	0	7	6	0	4	60.7
28	46	25	19	20	19	3	13	10	1	6	0	1	4	0	0	50.2
29	22	24	23	6	20	12	3	0	3	1	0	1	0	0	0	25.4
Post-rainy season (76 mm)																
30	23	11	23	13	0	9	3	0	5	1	0	3	0	0	1	26.1
31	20	13	10	8	0	3	5	0	1	3	0	0	1	0	0	24.2
32	10	25	3	3	0	1	1	0	0	0	0	0	0	0	0	11.5
33	5	0	1	1	0	1	0	0	0	0	0	0	0	0	0	6.9
34	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	4.4
35	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.5
36	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	1.0

Table 10. Decadal rainfall (mm) for a specified probability using gamma distribution and the mean decadal rainfall at Anantapur (database: 1911-1989; section: 2.5.1).

Decade No	Rainfall (mm) at probability levels (%)					Mean (mm)
	90	75	50	25	10	
1	0	0	0	0	0	2
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	3
5	0	0	0	0	0	1
6	0	0	0	0	1	1
7	0	0	0	0	0	1
8	0	0	0	0	1	1
9	0	0	0	0	8	3
10	0	0	0	0	13	4
11	0	0	0	0	17	5
12	0	0	0	0	18	6
13	0	0	1	0	33	10
14	0	0	8	0	46	17
15	0	3	16	1	71	27
16	0	2	13	8	69	26
17	0	0	3	16	34	11
18	0	1	8	13	43	16
19	0	0	11	3	36	13
20	0	0	5	8	69	23
21	0	2	9	5	66	24
22	0	0	14	8	49	17
Pre-rainy season						
23	0	1	13	11	63	22
24	0	0	32	5	101	5
25	0	2	38	9	73	27
26	0	7	30	14	148	57
Rainy-season						
27	1	11	13	13	151	61
28	0	6	9	32	129	50
29	0	0	4	38	70	25
Post-rainy season						
30	0	0	0	30	77	26
31	0	0	0	13	75	24
32	0	0	0	9	38	12
33	0	0	0	4	25	7
34	0	0	0	0	15	4
35	0	0	0	0	11	3
36	0	0	0	0	1	1
Annual	345	432	545	676	810	565

Table 11. Total number of rainy days during a year, and during the growing season at Anantapur (database: 1911-1989; section: 2.6.1 and 2.6.2).

Year	[illegible] during a year	[illegible] number of rainy days in a year					Rainfall during the growing season	Total number of rainy days during the growing season				
		All rains	≥2.5	≥10	≥20	≥30		All rains	≥2.5	≥10	≥20	≥30
1911	464	51	31	13	7	4	188	10	8	6	3	1
1912	721	61	43	22	10	6	473	33	23	11	7	6
1913	583	47	32	13	7	4	499	37	25	10	6	4
1914	424	40	35	13	7	3	358	29	26	11	7	3
1915	771	69	45	17	10	6	•491	38	25	13	8	4
1916	764	76	49	22	13	5	554	44	31	15	11	5
1917	945	62	42	26	18	11	465	36	26	18	9	5
1918	498	45	26	15	10	6	240	20	14	8	5	3
1919	976	67	52	25	15	10	678	45	35	16	10	7
1920	394	37	25	11	7	3	208	13	11	5	3	3
1921	715	43	34	19	11	7	554	29	25	13	8	5
1922	497	43	29	12	10	5	154	18	12	4	3	1
1923	246	25	18	8	4	3	154	13	11	6	3	2
1924	734	38	30	17	11	6	522	24	21	11	8	4
1925	537	50	38	14	8	4	258	17	14	8	5	1
1926	530	26	20	9	7	5	277	9	9	5	3	3
1927	733	59	38	15	10	8	480	40	27	9	6	5
1928	526	50	31	13	8	6	402	35	22	10	8	5
1929	512	46	34	16	6	4	295	14	14	8	5	4
1930	685	63	46	26	10	5	519	40	27	20	8	5
1931	371	43	25	11	5	5	204	22	10	5	4	4
1932	733	63	36	21	11	7	487	38	20	13	6	4
1933	728	59	44	21	9	6	510	35	28	14	5	5
1934	234	40	21	7	1	1	143	19	10	5	1	1
1935	540	47	36	13	8	6	389	28	24	10	7	5
1936	443	43	35	12	5	3	246	19	16	6	3	2
1937	774	46	35	19	10	8	598	31	21	13	8	7
1938	750	51	42	21	12	7	639	36	32	18	10	7
1939	539	58	35	18	12	2	317	32	19	10	8	2
1940	709	44	35	22	12	5	438	20	16	11	7	[illegible]
1941	530	41	28	16	6	5	406	27	18	10	6	[illegible]
1942	300	27	14	8	5	2	209	14	6	5	3	2
1943	522	46	35	20	9	4	275	23	18	13	6	[illegible]
1944	517	33	23	11	9	7	417	22	14	9	8	[illegible]
1945	416	34	19	11	7	6	279	19	13	8	5	[illegible]
1946	282	22	13	6	6	3	161	12	7	3	3	[illegible]
1947	615	63	41	16	8	3	464	36	28	12	7	[illegible]
1948	391	39	30	11	3	1	140	16	12	6	1	0
1949	512	47	29	11	6	5	289	23	16	7	3	[illegible]
1950	457	35	26	13	8	5	330	26	18	10	6	[illegible]
1951	528	51	29	20	12	5	265	34	19	10	5	1
1952	351	55	34	8	5	2	192	37	20	3	2	1
1953	858	59	43	26	14	10	754	49	39	23	12	9
1954	335	31	25	12	5	2	168	18	13	6	3	0
1955	599	66	34	19	10	5	351	39	21	14	7	3
1956	854	78	47	23	13	8	474	43	29	17	8	3
1957	548	56	35	13	8	5	454	41	24	9	8	5
1958	540	62	41	14	7	4	437	42	29	10	7	4
1959	587	39	25	18	11	6	487	30	20	14	9	6
1960	555	44	25	16	7	6	444	21	15	12	7	6
1961	437	41	24	12	7	5	288	32	18	9	5	3
1962	619	65	48	18	9	7	271	30	24	8	3	2
1963	510	58	37	16	7	5	372	40	25	12	5	4
1964	655	65	37	18	11	5	611	47	33	17	11	5
1965	363	39	21	10	7	3	265	30	15	7	5	2
1966	623	60	42	17	9	7	469	38	28	13	8	6
1967	578	47	32	14	7	6	461	26	17	10	6	5
1968	552	53	40	14	6	3	295	20	16	7	3	2
1969	553	44	28	12	9	7	362	24	18	8	6	5
1970	663	48	35	19	10	8	514	35	25	15	8	6

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(Table 11 continued from the previous page)

Year	Rainfall during a year	Total number of rainy days in a year					Rainfall during the growing season	Total number of rainy days during the growing season				
		All rains	≥2.5	≥10	≥20	≥30		All rains	≥2.5	≥10	≥20	≥30
1971	582	49	32	15	7	6	388	26	17	10	5	4
1972	558	48	37	15	8	5	280	11	9	7	5	4
1973	721	46	28	16	14	10	491	31	18	10	9	6
1974	615	45	28	16	8	7	523	35	24	13	6	5
1975	699	58	38	22	12	6	575	42	26	17	11	5
1976	308	28	20	8	4	3	144	6	5	4	3	2
1977	765	49	39	26	12	8	451	32	24	16	8	5
1978	513	58	39	11	5	4	322	25	16	7	4	3
1979	627	60	39	18	9	5	372	21	12	11	7	4
1980	224	39	20	6	2	1	69	11	8	2	1	0
1981	528	53	37	16	7	5	399	27	23	12	7	5
1982	625	37	26	14	12	9	148	15	8	3	3	2
1983	725	51	35	21	13	7	543	38	29	18	10	5
1984	176	30	22	6	2	0	130	20	15	4	2	0
1985	392	45	33	13	5	3	301	31	21	10	5	3
1986	436	48	27	13	8	3	366	30	19	12	7	3
1987	502	44	29	10	8	4	365	22	17	8	7	3
1988	915	67	48	28	16	9	793	55	40	24	13	8
1989	821	51	36	17	12	8	688	33	26	14	10	6
Mean	565	49	33	16	9	5	380	28	20	10	6	4
Max	945	78	52	28	18	11	793	55	40	24	13	9
Min	176	22	13	6	1	0	69	6	5	2	1	0
Sd±	170	12	9	5	3	2	158	11	8	5	3	2

Table 12. Years with extremes for total number of rainy days in a year, and during the growing season at Anantapur (database: 1911-1989; section: 2.6.1 and 2.6.2).

