AGROCLIMATOLOGY IN CROP PLANNING FOR CENTRAL ZONE OF KERALA

By

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THESIS

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DEPARTMENT OF AGRICULTURAL METEOROLOGY
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DECLARATION

I hereby declare that this thesis entitled "AGROCLIMATOLOGY IN CROP PLANNING FOR CENTRAL ZONE OF KERALA "is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree,diploma ,associateship, fellowship or other similar title of any other university or society.

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Dedicated to

My beloved parents

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Ajith, K.
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Introduction

INTRODUCTION

With the ever increasing need for food, shelter and energy, the subject of maximizing the produce from land by agriculture has become the most important problem for the entire human race. The problem is all the more important and perhaps, belongs to priority number one for an agricultural country like India.

The saying that farmers learn to live with the limitations of their local climatic conditions through trial and error over generations is no more wholly true. Past experience provides them with very broad information on rainfall, floods, droughts etc. Yet, for modern agriculture this is not enough. It is now patently clear that for deriving the maximum yield from agriculture, one must have a proper knowledge of agroclimatic conditions.

The full potential of climate as an agricultural resource has not been used or ever realized. As a result, several crops are grown traditionally in areas without any consideration for the suitability of climate. Thus, on the one hand, poor yields of crops are obtained and on the other, much of the production potential of this vast resource is left unutilized. It is impossible to tame the weather on a large scale, or even be in complete harmony with it. However, it is inevitable to make adjustment with the weather to extract the maximum benefit from this resource. In this context, knowledge on agroclimatology of a region is a valuable tool in crop planning.

With a geographical area of 38,863 sq. km, Kerala is one of the smallest states of Indian Union. It forms only 1.18 per cent of the total area of the country. The state lies at the south-west corner of the Indian peninsula, between 8° 18' and 12° 48' north latitudes, 74° 52' and 77° 22' east longitudes. Its coastal line is 880 km long and its breadth varies from 130 km in the middle to 32 km in the extremities.

The central zone of Kerala comprises the districts of Ernakulam, Thrissur, Palakkad and Malappuram. *Pokkali, kole* and high ranges are not included in this zone. The total geographical area of the zone is 9,831 sq. km. Twelve soil associations have been identified in the central zone (NARP Status Report, 1989). Variation in the amount and distribution of rainfall is seen over the zone. Higher amounts of rainfall are generally observed in the eastern region adjacent to the Western Ghats.

The topography of central zone is a peculiar one. The forest clad Western Ghats form the eastern boundary. From the Western Ghats, the land mass undulates to the golden shores of Arabian Sea, presenting a series of evergreen hills and valleys. Numerous rivers and streams flow west wards from the Western Ghats criss-crossing the hills and valleys until they empty into the Arabian Sea.

The land on the west coast is more or less flat and is adorned by lakes and lagoons. Due to these diverse characteristics of the land and consequent plant growth, the zone is classified into three distinct regions *viz.*, the high land, the mid land and the low land.

The high land region comprises the ghats, and most of the reserve forests. The major produces are teak wood, rose wood and numerous other varieties of hard and soft wood trees. The annual rainfall is very high in this region compared to others and is most suited for plantation crops like tea, coffee, cardamom and rubber.

The middle land region is famous for its diverse crops, while rice is grown in valleys, coconut, arecanut, rubber, pepper and tapioca are grown on the slopes of the hills. Thus, major and minor crops are cultivated intermixed with one another.

Paddy and coconut are the main crops in the low land region. Fishing is also an important source of livelihood of the people in this region.

Thus, for the NARP central zone as a whole, paddy, coconut, arecanut, pepper, rubber, tapioca, banana and cashew are the important crops. Paddy is cultivated in all the three seasons viz., *virippu* (June-September), *mundakan* (October-December) and *puncha* (January-March). *virippu* crops are mainly rainfed while *mundakan* crop requires irrigation in addition to the rainfall. *Puncha* crops are solely dependent on irrigation. The other important seasonal crops are pulses, ragi, sesamum, tapioca, groundnut, ginger, turmeric etc. Rubber is cultivated in mid land region.

Thus, agriculture in the central zone is unique due to wide variety of crops - seasonal, annual and perennial, prevalence of intercropping and mixed farming, existence of high value plantation and spice crops, high pressure of population on land resulting in tiny holdings etc. Explosion of population has increased the pressure on land and land available for cultivation reduced. Hence, it has become imperative to produce more from the available land.

Absence of scientific and systematic crop planning, consistent with land capability and ecological sustainability has stood in the way of achieving a break through in agricultural production (Agricultural Development Policy, 1992). One of the ways to achieve high productivity is to determine the appropriate crop combination and adopting the same with efficiency. Crop planning based on agroclimatic potential will thus become a valuable tool in planning production strategies.

Hence, the present investigation was taken up with the following objectives:

1. To study rainfall variability in the central zone of Kerala.
2. To compute weekly PET for the central zone of Kerala.
3. To determine weekly index of moisture adequacy (IMA) for various locations in the central zone of Kerala.
4. To determine water availability periods for these locations.
5. To examine the viability of important crops.

Review of Literature

REVIEW OF LITERATURE

2.1. Dependable precipitation

Hargreaves (1975) defined dependable precipitation as the amount that is normally equalled or exceeded three-fourths of the time. It is the 75 percentage statistical probability of occurrence (or exceedence). Mean rainfall data has little value in rainfed agriculture. It gives only trends of certain climatic patterns and can be useful as a tool to indicate agroclimatic homogeneous zones, to some extent, but do not give any information on rainfall variability (Hargreaves, 1977; Neuwolt, 1981). In rainfed agriculture, for understanding the probability of success in cropping, one must consider the assured rainfall received in three out of four years, which is otherwise known as dependable precipitation (DP), dependable rainfall or 75 per cent probability rainfall.

The best method to determine the rainfall probability is to fit the data to incomplete gamma distribution (Chan, 1984; Mondel *et al.*, 1983; Stern and Coe, 1982; Sarker *et al.*, 1978). However, the simple ranking method described by Doorenbos and Pruitt (1977) and Frere and Papov (1982) does not involve complicated statistics and hence, is used for computing rainfall probabilities for all the stations in the central zone. Use of probabilities of monthly total rainfall for agronomic purpose has been reported by Manning (1956); Baliga and Sridharan (1968).

Virmani (1975) considered crop growth period for three different available water storage capacities and worked out length of growing season at different probabilities of assured rainfall.

Virmani *et al.* (1978) reported the use of initial and conditional rainfall probabilities for obtaining agronomically relevant information.

Month is a fairly long period for critical crop growth phases which are usually of a week or ten days duration. The soil water holding capacity can usually buffer moisture availability for one week or more, so that weekly rainfall models can be used (Sarker, 1978).

Sarker *et al.* (1978) have analysed weekly rainfall in the dry farming tract of Karnataka by fitting gamma distribution probability model. Khambete and Kanade (1980) also made weekly rainfall analysis of dry farming tract of Karnataka.

Hargreaves *et al.* (1985) determined precipitation probabilities from the monthly values of precipitation for the 30 years period (1931-60) ranked by the World Meteorological Organisation and stated that the accuracy of the analysis depends more on the length of record than on the method used.

Santhosh and Prabhakaran (1988) applied a first order Markov chain model to daily rainfall data to characterise the rainfall pattern of five selected stations of northern Kerala. Suitable probability distributions were fitted to estimate the rainfall probabilities.

Analysis of the lowest assured weekly rainfall at different probability levels using the incomplete gamma distribution was found suitable for planning rainfed crops and related rainwater conservation measures for hilly regions of Himachal Pradesh (Verma, *et al.*, 1994).

Biswas and Phadtare (1995) computed rainfall probability at different levels of 16 stations of *Konkan* region by fitting gamma distribution model to weekly rainfall and suggested a suitable cropping pattern based on rainfall probabilities, soils and existing cropping pattern of the region.

Subudhi *et al.* (1996) computed dependable rainfall at 40, 50, 60 and 75 per cent probability levels for Bhadrak and Balasore districts of Orissa by using monthly rainfall data. Variation of mean annual rainfall, coefficient of variation and standard error were calculated. They reported that rainfall probability at 60 per cent and 70 per cent may assist crop planning and irrigation planning, respectively.

Rao, *et al.* (1998) assessed the probability of receiving adequate rain for successful crop establishment by using daily rainfall data for Anantapur, Nandyal and Lam from 1969-1984. The implications for crop production were discussed and the probability of receiving a minimum monthly rainfall of 50, 75 and 100 mm at each location was calculated.

2.2. Potential Evapotranspiration (PET)

There are many methods developed from time to time by various workers to estimate PET. Some of them are by Thornthwaite (1948), Penman (1948), Montieth (1965), Van Bavel (1966), Linacre (1967), Taylor (1972), Hargreaves (1977) etc. The widely accepted concept of potential evapotranspiration was put forth by Thornthwaite (1948) and Penman (1948) independently.

Thornthwaite (1948) defined potential evapotranspiration as 'the maximum amount of water that would evaporate and transpire from a thickly vegetated extensive territory with no deficiency of water for full use at any time'. Thornthwaite (1948) described the biological and physical importance of evapotranspiration in climatic delineation. He developed an equation for estimating potential evapotranspiration.

Sanderson (1950) reported that measurements of daily evaporation at Toronto over a vegetated soil surface were favourably compared with the PET estimated by the Thornthwaite formula.

Penman *et al.* (1956) defined PET as the 'evaporation from an extended surface of short green crop, actively growing, completely shading the ground, of uniform height and not short of water'.

Thermal efficiency (same as PET) for several Indian stations according to Thornthwaite formula were first reported by Subrahmanyam (1956a). Palmer and Havens (1958) provided a graphical solution for Thornthwaite's equation.

Matejka (1972) mapped and tabulated Thornthwaite's potential evapotranspiration estimates calculated for 141 meteorological stations throughout Czechoslovakia, discussing their distribution in relation to bioclimatic zones and altitudinal zones of forest associations.

Deo and Amissah (1973) estimated potential evapotranspiration rates over a grass sward at Guelph, Canada using the methods of (a) Penman and (b) Thornthwaite. There was no difference between the two methods, if annual totals were considered, but when using monthly totals, estimates using (a) were higher than when using (b) from May to July; from July onwards estimates with (b) were higher than with (a).

Coulter (1973) compared the estimates of potential evapotranspiration by the Penman formulae with estimates based on evaporation tank data and found to agree well at a number of stations, but tank estimates were greater when the aerodynamic term was large. Potential evapotranspiration values calculated for months and for five day periods were closely correlated with corresponding tank evaporation values. Except when ET was near that corresponding to wet conditions over a wide area, Thornthwaite's estimates were considerably lower than those derived from combination formulae or tank estimates.

Tarsia (1975) reviewed the commonest methods of measuring potential evapotranspiration, with special reference to the formulae of Thornthwaite, Turc and Penman, and provided evidence for concluding that Penman's formula gives the best results.

Ulehla and Smolik (1975) simplified the Thornthwaite method for estimating potential evapotranspiration using the linear relationship between monthly totals of potential evapotranspiration and the respective monthly mean temperatures. Data from Pohorelice during 1952-69 were used as an example.

Thermal efficiency values for thirteen stations in Andhra Pradesh have been reported by Subrahmanyam and Hemamalini (1977).

Subramaniam and Rao (1980) reported that the PET values computed using the Thornthwaite formula were in better agreement in per humid (in Vengurla), humid (in

Bombay) and sub humid (in Chanda) climate whereas the deviations were more from semi arid and arid climates.

Dumario and Cattaneo (1982) used Penman's equation for estimating potential evapotranspiration for data from 186 sites in Argentina. Charts for the whole year were presented and compared with values obtained by the methods of Thornthwaite, Papadakis and Grassi-Christiansen and with estimations of ETo (reference crop evapotranspiration) obtained from evaporation measurements corrected for variable zonal factors according to the probable magnitude of the oasis effect.

Franco (1983) presented simplifications of the Thornthwaite, Penman and Turc methods of calculating evapotranspiration. The method involved replacing daily values for some parameters by values for a hypothetical mean day value. Values for the parameters are given for N and S latitudes in the different months of the year.

Bosnjak (1986) developed regression equations and correlation indices for converting calculated potential evapotranspiration using the formulae of Penman Blaney and Criddle, Thornthwaite and Alpat'ev into potential evapotranspiration of maize. The results gave fairly reliable simulations for Vojvodina province and analogous areas in Yugoslavia.

Stone (1988) developed a BASIC computer program for calculating daily potential evapotranspiration by the method of Thornthwaite and Mather.

Roth and Gunther (1992) measured the water consumption of winter wheat, spring barley, potatoes and sugar beet in weighable lysimeters, situated in farm fields in Germany. The results obtained with the lysimeters are compared with the pan-evaporation (two different pans) and the results of four evapotranspiration equations.

2.3. Water balance

The concepts of water balance was put forth by Thornthwaite in (1948). Thornthwaite evolved a book keeping procedure from which it is possible to calculate actual evapotranspiration (AET), water surplus (WS) and water deficit (WD), by comparing PET and rainfall.

Thornthwaite and Mather (1955) revised assumptions and methods of computations of the book keeping procedure. The water balance of India according to these modified concepts was discussed by Subrahmanyam (1956b).

Subramaniam (1964) in an attempt to use the knowledge of applied climatology in order to examine as to what extent Thornthwaite's scheme could be used for explaining the natural vegetation of the Mysore state, observed that, despite the sparcity of stations and scantiness of data, the correspondences were so marked and convincing that they justified the applicability of water balance concepts to practical problems and thus there established the rationality of the approach.

Pinto and Preuss (1975) prepared a computer program in FORTRAN for the evaluation of water balance according to the method proposed by Thornthwaite and Mather. The maximum water storage term can be modified according to the crop considered. Monthly values of soil water retention were calculated on a mathematical basis.

Queiroz and Correa (1979) calculated the water balance for 10-day periods in Ponta Grossa using the method of Thornthwaite and Mather. Several periods of water deficiency and excess were identified.

Subramaniam and Rao (1979 and 1980) studied the broad scale patterns of water balance for Rajasthan with particular reference to its latitudinal and longitudinal variation. Subramaniam *et al.* (1980) presented the climatic water budget for Andhra Pradesh as a whole. Subramaniam and Rao (1981) compared the spatial distribution of annual IMA with crop combination maps of Maharastra.

Subramaniam and Murthy (1982) calculated the climatic water balances of five stations of Kerala state. They also classified climates of Kerala both on thermal and moisture regimes following Thornthwaite's scheme. Subramaniam and Rao (1982) presented the water balance and crops in Karnataka. They calculated climatic water balance elements and water balance indices for all the meteorological stations in the state. They compared the general distribution of crops and IMA to identify the limits for certain crops.

Franco (1983b) presented five programs for computing water balance by Thornthwaite-Mather method using TEXAS TI 59/PC-100C equipment. Hanna (1983) discussed the following (a) the water balance of crops, (b) the measurement of soil water in the field, (c) relationships between the environment and growth, (d) statistical models of climate and yield, (e) moisture indices, (f) application of statistical models and (g) models of the soil-plant-atmosphere.

Swaminadhan and Shanthakumari (1983) studied water balance for selected stations in Madurai district of Tamil Nadu to find out the water surplus/deficit and to suggest the cropping season. They proposed to suggest suitable cropping seasons for the district. Vinayak (1983) computed water balance and indices for six stations in Kerala for finding the impact of soil moisture conditions on crop yields.

Subramaniam and Rao (1985) presented monthly and weekly water balances of a dry subhumid coastal station of Andhra Pradesh. They used the concept of aridity to identify the drought years with different intensities and also delineated water availability periods.

Donker (1987) prepared a computer program (WTRBLN) to calculate water balance based on the basis of long-term average monthly precipitation, potential evapotranspiration and combined soil and vegetation characteristics, according to the method proposed by Thornthwaite and Mather. Three additions to the original method are implemented (1) direct runoff can be taken into account (2) reference potential evapotranspiration can be adjusted to crop potential evapotranspiration by the factors and (3) a successive approximation method can be selected by the user if the climate is so dry that the soil never reaches field capacity.

Amorim and Silva (1989) defined the water balance according to Thornthwaite and Mather. It's calculation was described and examples of its' application to different regions of Brazil were presented with the help of tables and graphs.

Agnese *et al.*, (1989) computed water balance using Eagleson water balance model and a comparison with the more simplified Thornthwaite model showed marked differences in results.

Chakraborty and Chakraborty (1990) used daily rainfall data during 1976-85 for estimating assured rainfall pattern, conditional probability analysis and water balance analysis for the Berhampore region in the Murshidabad district of West Bengal.

Water balance analysis was made for different soil types in the region with available water capacity of 200, 250 and 300 mm/m soil depth. The use of the information obtained from those analyses for crop planning in the region was discussed.

Zahler (1991) determined moisture deficiencies for *C. arabia* in the Distrito Federal, Brazil, using 1931-1960 meteorological data. The water balance was calculated by Thornthwaite and Mather's method, considering a soil moisture retention of 125 mm.

Victor *et al.* (1991b) observed that crop water use estimated from the FAO water balance model which can be used to quantify the crop yields. Their analysis can permit evaluation of the suitability of a given crop for production at the planting site.

Kerkides *et al.* (1997) calculated water balance, for 31 locations in Greece on the basis of long-term average monthly precipitation, evapotranspiration and combined soil and vegetation characteristics, using the method of Thornthwaite and Mather.

2.4. Water availability periods

Though, rainfall is the main source of water, the actual availability does not depend on rainfall alone as it should be balanced against the amounts due to evapotranspiration. Based on this, Cocheme and Franquin (1967) classified water availability periods. George and Krishnan (1969) and Raman and Murthy (1971) attempted for assessing the water availability periods based on climatic and soil conditions. Krishnan (1971) and Murthy (1973, 1976) determined water availability periods using actual evapotranspiration (AET) and potential evapotranspiration (PET). All these methods utilized monthly or weekly mean rainfall.

Gadre and Umrani (1972) used monthly rainfall data for various tahsils in Sholapur district, Maharashtra, and balanced against potential evapotranspiration values of Jeur and Sholapur for the Western and Eastern regions respectively and the water availability periods for each tahsil were delineated. The cropping pattern for each tahsil based on these periods was indicated.

Oswal and Saxena (1980) presented the analysis of rainfall data in the dry land districts of Haryana and revealed that only one crop is possible yearly on rainfall alone. The meteoric water availability period was found to be twelve, nine, seven and four weeks respectively at Mohindergarh, Hissar, Biwani and Sirsa.

Subramaniam and Rao (1981) assessed the water availability periods for crop planning in Rajasthan on the basis of monthly rainfall and monthly potential and actual evapotranspiration during 1901-77.

Subramaniam and Rao (1983) presented a method using PET and dependable rainfall to determine water availability for optimisation of crop growth in Karnataka.

Moisture Availability Index (MAI)

Hargreaves (1971) defined the MAI as the dependable precipitation divided by potential evapotranspiration. He gave equations and methods for it's computation.

Hargreaves (1975) suggested an agroclimatic classification considering the length of growing season based on MAI which is the ratio of 75 per cent probability rainfall to the potential evapotranspiration (PET).

Sarker and Biswas (1986) suggested that MAI may be calculated on weekly basis and dependable rainfall be considered at 50 per cent probability level. Further, they considered different values of MAI and duration as appropriate to various crop phases for agroclimatic classification of dry farming tract of India.

Khambete (1992) devised a water availability index and applied it to the dry farming tract of Karnataka. Using this index along with information on soils and crop water requirements, cropping pattern in each agroclimatic zone was assessed.

Prabhakaran *et al.* (1992) grouped 77 raingauge stations in Kerala into nine clusters based on MAI and principal component analysis technique.

Moisture Adequacy Index (IMA)

Subrahmanyam *et al.* (1963) studied for the first time the relationship of the moisture adequacy index in relation to the distribution of some important crops in the Indian region and observed that the IMA values could explain the crop distribution.

Bishnoi (1980) studied the behaviour of moisture adequcy index and its utilization for exploiting the agricultural potential in Punjab and Haryana. The moisture adequacy indices, the ratios of actual evapotranspiration to the potential evapotranspiration, have been found to follow closely the Beta distribution. The goodness of fit of the Beta distribution to the moisture index frequency distribution was tested using the Kolmogorov-Smirnov test for 144 station months and 36 seasonal curves. Twenty five moisture adequacy curves failed the K-S tests. The probability distribution of moisture adequacy indices has been further used to assess irrigation requirement, optimum evapotranspiration, water mangement, land use pattern and crop planning aspects for optimum utilization of available natural resources in the region.

Victor *et al.* (1982) computed monthly values of moisture adequacy index for groundnut during 1941-72. The frequency distribution closely followed a beta distribution. The probabilities at threshold values of moisture adequacy index (actual evaporation/potential evaporation) less than or equal to 0.5 and more than or equal to 0.9 were evaluated. For 44 per cent of the time, the top soil layer (0-15 cm) remained dry continuously for more than two weeks. They reported that damage to groundnut in the Delhi region from severe dry weather may occur on an average once in four years.

Subramaniam (1983) has classified agroecological zones of India on the basis of index of moisture adequacy instead of mere rainfall, because rainfall never fully reflects the moisture status of a region and plants do not depend on rainfall alone. In addition to this, he pointed out that the significant role played by soil for the storage of water should not be overlooked.

Subramaniam and Rao (1984) have calculated climatic water balance elements and moisture adequacy over Karnataka. The result of the analysis of moisture adequacy were compared with the distribution of crops to identify the limits of moisture adequacy for high productivity.

Crop planning

Bhatia *et al.* (1975) analysed 20 years data on distribution of rainfall at Rehmankhera (Lucknow), Uttar Pradesh. They reported that data on weekly rainfall are more important than data on monthly and yearly rainfall for selection of suitable crops and their cultivars for cultivation in the monsoon season. The probability of drought occurrence was once in 10 years.

Sastry (1976) presented the interaction of the rice crop with climate and discussed with particular reference to both rainfed and irrigated rice crops in South and SE Asia.

Venkataraman (1979) analysed the probabilities of weekly rainfall amounts for 16 district level stations covering the dry farming tract of Maharashtra to find out, stationwise, the time and duration of rainy season, crop growth periods and mid-seasonal dry spells. Information on the *kharif* and *rabi* season crops of different maturity that can be grown in these districts was given.

Saksena *et al.* (1979) made an attempt to study the distributions of dry and wet spells and the pattern of occurrence of rainfall in short intervals of 5, 10 and 15 day periods. Expected lengths of dry and wet spells for various levels of conditional probabilities were obtained through empirical relations. The use of these expected lengths and pattern of occurrence of rainfall in crop planning was shown with the jowar crop for Jalgaon district, Maharastra.