A. During a year

Threshold rainfall (mm)	No. of rainy days during a year Mean	Maximum (Year)	Minimum (Year)
All rains	49	78 (1956)	22 (1946)
≥ 2.5	33	52 (1919)	13 (1946)
≥ 10	16	28 (1988)	6 (1946, 1980)
≥ 20	9	18 (1917)	1 (1934)
≥ 30	5	11 (1917)	0 (1984)

B. During the growing season

Threshold rainfall (mm)	No. of rainy days during the growing season Mean	Maximum (Year)	Minimum (Year)
All rains	28	55 (1988)	6 (1976)
≥ 2.5	20	40 (1988)	5 (1976)
≥ 10	10	24 (1988)	2 (1934,1948)
≥ 20	6	13 (1988)	1 (1980)
≥ 30	4	9 (1953)	0 (1948,1954, 1980,1984)

Table 13. Dry spells between rainy days in a year, and during the growing season at Anantapur (database: 1911-1989; section: 2.7.1 and 2.7.2)

Year	Dry spell in a year					Dry spell during growing season				
	All rains	≥2.5	≥10	≥20	≥30	All rains	≥2.5	≥10	≥20	≥30
1911	7	11	26	52	73	3	4	5	15	29
1912	6	9	16	33	52	3	4	8	13	13
1913	8	12	26	46	73	4	6	12	19	27
1914	9	11	26	46	91	4	5	11	18	31
1915	5	8	20	33	52	3	4	8	13	27
1916	5	8	16	26	61	2	4	7	9	16
1917	6	9	13	19	30	3	5	8	13	20
1918	8	13	23	33	52	5	7	12	16	24
1919	5	7	14	23	33	3	4	9	14	20
1920	10	15	30	46	91	3	4	7	12	12
1921	8	10	18	30	46	5	5	10	17	27
1922	8	13	28	33	61	7	11	32	32	64
1923	14	20	40	73	91	7	10	16	24	32
1924	9	13	20	30	52	5	6	10	14	28
1925	7	10	24	40	73	4	5	8	13	33
1926	13	17	36	46	61	4	4	7	12	12
1927	6	9	23	33	40	3	5	14	21	21
1928	7	12	26	33	52	3	6	12	15	20
1929	8	10	21	52	73	2	2	3	5	7
1930	6	8	13	33	61	3	5	7	15	23
1931	8	15	30	61	61	5	11	20	26	26
1932	6	10	17	30	46	3	6	9	20	30
1933	6	9	17	36	52	3	4	7	20	20
1934	9	19	46	182	182	5	12	19	48	48
1935	8	11	26	40	52	3	3	7	10	15
1936	8	11	28	61	91	6	7	18	27	35
1937	8	11	18	33	40	4	6	10	16	18
1938	7	9	17	28	46	2	2	4	7	9
1939	6	10	19	28	121	3	6	11	13	53
1940	8	11	16	28	61	3	3	5	7	13
1941	9	13	21	52	61	3	5	9	14	17
1942	13	26	40	61	121	8	19	23	38	57
1943	8	10	17	36	73	3	3	4	8	19
1944	11	16	30	37	46	6	9	14	15	20
1945	10	18	30	46	52	4	6	10	16	20
1946	16	26	52	52	91	6	10	18	18	23
1947	6	9	21	40	91	2	3	6	11	26
1948	9	13	30	91	183	5	6	12	37	74
1949	8	12	30	52	61	4	6	11	22	22
1950	10	13	26	40	61	5	7	12	20	23

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Table 13 continued from the previous page)

Year	Dry spell in a year					Dry spell during growing season				
	All rains	≥2.5	≥10	≥20	≥30	All rains	≥2.5	≥10	≥20	≥30
1951	7	12	17	28	61	4	8	13	25	74
1952	7	11	41	61	122	3	5	26	35	52
1953	6	8	13	24	33	2	3	4	8	11
1954	11	14	28	61	121	5	6	14	27	81
1955	5	11	18	33	73	2	4	6	11	30
1956	5	8	15	26	41	2	3	6	12	25
1957	6	10	26	40	61	3	5	14	16	25
1958	6	9	24	46	91	3	5	14	20	47
1959	9	14	19	30	52	4	6	8	13	19
1960	8	14	21	46	52	4	5	7	11	13
1961	9	15	28	46	61	5	8	17	30	50
1962	6	7	19	36	52	3	4	13	33	50
1963	6	10	21	46	61	3	4	8	20	25
1964	6	10	19	30	61	3	4	7	12	25
1965	9	17	33	46	91	4	8	16	23	38
1966	6	9	21	36	46	3	4	10	15	20
1967	8	12	26	46	52	3	5	9	14	17
1968	7	9	24	52	91	2	2	5	9	12
1969	8	13	28	36	46	4	6	11	14	16
1970	7	10	18	33	40	3	4	6	12	16
1971	7	11	23	46	52	3	4	7	13	17
1972	7	10	23	41	61	2	3	4	5	6
1973	8	13	21	26	33	4	7	12	14	18
1974	8	13	23	40	46	4	6	12	23	28
1975	6	9	17	30	52	2	4	6	10	17
1976	13	18	41	73	91	7	8	10	13	20
1977	7	9	13	28	40	4	5	8	16	21
1978	6	10	30	61	73	3	6	12	17	22
1979	6	10	19	36	61	2	4	4	7	12
1980	9	17	52	122	183	4	6	15	23	46
1981	7	10	21	46	61	3	3	6	11	15
1982	10	14	24	28	36	6	12	28	28	42
1983	7	10	17	26	46	3	4	7	12	24
1984	12	16	52	122	365	5	6	23	46	91
1985	8	11	26	61	91	3	4	8	17	28
1986	7	13	26	40	91	4	7	11	18	43
1987	8	13	33	40	73	4	5	10	12	27
1988	5	7	13	21	37	2	3	6	10	17
1989	7	10	20	28	40	3	4	7	9	15
Mean	8	12	25	44	72	4	6	11	17	28
Max	16	26	52	182	365	8	19	32	48	91
Min	5	7	13	19	30	2	2	3	5	6
Sd±	2	4	9	24	46	1	3	6	9	17

Table 14. Years with extreme dry spells during a year, and during the growing season at Anantapur (database: 1911-1989 section: 2.7.1 and 2.7.2).

A. During a year

Threshold rainfall (mm)	Dry spells during a year Mean (days)	Maximum. (Year)	Minimum (Year)
All rains	8	16 (1946)	5 (1915,1916,1919, 1955,1956,1988)
≥ 2.5	12	26 (1942)	7 (1919,1962,1988)
≥ 10	25	52 (1980)	13 (1917,1930,1953 1977,1988)
≥ 20	44	182 (1934)	19 (1917)
≥ 30	72	365 (1984)	30 (1917)

B. During the growing season

Threshold rainfall (mm)	Dry spells during the growing season Mean (days)	Maximum (Year)	Minimum (Year)
All rains	4	8 (1942)	2 (1916,1929,1938, 1953,1955,1956, 1968,1972,1975, 1979,1988)
≥ 2.5	6	19 (1942)	2 (1929,1938,1968)
≥ 10	11	32 (1922)	3 (1929)
≥ 20	17	48 (1934)	5 (1929)
≥ 30	28	91 (1984)	6 (1972)

Table 15. Generalised characteristics of daily rainfall at Anantapur (database 1911-1989; section: 2.8.1).

Month	Mean total number of rainy days		Highest no. of rainy days		Lowest no. of rainy days		Extremes of rainfall during single rainy day		Mean duration (d) between rains during the month (lowest-highest)
	All rains	≥2.5	All rains	≥2.5	All rains	≥2.5	Highest (*)	Lowest	
January	0.3	0.2	4	2	0	0	82.6 (25)	0.3	30 (2-31)
February	0.4	0.3	3	3	0	0	63.0 (30)	1.0	28 (2-28)
March	0.5	0.4	4	3	0	0	32.8 (41)	0.3	29 (2-31)
April	1.8	1.2	6	6	0	0	67.1 (144)	0.1	24 (2-30)
May	4.7	3.1	10	7	0	0	82.6 (373)	0.2	13 (2-31)
June	5.2	3.2	12	7	0	0	113.8 (412)	0.1	13 (2-30)
July	6.6	3.7	19	11	1	0	180.0 (523)	0.1	12 (2-31)
August	7.2	4.5	20	17	0	0	118.6 (572)	0.2	13 (2-31)
September	9.1	6.6	18	16	0	0	130.2 (720)	0.1	9 (2-30)
October	7.6	5.4	19	16	0	0	145.2 (598)	0.2	11 (2-31)
November	4.0	2.6	12	8	0	0	99.3 (313)	0.1	19 (2-31)
December	1.2	0.7	5	5	0	0	49.3 (95)	0.2	28 (2-30)

(*) Mean number of rainy days in a month.

Table 16. Length of the rainy season (days) and total amount of rainfal (mm) before, during, and after the start of the rainy season. The annual rainfall and the percentage of rain falling during the growing season are also shown (database 1911-1989; section 2.9.1 and 2.9.2).

Year	Rainy season Start[a]	End[b]	Length[c]	Rainfall total Before (mm)	During (mm)	After (mm)	Annual rainfall (mm)	Growing season (%)
	<---(Julian days)--->							
1911	261	290	30	215	188	60	463	41
1912	196	285	90	87	473	160	721	66
1913	156	289	134	80	499	4	583	86
1914	161	286	126	36	358	30	424	84
1915	197	304	108	170	491	109	770	64
1916	179	277	99	39	554	170	763	73
1917	154	274	121	244	465	235	944	49
1918	180	274	95	117	240	140	497	48
1919	156	293	138	125	678	171	975	70
1920	246	283	38	176	208	10	394	53
1921	153	288	136	45	554	116	715	78
1922	155	283	129	181	154	162	497	31
1923	179	274	96	92	154	1	246	63
1924	186	297	112	138	522	74	734	71
1925	224	289	66	160	258	118	536	48
1926	252	287	36	243	277	10	530	52
1927	159	285	127	57	480	195	732	66
1928	178	296	119	124	402	0	525	76
1929	260	286	27	127	295	90	511	58
1930	165	304	140	92	519	73	684	76
1931	172	274	103	75	204	92	370	55
1932	155	275	121	39	487	207	732	66
1933	203	301	99	154	510	63	727	70
1934	208	304	97	82	143	9	233	61
1935	229	302	74	150	389	0	539	72
1936	173	279	107	106	246	91	442	56
1937	161	285	125	161	598	15	773	77
1938	213	281	69	108	639	2	749	85
1939	169	274	106	70	317	151	538	59
1940	253	305	53	186	438	85	709	62

Continued >>>

[a]**Start of rainy season (X)**: as the first day between June 1 and October 1 when at least a total of 20 mm of rain is received in five days (not necessary consecutive days), and at least there is one rainy day with >2.5 mm rainfall in the next 10 days.
[b]**End of rainy season (Y)**: as the last day of the first dry spell of 10 days ending between October 1 and November 30.
[c]**Length of rainy season**: the difference between the start and end of rain is the length of rainy season (Y-X).

(Table 16 continued from previous page)

Year	Rainy season Start	End	Length	Rainfall total Before (mm)	During (mm)	After (mm)	Annual rainfall (mm)	Growing season (%)
	<---(Julian	days)	--->					
1941	204	289	86	69	406	55	530	77
1942	161	274	114	60	209	31	299	70
1943	243	301	59	191	275	56	521	53
1944	181	303	123	99	417	0	516	81
1945	200	279	80	104	279	32	415	67
1946	204	274	71	120	161	0	282	57
1947	216	293	78	107	464	43	614	76
1948	219	293	75	88	140	163	391	36
1949	185	274	90	133	289	90	512	56
1950	176	293	118	95	330	31	456	72
1951	154	302	149	260	265	3	528	50
1952	195	299	105	120	192	38	350	55
1953	201	302	102	104	754	0	858	88
1954	200	281	82	41	168	126	335	50
1955	213	302	90	218	351	31	599	59
1956	206	305	100	226	474	153	853	56
1957	154	279	126	59	454	35	547	83
1958	152	294	143	80	437	23	540	81
1959	168	281	114	83	487	17	586	83
1960	198	278	81	68	444	42	554	80
1961	154	304	151	129	288	20	436	66
1962	176	276	101	109	271	239	619	44
1963	197	298	102	135	372	2	509	73
1964	166	293	128	14	611	30	655	93
1965	159	274	116	36	265	62	362	73
1966	156	278	123	57	469	97	622	75
1967	197	282	86	108	461	8	577	80
1968	252	288	37	171	295	86	551	53
1969	207	304	98	179	362	11	552	65
1970	202	295	94	148	514	0	663	78
1971	234	300	67	188	388	5	581	67
1972	260	285	26	179	280	99	557	50
1973	155	279	125	12	491	218	721	68
1974	162	302	141	90	523	1	614	85
1975	202	304	103	68	575	55	698	82
1976	235	275	41	117	144	46	307	47
1977	166	294	129	230	451	83	765	59
1978	188	274	87	73	322	118	513	63
1979	241	289	49	109	372	146	626	59
1980	229	275	47	96	69	59	224	31

Continued >>>

(Table 16 continued from previous page)

Year	Rainy season Start	End	Length	Rainfall total Before (mm)	During (mm)	After (mm)	Annual rainfall (mm)	Growing season (%)
	<---(Julian	days)	--->					
1981	204	280	77	51	399	77	528	76
1982	190	274	85	192	148	284	624	24
1983	156	278	123	143	543	39	725	75
1984	194	285	92	25	130	21	176	74
1985	202	285	84	66	301	25	392	77
1986	155	283	129	22	366	47	435	84
1987	216	297	82	102	365	35	501	73
1988	152	285	134	112	793	9	914	87
1989	188	279	92	128	688	4	821	84
Mean	192*	288*	97	115	380	70	565	66
Max	261	305	151	260	793	284	975	93
Min	152	274	26	12	69	0	176	24
Sd±	32	11	31	59	158	68	171	15

* Julian day 192 = July 11
* Julian day 288 = October 15

Table 17. Forward and backward accumulation of rainfall at Anantapur (database: 1911-1989; section: 2.9.3)

Year	Forward accumu Std. Wk.[b]	P%[c]	Backward accumlation Std.Wk.	P%
1911	18	1	52	99
1912	19	3	51	98
1913	20	4	50	96
1914	20	5	50	95
1915	20	6	50	94
1916	20	8	50	93
1917	20	9	50	91
1918	20	10	49	90
1919	20	11	49	89
1920	21	13	48	88
1921	21	14	48	86
1922	21	15	48	85
1923	21	16	48	84
1924	21	18	48	83
1925	21	19	47	81
1926	21	20	47	80
1927	21	21	47	79
1928	21	23	47	78
1929	22	24	47	76
1930	22	25	47	75
1931	22	26	47	74
1932	22	28	47	73
1933	22	29	47	71
1934	22	30	46	70
1935	22	31	46	69
1936	22	33	46	68
1937	22	34	46	66
1938	22	35	46	65
1939	23	36	46	64
1940	23	38	46	63
1941	23	39	45	61
1942	23	40	45	60
1943	23	41	45	59
1944	23	43	45	58
1945	23	44	45	56
1946	23	45	45	55
1947	23	46	45	54
1948	23	48	45	53
1949	24	49	45	51
1950	24	50	45	50
1951	24	51	45	49
1952	24	53	45	48
1953	24	54	45	46
1954	25	55	45	45
1955	25	56	45	44
1956	26	58	44	43
1957	26	59	44	41
1958	26	60	44	40
1959	26	61	44	39
1960	26	63	44	38

Continued >>>

[a]Forward accumlation refers to accumulation of >75 mm of rainfall from the standard week 18.

[b]Std. Wk. (standard week): The corresponding week receiving ≥75 mm and ≥20 mm rainfall respectively.

[c]P refers to the probability percentage.

[d]Backward accumulation refers to backward accumulation of >20 mm of rainfall from the standard week 52.

(Table 17 continued from previous page)

Year	Forward accumulation Std. Wk.	P%	Backward accumlation Std.Wk.	P%
1961	26	64	44	36
1962	26	65	44	35
1963	26	66	44	34
1964	26	68	44	33
1965	26	69	43	31
1966	26	70	43	30
1967	27	71	43	29
1968	27	73	43	28
1969	28	74	43	26
1970	28	75	43	25
1971	28	76	43	24
1972	29	78	43	23
1973	29	79	42	21
1974	29	80	42	20
1975	29	81	42	19
1976	29	83	42	18
1977	29	84	42	16
1978	30	85	41	15
1979	30	86	41	14
1980	30	88	41	13
1981	30	89	41	11
1982	30	90	41	10
1983	31	91	41	9
1984	31	93	40	8
1985	32	94	40	6
1986	32	95	40	5
1987	32	96	39	4
1988	32	98	37	3
1989	32	99	33	1

Table 18. Probability of dry spells for two consecutive, and three consecutive weeks at Anantapur during the growing season (database: 1911-1989; section: 2.9.3).