Krishnan *et al.* (1980) used systems analysis approach for crop planning in Jodhpur district of Rajasthan. The analysis of rainfall data during 1901-70 showed the presence of 3 main subsystems (early, normal and late) in the rainfall pattern. Information on crops suitable for cultivation in these subsystems in Bilara and Shergarh regions was given.

Bhattacharya and Parikh (1987) analysed daily rainfall data for 54 years (1927-80) of the Navsari region, Gujarat, to find the weekly expected rainfall at different percentages of chance of being exceeded for crop planning and irrigation scheduling.

Budhar and Gopalaswamy (1988) suggested improved cropping system for Barur tract of Dharmapuri district in Tamil Nadu on the basis of rainfall data from 1947-83.

Rao *et al.* (1988) carried out the rainfall probability analysis of three stations in Andhra Pradesh for crop planning. Daily rainfall data for Anantapur, Nandyal and Lam from 1969-1984 were used to assess the probability of receiving adequate rain for successful crop establishment.

Chakraborty *et al.* (1990) studied rainfall and its impact on cropping pattern in Hoogly district of West Bengal. Assured rainfall analysis, probability of having a specified amount of 20 mm rainfall/week (one-third the potential evapotranspiration ratio of the region) and a water balance approach were found quite effective to assess the water availability period for crop planning under rainfed condition.

Maliwal and Chatrola (1991) studied the rainfall pattern for crop planning in Bhal zone, Gujarat. Maraviya *et al.* (1991) analysed rainfall data for crop planning under dry land agriculture at Rajkot, Gujarat.

Budhar *et al.* (1991) suggested rainfall based cropping system in Palacode Taluk of North Western region of Tamil Nadu.. Kulandaivelu and Jayachandran (1992) classified drought and developed a crop plan for Tamil Nadu. The severity of drought was determined by the prevalent soil type in various regions. Drought prone areas were classified based on precipitation (P), potential evapotranspiration (PET) and soil type to provide more precise information in rainfall and to develop suitable crop plan. The P/PET ratio provides a measure of whether certain crops can be grown at a place or not. Based on the ratio, a climatic index was developed and the values were super imposed on a soil map to identify local drought prone areas, and to classify them as mild, moderate or severe.

Shranker *et al.* (1992) analysed rainfall data for 1981-89 recorded at Jabalpur, Madhya Pradesh to suggest strategies for crop planning during the rainy season. Budhar and Gopalaswamy (1992) presented annual, seasonal, monthly and weekly rainfall data and suitable cropping systems for the Uthangarai taluk of Dharmapuri district in Tamil Nadu.

Kavi (1992) studied rainfall characteristics in relation to crop planning at Raichur in Karnataka. Data were presented on seasonal rainfall and its percentage contribution to annual rainfall from 1961 to 1990.

Sehgal *et al.* (1993) presented generalized ranges of moisture availability periods for average deep soils in India for cereal, cotton, legume, oil and fibre crops which is very useful in crop planning.

Krishnasamy *et al.* (1994) carried out rainfall analysis and presented rainfall pattern and cropping system for dry land areas of Avanashi block of Coimbatore district.

Rout *et al.* (1994) studied rainfall pattern and suggested cropping system for sustainable production in Umerkote block of Koraput in Orissa. Chaudhary (1994) suggested a crop plan through rainfall analysis in Bastar district of Madhya Pradesh. The probability of rainfall occurrence and the consequences for crop production are studied with particular reference to rice.

Singh *et al.* (1994) studied rainfall variability and its relationship with rainfed crop planning at Rewa, Sidhi, Satna and Shahdol districts in Madhya Pradesh. Rainfall and number of rainy days recorded for the period from 1968 to 1990 were analysed with respect to monthly, seasonal and annual variations and drought, normal and abnormal months were calculated using frequency analysis. It is concluded that *rabi* cereals and pulses are more suited to Rewa and Satna districts, whereas *kharif* oilseeds and pulses and *rabi* oil seed crops are more suited to Shahdol and Sidhi districts.

In a study by Verma *et al.* (1994), analysis of the lowest assured weekly rainfall at different probability levels using incomplete gamma distribution was found suitable for planning rainfed crops and related rainwater conservation measures for hilly regions of Himachal Pradesh.

Challa (1995) prepared a case study from Gulbarga district, Karnataka on rainfall probability and crop growing periods for soil based crop planning. Manohar and Megeri (1995) studied crop planning under rainfed conditions in dry land agriculture. Daily rainfall data from a period of 72 years (1917-88) recorded at the Regional Research Station, Raichur in Karnataka were analysed. Periods of assured rainfall were identified and planting schedules for crops of 75 and 120 day duration were calculated.

Rema and Chakor (1995) presented crop planning in relation to rainfall pattern in Paonta valley of Himachal Pradesh. Rainfall data from the last 28 years (1966-93) for the region were analysed. Weibull's method of frequency analysis was used for predicting rainfall at weekly intervals at three probability levels (20, 50 and 80%).

Sharma *et al.* (1996) analysed the daily rainfall data recorded during 1969-93 at the Regional Agricultural Research Station, Diphu, Assam for annual, seasonal, monthly and weekly periods to suggest suitable rainfed cropping system for the hill zone of Assam.

Subudhi (1996) computed dependable rainfall at 40, 50, 60 and 70 per cent probability levels for Bhadrah and Balasore districts of Orissa. Variation of mean annual rainfall, coefficient of variation and standard error were calculated. He opined that rainfall probability at 60 per cent and 70 per cent may assist crop planning and irrigation planning respectively.

Materials and Methods

MATERIALS AND METHODS

The present work was undertaken with the objective to determine weekly index of moisture adequacy (IMA) and water availability periods for various locations in the central zone of Kerala and to examine the viability of important crops. Location map of the central zone of Kerala is shown in Fig. 1.

3.1 Collection of data

3.1.1 Meteorological data

Daily rainfall data for the period 1978-97 were collected from 26 stations in the central zone from the India Meteorological Department, Thiruvananthapuram. Table 1 shows the name, latitude, longitude of the stations under study and the period of data collected. Fig.2 shows the location of the stations in the central zone.

Daily data on maximum and minimum temperature, wind speed, maximum and minimum relative humidity and bright sunshine hours for Kochi, Palakkad, Pattambi and Vellanikkara were collected.

3.1.2 Crop data

Block wise information on area and production of various crops were collected from the publications of the Bureau of Economics and Statistics, Govt. of Kerala.

3.1.3 Soil data

Data on soil types were collected from the publications of KAU and Soil Survey Department of Kerala.

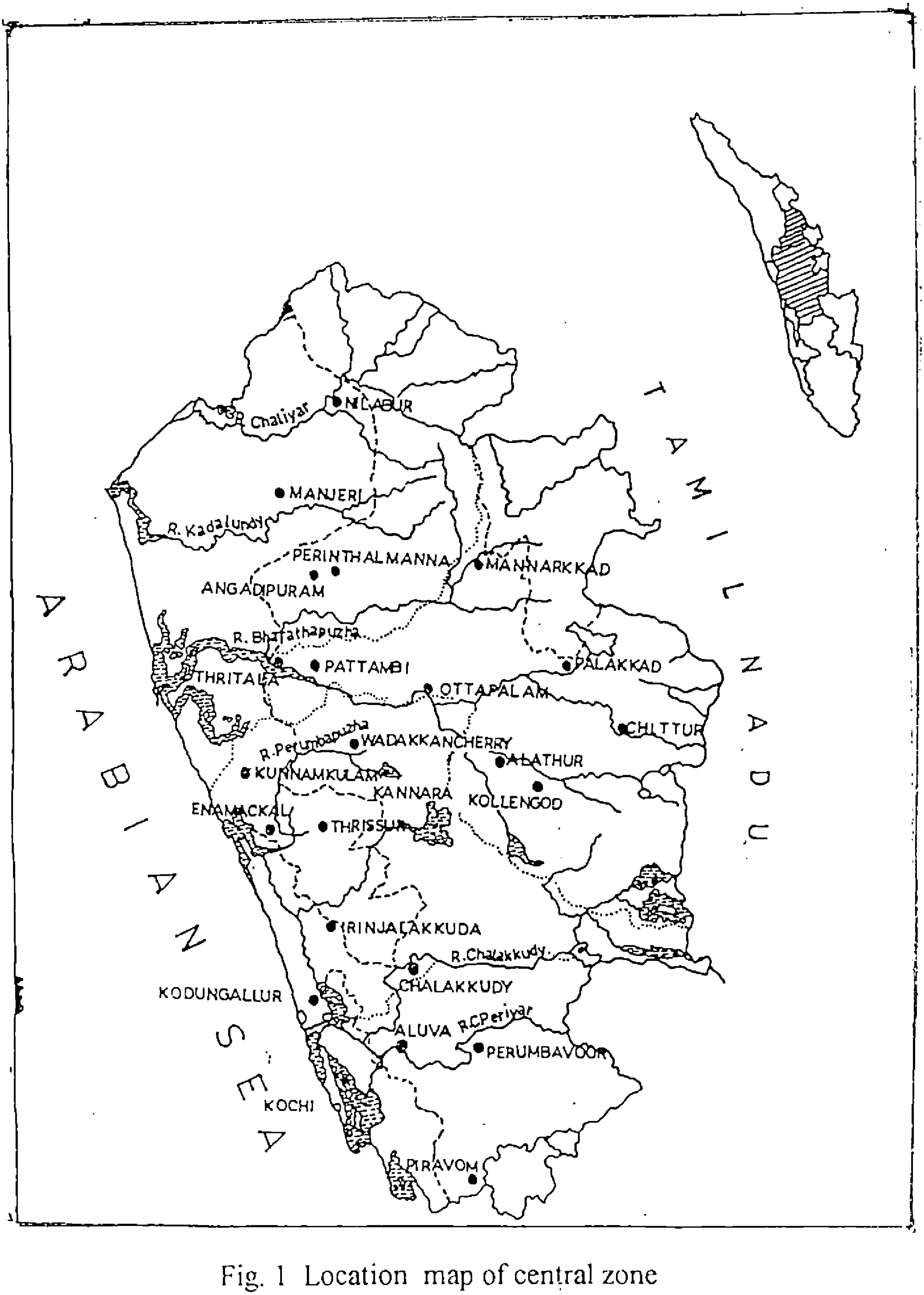

Fig. 1 Location map of central zone

Table 1. · Name of stations under study with period of rainfall data used

Sl No.	Name of station	Latitude	Longitude	Period
1.	Alathur	10 38′ N	76 31′ E	1978-1997
2.	Aluva	10 07′ N	76 22′ E	1982-1997
3.	Angadipuram	10 62′ N	76 15′ E	1986-1997
4.	Chalakkudy	10 18′ N	76 20′ E	1984-1997
5.	Chittur	10 42′ N	76 45′ E	1978-1997
6.	Enamackal	10 30′ N	76 05′ E	1985-1997
7.	Irinjalakuda	10 22′ N	76 14′ E	1984-1997
8.	Kannara	10 30′ N	76 10′ E	1985-1997
9.	Kochi	09 58′ N	76 18′ E	1978-1997
10.	Kodungallur	10 03′ N	76 22′ E	1980-1997
11.	Kollengode	10 37′ N	76 43′ E	1981-1997
12.	Kunnamkulam	10 38′ N	76 00′ E	1980-1997
13.	Manjeri	11 07′ N	76 08′ E	1984-1997
14.	Mannarkkad	10 09′ N	76 34′ E	1978-1997
15.	Nilambur	11 17′ N	76 14′ E	1978-1997
16.	Ottapalam	11 40′ N	76 15′ E	1978-1997
17.	Palakkad	10 47′ N	76 39′ E	1978-1997
18.	Parambikulam	10 20′ N	76 45′ E	1985-1997
19.	Pattambi	10 48′ N	76 12′ E	1985-1997
20.	Perinthalmanna	10 58′ N	76 13′ E	1984-1997
21.	Perumbavoor	10 05′ N	76 17′ E	1985-1997
22.	Piravom	09 48′ N	76 28′ E	1981-1997
23.	Ponnani	10 47′ N	76 23′ E	1988-1997
24.	Thritala	10 50′ N	76 06′ E	1985-1997
25.	Thrissur (Vellanikkara)	10 31′ N	76 13′ E	1983-1997
26.	Wadakkancherry	10 35′ N	76 10′ E	1986-1997

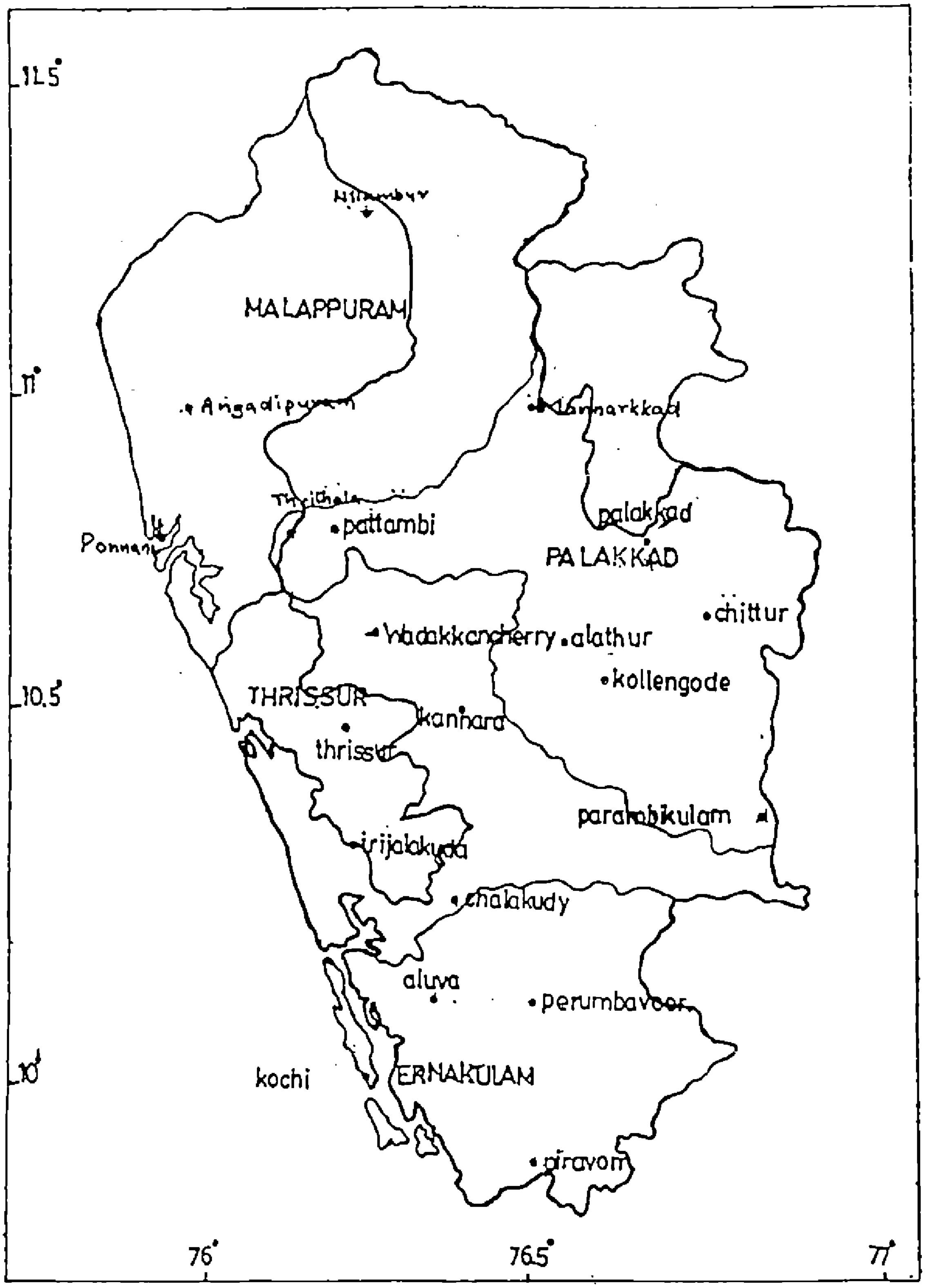

Fig. 2 Stations in central zone under study

3.2 Methodology

The daily weather data has been analysed on weekly, monthly, seasonal and annual basis. Mean values for the above periods have been computed for maximum temperature, minimum temperature, relative humidity, wind speed and sunshine hours, while totals were computed for rainfall for all the years. Seasons have been identified as per the following:

Season	Period
1. Summer	March to May
2. South West Monsoon	June to September
3. North East Monsoon	October to November

3.2.1 Rainfall

Mean weekly, monthly, seasonal and annual rainfall were worked from the totals obtained as above. Coefficient of variation for the above periods were also woked out. Spatial variation mean rainfall and coefficient of variation during the different seasons over the central zone has been presented.

Mean monthly rainfall data gives only trends of certain climatic patterns and can be useful as a tool to indicate agroclimatic homogeneous zones, to some extent, but they do not give any information on rainfall variability (Hargreaves, 1977 and Neuwolt, 1981). In rainfed agriculture, it is important to know the amount of rainfall that can be expected at least in 3 out of 4 years rather than simple mean rainfall. This is known as the **dependable rainfall** i.e., rainfall received at 75 per cent probability level. A simple ranking method as described by Doorenbos and Pruitt (1977) and Frere and

Papov (1982) was used for the computation of dependable rainfall for the stations in the central zone. The method is as follows:

The monthly rainfall records for every station were arranged in decreasing order and each record was assigned a ranking number 'm'. Every ranking number has a probability level Fa(m) which is expressed as,

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

where, n = Number of records.

The rank number which has a probability level of 75 per cent and 90 per cent was calculated. The rainfall record corresponding to this rank number gave the rainfall having the corresponding probability. Weekly dependable rainfall at 75 per cent and 90 per cent were calculated using the above mentioned ranking method.

Estimation of probabilities of receiving a given amount of rainfall is very useful for agricultural operational planning like man power requirement, fertilizer application, spraying against pest and diseases, etc. These will also indicates the probability of occurrence of dry and wet spells. As month is too long a period for agricultural operational planning, analysis on weekly rainfall was carried out. Both the initial and conditional probabilities of receiving 30 mm or more rainfall per week were worked out, following the methodology given by Virmani *et al.* (1982) which is as follows:

If the rainfall in a particular week is more than the specified amount, it is called a *Wet week* (W) otherwise called a *Dry week* (D).

$P(Wj) = N(Wj)/N$

Where $P(Wj)$ is the probability of receiving a certain amount of rainfall during the jth week

$N(Wj)$ is the Number of occurence of W during the j th week

N is Number of observation

Hence, $P(Dj) = 1 - P(Wj)$

Similarly probability of next week being wet, if the current week is *wet* P(w/w) were also worked out. Initial and conditional probabilities of receiving 30mm or more rainfall were worked out for all the stations and those for Palakkad, Kochi, Pattambi and Vellanikkara are presented graphically.

3.2.2. Potential Evapotranspiration (PET)

The potential evapotranspiration has been computed on a weekly basis for the four stations Kochi, Palkkad, Pattambi and Vellanikkara, where data on temperature, humidity, wind and sunshine duration are available. The method suggested by Doorenbos and Pruitt (1977) is used as it is widely accepted. The method is as follows:

$$ETo = c\,[W.Rn + (1-w)\,.\,f(u)\,.\,(ea-ed)]$$

where ETo = Reference crop evapotranspiration in mm/day

W = Temperature - related weighting factor

Rn = Net radiation in equivalent evaporation in mm/day

f(u) = Wind related function

(ea-ed) = Difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air, both in m bar

c = adjustment factor to compensate for the effect of day and night weather conditions.

PET for all the raingauge stations has been interpolated based on topography.

3.2.3. Water Balance Studies

Water balances have been computed following the book-keeping method of Thornthwaite and Mather (1955). The field capacity of the soil to hold moisture was assumed considering the type of soil and vegetation. Weekly water balances for all the stations have been computed by taking the dependable rainfall and the interpolated PET. The spatial variation of actual evapotranspiration, water surplus and water deficit over the central zone is presented.

3.2.4. Index of moisture adequacy

The index of moisture adequacy (IMA) is the ratio of the actual evapotranspiration to the potential evapotranspiration, expressed as a percentage. This can be used for assessing the moisture status in relation to the water need at a place.

IMA quantifies the moisture supply to potential need which becomes unity under conditions of potential water supply. The index of moisture adequacy can be utilised for determination of crop distribution and estimation of irrigation scheduling. IMA for all the stations in the central zone has been computed.

3.2.5. Water availability periods

The knowledge on the length of water availability periods will help understand irrigational needs of crop at different phenological stages. Though, rainfall is the main source of water, the actual availability does not depend on rainfall alone as it should be balanced against the amounts due to evaporation. There are several methods for assessing the water availability periods based on monthly or weekly mean rainfall. However, mean rainfall data has limited utility and hence, Subramaniam and Kesava Rao (1983) have presented a method to determine water availability for optimisation of crop growth. The method requires computation of water balances using dependable rainfall and comparison of AET with PET. The four water availability periods defined are as follows:

Humid period	: AET $\geq$ PET/2
Sub humid period	: PET/2 > AET > PET/4
Semi dry period	: PET/4 > AET > PET/8
Dry period	: PET/8 > AET

Following the above, the number of days under different categories were worked out for all the stations. Moisture availability periods were estimated by combining the humid and sub humid periods. The number of days under humid period and sub humid period were added to get the total number of moist days.

3.2.6. Cropping pattern

Cropping pattern for each block was worked out following the method described by National Commission on Agriculture (1976). In order to have a broad picture of crop distribution in the zone and to facilitate analysis, the crops and their areas were coded using crop symbols and numerical subscripts.

The codes for crops are as follows:

Crop	Code
Paddy	Pd
Oilseeds other than groundnut (including coconut)	O
Plantations other than spices and coconut	L
Fruit crops	Fr
Spices	Sp
Tapioca	Ta

The percentage areas of crops are denoted as follows:

Area coverage (per cent of gross cropped area)	Code (used as numerical subscript)
70 or more	1
50 - 69	2
30 - 49	3
10 - 29	4
less than 10	5

For example, the code L1 shows that coconut occupies more than 70 per cent of the gross cropped area. When the same distribution of crops was found to hold good for two or more adjacent blocks, a pattern was obtained. The various cropping patterns thus obtained are discussed in relation to water availability periods.

3.2.7. Computer programs

Computer programs in BASIC and FORTRAN were developed to convert the daily weather data into standard week, month and seasonal formats. Programs were also developed for computing initial and conditional probabilities of rainfall using Markov chain model, PET following modified Penman and weekly Thornthwaite's water balances.