Std. Wk.	Dry	Dry/Dry	P of dry spells 2 week	P of dry spells 3 week
Pre-rainy season				
25	82	67	34	20
26	63	42	37	20
27	76	58	40	17
28	73	53	31	15
29	65	42	31	13
30	67	48	28	17
31	63	42	38	16
32	77	61	31	10
33	62	41	20	7
34	59	33	21	7
35	65	35	20	4
36	57	32	11	1
Rainy season				
37	47	19	5	1
38	34	11	6	1
39	39	16	6	1
40	41	16	8	3
41	44	20	17	8
Post-rainy season				
42	61	39	27	10
43	63	44	24	11
44	63	38	29	18
45	68	46	42	28
46	78	62	53	39
47	82	67	61	50
48	87	75	71	57
49	91	81	74	71
50	91	81	88	80
51	99	96	90	0
52	96	91	0	0

Table 19. Monthly statistics on maximum air temperature and its probabilities (database: 1911-1989; section: 3.1).

Month	Mean temp (°C)	Standard deviation (Sd±)	CV %	Maximum Temp (°C)	Range (°C)	Absolute Temp (°C)	Probability (%) of Maximum Temperature				
							≥25°C	≥30°C	≥35°C	≥40°C	≥45°C
January	30.4	0.2	0.8	31.0	2.0	34.2	100	97	0	0	0
February	33.6	0.4	1.3	35.3	3.4	38.6	100	94	0	0	0
March	37.1	0.4	1.0	38.4	3.0	41.1	100	100	100	0	0
April	39.6	1.2	3.1	50.3	11.9	43.4	100	100	100	1	0
May	39.0	0.5	1.3	41.1	4.6	43.3	100	100	100	3	0
June	35.0	0.6	1.7	38.7	6.4	41.2	100	100	3	0	0
July	33.2	0.4	1.3	35.2	3.4	37.8	100	100	1	0	0
August	32.4	0.4	1.3	33.7	2.7	37.5	100	100	0	0	0
September	32.3	0.5	1.7	34.6	4.5	37.0	100	97	0	0	0
October	31.9	0.4	1.3	34.0	3.5	36.5	100	100	0	0	0
November	30.0	0.4	1.2	31.7	3.0	34.2	100	3	0	0	0
December	29.4	0.4	1.3	30.8	2.8	33.5	100	6	0	0	0
Annual	33.7	0.3	0.8	35.2	2.3	33.5	--	--	--	--	--

Table 20. Monthly statistics of minimum air temperature and its probabilities at Anantapur (database 1911-1989; section: 3.2

Month	Mean temp (°C)	Standard deviation (Sd±)	CV %	Minimum Temp (°C)	Range (°C)	Absolute Minimum (°C)	Probability (%) of Minimum Temperature ≥10°C	≥15°C	≥20°C	≥25°C	≥30°C
January	16.9	0.4	2.6	15.3	3.2	12.5	100	100	0	0	0
February	19.4	0.5	2.5	17.0	1.9	14.0	100	100	0	0	0
March	22.0	0.4	1.6	20.8	2.7	17.0	100	100	100	0	0
April	25.5	1.5	5.8	22.7	15.3	17.0	100	100	100	8	0
May	26.0	0.5	1.8	23.4	5.3	18.2	100	100	100	95	0
June	24.6	0.5	1.9	22.4	5.2	20.0	100	100	100	0	0
July	23.8	0.3	1.3	22.2	2.4	16.5	100	100	100	0	0
August	23.4	0.2	1.1	22.4	2.2	20.9	100	100	100	0	0
September	23.0	0.3	1.2	21.6	2.4	19.8	100	100	100	0	0
October	22.0	0.3	1.2	20.9	2.0	16.5	100	100	100	0	0
November	19.5	0.5	2.5	17.1	4.2	13.0	100	100	1	0	0
December	17.6	0.3	2.0	15.5	3.3	11.5	100	100	0	0	0
Annual	22.0	0.3	1.4	20.9	2.9	11.5	--	--	--	--	--

Table 21. Monthly statistics on heat units at Anantapur, (database: 1911-1989; section: 3.3)

Month	Mean Heat units	Range		Standard deviation (Sd±)
		Maximum value	Minimum value	
January	14.2	15.0	12.8	0.4
February	15.7	16.5	14.0	0.4
March	16.5	17.4	10.0	0.8
April	18.7	19.3	15.5	0.6
May	19.2	19.6	10.0	1.2
June	18.8	19.0	17.0	0.4
July	17.4	18.8	10.0	0.9
August	17.4	18.4	10.0	1.3
September	17.6	18.3	16.9	0.2
October	16.8	17.3	15.3	0.4
November	14.2	15.7	12.3	0.4
December	13.1	14.3	10.8	0.4
Annual	16.6	17.5	12.9	0.6

Maximum upper limit of 34°C
Minimum lower limit of 6°C
Base temperature: 10°C

Table 22. Monthly statistics on wind speed and wind direction at Anantapur (database 1976-1989; section: 4.1).

Month	Wind speed (Km h^{-1})	Wind direction
January	9	North East
February	8	North East
March	8	North East
April	9	North East
May	13	North East
June	18	South West
July	20	South West
August	20	South West
September	11	South West
October	6	North East
November	6	North East
December	8	North East
Annual	11	-

Table 23. Monthly statistics on relative humidity, atmospheric pressure and vapor pressure at Anantapur (database: 1976-1989; section: 4.2).

Month	Relative humidity (%)		Mean atmospheric pressure (mb)	Vapor pressure deficit (mb)
	Morning (0720 hr)	Afternoon (1400 hr)		
January	82	43	973	16.0
February	65	32	971	13.8
March	61	26	970	13.4
April	55	25	968	17.8
May	64	31	965	21.1
June	70	42	965	23.2
July	78	50	965	23.4
August	81	53	966	23.5
September	80	51	967	23.2
October	77	47	969	23.5
November	80	49	972	19.0
December	83	49	974	17.2
Annual	66	41	967	19.6

Table 24. Mean daily and monthly statistics for pan evaporation and potential evapotranspiration at Anantapur (databas 1911-1989; section: 4.3).

Month	Pan evaporation Daily (mm)	Pan evaporation Monthly (mm)	Potential evapotranpiration Daily (mm)	Potential evapotranpiration Monthly (mm)
January	5.7	176.7	4.3	132.8
February	8.0	224.0	6.0	168.0
March	10.0	310.0	7.5	232.5
April	11.0	330.0	8.3	248.3
May	10.9	337.9	8.2	254.3
June	9.4	282.0	7.1	212.3
July	8.2	254.2	6.2	191.3
August	7.6	235.6	5.7	175.5
September	5.7	171.0	4.4	131.3
October	5.2	161.2	3.9	120.0
November	5.0	150.0	3.8	112.5
December	4.9	151.9	3.7	114.8
Annual	7.6	210.0	5.8	174.5

Table 25. Monthly statistics on climatic water balance at Anantapur (database: 1976 -1989; section: 4.3.2).

Month	Mean rainfall (mm)	Mean PET (mm)	Mean R/PET[a]	Mean DP (75%)	Mean MAI[b]
January	2.8	132.8	0.02	1	0.007
February	3.9	168.0	0.02	1	0.006
March	4.5	232.5	0.02	1	0.004
April	14.4	248.3	0.06	4	0.016
May	54.1	254.3	0.21	22	0.086
June	52.9	212.3	0.25	27	0.127
July	60.2	191.3	0.31	16	0.084
August	74.4	175.5	0.42	18	0.103
September	144.5	131.3	1.10	62	0.472
October	101.7	120.0	0.85	35	0.292
November	42.6	112.5	0.38	7	0.062
December	8.9	114.8	0.08	1	0.009
Annual	565.1	2093.6	-	-	-

[a]R/PET Calculated as the ratio of rainfall to potential evapotranspiration (PET).

[b]MAI (Moisture availability index) calculated as ratio of DP (Dependable precipitation) to potential evapotranspiration (PET).

Table 26. Weekly climatic water balance at Anantapur (database: 1911-1989; section: 4.3.3).