Results and Discussion

RESULTS AND DISCUSSION

The results and discussion of the present study "Agroclimatology in crop planning for central zone of Kerala" conducted at the Department of Agricultural Meteorology, College of Horticulture, Vellanikkara are presented in this chapter. The study was undertaken to determine weekly index of moisture adequacy (IMA) and water availability periods for various locations in the central zone and to examine the viability of important crops.

4.1. Area under study

The topography of central zone is highly varied due to the presence of mountains, hills, valleys and slopes. The physiographic features of eastern part is very much dissimilar to the western parts. But when one moves from North to South, the geographical features are almost similar. So the zone can be broadly classified into three divisions namely high land, midland and low land, each of them running parallel from north to south. The variation in the topography effects a wide variation in the type of crops cultivated in this region.

There are six major rivers in the central zone. They are Periyar, Chalakkudy, Perumbapuzha, Bharathapuzha, Kadalundy and Chaliyar. The tributaries of these rivers form a network of streams and as a result of the westward slope all the rivers flow towards west. On the western side there is a continuous stretch of lagoons and backwaters which are interconnected by canals which are manmade or natural and this facilitates water transport.

4.2.1. Rainfall

Precipitation is the primary source of water to earth. It has been estimated that if the total average precipitation for the year were spread evenly over the earth's surface, it would form a layer about 100 cm deep. Deficient rains limit crop growth and heavy rains are even more harmful to crops. Mean rainfall for the whole central zone of Kerala was calculated annually and seasonally by taking the data of 26 rain gauge stations. The mean annual rainfall for the zone was 2443 mm. The mean rainfall during southwest, northeast and summer seasons were 1847 mm, 397 mm and 159 mm respectively. Hargreaves (1975) suggested that the mean data has little value in rainfed agriculture and dependable precipitation should be worked out. So the coefficient of variation and probability rainfall at 75 per cent and 90 per cent were worked out. The rainfall analysis for different stations in the central zone is presented in table 2(a-m). The spatial variation of annual and seasonal mean rainfall, coefficient of variation and probability rainfall at 75 per cent and 90 per cent are presented below:

4.2.1.1 Spatial distribution of mean rainfall

Spatial distribution of mean rainfall is shown in Fig. 3. The annual mean rainfall increases from east to west. In the coastal areas, there are a few stations which receive more than 3000 mm rainfall. These are Kunnamkulam, Kodungallur, Kochi and Piravom. The eastern part of the zone receives less rainfall compared to the western part and Chittur receives less than 1500 mm.

During southwest monsoon season also, the same trend is seen. An increase in rainfall is found from east to west. The rainfall does not change considerably as one

Table 2 (a). Rainfall analysis for different stations in the central zone (in mm)

Station: Alathur — No. of years: 20 (1978-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	2.5	1.4	16.1	54.2	121.9	399.7	513.9	303.6	158.3	201.9	128.1	18.4	192.2	1375.5	330.1	1920.0
75%	0.0	0.0	0.0	8.1	75.3	288.0	431.2	231.1	63.1	124.0	71.1	0.0	127.0	1229.6	203.4	1658.4
90%	0.0	0.0	0.0	0.2	27.6	213.0	336.8	201.2	34.0	67.8	7.1	0.0	55.4	1056.9	149.2	1442.7
SD	7.3	3.8	22.7	70.1	81.0	156.6	128.1	113.7	110.9	102.4	89.5	36.8	102.6	291.7	138.7	382.8
CV%	296.7	271.5	141.0	129.4	66.4	39.2	24.9	37.4	70.0	50.7	69.9	200.5	53.4	21.2	42.0	19.9

Station: Aluva — No. of years: 16 (1982-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	4.3	1.8	11.8	42.0	69.9	679.2	677.3	417.6	302.1	271.3	167.2	53.0	123.7	2076.1	438.5	2697.5
75%	0.0	0.0	0.0	0.0	0.0	528.4	516.3	290.1	140.6	156.4	61.1	12.1	0.0	1813.2	304.1	2356.9
90%	0.0	0.0	0.0	0.0	0.0	355.7	329.5	242.0	87.3	135.6	32.9	0.6	0.0	1577.1	191.3	1985.2
SD	10.1	4.5	22.6	65.8	106.7	208.1	232.4	131.2	175.3	119.3	130.0	55.2	168.6	357.3	190.8	609.5
CV%	233.8	252.9	191.4	156.7	152.7	30.6	34.3	31.4	58.0	44.0	77.7	104.1	136.2	17.2	43.5	22.6

SMR = Summer (March-May); SWM = Southwest Monsoon (June-September); NEM = Northeast Monsoon (October-November)

Table 2 (b). Rainfall analysis for different stations in the central zone (in mm)

Station: Angadipuram

No. of years: 12 (1986-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	0.0	4.1	8.2	58.7	92.0	564.9	670.1	341.1	234.7	259.0	178.3	24.0	158.9	1810.8	437.3	2435.0
75%	0.0	0.0	0.0	0.0	0.0	454.3	502.4	249.1	185.6	110.0	90.6	0.0	0.0	1516.2	380.4	1955.9
90%	0.0	0.0	0.0	0.0	0.0	371.5	309.7	70.4	45.5	40.6	21.6	0.0	0.0	1123.8	91.0	1632.6
SD	0.1	9.6	13.0	63.6	113.3	145.2	284.3	150.6	103.2	134.6	125.8	40.6	161.5	489.0	189.6	659.3
CV%	331.7	236.0	158.3	108.4	123.2	25.7	42.4	44.2	44.0	52.0	70.5	169.1	101.6	27.0	43.4	27.1

Station: Chalakudy

No. of years: 14 (1984-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	5.2	0.4	5.2	69.9	92.6	735.0	678.2	431.7	293.1	327.0	135.2	52.9	167.7	2138.0	462.2	2826.4
75%	0.0	0.0	0.0	0.0	0.0	571.0	484.3	290.6	120.3	237.9	39.3	0.0	0.0	1787.7	368.0	2333.9
90%	0.0	0.0	0.0	0.0	0.0	471.0	359.1	262.0	84.6	174.4	22.7	0.0	0.0	1709.8	230.6	2200.0
SD	17.6	1.0	8.3	91.7	144.0	197.0	212.0	132.9	174.8	114.3	84.3	68.8	216.9	376.1	145.6	600.5
CV%	340.6	258.1	158.2	131.2	155.5	26.8	31.3	30.8	59.6	34.9	62.4	129.9	129.3	17.6	35.1	21.2

SMR = Summer (March-May); SWM = Southwest Monsoon (June-September); NEM = Northeast Monsoon (October-November)

Table 2 (c). Rainfall analysis fordifferent stations in the central zone (in mm)

Station: Chitoor | **No. of years: 20 (1978-97)**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	2.3	7.1	10.2	45.3	95.1	290.6	374.9	237.6	118.7	149.0	104.5	27.8	150.5	1021.8	253.5	1462.9
75%	0.0	0.0	0.0	0.0	43.0	176.8	262.0	182.6	29.9	65.6	77.8	0.0	64.7	909.0	191.4	1355.9
90%	0.0	0.0	0.0	0.0	10.8	110.8	234.6	140.6	22.8	42.0	10.0	0.0	29.4	816.7	76.0	1143.4
SD	8.7	19.9	19.4	57.8	73.6	121.1	103.9	78.3	103.3	101.9	62.1	67.3	110.4	155.3	111.7	215.6
CV%	375.3	282.2	190.9	127.7	77.5	41.7	77.7	33.0	87.0	68.4	59.4	242.2	73.4	15.2	44.1	14.7

Station: Enamakal | **No. of years: 13 (1985-97)**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	5.7	3.8	7.3	41.3	133.7	611.3	382.2	293.6	205.8	182.4	206.5	23.8	182.2	1492.9	388.9	2097.3
75%	0.0	0.0	0.0	0.0	0.0	431.0	238.2	197.9	138.0	73.1	164.1	9.1	0.0	1078.4	277.2	1700.8
90%	0.0	0.0	0.0	0.0	0.0	346.6	141.6	147.0	68.5	42.4	13.4	5.5	0.0	1020.6	95.8	1525.9
SD	19.7	12.1	10.3	49.5	213.4	202.3	186.2	118.0	111.3	148.5	97.5	18.6	256.0	388.2	193.3	413.3
CV%	343.9	318.7	141.7	119.9	159.7	33.1	48.7	40.2	54.1	81.4	47.2	78.3	140.5	26.0	49.7	19.7

SMR = Summer (March-May); SWM = Southwest Monsoon (June-September); NEM = Northeast Monsoon (October-November)

Table 2 (d). Rainfall analysis for different stations in the central zone (in mm)

Station: Irinjalakuda

No. of years: 14 (1984-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	0.0	0.3	1.8	27.3	71.6	746.3	665.5	380.0	278.9	281.2	125.6	29.1	100.7	2070.8	406.9	2607.7
75%	0.0	0.0	0.0	0.0	0.0	545.6	477.1	270.2	127.8	134.6	38.0	0.0	0.0	1756.3	226.8	2160.7
90%	0.0	0.0	0.0	0.0	0.0	294.0	378.0	183.0	57.5	88.2	9.5	0.0	0.0	1236.0	132.7	1460.8
SD	0.0	1.0	6.4	43.8	123.5	257.3	226.5	136.7	199.1	143.7	113.0	39.9	158.4	547.7	213.5	763.7
CV%	0.0	360.6	360.6	160.7	172.5	34.5	34.0	36.0	71.4	51.1	90.0	137.4	157.3	26.4	52.5	29.3

Station: Kannara

No. of years: 13 (1985-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	2.5	0.5	2.2	37.4	78.5	651.7	673.4	423.5	268.2	259.2	105.7	22.5	118.1	2016.8	365.0	2525.4
75%	0.0	0.0	0.0	0.0	0.0	543.0	517.4	355.8	107.7	156.8	30.6	0.0	0.0	1784.8	189.2	2315.1
90%	0.0	0.0	0.0	0.0	0.0	403.3	386.5	265.3	77.4	95.2	14.3	0.0	0.0	1755.6	141.5	2090.1
SD	8.7	1.8	6.9	46.8	94.7	151.3	191.4	113.3	162.3	123.0	89.3	29.1	122.5	270.8	164.7	335.7
CV%	346.4	325.6	314.1	125.3	120.6	23.2	28.4	26.8	60.5	47.5	84.5	129.0	103.7	13.4	45.1	13.3

SMR = Summer (March-May); SWM = Southwest Monsoon (June-September); NEM = Northeast Monsoon (October-November)

Table 2 (e). Rainfall analysis for different stations in the central zone (in mm)

Station: Kochi

No. of years: 20 (1978-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	27.4	24.5	32.5	86.2	229.3	797.9	606.4	419.6	276.6	313.2	177.1	42.9	348.1	2100.6	490.3	3033.8
75%	0.0	0.0	1.5	57.6	87.1	614.2	456.8	300.7	92.8	183.7	118.4	6.0	187.5	1798.4	355.4	2604.0
90%	0.0	0.0	0.0	36.8	34.8	534.3	308.1	205.7	74.0	104.8	60.6	0.2	134.1	1555.5	198.9	2483.1
SD	50.6	44.4	33.4	42.7	193.8	258.9	176.0	131.9	178.3	147.5	89.9	48.0	200.6	357.8	167.4	377.0
CV%	185.0	180.8	102.7	49.6	84.5	32.5	29.0	31.4	64.5	47.1	50.8	111.7	57.6	17.0	34.1	12.4

Station: Kodungallur

No. of years: 18 (1980-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	4.1	2.5	4.0	27.4	115.9	806.5	794.4	494.7	364.4	289.3	130.0	38.0	147.3	2460.1	419.4	3071.4
75%	0.0	0.0	0.0	0.0	0.0	698.8	529.6	360.5	181.7	137.0	54.5	0.0	0.0	2007.3	228.2	2434.8
90%	0.0	0.0	0.0	0.0	0.0	395.8	293.2	304.7	111.1	94.0	14.0	0.0	0.0	1742.5	144.9	2117.9
SD	14.1	5.7	9.3	43.5	208.8	231.7	365.1	163.9	203.9	196.9	125.3	53.0	249.1	561.3	274.7	899.1
CV%	344.7	226.4	232.3	159.1	180.1	28.7	46.0	33.1	56.0	68.1	96.4	139.3	169.1	22.8	65.5	29.3

SMR = Summer (March-May); SWM = Southwest Monsoon (June-September); NEM = Northeast Monsoon (October-November)

Table 2 (f). Rainfall analysis for different stations in the central zone (in mm)

Station: Kollenkode

No. of years: 17 (1981-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	0.3	0.6	5.3	19.0	39.4	345.8	431.4	302.9	132.4	154.0	105.6	21.1	63.7	1212.4	259.6	1557.6
75%	0.0	0.0	0.0	0.0	0.0	216.6	344.0	225.5	41.7	92.6	52.3	0.0	0.0	1134.1	175.5	1385.2
90%	0.0	0.0	0.0	0.0	0.0	164.2	291.3	220.9	23.8	60.8	32.3	0.0	0.0	927.1	121.4	1281.7
SD	1.1	2.4	17.2	38.5	56.0	148.2	95.2	79.1	80.0	93.3	63.2	37.4	86.2	208.4	126.4	264.0
CV%	400.0	400.0	326.1	202.9	142.0	42.8	22.1	26.1	60.4	60.6	59.9	177.2	135.4	17.2	48.7	16.9

Station: Kunnamkulam

No. of years: 18 (1980-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	4.2	0.9	7.1	34.9	73.0	877.9	773.3	491.5	335.8	306.5	144.5	18.8	114.9	2478.5	451.0	3068.3
75%	0.0	0.0	0.0	0.0	0.0	699.0	547.4	351.0	166.5	174.8	71.1	0.0	0.0	2096.3	255.4	2591.5
90%	0.0	0.0	0.0	0.0	0.0	524.3	438.9	298.5	100.6	62.1	6.6	0.0	0.0	1948.1	108.7	2441.9
SD	17.5	3.1	18.7	61.7	144.3	207.5	253.2	141.4	211.1	183.4	110.6	23.6	183.4	394.3	241.1	562.1
CV%	412.3	359.9	262.5	176.9	197.8	23.6	32.7	28.8	62.9	59.8	76.5	125.8	159.6	15.9	53.4	18.3

SMR = Summer (March-May); SWM = Southwest Monsoon (June-September); NEM = Northeast Monsoon (October-November)

Table 2 (g). Rainfall analysis for different stations in the central zone (in mm)

Station: Manjeri

No. of years: 14 (1984-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	1.5	1.7	15.4	61.6	73.4	677.1	674.6	377.8	216.1	282.4	185.2	103.9	150.3	1945.7	467.5	2670.6
75%	0.0	0.0	0.0	0.0	0.0	552.6	453.5	308.5	132.1	217.9	44.8	45.5	0.0	1677.4	336.6	2251.8
90%	0.0	0.0	0.0	0.0	0.0	468.6	317.7	223.7	53.5	58.0	16.4	10.0	0.0	1366.2	75.9	2220.5
SD	4.4	4.2	24.7	108.8	110.1	160.4	296.1	96.2	127.3	131.2	133.0	85.0	231.0	393.5	224.8	528.7
CV%	294.7	245.7	161.0	176.6	150.1	23.7	43.9	25.5	58.9	46.5	71.8	81.8	153.7	20.2	48.1	19.8

Station: Mannarkkad

No. of years: 20 (1978-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	2.6	6.2	19.4	87.5	123.9	476.0	511.5	336.8	227.1	258.9	124.2	14.3	230.8	1551.3	383.2	2188.4
75%	0.0	0.0	0.0	13.3	66.7	318.3	394.9	261.5	139.4	157.2	44.8	0.0	95.6	1217.8	272.6	1690.9
90%	0.0	0.0	0.0	0.9	23.5	250.2	233.3	167.4	49.3	88.2	5.7	0.0	77.1	967.5	161.8	1531.3
SD	6.0	10.2	30.2	94.5	70.4	183.3	208.3	107.8	135.7	124.2	111.0	18.7	136.8	375.3	170.8	494.5
CV%	234.7	165.7	156.0	108.0	56.8	38.5	40.7	32.0	59.8	48.0	89.3	130.8	59.3	24.2	44.6	22.6

SMR = Summer (March-May); SWM = Southwest Monsoon (June-September); NEM = Northeast Monsoon (October-November)

Table 2 (h). Rainfall analysis for different stations in the central zone (in mm)

Station: Nilambur | No. of years: 20 (1978-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	3.5	1.5	10.0	40.1	90.6	655.9	648.9	424.9	175.7	209.4	133.5	26.9	140.7	1905.4	342.9	2420.8
75%	0.0	0.0	0.0	0.0	50.8	498.4	506.0	252.1	80.1	115.4	69.1	0.0	98.9	1435.5	229.7	2068.4
90%	0.0	0.0	0.0	0.0	29.4	349.2	307.6	222.0	56.8	72.3	35.7	0.0	47.3	1098.0	165.4	1155.0
SD	8.9	3.5	12.9	38.5	53.5	234.7	232.3	210.5	103.7	110.1	68.5	36.4	68.5	534.1	112.4	558.7
CV%	252.7	242.1	129.0	96.2	59.1	35.8	35.8	49.5	59.0	52.6	51.3	135.4	48.7	28.0	32.8	23.1

Station: Ottapalam | No. of years: 20 (1978-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	11.1	3.9	12.1	68.6	116.7	557.0	592.3	346.0	172.3	237.5	120.5	13.8	197.4	1667.6	358.0	2251.8
75%	0.0	0.0	0.0	0.0	51.9	405.8	436.6	281.6	71.8	167.9	45.0	0.0	124.9	1393.0	231.4	1993.1
90%	0.0	0.0	0.0	0.0	16.2	295.5	385.5	245.0	31.5	120.5	10.7	0.0	81.8	1139.1	211.1	1677.7
SD	38.6	9.3	18.5	82.9	79.2	195.7	165.2	123.9	106.3	88.4	99.9	18.7	99.5	361.9	131.5	391.3
CV%	347.2	238.9	152.4	120.8	67.9	35.1	27.9	35.8	61.7	37.2	82.9	136.1	50.4	21.7	36.7	17.4

SMR = Summer (March-May); SWM = Southwest Monsoon (June-September); NEM = Northeast Monsoon (October-November)

Table 2 (j). Rainfall analysis for different stations in the central zone (in mm)

Station: Pattambi **No. of years: 13 (1985-97)**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	0.0	0.0	10.7	26.3	57.4	644.7	666.5	334.4	203.0	260.6	133.9	90.0	94.4	1848.6	394.5	2427.4
75%	0.0	0.0	0.0	0.0	0.0	519.5	515.1	245.8	71.4	179.7	55.8	0.0	0.0	1580.9	332.1	2158.3
90%	0.0	0.0	0.0	0.0	0.0	281.3	334.3	235.0	44.6	99.1	26.6	0.0	0.0	1179.1	158.4	2011.4
SD	0.0	0.0	18.8	39.0	62.2	203.6	232.5	79.3	119.3	103.6	85.4	241.1	96.9	383.0	118.5	364.7
CV%	0.0	0.0	175.7	148.5	108.4	31.6	34.9	23.7	58.8	39.8	63.8	268.0	102.7	20.7	30.0	15.0

Station: Perinthalmanna **No. of years: 14 (1984-97)**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	0.0	3.0	7.5	70.1	99.0	632.2	635.8	355.0	213.2	287.6	165.4	22.6	176.7	1836.2	453.0	2491.5
75%	0.0	0.0	0.0	0.0	0.0	493.8	497.1	273.8	99.5	245.5	40.8	0.0	0.0	1603.8	331.6	2082.4
90%	0.0	0.0	0.0	0.0	0.0	425.1	315.7	245.8	18.5	14.2	11.5	0.0	0.0	1339.0	25.7	1702.6
SD	0.1	10.0	12.5	89.5	133.0	155.9	225.6	90.2	115.6	132.3	146.4	40.1	208.4	340.2	221.7	538.2
CV%	360.6	333.3	167.0	127.5	134.3	24.7	35.5	25.4	54.2	46.0	88.5	177.4	118.0	18.5	48.9	21.6

SMR = Summer (March-May); SWM = Southwest Monsoon (June-September); NEM = Northeast Monsoon (October-November)

Table 2 (k). Rainfall analysis for different stations in the central zone (in mm)

Station: Perumbavoor

No. of years: 13 (1985-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	10.1	4.7	5.5	39.2	68.7	703.7	641.3	394.1	308.7	313.6	165.7	41.2	113.4	2047.8	479.2	2696.5
75%	0.0	0.0	0.0	0.0	0.0	565.3	442.7	342.6	156.4	192.3	114.0	1.0	0.0	1860.2	348.6	2358.4
90%	0.0	0.0	0.0	0.0	0.0	341.9	367.6	212.0	116.0	123.9	39.7	0.0	0.0	1440.2	264.3	1793.3
SD	20.9	12.2	10.6	54.3	105.4	216.3	185.8	95.2	200.0	123.2	89.9	57.5	151.7	350.1	134.2	516.9
CV%	206.5	258.3	193.1	138.6	153.4	30.7	29.0	24.2	64.8	39.3	54.2	139.5	133.7	17.1	28.0	19.2

Station: Piravom

No. of years: 17 (1981-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	7.1	2.2	4.9	49.8	74.4	815.6	727.2	486.6	326.6	348.4	209.8	57.2	129.1	2355.9	558.3	3109.7
75%	0.0	0.0	0.0	0.0	0.0	583.4	510.5	318.0	98.8	220.1	132.8	14.8	0.0	2042.8	372.8	2472.9
90%	0.0	0.0	0.0	0.0	0.0	447.3	381.7	210.0	78.7	164.0	83.3	0.0	0.0	1620.4	274.6	2080.9
SD	20.6	8.8	12.5	96.3	125.8	239.4	288.6	176.9	245.6	177.7	114.5	96.5	205.9	574.7	249.3	995.0
CV%	290.8	400.0	253.8	193.4	169.1	29.4	39.7	36.3	75.2	51.0	54.6	168.8	159.5	24.4	44.7	32.0

SMR = Summer (March-May); SWM = Southwest Monsoon (June-September); NEM = Northeast Monsoon (October-November)

Table 2 (l). Rainfall analysis for different stations in the central zone (in mm)

Station: Ponnani — **No. of years: 10 (1988-97)**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	3.8	0.0	8.79	57.9	143.0	715.3	812.1	372.5	255.3	288.9	156.9	15.1	209.6	2155.2	445.9	2829.5
75%	0.0	0.0	0.0	0.0	0.0	550.3	622.4	232.9	163.8	173.8	66.3	0.0	0.0	1799.7	252.9	2223.6
90%	0.0	0.0	0.0	0.0	0.0	501.5	444.6	109.7	86.5	83.1	27.1	0.0	0.0	1708.9	118.0	1919.3
SD	7.7	0.0	12.3	78.8	211.5	171.9	267.8	158.9	111.4	131.8	131.3	18.6	237.1	440.4	195.8	635.1
CV%	201.5	0.0	141.0	136.2	147.9	24.0	33.0	42.7	43.6	45.6	83.6	123.4	113.1	20.4	43.9	22.4

Station: Thritala — **No. of years: 13 (1985-97)**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	0.5	0.0	10.8	27.5	64.9	604.1	653.5	329.0	217.9	214.5	134.5	11.5	103.1	1804.4	349.0	2268.5
75%	0.0	0.0	0.0	0.0	0.0	476.0	430.5	249.1	114.7	143.1	45.8	0.0	0.0	1508.6	179.5	1752.2
90%	0.0	0.0	0.0	0.0	0.0	396.9	313.9	222.2	29.2	17.0	6.5	0.0	0.0	1288.6	38.2	1641.4
SD	1.7	0.0	17.8	41.7	88.9	150.3	284.2	74.9	117.4	111.7	101.7	18.5	126.9	393.6	176.5	539.6
CV%	346.4	0.0	165.2	151.8	137.0	24.9	43.5	22.8	53.9	52.1	75.6	161.1	123.0	21.8	50.6	23.8

SMR = Summer (March-May); SWM = Southwest Monsoon (June-September); NEM = Northeast Monsoon (October-November)

Table 2 (m). Rainfall analysis for different stations in the central zone (in mm)

Station: Thrissur

No. of years: 16 (1983-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	2.7	2.8	8.7	67.1	161.5	728.0	696.7	440.1	265.6	303.5	110.8	23.3	237.2	2130.4	414.3	2810.7
75%	0.0	0.0	0.0	22.1	64.7	506.2	548.2	322.4	88.1	205.9	15.2	0.3	146.9	1740.8	250.5	2481.3
90%	0.0	0.0	0.0	5.7	38.8	396.4	367.9	278.8	60.8	114.7	8.0	0.0	61.1	1687.6	177.4	2356.4
SD	5.6	6.7	11.8	53.2	138.0	197.2	201.5	132.0	183.7	116.3	99.6	24.7	154.4	379.1	165.3	422.2
CV%	211.0	234.4	135.2	79.3	85.5	27.1	28.9	30.0	69.1	38.3	90.0	106.0	65.1	17.8	39.9	15.0

Station: Wadakkancherry

No. of years: 12 (1986-97)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SMR	SWM	NEM	Year
Mean	0.8	0.0	1.6	55.8	123.7	641.2	694.9	396.6	303.8	261.6	130.6	11.4	181.1	2036.5	392.2	2621.9
75%	0.0	0.0	0.0	0.0	0.0	540.1	539.3	309.9	245.8	124.3	26.8	0.0	0.0	1748.0	269.0	2099.2
90%	0.0	0.0	0.0	0.0	0.0	477.0	350.2	195.7	149.5	21.9	8.1	0.0	0.0	1541.2	65.7	2059.4
SD	2.5	0.0	3.9	76.1	158.0	120.1	238.2	149.8	100.7	149.5	119.6	20.8	197.9	362.5	201.0	518.0
CV%	331.7	0.0	237.5	136.4	127.7	18.7	34.3	37.8	33.1	57.2	91.6	181.8	109.3	17.8	51.2	19.8

SMR = Summer (March-May); SWM = Southwest Monsoon (June-September); NEM = Northeast Monsoon (October-November)

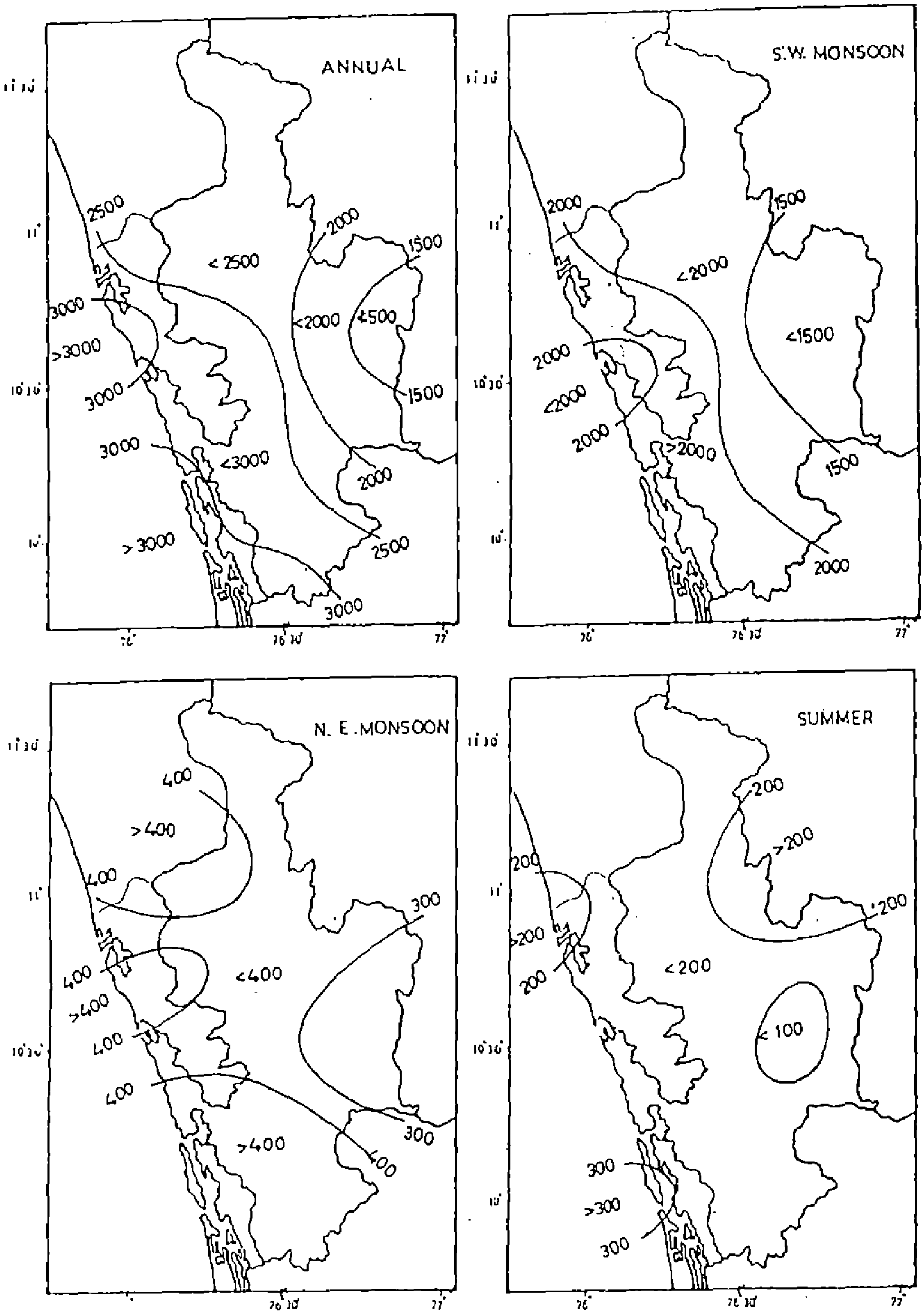

Fig.3 Distribution of mean rainfall (mm)

moves from south to north. It is found that generally, areas having similar amount of rainfall are seen in parallel strips running from south to north.

Southern part of the zone receives more rainfall during northeast monsoon season i.e., more than 400 mm rainfall. There are certain pockets in the coastal area and northern part which receive more than 400 mm. These are areas in an around Manjeri, Angadipuram, Perinthalmanna and Kunnamkulam. Stations on the eastern side i.e., Chittur and Parambikulam receive less than 300 mm and these regions receive the least rainfall during the northeast monsoon season.

During summer season, almost all the stations in the zone receive less than 200 mm rainfall, while Kochi as an exception receives more than 300 mm. A small pocket at Kollengode receives less than 100 mm rainfall.

4.2.1.2 Spatial distribution of coefficient of variation (CV)

Subudhi *et al.* (1996) computed coefficient of variation and variation of mean annual rainfall for Bhadrak and Balasore districts of Orissa using monthly rainfall data. Similarly the CV of rainfall for the central zone was worked out annually and seasonally. Variation of the CV of rainfall over the central zone is illustrated in the Fig. 4. It can be seen from the figure that the annual CV exceeds 30 per cent in the southeastern part. The CV is less than 20 per cent in the central part of the zone while in the northern region, it varies between 20 and 30 per cent.

During the southwest monsoon season, the CV is more than 20 per cent in the northern parts. Except for some isolated pockets, the CV in the southern parts is less than 20 per cent. These are areas near Piravom, Kodungallur and Irinjalakuda.

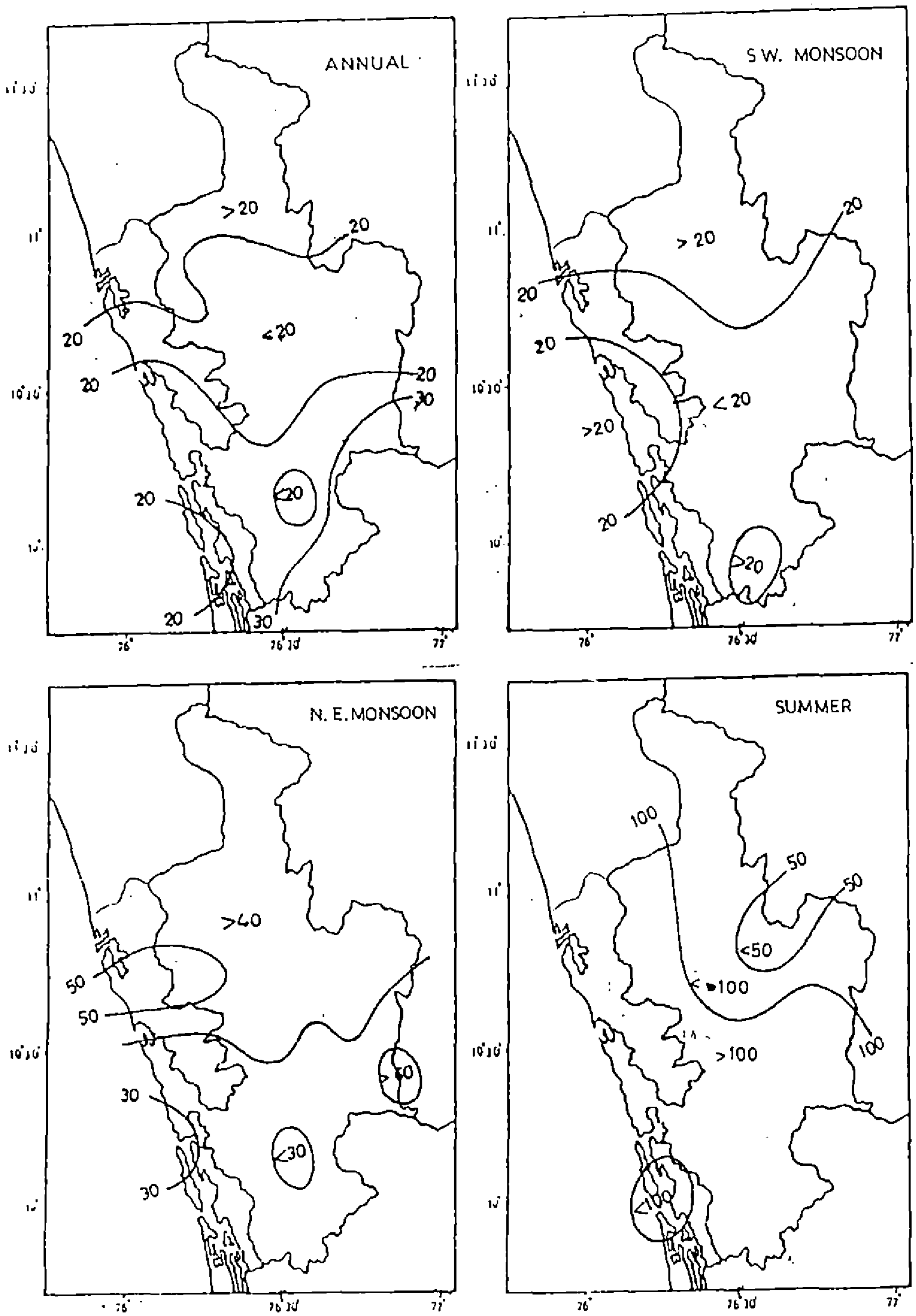

Fig. 4 Distribution of coefficient of variation of rainfall(%)

During the northeast monsoon season, the CV is very high in the northern part of the zone and exceeds 40 per cent. At Kunnamkulam and Parambikulam, the CV is 50 and 60 per cent respectively. In summer, the CV is more than 100 per cent for majority of the stations. Palakkad experiences a CV of less than 50 per cent.

4.2.1.3 Spatial distribution of rainfall at 75 per cent probability level

Spatial distribution of rainfall at 75 percent probability level is shown in Fig. 5. It can be seen from the figure that annual rainfall at 75 per cent probability level increases from east to west. Dependable rainfall at Kunnamkulam and Kochi is more than 2500 mm. There is not much variation from south to north.

During the southwest monsoon season also a similar trend is observed. Chittur and Parambikulam recorded the least values i.e., less than 1000 mm whereas, two stations near the coastal area viz., Kunnamkulam and Kochi have high values. For majority of stations the rainfall expected at 75 per cent probability is between 1500 and 2000 mm. Similar work for calculating the dependable rainfall was done by Rao *et al.* (1998) for Anantapur, Nandyal and Lam from 1969 to 1984.

Rainfall at 75 per cent probability level during northeast monsoon season also shows similar trend as that of southwest monsoon season except the fact that in coastal areas the rainfall is low i.e., less than 300 mm. The southern part, northern part and a narrow strip running through the centre of the zone experience high rainfall i.e., more than 300 mm. Chittur and Parambikulam have lower values during this season also. Except for the northeastern parts, all the central zone has zero rainfall at 75 per cent probability level during summer.

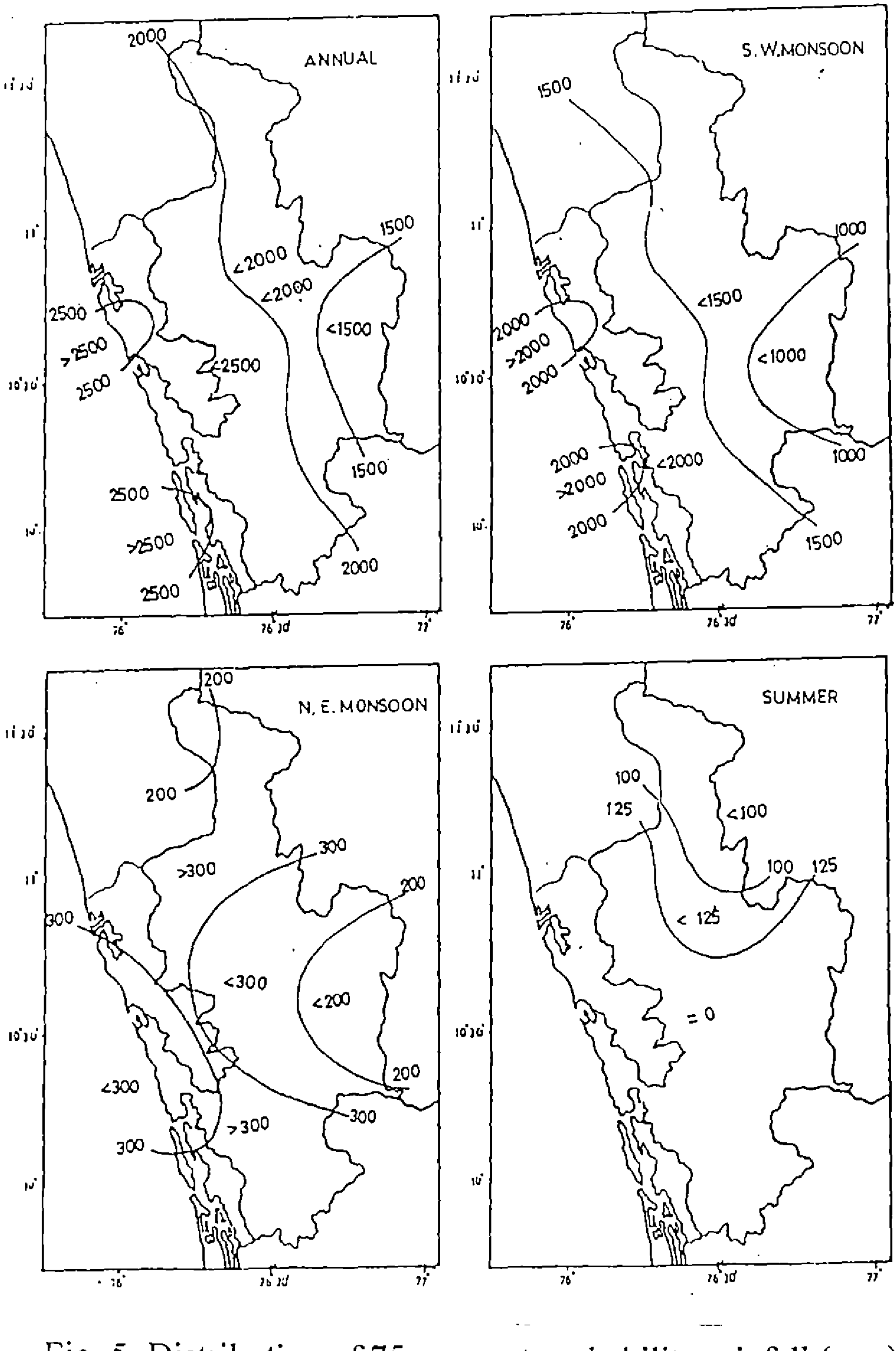

Fig. 5 Distribution of 75 per cent probability rainfall (mm)

4.2.1.4 Spatial distribution of rainfall at 90 per cent probability level

This is illustrated in Fig. 6. Annual rainfall at 90 per cent probability level is high in the northern part of the zone. In the southern part of the zone the amount of rainfall increases from east to west. Parambikulam has the least rainfall at 90 per cent probability level.

During southwest monsoon season the rainfall increases from east to west. There is not much difference in the amount of rainfall in the north south direction. Most of the parts of coastal area experience more than 1500mm. Parambikulam recorded very low amount of rainfall i.e., 168 mm. The spatial distribution of rainfall at 90 per cent probability level is erratic during the north east monsoon season. In the southern regions the rainfall is more but in the northern region no particular trend is observed. The rainfall is low in the western ghats.

During summer the rainfall in most of the stations at 90 per cent probability level is zero. The stations in the north east part of the zone recorded some amount of rainfall, but it is less than 100 mm.

4.2.1.5 Initial and conditional rainfall probabilities of receiving > 30 mm

The initial and conditional rainfall probabilities of getting more than 30 mm at Palakkad, Kochi, Pattambi and Vellanikkara are worked out. It is useful in finding the sowing time of crop irrigation scheduling etc. as reported by Virmani *et al.* (1978). For this analysis Markov chain model was used, as used by Santhosh and Prabhakaran (1988). The results of the analysis are presented and Fig. 7 shows the results for Kochi. It can be seen from the figure that at Kochi, the initial probability of getting 30 mm rainfall per week is 75 per cent or more during 23rd week (04-10 June)

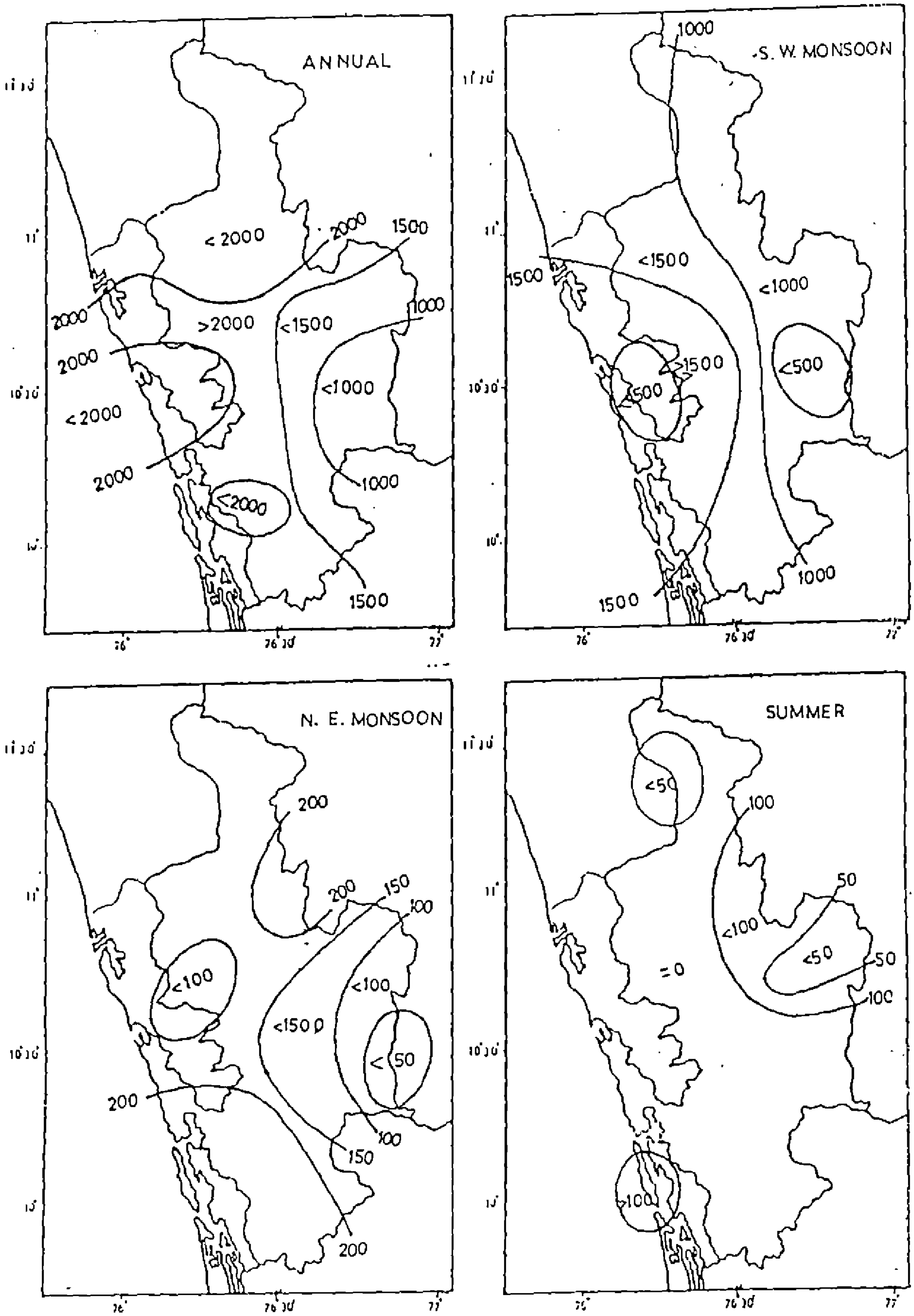

Fig. 6 Distribution of 90 per cent probability rainfall (mm)