Week	Mean Rain (mm)	Mean PET (mm)	Mean AE (mm)	Mean AE/PET	Mean DP (75%)	Mean MAI	Mean Deficit (mm)	Mean Run-off (mm)	Mean SMOS (mm)
1	1.3	28.0	1.8	0.07	0.6	0.021	0.9	0.0	1.[illegible]
2	1.2	29.0	1.3	0.04	0.6	0.021	0.7	0.0	1.[illegible]
3	0.3	31.0	1.2	0.04	0.8	0.026	0.7	0.0	0.[illegible]
4	0.1	33.0	1.0	0.03	0.9	0.027	0.6	0.0	0.[illegible]
5	2.3	36.0	1.6	0.04	0.5	0.014	0.2	0.3	1.2
6	0.3	39.0	1.5	0.04	0.0	0.000	0.7	0.0	0.[illegible]
7	0.1	42.0	1.3	0.03	0.2	0.007	0.5	0.0	0.1
8	0.8	44.0	1.4	0.03	0.0	0.000	0.1	0.0	0.1
9	0.9	47.0	1.7	0.04	0.6	0.005	0.1	0.0	0.1
10	0.5	50.0	1.4	0.03	0.7	0.014	0.1	0.0	0.1
11	0.6	52.0	1.5	0.03	0.7	0.013	0.1	0.0	0.0
12	1.2	54.0	2.1	0.04	0.7	0.013	0.1	0.0	0.0
13	2.5	55.0	3.5	0.06	0.7	0.013	0.3	0.0	0.0
14	2.2	56.0	3.2	0.06	0.8	0.014	0.3	0.0	0.0
15	2.6	57.0	3.6	0.06	0.8	0.014	0.4	0.0	0.0
16	4.7	58.0	5.5	0.10	0.9	0.016	0.6	0.0	0.4
17	3.1	58.0	4.7	0.08	0.9	0.016	1.0	0.0	0.0
18	7.3	58.0	8.3	0.14	1.1	0.019	0.8	0.0	0.4
Pre-rainy									
19	7.0	58.0	8.5	0.15	1.3	0.022	1.4	0.0	0.3
20	13.7	57.0	14.5	0.25	2.1	0.037	1.6	0.0	1.2
21	17.9	55.0	17.6	0.32	2.8	0.051	2.3	0.0	2.9
22	15.4	54.0	18.1	0.34	2.8	0.052	3.8	0.0	1.4
23	19.5	52.0	17.9	0.35	3.1	0.060	1.9	0.0	3.8
24	8.6	50.0	11.4	0.23	1.3	0.026	2.9	0.0	1.4
25	6.3	48.0	7.1	0.15	1.5	0.031	0.8	0.0	0.9
26	12.9	47.0	11.3	0.24	2.3	0.049	0.6	0.0	2.7
27	8.4	46.0	9.8	0.21	1.8	0.039	2.0	0.0	1.5
28	11.0	44.0	9.7	0.22	1.8	0.041	0.7	0.0	3.0
29	21.3	43.0	12.9	0.30	2.3	0.053	0.8	0.0	6.6
30	15.5	42.0	14.1	0.34	2.4	0.057	2.9	3.9	7.6
31	13.0	41.0	13.9	0.34	2.1	0.051	3.9	0.5	6.8
32	11.1	40.0	11.0	0.28	1.4	0.035	3.4	0.0	5.9
33	16.9	39.0	13.3	0.34	2.4	0.062	2.4	1.0	8.0
34	23.2	38.0	14.8	0.39	2.2	0.058	2.5	1.6	12.7
35	19.4	36.0	15.1	0.42	2.8	0.078	4.7	3.7	14.3
36	16.3	34.0	16.7	0.49	4.1	0.121	5.8	2.8	13.2
37	32.2	32.0	18.4	0.57	8.5	0.266	3.4	0.6	22.8
Rainy									
38	51.7	30.0	22.6	0.75	6.3	0.210	4.1	4.2	38.6
39	39.3	29.0	23.8	0.82	4.6	0.159	7.5	13.4	39.5
40	30.8	29.0	22.3	0.77	3.4	0.117	7.1	14.6	38.8
41	31.0	28.0	21.4	0.77	2.3	0.082	8.5	9.2	37.1
42	15.7	27.0	20.7	0.77	2.1	0.078	10.7	11.3	30.8
Post-rainy									
43	19.9	27.0	18.6	0.69	1.7	0.063	9.3	1.3	28.3
44	13.6	27.0	16.1	0.60	1.4	0.052	8.1	3.9	23.3
45	17.3	26.0	14.8	0.57	1.1	0.042	7.5	2.5	22.2
46	8.0	26.0	12.4	0.48	0.9	0.035	7.3	3.6	16.8
47	5.3	26.0	10.2	0.39	0.7	0.027	6.5	0.9	11.9
48	3.8	26.0	7.6	0.29	0.7	0.027	5.2	0.0	8.2
49	2.6	26.0	5.2	0.20	0.7	0.027	3.8	0.0	5.6
50	3.5	26.0	4.5	0.17	0.7	0.027	2.5	0.0	4.6
51	0.5	26.0	2.8	0.11	0.7	0.027	2.3	0.0	2.3
52	1.0	27.0	2.0	0.07	0.7	0.026	1.2	0.0	1.5

Rain= 565.6 mm;
PET = Potential evapotranspiration;
AE = Actual evaporation;
AE/PET = Ratio of actual evaporation and potential evapotranspiration;
DP = Dependable precipitation;
MAI = Moisture availability index;
Deficit = 147.6 mm;
Run off = 79.5 mm;
(Soi[illegible]isture) = 433.2 mm.

Table 27. Monthly statistics for cloudiness, sunshine hours, daylength and solar radiation at Anantapur (database: 1911-1989; section: 5.0).

Month	Cloudiness (Oktas)	Sunshine h mon⁻¹	Sunshine h day⁻¹	Daylength h	Daylength min	Radiation MJ(daily)
January	2	279	9.0	12	03	20.2
February	2	252	9.0	12	08	22.7
March	2	310	10.0	12	15	23.9
April	3	300	10.0	13	07	23.8
May	5	310	10.0	13	12	23.0
June	6	210	7.0	13	13	19.1
July	7	155	5.0	13	10	16.2
August	7	186	6.0	13	02	17.3
September	6	210	7.0	12	12	18.7
October	6	248	8.0	13	05	18.1
November	4	241	8.0	12	07	18.7
December	3	248	8.0	12	00	18.7
Annual	4	220	8.0	13	02	20.0

Table 28. Initial and conditional probability of rainfall for week # 25 for Anantapur station receiving more than 10 mm rainfall based on 79 years of rainfall data (database 1911-1989; section: Appendix A).

Year	Rainfall data		No. of weeks		
	Week # 25	Week # 26	W	W/W	W/D
1911	0.0	6.9	0	0	1
1912	1.8	17.8	0	0	2
1913	1.3	10.2	0	0	3
1914	0.0	3.3	0	0	3
1915	4.6	6.6	0	0	3
1916	2.5	28.5	0	0	4
1917	7.9	26.9	0	0	5
1918	0.8	25.5	0	0	6
1919	33.0	3.3	1	0	6
1920	6.6	7.1	1	0	6
1921	0.0	0.0	1	0	7
1922	0.0	0.0	1	0	7
1923	1.3	20.3	1	0	7
1924	0.0	0.8	1	0	7
1925	22.6	2.3	2	0	7
1926	0.0	113.8	2	0	8
1927	0.0	18.3	2	0	9
1928	0.0	38.3	2	0	10
1929	0.0	14.2	2	0	11
1930	0.0	5.6	2	0	11
1931	35.3	8.2	3	0	11
1932	0.0	12.7	3	0	12
1933	0.0	0.0	3	0	12
1934	0.0	1.1	3	0	12
1935	1.0	16.1	3	0	13
1936	26.7	3.8	4	0	13
1937	20.6	0.0	5	0	13
1938	13.0	0.0	6	0	13
1939	30.5	50.6	7	1	13
1940	0.0	0.0	7	1	13
1941	13.0	5.8	8	1	13
1942	5.1	1.3	8	1	13
1943	0.0	19.8	8	1	14
1944	0.0	80.6	8	1	15
1945	0.0	0.0	8	1	15
1946	0.0	0.0	8	1	15
1947	19.3	7.4	9	1	15
1948	0.0	0.8	9	1	15
1949	0.5	18.8	9	1	16
1950	5.8	26.7	9	1	17
1951	0.0	0.0	9	1	17
1952	6.6	0.0	9	1	17
1953	0.0	0.0	9	1	17
1954	0.0	0.0	9	1	17
1955	2.8	8.4	9	1	17
1956	3.3	4.9	9	1	17
1957	9.4	2.6	9	1	17
1958	0.0	5.6	9	1	17
1959	53.1	25.9	10	2	17
1960	0.7	12.0	10	2	18
1961	42.6	0.0	11	2	18
1962	0.0	32.0	11	2	19
1963	0.0	21.1	11	2	20
1964	20.6	0.0	12	2	20
1965	0.0	11.0	12	2	21
1966	11.3	0.0	13	2	21
1967	1.0	3.5	13	2	21
1968	9.3	14.3	13	2	22
1969	2.3	63.8	13	2	23
1970	9.0	3.4	13	2	23