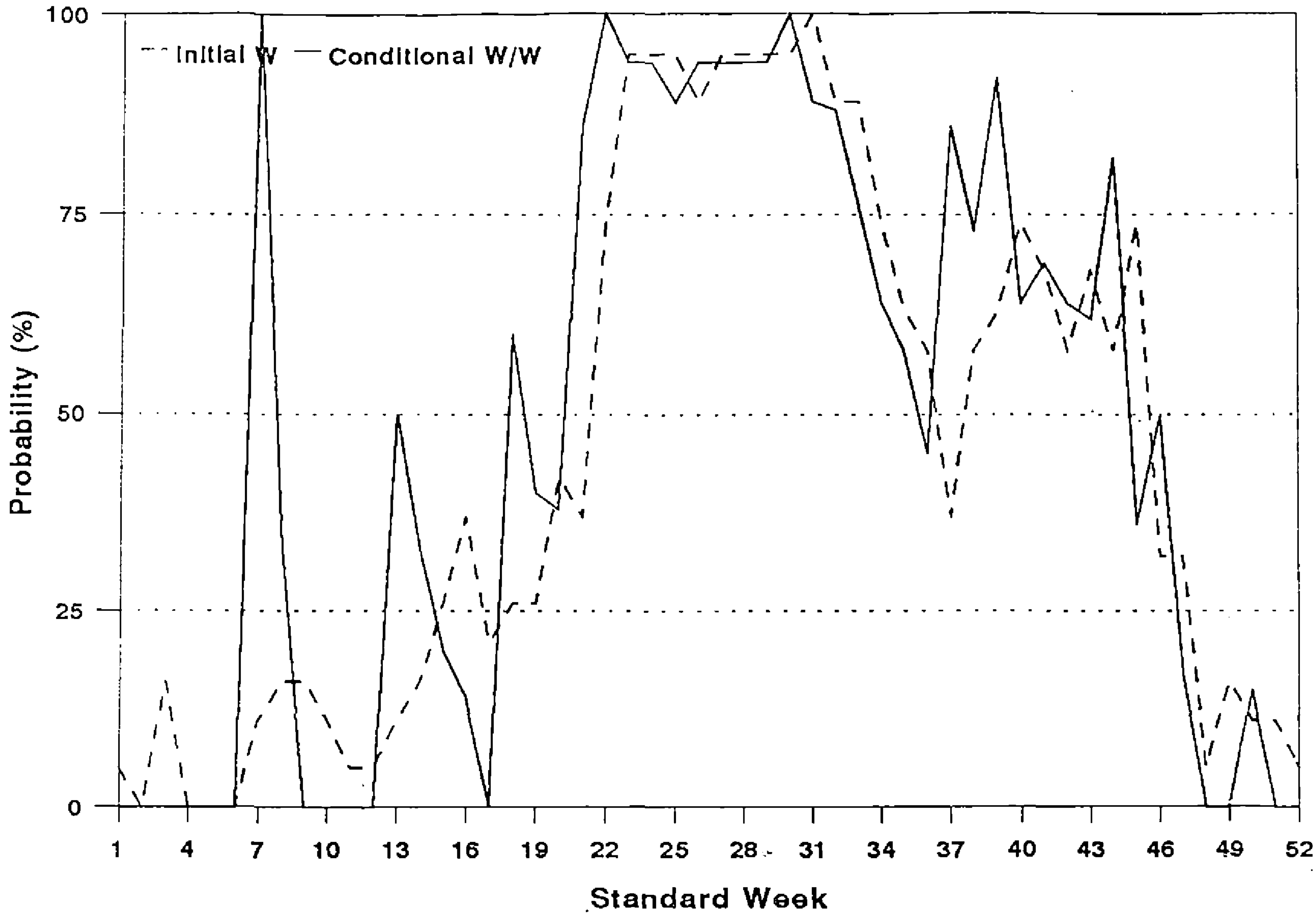

Fig. 7 Initial and conditional rainfall probabilities of receiving > 30 mm at Kochi

to 33rd week (13-19 August) and conditional probability of wet week followed by wet week (w/w) having rainfall greater than or equal to 30 mm per week was more than 75 per cent during the period 22nd week (28 May to 3 June) to 33rd week (13 August to 19 August). The conditional probability is more than 75 per cent in the 7th,33rd, and 39th weeks. From this analysis it can be inferred that rainy season in this area extends from 23rd week to 33rd week (4 June to 19 August).

Fig.8 shows the results of initial and conditional probability rainfall at Palakkad. At Palakkad the initial probability of getting 30 mm rainfall per week is 75 per cent or more is during the 24th week to 35th week (11 June 11 to 2 September). The conditional probability of wet week followed by wet week (w/w) having rainfall greater than or equal to 30 mm per week was more than 75 per cent during 22nd to 35th week (8 May to 2 September). For conditional probability more than 75 per cent value is observed very early in the 15th week itself but it is only for one week period. So it can be concluded that rainy season starts on 28th May at Kochi and it extends up to 35th week and sowing of crops can be done during last week of May.

The results of the analysis carried out for finding the initial and conditional probabilities of getting 30 mm rainfall at Pattambi is presented in Fig.9. The results show that initial probability of getting 30 mm rainfall per week is 75 per cent or more during 22nd week to 35th week (28 May to 2 September) and conditional probability of wet week followed by wet week (w/w) having rainfall greater than or equal to 30 mm per week was more than 75 per cent during the period 22nd to 34th week (28 May to 26 August). This shows that the starting of rainy season during the 22nd week and it goes

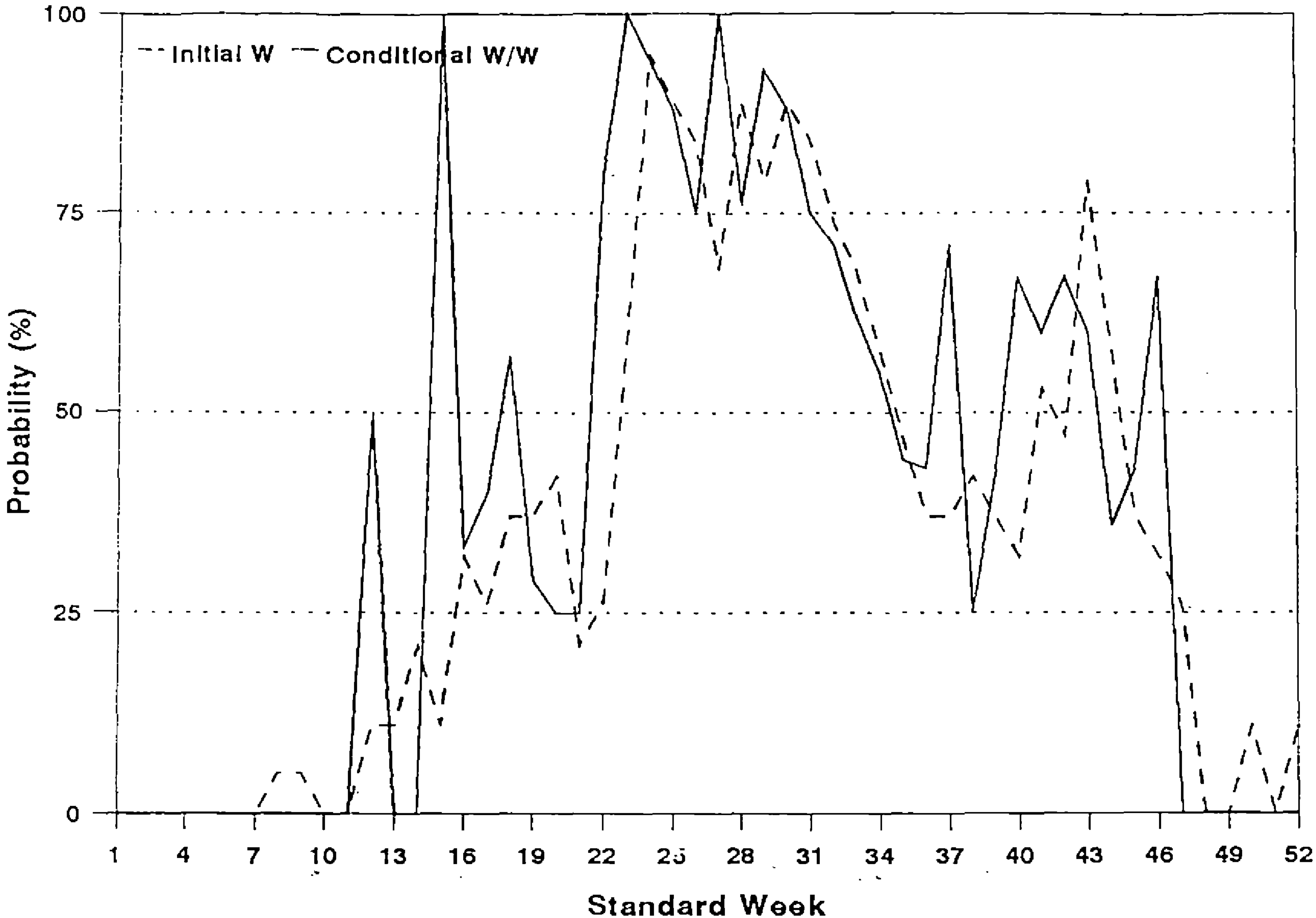

Fig. 8 Initial and conditional rainfall probabilities of receiving > 30 mm at Palakkad

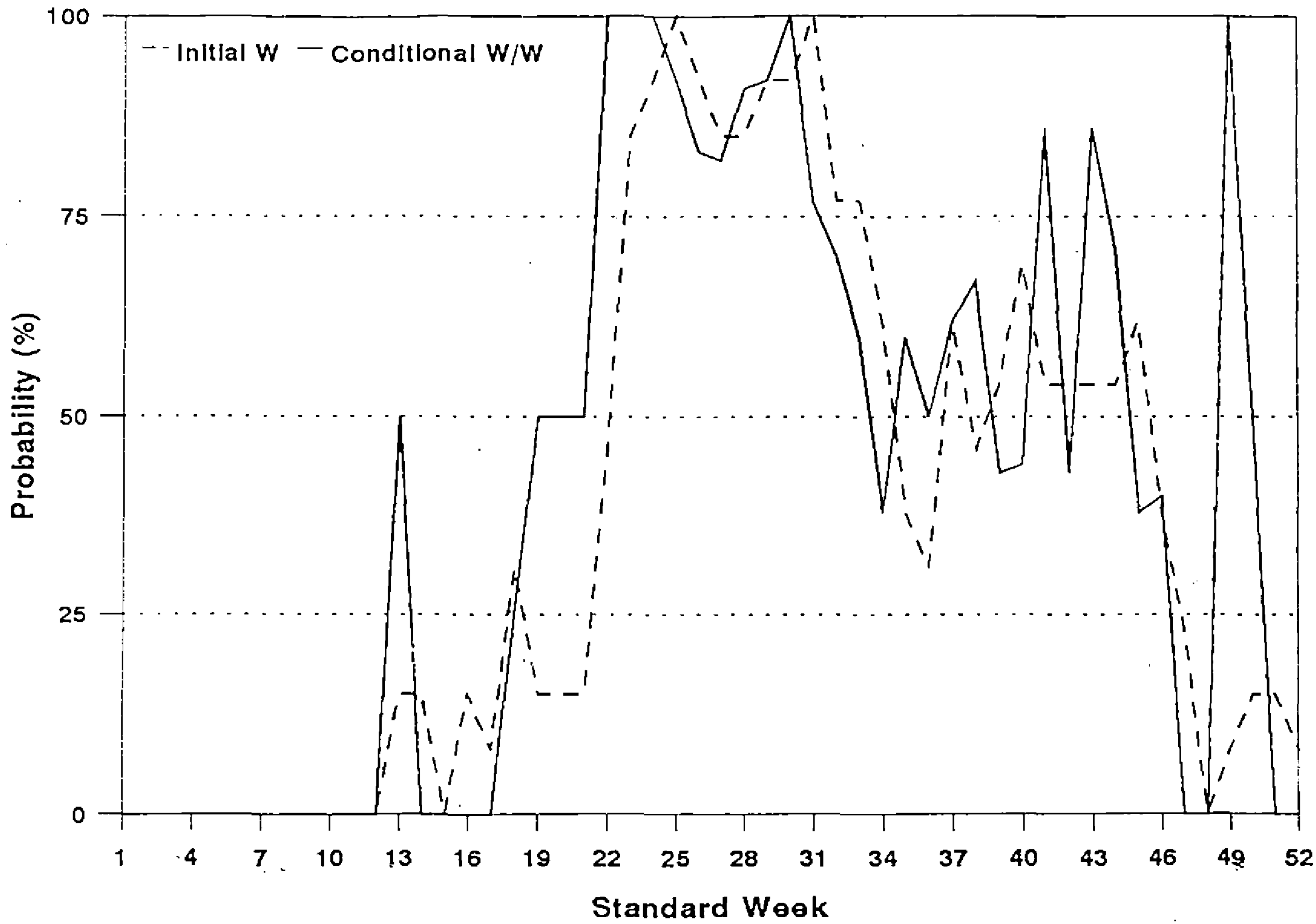

Fig.9 Initial and conditional rainfall probabilities of receiving > 30 mm at Pattamb

up to 34th week and sowing of crops can be taken up around 18th week (28 May-06 May).

The results of the analysis for initial and conditional probabilities of getting more than 30 mm rainfall at Vellanikkara is given in Fig.10. The initial probability of receiving more than 30 mm rainfall in this station is above 75 per cent during the period 22nd to 36th week (28 May to 9 September) and conditional probability of receiving more than 30 mm rainfall is during 21st week to 34th week (21 May to 9 September). So it can be concluded that rainy season starts from 21 May and extends up to 9th September and the appropriate time for sowing is last week of May.

4. 2. 2. Temperature and relative humidity

Mean values for maximum and minimum temperature was worked out monthly annually and seasonally for Kochi, Palakkad and Vellanikkara and is presented in table 3. The highest maximum temperature is observed at Kochi during April (33.0° C) and the lowest maximum temperature is observed during July and August. The maximum temperature during southwest monsoon season, northeast monsoon season, summer and annually were 29.9° C, 31.1° C, 32.7° C and 31.3° C respectively. The lowest minimum temperature for Kochi is 22.8° C observed during January. The values during southwest, northeast and summer 24.0° C, 24.1° C and 25.8° C respectively. Annual minimum temperature is 24.3° C. The maximum relative humidity was found highest during July and August (91%). The lowest minimum relative humidity was observed during January (61%).

At Vellanikkara, highest maximum temperature is observed during March (36.2 °C) and the lowest maximum temperature is observed during July (29° C). The

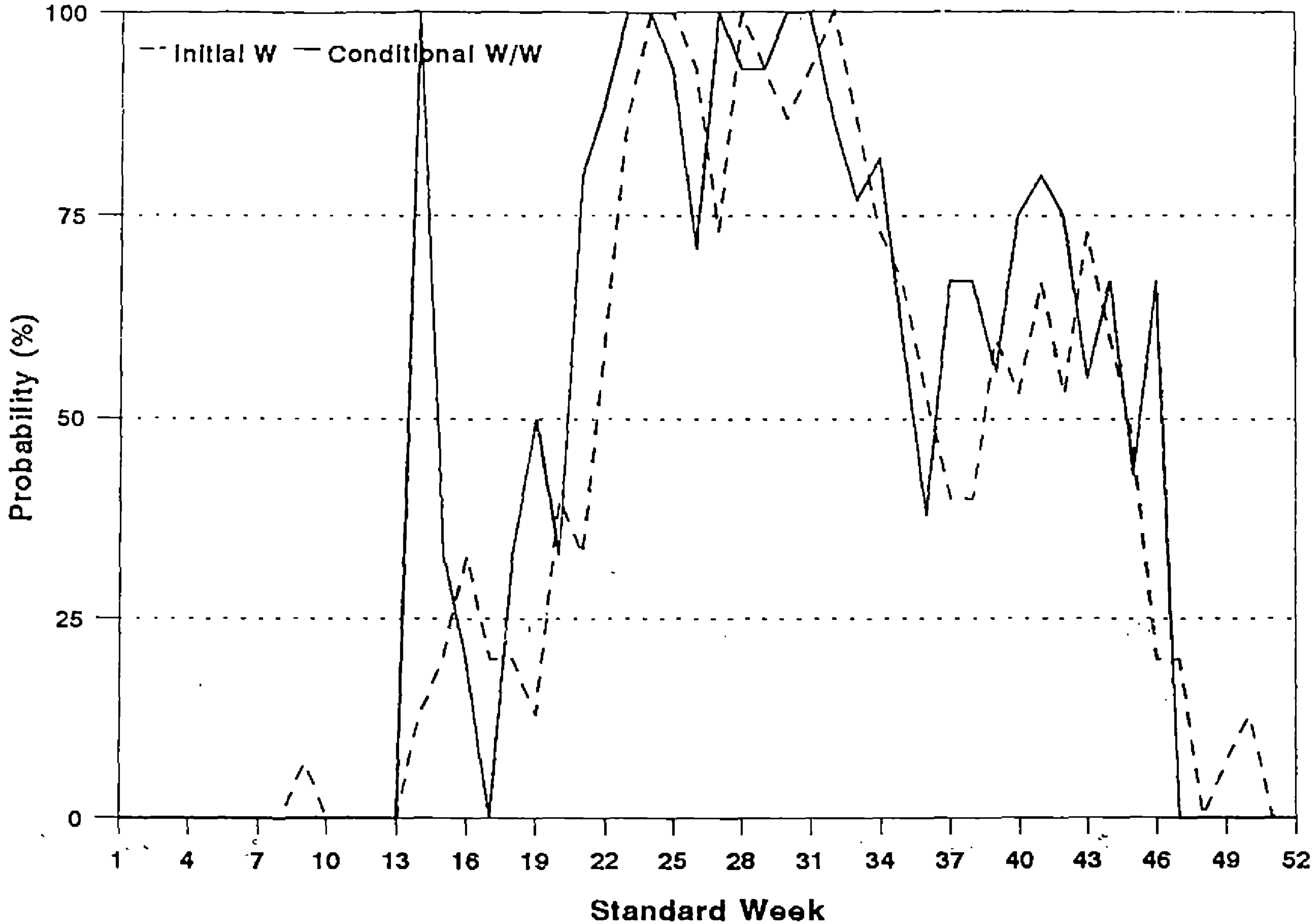

Fig.10 Initial and conditional rainfall probabilities of receiving > 30 mm at Vellanikkara

Table 3. Mean temperature (deg C) and relative humidity (%) for important stations in the central zone

Kochi

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	SWM	NEM	ANNUAL
Max temp	31.9	32.3	32.7	33.0	32.5	30.4	29.5	29.5	30.2	30.8	31.4	32.0	32.7	29.9	31.1	31.3
Min temp	22.8	24.3	25.4	26.0	25.9	24.2	23.7	23.9	24.2	24.2	24.0	23.2	25.8	24.0	24.1	24.3
RH Max	74	79	77	77	81	90	91	90	87	84	82	75	78	90	83	82
RH Min	61	66	68	70	73	83	83	82	79	77	72	64	70	82	74	73

Vellanikkara

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	SWM	NEM	ANNUAL
Max temp	32.8	34.8	36.2	35.6	34.0	30.1	29.0	29.4	30.5	31.4	31.7	31.9	35.3	29.8	31.7	32.2
Min temp	22.1	22.5	23.8	25.0	24.8	23.4	23.0	23.2	23.3	23.1	22.9	22.6	24.5	23.2	23.0	23.3
RH Max	72	77	82	84	86	93	95	94	92	87	83	75	84	93	85	85
RH Min	41	38	42	53	60	78	80	77	70	69	62	49	52	76	66	60

Palakkad

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM	SWM	NEM	ANNUAL
Max temp	33.0	35.7	37.5	37.1	34.7	30.0	28.7	29.0	30.3	31.6	31.7	31.8	36.4	29.5	31.6	32.5
Min temp	21.8	22.5	23.9	25.0	24.7	23.0	22.6	22.7	23.1	23.1	23.0	22.2	24.5	22.8	23.0	23.1
RH Max	72	71	72	76	79	89	91	91	87	85	80	75	76	90	83	81
RH Min	48	41	40	52	61	80	83	82	75	73	67	59	51	80	70	63

maximum temperature during southwest monsoon season, northeast monsoon season and summer were 29.8° C, 31.7° C and 35.3° C respectively. The lowest minimum temperature for Vellanikkara (22.1° C) is observed during January. The values during southwest, northeast and summer seasons are 23.2° C, 23.0° C and 24.5° C respectively. Annual minimum temperature is 23.3° C. The maximum relative humidity was found highest during July(95%). The lowest minimum relative humidity was observed during February (38%).

At Palakkad the highest maximum temperature is observed during March (37.5° C) and the lowest maximum temperature is observed during August (29.0° C). The maximum temperature during southwest monsoon season, northeast monsoon season and summer were 29.5° C, 31.6° C and 36.4° C respectively. The lowest minimum temperature for Vellanikkara (21.8° C) is observed during January. The values during southwest, northeast and summer seasons are 22.8° C, 23.0° C and 24.5° C respectively. Annual minimum temperature is 23.1° C. The maximum relative humidity was found highest during July and August (91%). The lowest minimum relative humidity was observed during March (40%).

4.3. Water balance

Thornthwaite and Mather (1955) put forth revised book-keeping procedure of computing water balance. Inadequate water supply and adverse temperature are the two universal risks in agricultural production. In tropics, precipitation, thus moisture availability to crops, shows relatively wide variations compared to temperature. The availability of water in right quantity at the right time and its management with suitable agronomic practices are essential for good plant growth and yield. In order to assess the water availability, soil moisture is to be taken into account and the set water available to the crop through soil moisture can be estimated using water budgeting technique. The term water balance refers to the climatic balance obtained, by comparing the marks of precipitation as income with evapotranspiration as loss or expenditure, soil being medium for storing water during periods of excess precipitation and utilizing or releasing moisture during periods of deficient precipitation. Subramaniam (1964) computed water balance for Mysore State for explaining the viability of natural vegetation. The climatic water balances of five stations in Kerala state were calculated by Subramaniam and Murthy (1982). They also classified climates of Kerala both on thermal and moisture regimes following Thornthwaite Scheme. Swaminathan and Santhakumari (1983) studied water balance for selected staions in Madhurai district of Tamil Nadu to find out the water surplus/deficit and to suggest cropping season. Similar computations were attempted in the present study.