Continued >>>

(Table 28 continued from previous page)

Year	Rainfall data		No. of weeks		
	Week # 25	Week # 26	W	W/W	W/D
1971	4.2	0.0	13	2	23
1972	28.8	0.0	14	2	23
1973	0.0	38.0	14	2	24
1974	0.0	0.0	14	2	24
1975	3.0	0.0	14	2	24
1976	8.4	2.6	14	2	24
1977	2.0	5.0	14	2	24
1978	7.5	0.0	14	2	24
1979	4.8	0.0	14	2	24
1980	0.0	0.0	14	2	24
1981	4.7	1.2	14	2	24
1982	0.0	54.2	14	2	25
1983	0.0	11.9	14	2	26
1984	0.0	0.0	14	2	26
1985	4.5	0.0	14	2	26
1986	1.6	0.0	14	2	26
1987	4.2	82.7	14	2	27
1988	0.2	2.2	14	2	27
1989	0.0	10.2	14	2	28

Table 29. Gamma distribution of rainfall for week # 25 for 79 years of Anantapur (database 1911-1989; section: Appendix B).

Year	Rainfall	ln x
1911	0.0	0.00000
1912	1.8	0.58779
1913	1.3	0.26236
1914	0.0	0.00000
1915	4.6	1.52606
1916	2.5	0.91629
1917	7.9	2.06686
1918	0.8	-0.22314
1919	33.0	3.49651
1920	6.6	1.88707
1921	0.0	0.00000
1922	0.0	0.00000
1923	1.3	0.26236
1924	0.0	0.00000
1925	22.6	3.11795
1926	0.0	0.00000
1927	0.0	0.00000
1928	0.0	0.00000
1929	0.0	0.00000
1930	0.0	0.00000
1931	35.3	3.56388
1932	0.0	0.00000
1933	0.0	0.00000
1934	0.0	0.00000
1935	1.0	0.00000
1936	26.7	3.28466
1937	20.6	3.02529
1938	13.0	2.56495
1939	30.5	3.41773
1940	0.0	0.00000
1941	13.0	2.56495
1942	5.1	1.62924
1943	0.0	0.00000
1944	0.0	0.00000
1945	0.0	0.00000
1946	0.0	0.00000
1947	19.3	2.96011
1948	0.0	0.00000
1949	0.5	-0.69315
1950	5.8	1.75786
1951	0.0	0.00000
1952	6.6	1.88707
1953	0.0	0.00000
1954	0.0	0.00000
1955	2.8	1.02962
1956	3.3	1.19392
1957	9.4	2.24071
1958	0.0	0.00000
1959	53.1	3.97218
1960	0.7	-0.35667
1961	42.6	3.75185
1962	0.0	0.00000
1963	0.0	0.00000
1964	20.6	3.02529
1965	0.0	0.00000
1966	11.3	2.42480
1967	1.0	0.00000
1968	9.3	2.23000
1969	2.3	0.83290
1970	9.0	2.19720

Cont'd >>>

(Table 29 continued from previous page)

Year	Rainfall	ln x
1971	4.2	1.43510
1972	28.8	3.36040
1973	0.0	0.00000
1974	0.0	0.00000
1975	3.0	1.09860
1976	8.4	2.12820
1977	2.0	0.69310
1978	7.5	2.01490
1979	4.8	1.56860
1980	0.0	0.00000
1981	4.7	1.54760
1982	0.0	0.00000
1983	0.0	0.00000
1984	0.0	0.00000
1985	4.5	1.50410
1986	1.6	0.47000
1987	4.2	1.43510
1988	0.2	-1.60940
1989	0.0	0.00000

Table 30. Comparison of rainfall characteristics of Anantapur and Hyderabad (database 1911-1989 for Anantapur and 1901-1970 for Hyderabad; section: Appendix A).

Characteristics	Location	
	Anantapur	Hyderabad
1. Latitude	14° 41′	17° 27′
2. Longitude	77° 37′	77° 37′
3. Altitude (meters)	349	545
4. Mean rainfall (mm)	565	764
5. Dependable-precipitation (mm)	444	602
6. Mean potential-evapotranspiration (mm)	2094	1758
7. Coefficient of variation (%)	30	26
8. Water holding capacity (mm)	50	150
9. Thornthwaite moisture index	-73.0	-56.5
10. Rainfall characteristics:		
a. Start of the rainy season	July 11 (±32)[$$]	June 12 (±9)
b. End of the rainy season	Oct 15 (±11)	Nov 8 (±9)
c. Length of the rainy season	97 days (+31)	130 days (±14)

$$ - Standard deviation.

FIGURES

Fig.1. Geographical location of Anantapur in Andhra Pradesh, India.

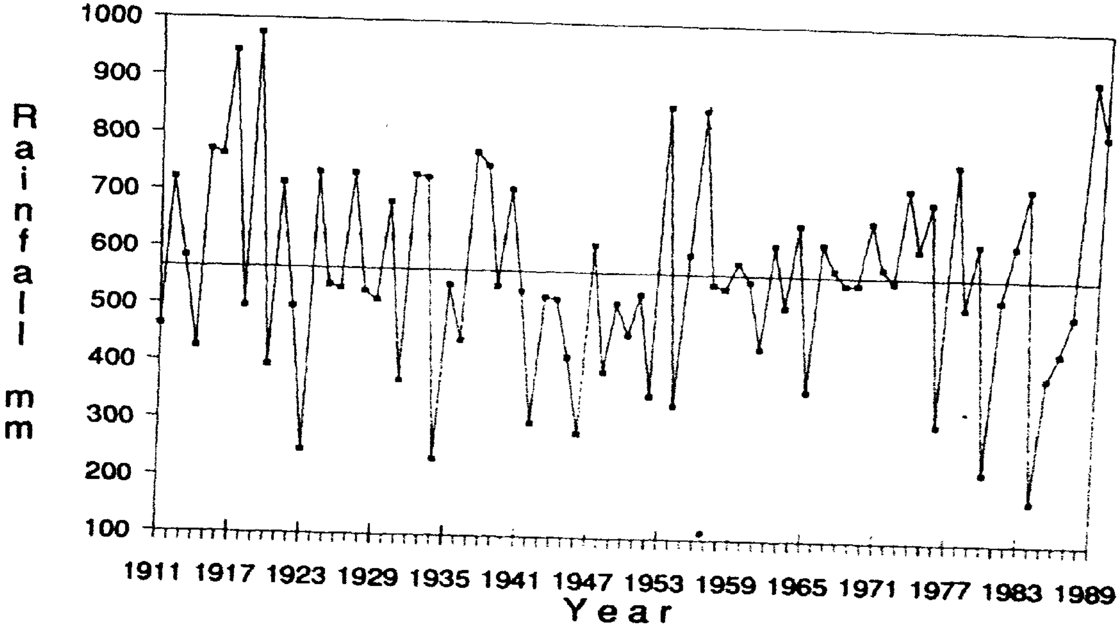

Fig.2. Variability in annual rainfall at Anantapur (database 1911-1989).

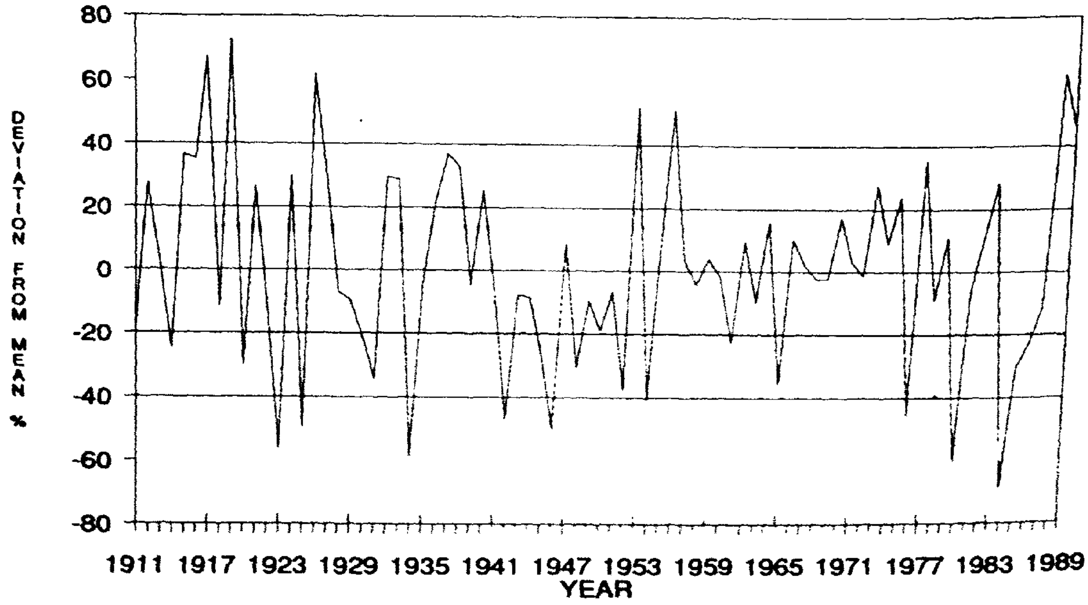

Fig.3. Percentage deviation of annual rainfall from the mean rainfall at Anantapur (database 1911-1989).