The water balance elements for all the 26 stations in the central zone of Kerala were worked out and the results are presented in Table 4. The annual AET, water surplus, and water deficit is illustrated in figures. The results obtained are as follows.

4.3.1. Spatial distribution of actual evapotranspiration

Actual evapotranspiration (AET) represents the amount of water loss actually taken place in the form of evapotranspiration. The estimation of AET by

Table 4. Annual water balance parameters for 14 stations in the central zone

Stations	Dependable Rainfall (mm)	PET (mm)	AET (mm)	WD (mm)	WS (mm)	IMA (%)
Alathur	631	1917	631	1286	0	33
Angadipuram	854	1868	617	1251	237	33
Aluva	1037	1896	624	1272	413	33
Chalakkudy	1172	2003	716	1287	456	36
Chittur	380	1917	380	1537	0	20
Enamackal	741	2003	631	1372	110	32
Irinjalakkuda	964	2003	593	1410	371	30
Kochi	1073	1896	686	1210	387	36
Kodungallur	1167	1896	786	1210	521	34
Kannara	1066	2003	641	1362	425	32
Kunnamkulam	1281	2003	667	1336	614	33
Kollengod	547	1917	547	1370	0	29
Manjeri	861	1868	569	1299	292	30
Mannarkkad	583	1917	583	1334	0	30
Nilambur	678	1868	580	1288	98	31
Ottapalam	852	1917	630	1287	222	33
Parambikulam	311	1917	311	1606	0	16
Perumbavoor	1057	1896	751	1145	306	40
Palakkad	89	1917	589	1328	0	31
Perinthalmanna	899	1868	629	1239	270	34
Ponnani	1064	1868	596	1272	468	32
Pattambi	918	1868	617	1251	301	33
Piravom	1235	1896	779	1117	456	41
Thritala	832	1868	576	1292	256	31
Wadakkenchery	1049	2003	635	1368	913	32
Vellanikkara	1134	2003	665	1338	469	33

water balance approach is the easiest and a practicable method. Measurement of AET in practise is difficult because of its dependence on many factors such as soil type, method of land cultivation, type of plant cover and moisture condition of soil profile. Higher the value, AET indicates water potential of the area, as it shows the water availability in relation to the PET. Areas of high rainfall not necessarily coincide with higher AET values, because AET depends not only on the amount of rainfall but also on its distribution, stored moisture and PET.

Distribution of annual AET over central zone is illustrated in Fig.11. It can be seen from the figure that annually, the AET varies from less than 400 mm in the eastern region of the zone to more than 700 mm in the southern part of the zone. The lowest AET of 311 mm is observed at Parambikulam and a highest of 779 mm is observed at Piravom. A gradual increase of AET can be observed from northern part to southern part of the zone. At southern end of the zone higher values of AET is observed compared all other parts i.e., more than 700 mm. The midland and the coastal regions have AET values between 600 and 700 mm. Some small patches in the coastal areas can be seen where the values of AET is less than 600 mm. Similarly the northern and western regions of the zone have AET values less than 600 mm. Very low values of AET i.e., less than 400 mm is observed at Chittur and Parambikulam.

4.3.2. Water deficit (WD)

In order to have a clear understanding of the moisture problem, knowledge of the moisture deficit is basic to any understanding of the economic feasibility of

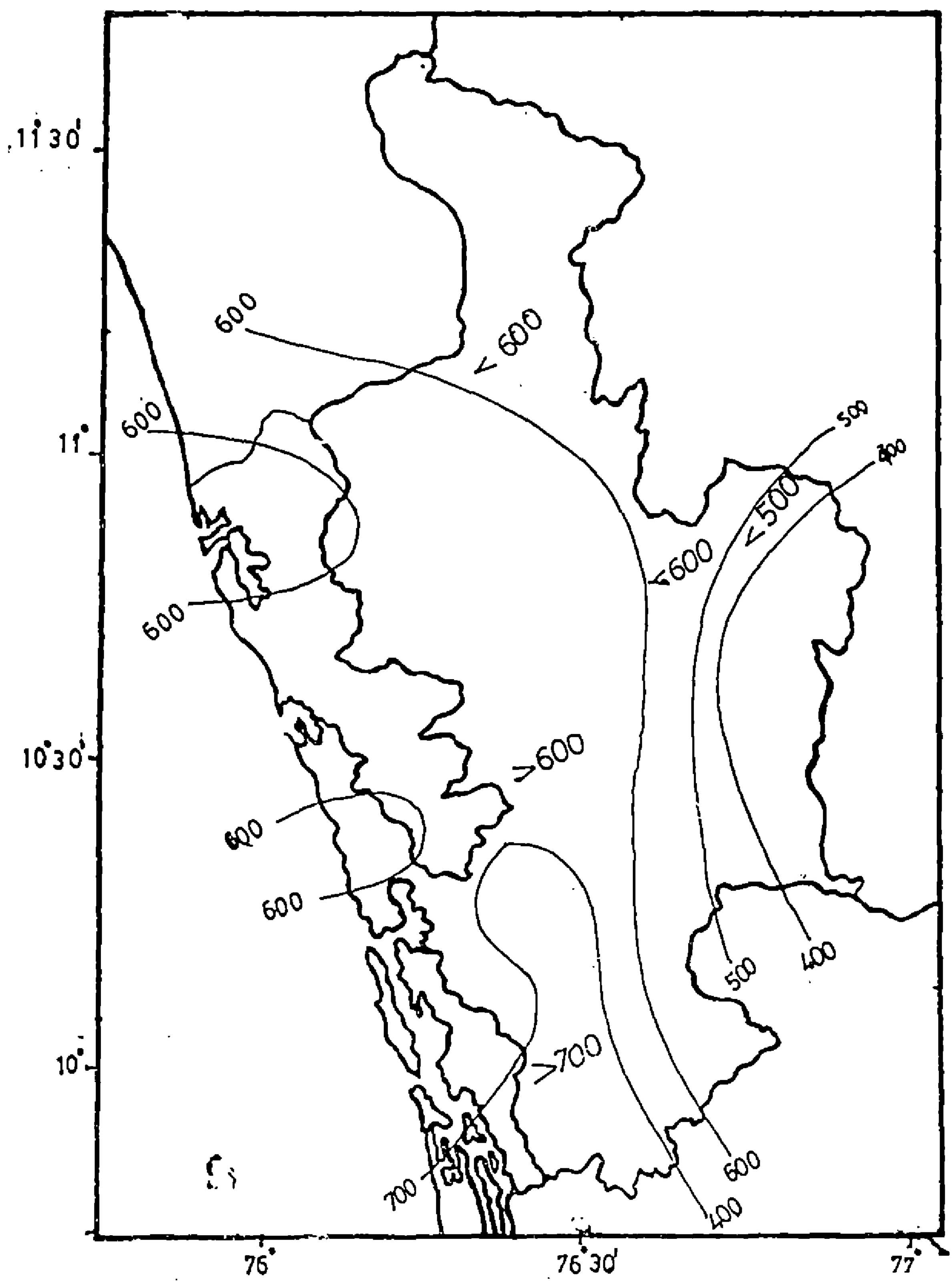

Fig. 11 Distribution of actual evapotranspiration (mm)

irrigation, for it provides information on the total volume of water needed at any time and gives a definite measure of drought. Water deficit is the amount by which AET falls short of PET and not the deficiency water between field capacity and permanent wilting point.

Spatial distribution of annual water deficit over the central zone is shown in Fig. 12. It can be seen from the figure that the WD varies from less than 1300 mm in the northern and southern parts of the zone to more than 1500 mm in the eastern part. When one moves from the north towards south in the eastern part of the zone water deficit increases and a highest of 1606 mm is observed at Parambikulam. The midland and coastal areas of the central part of the zone have higher values for WD compared to the northern and southern parts i.e., more than 1300 mm. In this region, Irinjalakuda has highest value for WD i.e., 1410 mm compared to the stations around that. Almost all the coastal region and midland of the northern and southern part have lesser WD value(< 1300 mm.)

4.3.3. Water surplus (WS)

The amount by which the precipitation exceeds AET, when the soil is at field capacity is called the water surplus. By definition, this water surplus is that water, which does not remain in the surface soil layers but is available for deep percolation to the water table and over land or subsurface flow to the water courses.

Spatial distribution of water surplus over central zone is shown in Fig. 13. It can be seen from the figure that water surplus is high in the midland and coastal

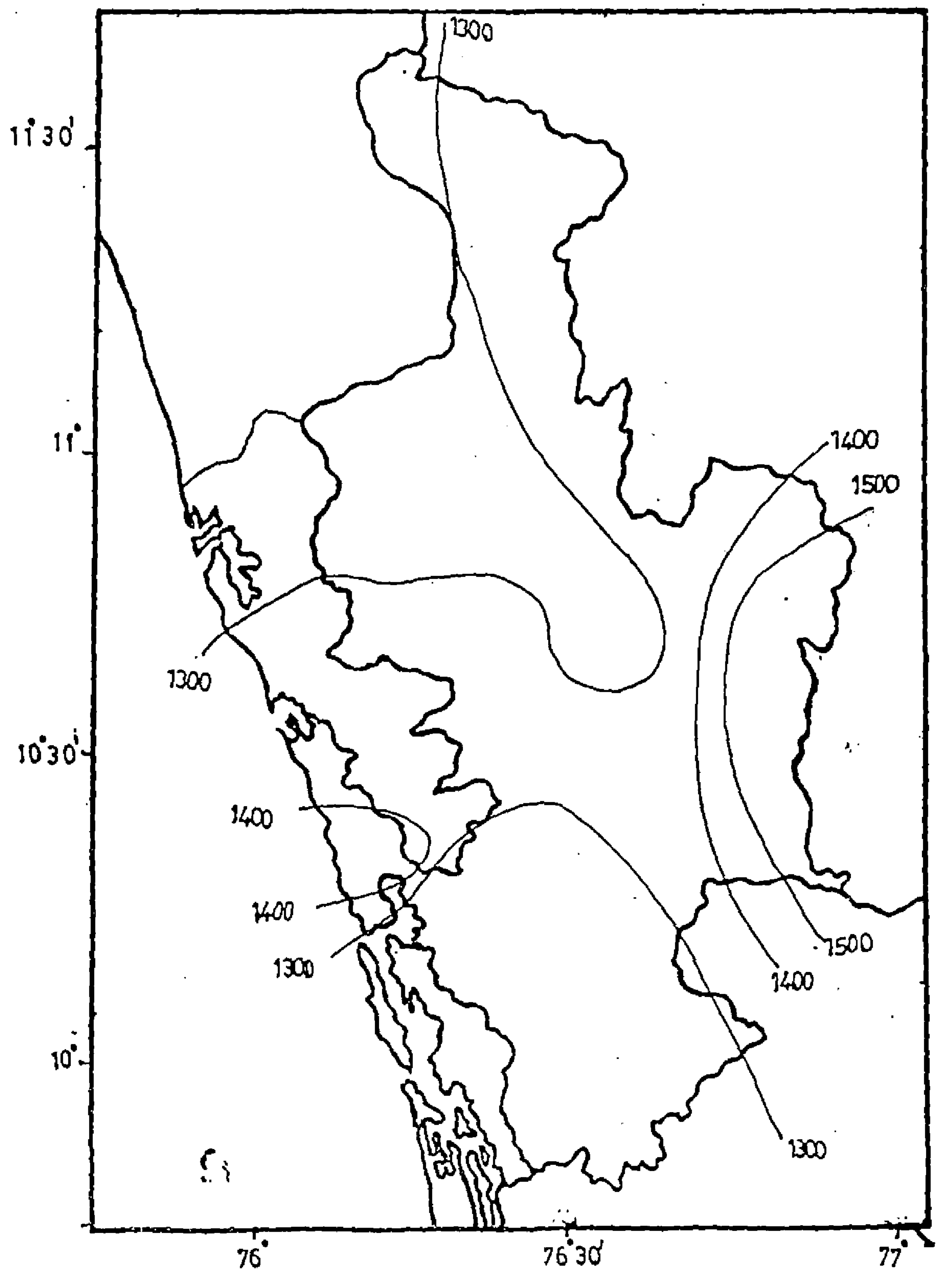

Fig. 12 Distribution of water deficit(mm)

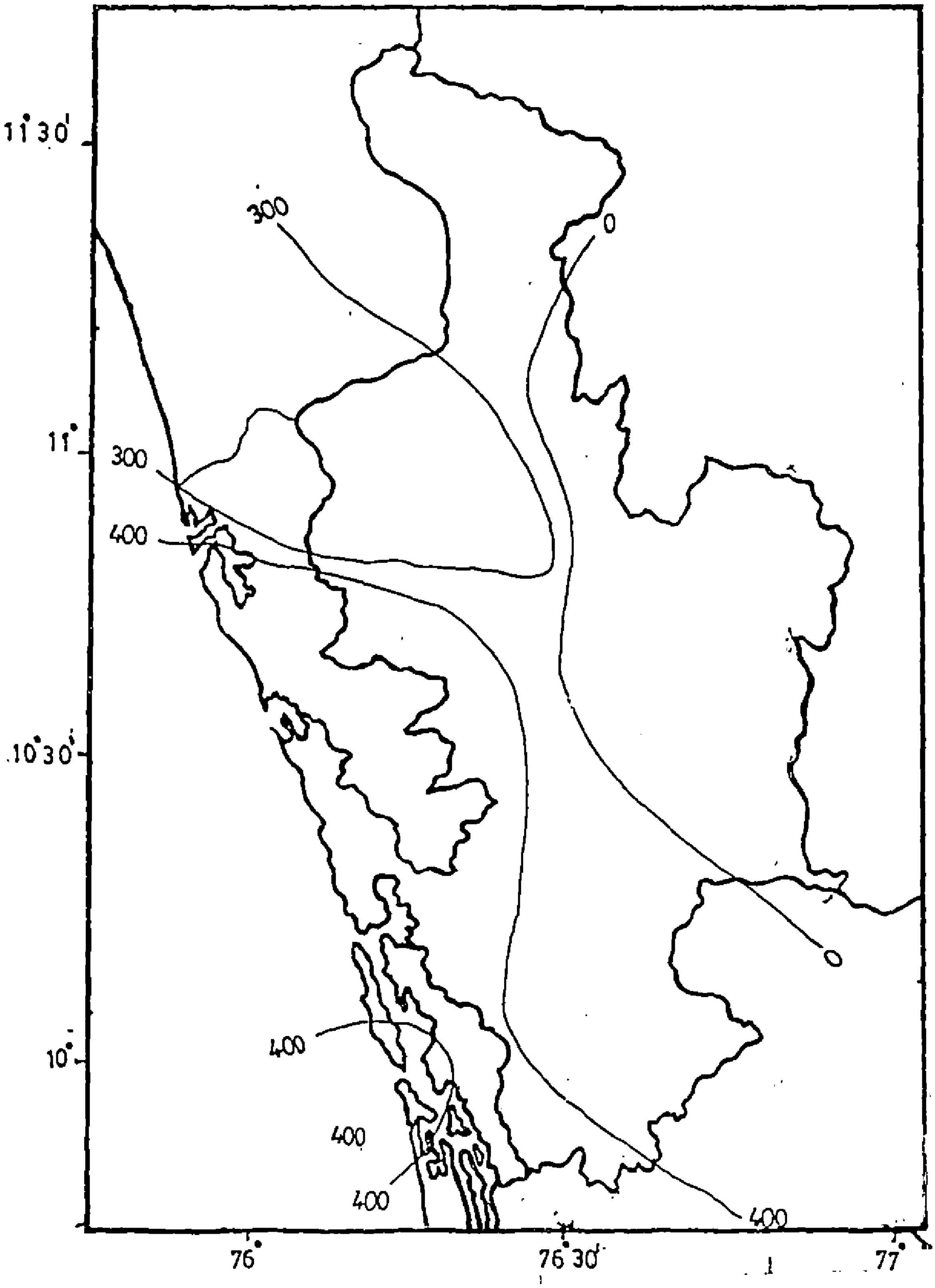

Fig. 13 Distribution of water surplus(mm)

areas of the zone. The highest value of 614 mm for WS is observed at Wadakkancherry (913) followed by Kunnamkulam (614 mm). Both these stations are located in the coastal region. Almost all stations in the coastal region have higher values of WS, i.e., more than 400 mm except a small patch around Kochi. The water surplus is lowest at the eastern part of the zone where there is no water surplus at all. The midland region of the northern part of the zone have lower values for WS i.e., less than 300 mm compared to the southern midland region. Even lower values of WS i.e., less than 100 mm is observed in high ranges of northern part.

4.3.4. Water availability periods

Though, rainfall is the main source of water, the actual availability does not depend on rainfall alone as it should be balanced against the amounts due to evapotranspiration. Based on this, Cocheme and Franquin (1967) classified water availability periods. George and Krishnan (1969) and Raman and Murthy (1971) attempted for assessing the water availability periods based on climatic and soil conditions. Krishnan (1971) and Murthy (1973, 1976) determined water availability periods using actual evapotranspiration (AET) and potential evapotranspiration (PET). All these methods utilized monthly or weekly mean rainfall. Subramaniam and Rao (1981) assessed the water availability periods for crop planning in Rajasthan on the basis of monthly rainfall .

Similarly the water availability periods for all the 26 stations in the central zone are worked out and is presented in Table 5. Water availability calendar for all the stations was prepared and it is presented in Fig.14. The humid and the sub humid

Table 5. Duration of water availability periods at different stations in the central zone

Station	Sub humid	Humid	Sub humid	Total No. of moist days
1. Piravom	30 May-1 Jun. (3)	2 Jun.-24 Nov. (176)	25 Nov.-18 Dec. (24)	203
2. Alathur	4-7 Jun. (4)	8 Jun.-18 Nov. (164)	19 Nov.-8 Dec. (20)	188
3. Perumbavoor	2-3 Jun. (2)	4 Jun.-21 Nov. (171)	22 Nov.-6 Dec. (15)	188
4. Chalakkudy	3-5 Jun. (3)	6 Jun-17 Nov. (165)	18 Nov.-6 Dec. (19)	187
5. Kochi	30 May-1 Jun. (3)	2 Jun.-15 Nov. (172)	16 Nov.-23 Nov. (8)	183
6. Perinthalmanna	4 Jun.-5 Jun. (2)	6 Jun.-9 Nov. (157)	10 Nov.-2 Dec (23)	182
7. Enamackal	14-15 Jun. (2)	16 Jun.-20 Nov. (158)	21 Nov.-7 Dec. (17)	177
8. Kunnamkulam	2-3 Jun. (2)	4 Jun.-10 Nov. (160)	11 Nov.-25 Nov. (15)	177
9. Vellanikkara	4-6 Jun. (3)	7 Jun.-3 Nov. (150)	4 Nov.-24 Nov. (21)	174
10. Angadippuram	3-5 Jun. (3)	6 Jun-11 Nov. (159)	12 Nov.-22 Nov. (11)	173
11. Kannara	6-7 Jun. (2)	8 Jun.-4 Nov. (150)	5 Nov.-25 Nov. (21)	173
12. Pattambi	6-8 Jun. (3)	9 Jun-4 Nov. (149)	5-23 Nov. (19)	171

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Table 5. Continued

Station	Sub humid	Humid	Sub humid	Total No. of moist days
13. Wadakkancherry	5-7 Jun. (3)	8 Jun.-3 Nov. (149)	4-22 Nov. (19)	171
14. Mannarkkad	1-11 Jun. (11)	12Jun-1Nov. (143)	2-16 Nov. (16)	170
15. Kodungallur	1-3 Jun. (3)	4 Jun-10 Nov. (160)	11-17 Nov. (7)	170
16. Aluva	4-6 Jun. (3)	7 Jun- 15 Nov. (162)	16 Nov.-18 (3)	168
17. Nilambur	3-6 June (4)	7 June-8 Nov. (155)	9- 16 Nov. (8)	167
18. Ponnani	4-5 Jun. (2)	6 Jun.-10 Nov. (158)	11-17 Nov. (7)	167
19. Manjeri	3-4 Jun. (4)	5 Jun.-21 Oct. (140)	22 Oct.-15 Nov. (29)	166
20. Irinjalakkuda	5-8 Jun. (3)	8 Jun.-3 Nov. (148)	4 Nov.-17 Nov. (14)	165
21. Ottapalam	6-8 Jun. (3)	8 Jun.-2 Nov. (147)	3 Nov.-16 Nov. (14)	164
22. Kollengode	9-12 Jun. (4)	13 Jun.-11 Nov. (152)	12 Nov.-17 Nov. (6)	162
23. Palakkad	7-9 Jun. (3)	10 Jun.-1 Nov. (145)	2 Nov.- 12 Nov. (11)	159

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Tabl 5. Continued

Station	Sub humid	Humid	Sub humid	Total No. of moist days
24. Thritala	6-7 Jun. (2)	8 Jun.-30 Oct. (145)	31 Oct.- 9 Nov. (10)	157
25. Chittur	11-13 Jun. (3)	14 Jun.-4 Sep. (83)	5 Sep.- 16 Sep. (12)	111
26. Parambikulam	13-14 Jun. (2)	14 Jun.-4 Jul. (20)	5 Jul. –11 Jul (7)	82