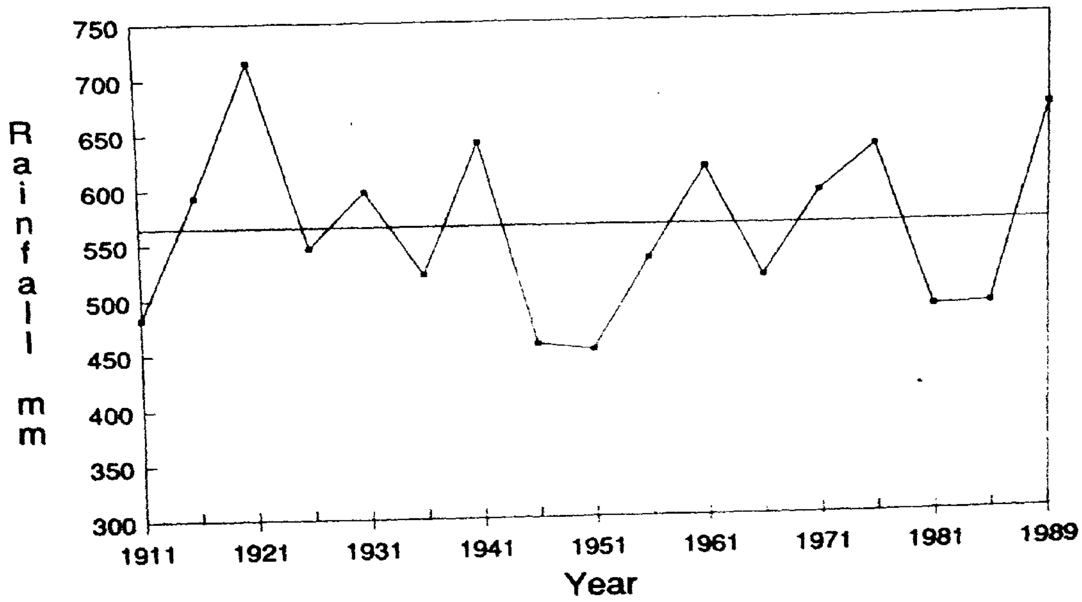

Fig.4. Five years moving average of annual rainfall exceeding specified minimum amounts at Anantapur (database 1911-1989).

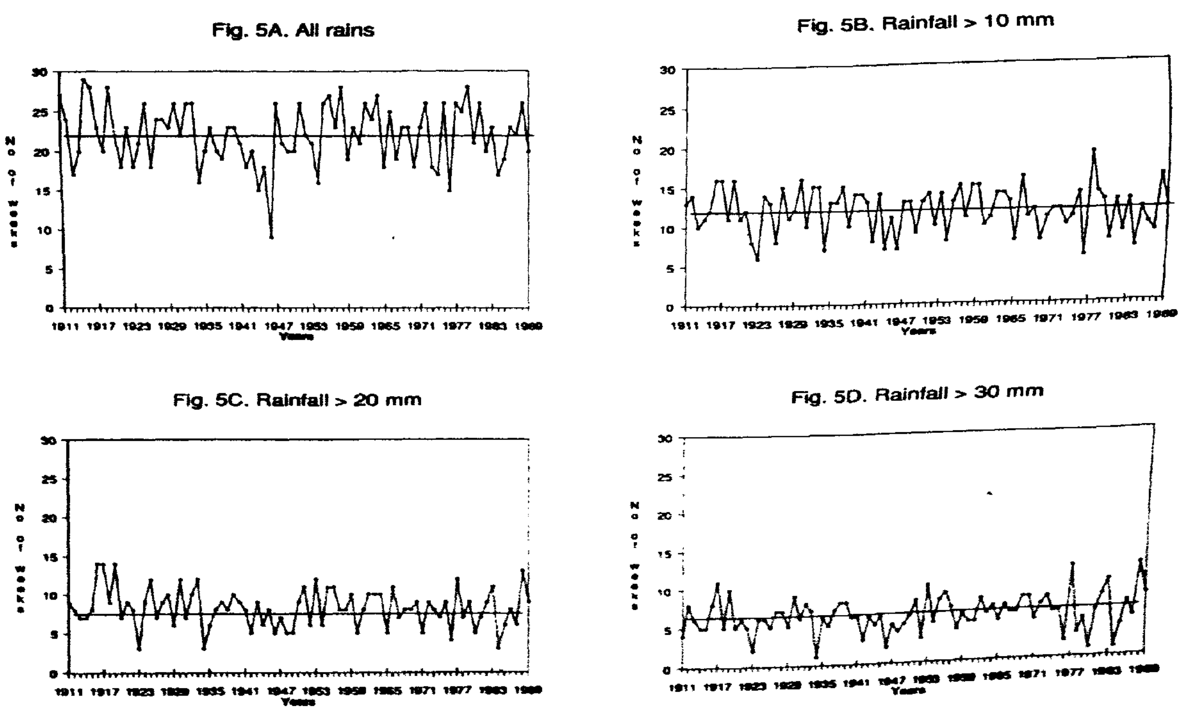

Fig.5. Number of weeks receiving rainfall exceeding specified minimum amounts at Anantapur (database 1911-1989).

Fig. 6A. Initial probability; P (W)

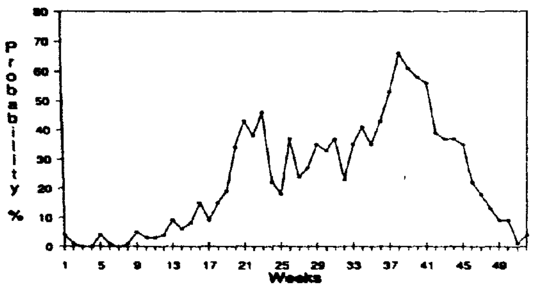

Fig. 6B. Conditional probability; P(W/W)

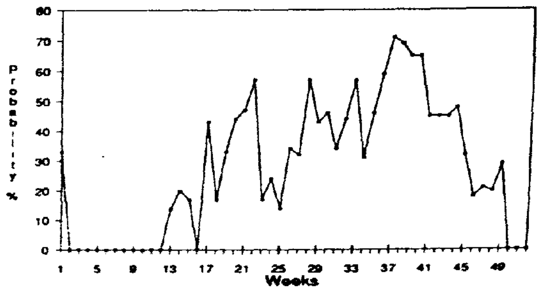

Fig. 6C. Conditional probability; P(W/D)

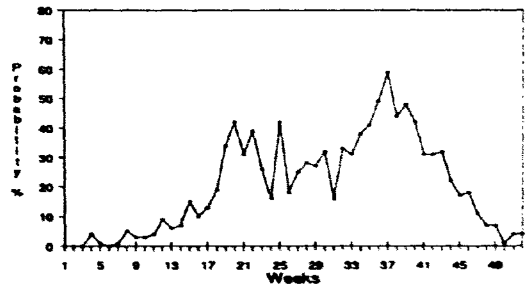

Fig.6. Initial and conditional probabilities of mean weekly rainfall ≥10 mm at Anantapur (database 1911-1989).