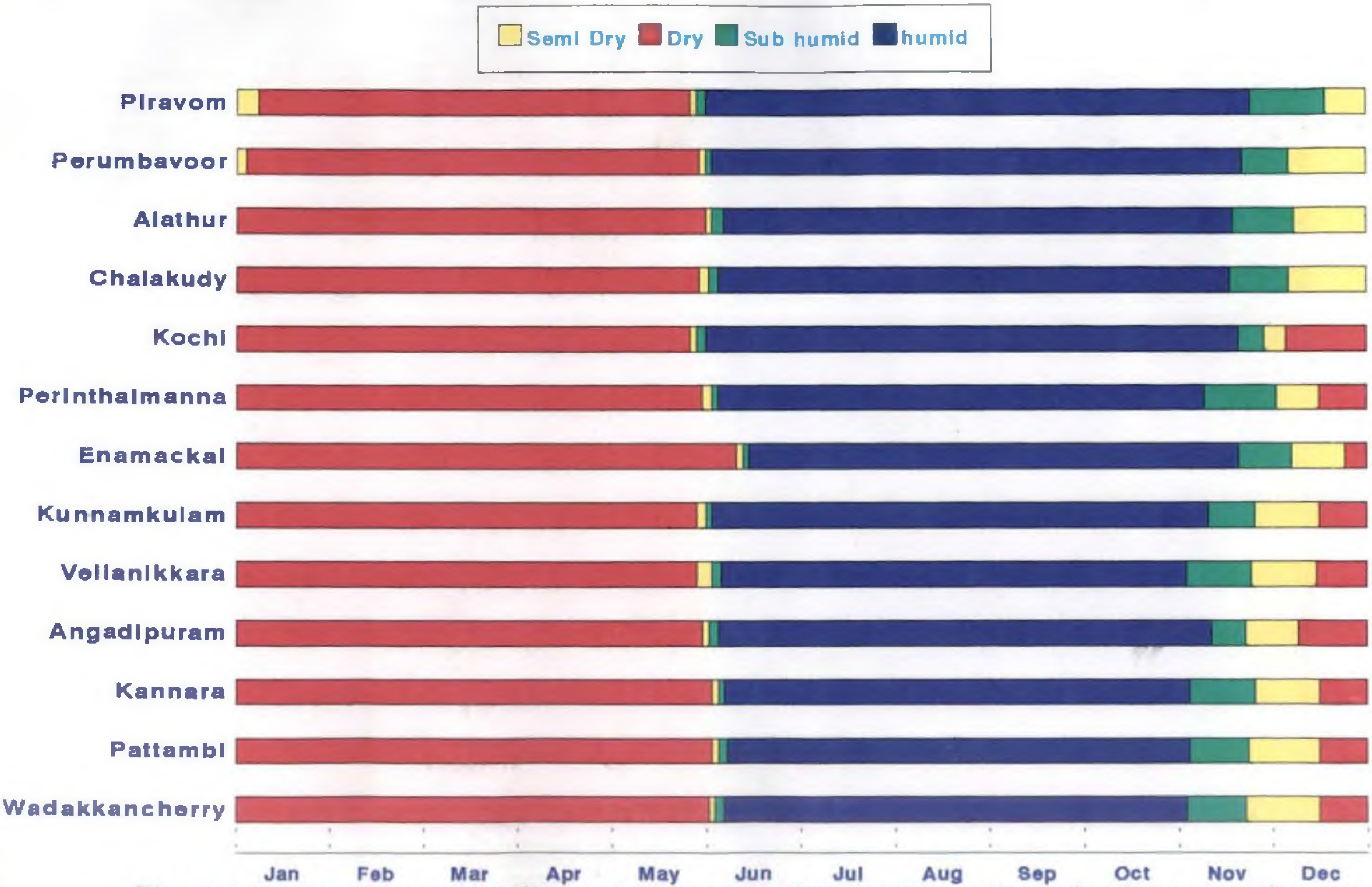

Fig. 14 (a) Water availability calendar for different locations in the central zone

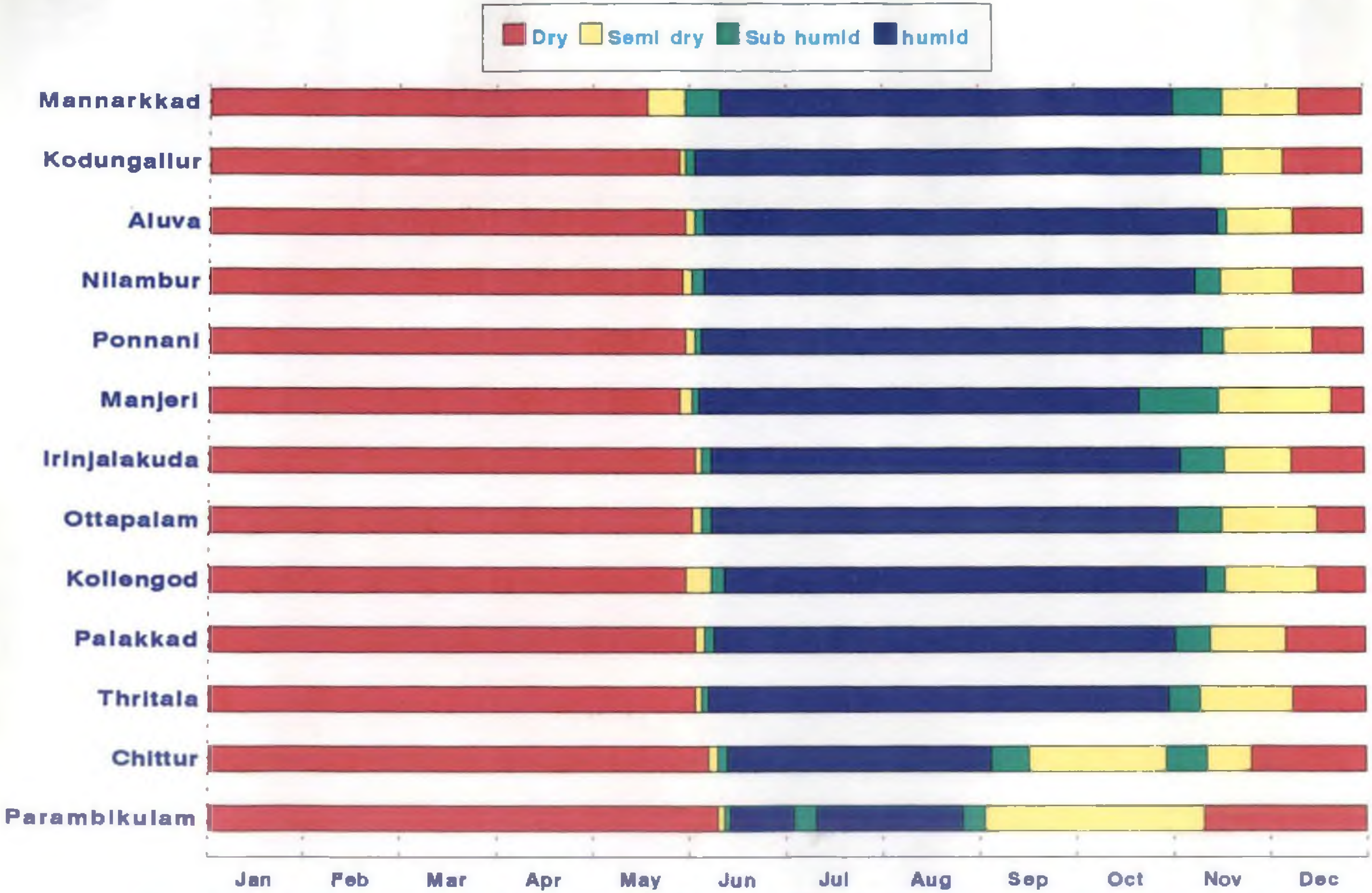

Fig. 14 (b) Water availability calendar for different locations in the central zone period is combined to obtain the total number of moist days (Fig.15). Piravom recorded the highest number of moist days (203) followed by Alathur (188) while Parambikulam recorded the least (82). All the stations except Piravom and Perumbavoor starts with a dry period in the beginning of the year. At Piravom and Perumbavoor the year starts with a semi dry period which lasts till first week of June and from June till end of the year there is no dry period. At Alathur and Chalakkudy from first week of June till last week of December there is no dry period. These four stations have the longest water availability period in the central zone. In all other stations the year ends with a dry period which extends for 10 days (Manjeri) to 36 days (Chittur). Parambikulam is having longest dry period at the end of the year. In most of the stations the water availability periods follow the following pattern. A long dry period is found at the beginning of the year followed by a very short semi dry and subhumid period. This is followed by a long humid period which generally extends from first week of June to last week of December. The humid period is followed by a sub humid period semi dry period and dry period. This pattern has got some exception at Chittur and Parambikulam. At Chittur there is a break in the second subhumid period which causes a semi dry period.

The total number of moist days was found high at the southern region of the zone while it was low in the south eastern part. The total number of moist days for various stations in the central zone ranges between 82 to 203. Most of the stations have total number of moist days more than 150. Generally, the water availability period starts in the 2nd week of June and extends upto 3rd week of November.

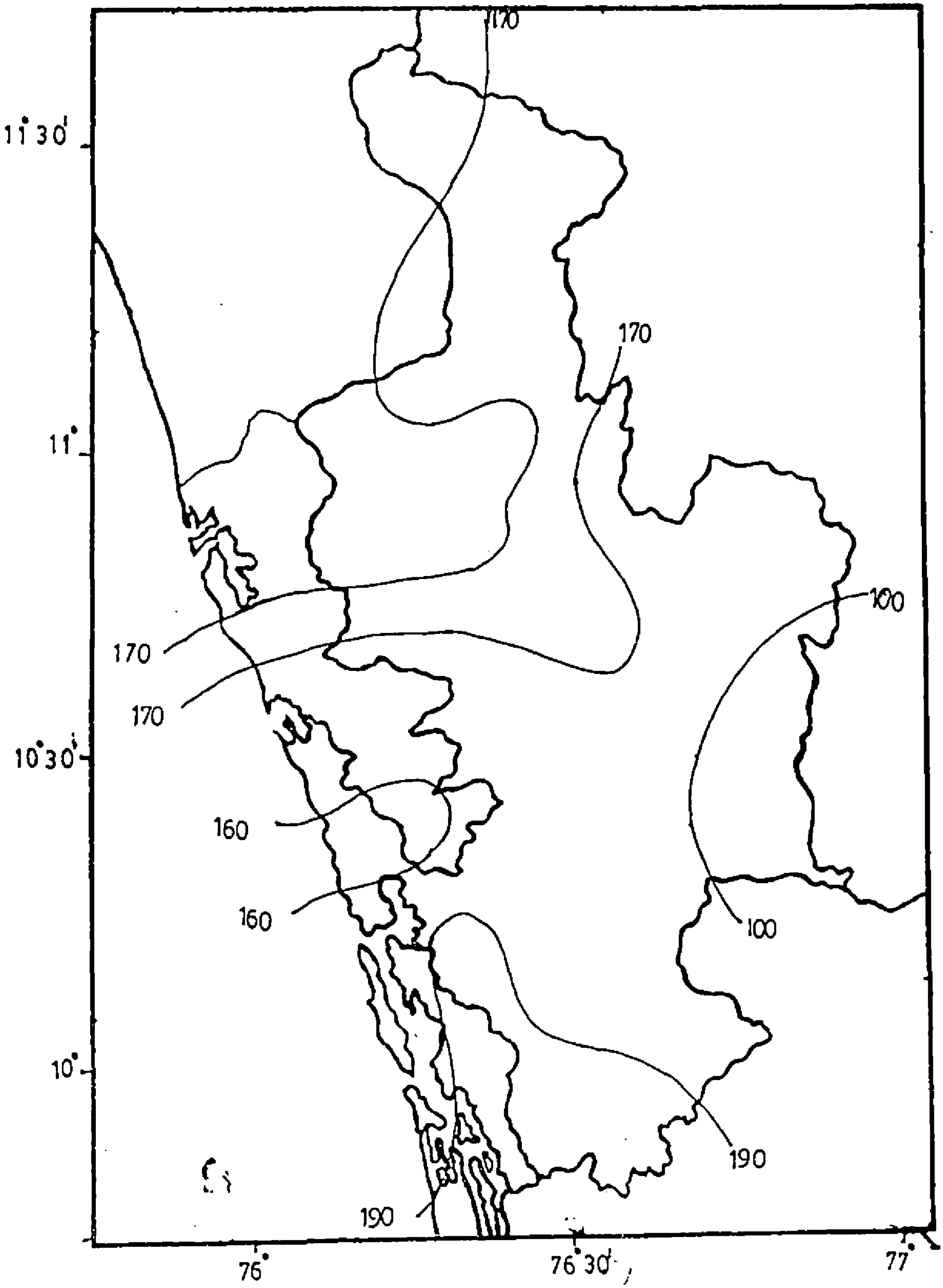

Fig. 15 Number of moist days over the central zone

4.3.5. Commencement and cessation of moist period

In most of the stations the moist period will start during the first week of June and extends up to November. At Kunnamkulam and Piravom the moist period starts early (last week of May). At Chittur and Parambikulam the moist period starts late and interrestingly it ends early. The commencement and cessation of moist period at different locations in the central zone is illustrated in Fig. 16

4.4. Cropping patterns

Rout et al. (1994) studied rainfall pattern and suggested cropping system for sustainable production in Umerkote block of Koraput in Orissa. Chaudhary (1994) suggested a crop plan through rainfall analysis in Bastar district of Madhya Pradesh. The probability of rainfall occurrence and the consequences for crop production are studied with particular reference to rice. Rao *et al.* (1988) carried out the rainfall probability analysis of three stations in Andhra Pradesh for crop planning. Daily rainfall data for Anantapur, Nandyal and Lam from 1969-1984 were used to assess the probability of receiving adequate rain for successful crop establishment. In all these studies rainfall data is used. But Sehgal *et al.* (1993) presented generalized ranges of moisture availability periods for average deep soils in India for cereal, cotton, legume, oil and fibre crops which is very useful in crop planning. In the present study the cropping pattern of central zone is analysed based on water availability periods.

The cropping pattern today is the cumulative effort of the generations of farmers who through trial and error have evolved a system based on the natural resource endowments as altitude, rainfall, topography soil etc. The configuration of these factors influence in evolving a singular agronomic environment where a particular cropping pattern fits in.Thus traditionally in the Highranges of Kerala, tea, coffee and cardamom showing a preference for cool humid climatic conditions and

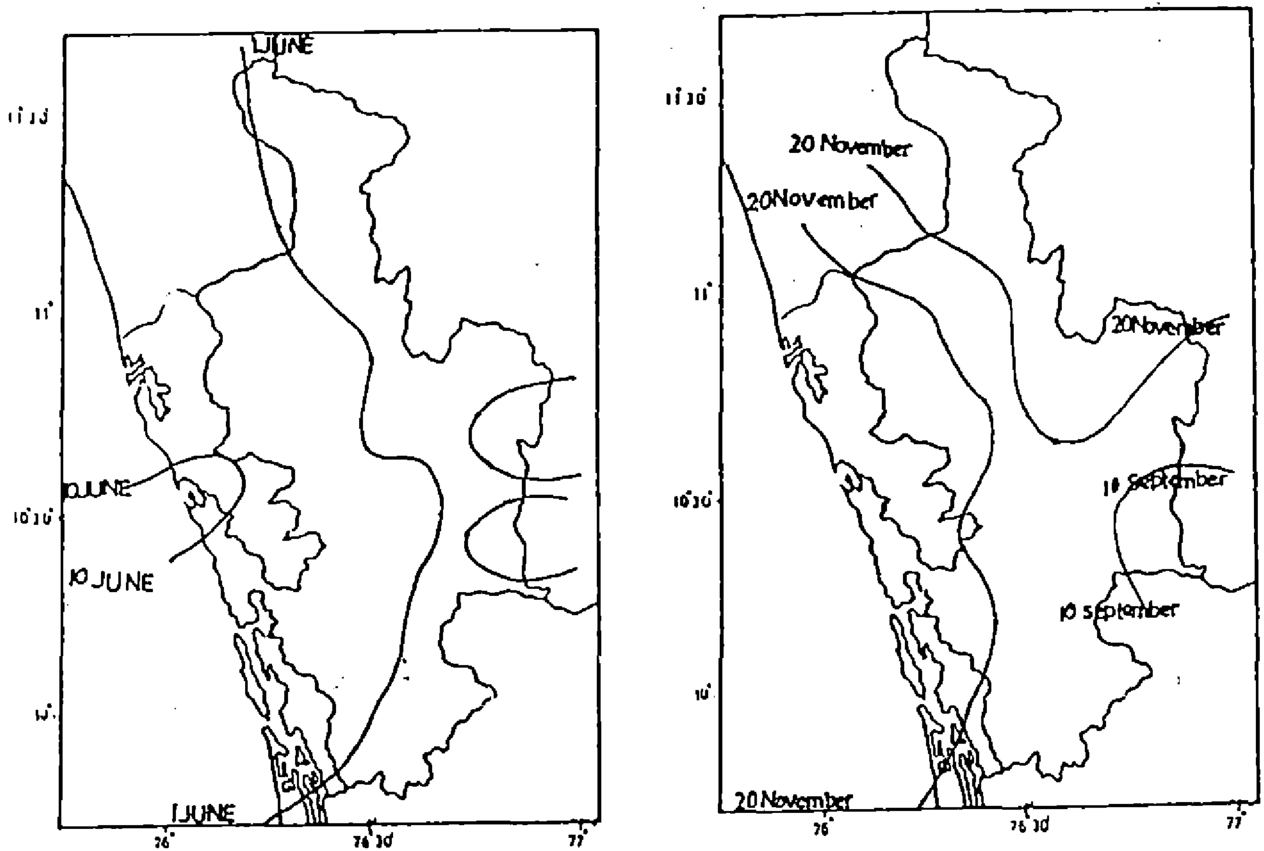

Fig. 16 Commencement and cessation of moist period

well drained soils, are grown. In the Highland region, rubber, pepper, coconut etc. are found flourishing as high rainfall and extremely undulating topography provide moist but well drained soil conditions. In the mid land, where the topography is mild, a variety of annual and seasonal crops which are quick ripening and requiring frequent disturbance of top soil are found preference. Rice and coconut are the two choice crops in the coastal and low land. The north eastern part of central zone has got a peculiar feature compared to the other parts of the state. These areas are plains. So paddy is a major crop in this region. Palakkad district and mid lands of central zone was identified as a paddy growing belt where the coastal area was found to be mostly occupied with coconut based farming system. The southern mid land comprises of rubber based cropping system. Majority of the spice produce of the zone is from this region. It was found out that coconut is unsuitable for Palakkad region as the humidity is very low.

The water availability periods prevailing in the central zone in relation to the crops is discussed below.

The cropping pattern present in the central zone was identified according to the method suggested by National Commission on Agriculture (1976) and as described in the chapter `Materials and Methods'. The cropping patterns of the zone was found out based on the data given by the Directorate of Economics and Statistics, Thiruvanthapuram and is presented in Table 6, 7 and 8. The crop data was analysed block wise, if was found that the cropping patterns fall under 3 major categories and are show below. Karmachandran (1986) also reported that there are 3 major categories of cropping pattern in the central zone.

Table 6 Area under important crops (Average for the years 1989-92)

(in hectares)

Sl.No.	Name of Block	Paddy	Tapioca	Coconut	Arecanut	Banana	Plantain	Rubber	Cashew	Pepper	Ginger	Total
1	Alangad	3566	139	3427	191	149	128	-	203	186	186	11557
2	Angamaly	8381	586	6535	230	754	324	2910	514	986	181	28557
3	Edappally	2370	150	3183	232	18	212	442	227	312	-	9516
4	Koovappady	7914	750	5370	248	470	228	4666	113	458	615	28746
5	Kothamangalam	5123	815	5598	323	230	264	11628	179	815	504	30602
6	Mulamthuruthi	2869	147	3252	188	29	151	3650	179	328	1	13664
7	Muvattupuzha	3877	1038	4042	193	169	270	11654	156	802	253	26232
8	Palluruthy	-	-	1777	90	-	19	-	19	11	-	2744
9	Pampakuda	4620	1050	3547	133	201	331	13105	110	1066	134	28909
10	Parakadavu	8076	418	3849	254	374	208	147	215	293	38	20604
11	Paravur	727	41	5668	374	11	109	-	187	134	-	7979
12	Vadavucode	8194	452	2872	308	128	164	8041	90	664	88	29197
13	Vazhakulam	8273	656	2500	202	298	180	2313	117	449	74	23334
14	Vypin	1193	12	4901	449	2	96	-	82	68	1	7996
15	Vyttila	-	4	2001	118	-	34	-	80	16	-	2485
	Block total		6258	58522	3538	2833	2718	58556	2471	6588	1892	274882
	Municipal total.		557	7152	316	113	329	2159	173	396	118	17107
	District		6815	65674	3854	2946	3047	60715	2644	6984	2010	

Table 7 Area under important crops (average for the years 1989-92)

(in hectares)

Sl.No.	Name of Block	Paddy	Tapioca	Coconut	Arecanut	Banana	Plantain	Rubber	Cashew	Pepper	Ginger	Total
1	Alathur	20752	2476	4632	90	326	482	3764	224	180	270	33196
2	Attapady	283	2337	1758	254	114	259	6725	113	588	58	12489
3	Chittur	9612	61	1903	8	13	138	45	3	2	2	11787
4	Coyalmannam	19535	487	1924	9	155	258	83	155	15	15	22636
5	Kollengode	24321	242	2649	12	5	208	-	7	1	14	27445
6	Mannarkkad	9664	872	5000	341	1297	396	7685	2072	808	46	28181
7	Nemmara	5098	263	963	65	60	104	760	4	10	40	7367
8	Ottappalam	9286	960	2358	40	103	356	583	228	120	36	14070
9	Palakkad	18331	827	3373	48	193	232	1362	415	93	35	24909
10	Pattambi	8825	719	4058	268	200	319	288	245	337	40	18299
11	Sreekrishnapuram	8168	604	2665	134	190	288	1700	394	373	45	14861
12	Thrithala	6629	385	3965	1381	110	587	224	207	190	38	13716

Table 8 Area under important crops (average for the years 1989-92)

(in hectares)

Sl.No.	Name of Block	Paddy	Tapioca	Coconut	Arecanut	Plantain	Rubber	Cashew	Pepper	Ginger	Total
1	Anthicad	3217	3	4630	81	75	-	89	31	1	8127
2	Cherpu	4520	22	3259	263	268	13	201	149	5	8700
3	Ollukkara	5378	314	3364	388	356	1122	488	579	35	12024
4	Puzhakkal	6734	140	3284	596	288	128	819	439	8	12436
5	Chowwannur	6744	47	3013	803	320	147	370	386	5	11835
6	Pazhavannu	8512	865	2458	96	295	5078	486	178	37	18005
7	Wadakkancherry	10000	398	3861	1186	592	2111	904	959	18	20029
8	Chavakkad	863	18	5606	87	66	-	134	16	-	6790
9	Mullasseri	2103	1	3768	159	56	-	99	32	1	6219
10	Talikulam	58	9	5929	220	88	-	187	13	-	6504
11	Chalakkudy	4110	774	5558	333	263	394	299	412	26	12169
12	Irinjalakuda	2684	137	3684	126	168	31	150	108	10	7098
13	Kodakara	4178	387	6256	292	670	858	656	922	20	14239
14	Mala	6573	460	6222	223	408	2	280	293	9	14470
15	Vellangallur	3753	115	4923	141	161	-	312	164	4	9573
16	Kodungallur	39	-	3403	166	73	-	47	21	-	3749
17	Mathilakam	296	2	6226	257	92	-	118	35	-	7026
18	Thrissur (M)	328	3	460	14	41	-	11	14	-	871
19	Chavakkad (M)	294	3	2136	19	12	-	83	11	-	2558
20	Chalakkudy (M)	1205	46	830	25	36	2	47	52	-	2443
21	Irinjalakuda (M)	855	10	1032	18	57	-	29	16	-	2017
22	Kodungallur (M)	74	-	1110	29	11	-	20	13	-	1257