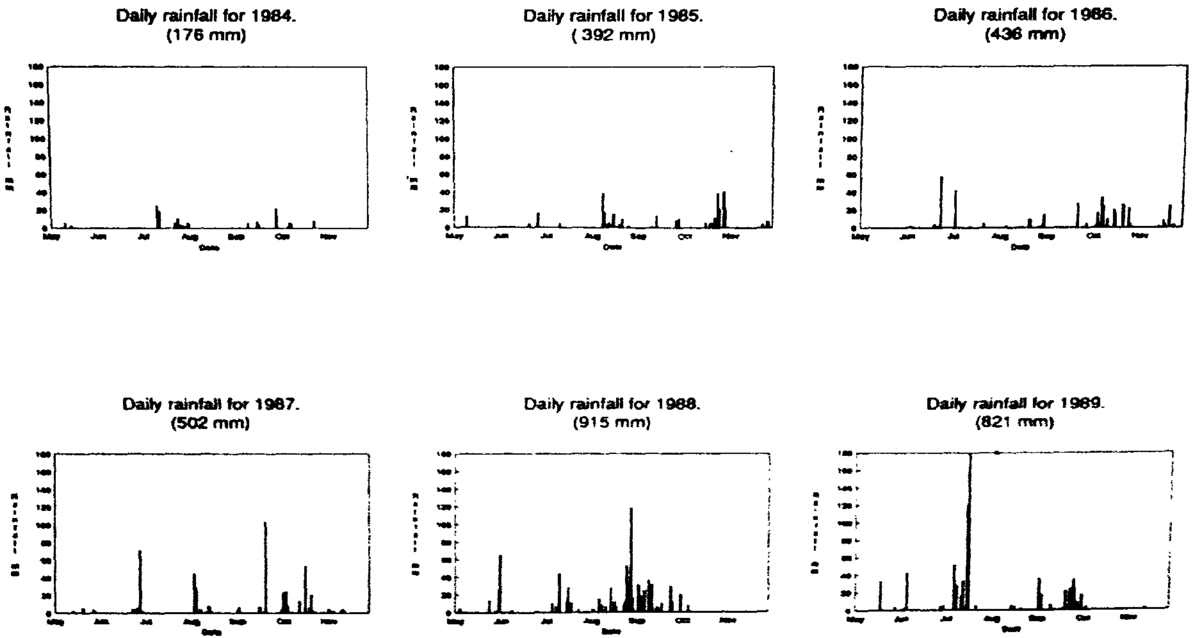

Fig.7. Variation in daily rainfall during 1984-1989 at Anantapur.

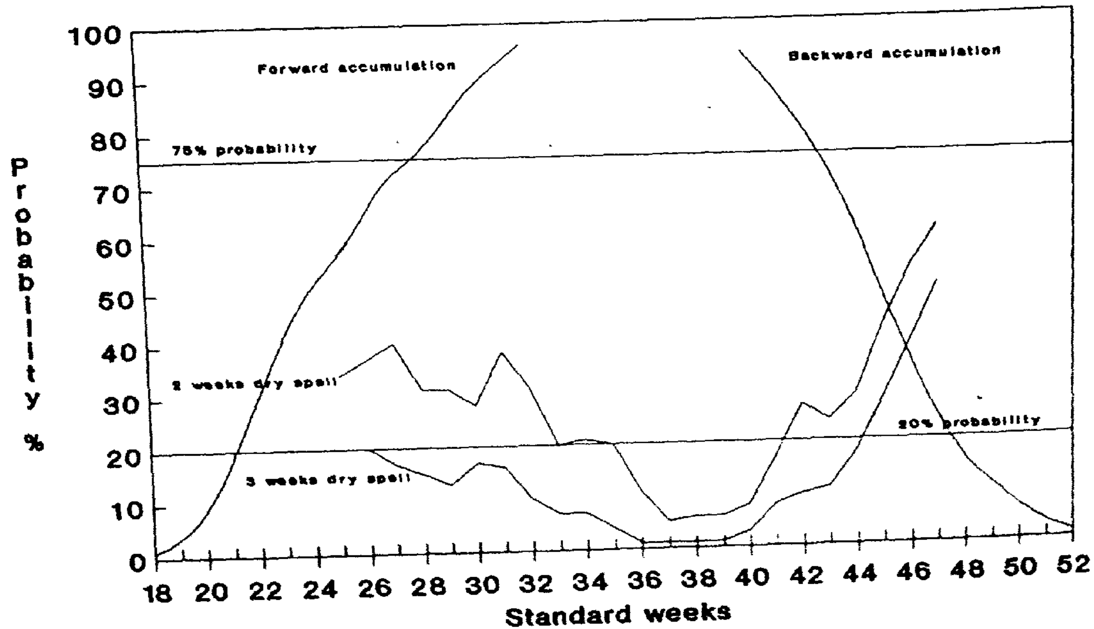

Fig.8. Forward and backward accumulation of rainfall along with probability of dry spells.

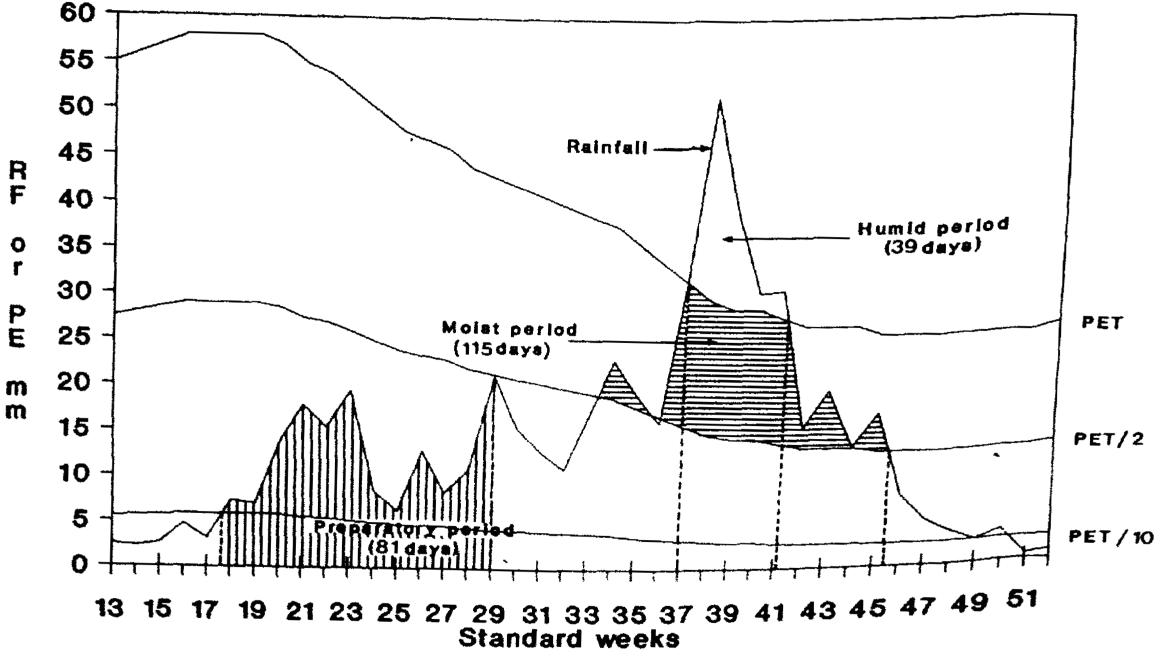

Fig.9. Climatic water balance at Anantapur (database 1911-1989).

Fig.10A. Initial probability; P (W)

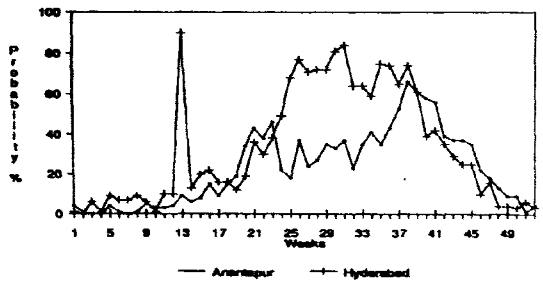

Fig.10B. Conditional probability; P(W/W)

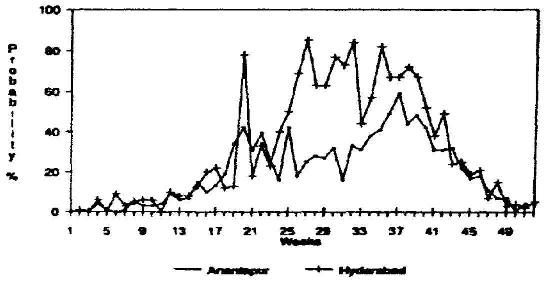

Fig.10C. Conditional probability; P(W/D)

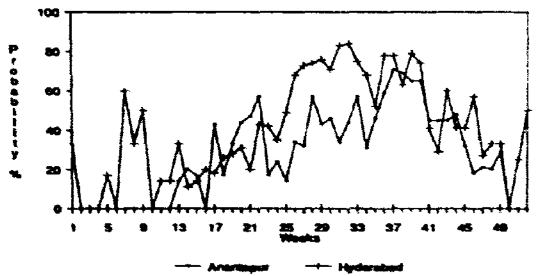

Fig.10. Mean rainfall and potential evaporation during different weeks at Anantapur.