Major group	Blocks under the Cropping pattern	Cropping pattern
Mainly paddy	Alathur	$Pd_2O_4L_4Fr_5$
	Chittur	$Pd_1O_4Fr_5$
	Koyalmannam	$Pd_1O_5Ta_5$
	Kollengod	Pd_1O_4
	Nenmara	$Pd_1O_5Ta_5$
	Ottappalam	$Pd_1O_5L_4Ta_5$
	Palakkad	$Pd_1O_4L_5Ta_5$
	Pattambi	$Pd_1O_4L_5Ta_5$
	Sreekrishnapuram	Pd_2O_4
	Cherpu	$Pd_2O_3L_5$
	Ollukkara	$Pd_3O_3L_4Sp_5Fr_5$
	Puzhakkal	$Pd_2O_4L_4Sp_5Fr_5$
	Chowwannur	$Pd_2O_4L_4Sp_5Fr_5$
	Puzhayannur	$Pd_3L_4O_4Ta_5$
	Wadakkencherry	$Pd_3O_4L_4Ta_5Sp_5$
	Mala	$Pd_3O_3L_5Fr_5Sp_5$
	Alangad	$Pd_3O_4Fr_5Sp_5$
	Angamaly	$Pd_4O_4Fr_5Sp_5$
	Koovappady	$Pd_4O_4L_4Sp_5Fr_5$
	Parakadevu	$Pd_3O_4Fr_5$
	Vadavukode	$Pd_4L_4O_5Sp_5$
	Vazhakkulam	$Pd_3O_4L_5Sp_5$
Mainly coconut	Anthikkad	O_2Pd_3
	Chavakkad	$O_1Pd_4L_5$
	Mullassery	$O_2Pd_3L_5$
	Thalikulam	$O_1L_5Fr_5$
	Chalakkudy	$O_3Pd_3L_5Sp_5Ta_5$
	Irinjalakkuda	$O_2Pd_5L_5Fr_5$
	Kodakara	$O_3Pd_4L_5Fr_5Sp_5$
	Vellangallur	$O_2Pd_3L_5Fr_5Sp_5$
	Kodungallur	$O_1Pd_3L_5Fr_5$
	Mathilakom	$O_1Pd_5L_5Fr_5$
	Palluruthy	O_2Pd_4
	Paravur	$O_1Pd_3L_5$
	Vypeen	$O_2Pd_4L_5$
	Vyttila	$O_1Pd_5L_5$
Plantations Other than Coconut	Mannarkkad	$L_3Pd_3O_4Fr_5$
	Kothamangalam	$L_3Pd_4O_4Sp_5$
	Mulanthuruthy	$L_4O_4Pd_4Sp_5$
	Moovattupuzha	$L_3O_4Pd_4Sp_5$
	Pampakuda	$L_3Pd_4O_4$

The cropping pattern in the central zone is presented in Fig. 17. In a broad sense, for most of the areas the cropping patterns evolved over the generations are found to be fairly in order with sound agronomic principles. In general plains and valleys are put to crops that tolerate excessive moisture such as rice. The hill tops and slopes of steep gradients, especially the upper portions, are put to perennial crops such as rubber, coconut, cashew etc., which can stand the moisture stress of the summer months The slopes with yield gradients are put to seasonal and annual crops which entail disturbance of top soil but will not result in soil erosion. The lower portions of the steeper slopes are put to crops are arecanut, pepper etc. demanding moist but will drained soils.

In designing cropping patterns for an area the critical water availability periods are to be isolated. The other critical factors are temperature and sunlight availability. Combinations of these factors are critical to enable a cropping pattern to flourish.

After identifying the cropping pattern it is essential to examine the suitability of the cropping patterns to the water availability periods, so as to obtain relevant information for optimum use of natural resources. With this objective the suitability of the existing cropping patterns to the different water availability periods were examined based on the information on soil types and environmental conditions for the growth of various crops and presented below.

At Palakkad a rice based cropping system predominates. The blocks Palakkad, Sreekrishnapuram, Ottapalam, Pazhayannur, Kuzhalmannam and Alathur

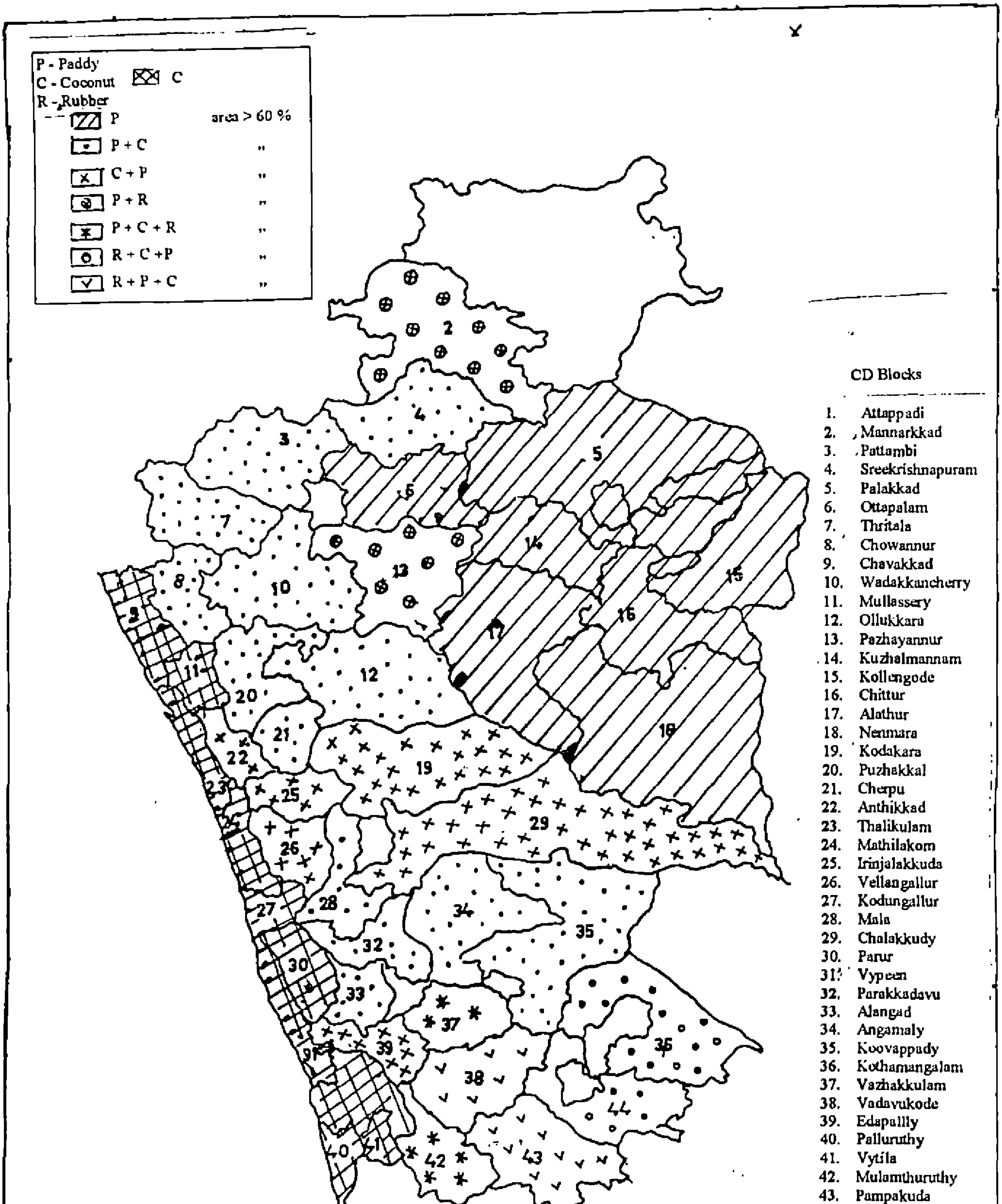

Fig. 17 Cropping pattern of the central zone

comes under this region. The important crops in this region are rice, coconut, rubber, fruits, species and tapioca in small patches At Alathur the first subhumid period starts as early as 28 May and the cropping season starts then onwards. This is followed by a humid period which extends for 146 days. The second subhumid period will start from 28 October and extends up to 20 November. It is observed that the total number of moist days in this station is 188. It can be infered that water is available for crops from last week of May to third week of November. So two crops of paddy is possible with out irrigation and summer crops are raised mainly with the help of assured irrigation from Malampuzha and Peechi irrigation projects. At Ottappalam also a similar trend for the moisture availability periods are observed with a total number of 164 moist days. But the start of sub humid period is late (5 June). At Palakkad it is observed that the water availability periods starts on 5 June and it extends only up to 10 November and the number of moist days is less. So in this area in addition to rice palmyra palms are observed in this are more than coconut palms. The soil and climatic conditions are favourable for the growth of cashew and mango. Out of the four important crops included in this cropping pattern paddy, cashew and mango are found suitable for this area.

In Chittur area of the central zone, the rainfall received in this area is very low during the three seasons, i.e., 1021 mm, 253 mm and 150 mm during south western monsoon, north east monsoon and summer respectively. The total number of moist days in this region is also very low (111). The water availability period starts from 15 June only and ends by 2 November. Paddy is the major crop in this area followed by coconut and fruits. The soils found in this area is black soil as extensions of black cotton soils of Coimbatore district of Tamil Nadu. They are dark in colour, low in organic matter, moderately alkaline high in clay content and CEC. This soil is suited for paddy. But the less water availability in this region is a major constraint for rice. However, paddy is the best crop suited for this area.

At Pattambi, Thrithala, Pazhayannoor, Puzhakal, Wadakkancherry and Cherpu blocks paddy is the major crop. Coconut is the next important crop except in Pazhayanoor where rubber is seen. Laterite soil predominates in this area with small patches of brown hydromorphic soil in the midland. At Thrithala and Wadakkencherry the water availability period starts from 2 week of June to 3 week of November. The number of moist days are 157 and 171 respectively. These rgions have fairly high duration of water availability periods. Cashew and arecanut also can be seen in this region. The soil types and moisture availability regimes are found to be suitable for these crops.

In the coastal area and in some parts of the midland coconut is the major crop. This include Chavakkad, Mullassery, Thalikulam, Anthicad, Kodakara, Chalakkudy, Irinjalakkuda, Mathilakom, Mala in Thrissur district and Parakkadavu, Parur, Vypeen, Edappally, Vyttila and Palluruthy in Ernakulam district. This area has got different types of soil which include sandy soil, riverine alluvium and acid saline soils. These region have fairly high water availability periods. At Kochi the water availability period starts by 30 May and it extends up to 23 Nov. 183 moist days is observed at Kochi. The stations Kodungallur, Chalakkudy and Kunnamkulam in this belt did not show much variation in the number of moist days. Rice comes next to coconut in this areas. As moisture availability is not a constraint for crop growth in this region, the soil conditions determine the cropping pattern in this region. In regions where saline soil is present rice is cultivated and where sandy soil is present coconut is cultivated.

In the southern part of the zone there is a rubber belt which includes Mulamthuruthy, Pampakuda, Muvattupuzha and Kothamangalam blocks. These areas come under midland region and the climatic conditions in this region is favourable for rubber cultivation. These areas records very high rainfall compared to other parts of the zone. Piravom, which comes in this area recorded the highest number of moist days (203). In addition to rubber, coconut, paddy and spices are also grown in this region. This region is best suited for rubber and spices.

Taking central zone as a whole the rainfall pattern has relatively wider base. Moisture is available over a longer period during the year. But in addition to the moisture availability the following should be considered before planning proper cropping systems. On the valley paddy is grown during summer with almost no risk of drought succeptibility. Since hard pan is relatively soft, the percolation are high on hill tops and slopes. Moisture is fairly adequate to grow summer rice in many areas with modest risk. Otherwise during summer months quick growing vegetables or pulse crops can be grown safely.

On the slopes coconut and arecanut can be grown as the soil is well drained and moist for most parts of the year. The slopes are very narrow and steep gradient. Hence, preference should be for perennial crops. The slopes receive a part of the benefit of percolation and infiltration moisture is available for longer period in valleys. for a given precipitation the period of moisture availability is less on hill slopes. So those crops which are relatively drought tolerant should be grown in these areas. The rubber cultivation in the southern part of the zone is a typical example for this.

In laterite soils the hard pan limits the root penetration. Further the presence of hard pan increases the surface run off and reduces the infiltration and percolation which ultimately limits moisture availability during the summer months. Coconut and cashew are the ideal choices for these areas. Where the laterite pan is hard only cashew can be grown.

On the lower reaches of the paddy lands which have been generally developed out of the valleys a third crop of paddy could be taken with better or no irrigation. This is possible in regions like Muvattupuzha, Kothamangalam and Mannarkkad.

There is scope for growing intercrops on the eastern parts of the zone except the Palakkad and Chittur area.since moisture is relatively more available in this region crops with marked preference for moisture such as plantains, tubers like yams and dioscorea could be grown as intercrops among the main crops of arecanut and coconut on the slopes. If perennial crops are the choice for intercropping, then pepper, nutmeg, cinnamon and cocoa offer scope. In choosing crops for intercropping, the crop characteristics like moisture requirements especially the tolerance towards drought during summer should be considered. The main principle is that the main crop and intercrop should not compete for moisture sunlight and nutrients.

By appending the above suggestion a viable cropping pattern for the central zone can be evolved.

Summary

SUMMARY

The summary of the study "Agroclimatology in crop planning for central zone of Kerala" is presented in this chapter. The study was undertaken to determine weekly index of moisture adequacy (IMA) and water availability periods for various locations in the central zone and to examine the viability of important crops.

Mean rainfall for the whole central zone of Kerala was calculated annually and seasonally by taking the data of 26 raingauge stations. The mean annual rainfall for the zone was 2443 mm. The mean rainfall during southwest, northeast and summer seasons were 1847 mm, 397 mm and 159 mm respectively. The spatial variation of annual and seasonal mean rainfall, coefficient of variation and probability rainfall at 75 per cent and 90 per cent are presented.

It was observed that the annual mean rainfall increased from east to west. In the coastal areas, there are a few stations which receive more than 3000 mm rainfall. During southwest monsoon season also, the similar trend was noticed. Areas having similar rainfall were seen in parallel strips running from south to north. Southern part of the zone was found to receive more rainfall during northeast monsoon season i.e. more than 400 mm rainfall. There are certain pockets in the coastal area and northern part which receive more than 400 mm. During summer season, almost all the stations in the zone receive less than 200 mm rainfall, while Kochi as an exception receives more than 300 mm.

It was noticed that the annual CV exceeded 30 per cent in the southeastern part. The CV was less than 20 per cent in the central part of the zone while in the northern region, it varied between 20 and 30 per cent. During the southwest monsoon season, the CV was more than 20 per cent in the northern parts. During the northeast monsoon season, the CV was very high in the northern part of the zone and exceeded 40 per cent. In summer, the CV was more than 100 per cent for majority of the stations.

Rainfall probabilities were worked using the ranking method suggested by Frere and Papov. It was observed that annual rainfall at 75 per cent probability level increases from east to west. During the southwest monsoon season also similar trend was observed. For majority of stations the rainfall expected at 75 per cent probability was between 1500 and 2000 mm. Rainfall at 75 per cent probability level during northeast monsoon season also showed similar trend as that of southwest monsoon season except the fact that in coastal areas the rainfall is low i.e., less than 300 mm. The southern part, northern part and a narrow strip running through the centre of the zone experience high rainfall i.e., more than 300 mm. Most of the stations in the central zone were found to have zero rainfall at 75 per cent probability level during summer.

Annual rainfall at 90 per cent probability level was high in the northern part of the zone. In the southern part of the zone the amount of rainfall increased from east to west. During southwest monsoon season also the rainfall increased from east to west.

Most of the parts of coastal area experienced more than 1500. The spatial distribution of rainfall at 90 per cent probability level was erratic during the north east monsoon season. During summer the rainfall in most of the stations at 90 per cent probability level was zero.

Initial and conditional probability of getting more than or equal to 30 mm rainfall per week was worked out for Kochi, Vellanikkara, Palakkad and Pattambi following Markov chain model. It could be seen that initial probability of getting 30 mm rainfall per week was 75 per cent or more during 23rd week to 33rd week and conditional probability of wet week followed by wet week (w/w) having rainfall greater than or equal to 30 mm per week was more than 75 per cent during the period 22nd week to 33rd week, at Kochi. The conditional probability was more than 75 per cent in the 7th, 33rd, 37th and 39th weeks.

Results showed that the initial probability of getting 30 mm rainfall per week was 75 per cent or more during the 24th week to 35th week, at Palakkad. The conditional probability of wet week followed by wet week (w/w) having rainfall greater than or equal to 30 mm per week was more than 75 per cent during 22nd to 35th week. The conditional probability for more than 75 per cent value was observed very early in the 15th week itself but it was only for one week period.

Results obtained for Pattambi showed that initial probability of getting 30 mm rainfall per week was 75 per cent or more during 22nd week to 35th week and conditional probability of wet week followed by wet week (w/w) having rainfall greater than or equal to 30 mm per week was more than 75 per cent during the period 22nd to 34th week . This showed that the starting of rainy season was in the 22nd week and it went up to 34th week and sowing of crops could be taken up around 18th week.

The initial probability of receiving more than 30 mm rainfall at Vellanikkara was found to be above 75 per cent during the period between 22nd to 36th week and conditional probability of receiving more than 30 mm rainfall was during 21st week to 34th week .

Monthly, seasonal and annual mean values for maximum and minimum temperature was worked out for Kochi, Palakkad and Vellanikkara . The highest maximum temperature was observed in Kochi during April (33.0 °C) The lowest minimum temperature observed for Kochi was 22.8 °C observed during January. At Vellanikkara, highest maximum temperature was noticed during March (36.2 °C) and the lowest minimum temperature for Vellanikkara (22.1 °C) was observed during January. At Palakkad the highest maximum temperature was observed during March (37.1 °C) and the lowest minimum temperature for Vellanikkara (21.8 C) was observed during January.

In order to assess the water availability, soil moisture was taken into account and the net water available to the crop through soil moisture could be estimated using water budgetting technique. The water balance elements for all the 26 stations in the central zone of Kerala were worked out following the method of Thornthwaite. Weekly PET was computed using the modified Penman method suggested by Doorenbos and Pruitt.

Annually, the actual evapotranspiration (AET) varied from less than 400 mm in the eastern region of the zone to more than 700 mm in the southern part of the zone. The lowest AET of 311 mm was observed at Parambikulam and a highest of 779 mm is observed at Piravom. A gradual increase of AET can be observed from northern part to southern part of the zone. At southern end of the zone higher values of AET were observed compared all other parts i.e., more than 700 mm. The midland and the coastal regions had AET values between 600 and 700 mm.

The midland and the central part of the zone had higher values of water deficit (WD) compared to the northern and southern parts i.e., more than 1300 mm. In this region, Irinjalakuda had highest value for WD i.e., 1410 mm compared to the stations around that. Almost all the coastal region and midland of the northern and southern parts were found to have lesser WD value of less than 1300 mm.

Water surplus (WS) was high in the midland and coastal areas of the zone. The highest value of WS, 614 mm was observed at Kunnamkulam followed by Kodungallur (821 mm) of coastal region. Almost all stations in the coastal region were found to have higher values of WS, i.e., more than 400 mm except a small patch around Kochi.

The water availability periods for all the 26 stations in the central zone were worked out following Subramanian and Rao. The humid and the sub humid period is combined to obtain the total number of moist days. Perumbavoor recorded the highest number of moist days (188) while Parambikulam recorded the least (73). The total number of moist days was found high at the southern region of the zone while it was low in the south eastern part. In most of the stations a 1st subhumid period followed by a humid period and a 2nd subhumid period can be seen. At Parambikulam a third subhumid period was observed.

The cropping pattern present in the central zone was identified according to the method suggested by National Commission on Agriculture (1976). The cropping patterns of the zone was found out based on the data given by the Directorate of Economics and Statistics, Thiruvananthapuram. The crop data was analysed block wise, and it was found that the cropping patterns fall under 3 major categories (1) mainly paddy (2) mainly coconut (3) plantations other than coconut. In the highland region, rubber, pepper, coconut etc. are found flourishing as high rainfall and extremely undulating topography provide moist and well drained soil conditions.

In general, plains and valleys are put to crops like rice which tolerate excessive moisture. The hill tops and upper reaches of slopes are put to perennial crops such as rubber, coconut, cashew etc., which can withstand the moisture stress during the summer months and do not require tillage operations that accelerate soil erosion. The slopes with low gradients are put to seasonal and annual crops which entail disturbance of top soil but will not result in soil erosion. The bottom reaches of slopes are put to crops such as arecanut, pepper etc. demanding moist but well drained soils.

The suitability of the existing cropping patterns to the different agroclimatic regions were examined based on the information on water availability periods.

Palakkad area has a predominate rice based cropping system. At Alathur, the first subhumid period was seen to start as early as on 28th May followed by the cropping season. Subsequently, humid period was found following which extended for 146 days. The second subhumid period started from 28 October and extended upto 20 November. It was observed that the total number of moist days in this station was 177. It can be seen that water was available for crops from last week of May to third week of November. At Ottappalam also a similar trend for the moisture availability periods was observed with a total number of 173 moist days. However, the start of sub humid period was late (5 June). At Palakkad, it was observed that the water availability period started on 5 June and it extended only up to 10 November and the number of moist days was less. Hence, in this area, in addition to rice, palmyra palms are observed in this area more than coconut palms. The soil and climatic conditions were found to be favourable for the growth of cashew and mango. Out of the four important crops included in this cropping pattern paddy, cashew and mango were found suitable for this area.

At Thrithala and Wadakkancherry, the water availability period was noticed to start from 2nd week of June to 3rd week of November. The number of moist days were seen to be 161 and 165 respectively. These regions have fairly high duration of water availability. Cashew and arecanut also could be seen in this region.

At Kochi, the water availability period starts by 1 June and it extends up to 16 November with 170 moist days. Kodungallur, Chalakkudy and Kunnamkulam stations of this belt did not show much variation in the number of moist days. Rice comes next to coconut in this areas. In the southern part of the zone there is a rubber belt which includes Mulamthuruthy, Pampakuda, Muvattupuzha and Kothamangalam blocks. These areas come under midland region and the climatic conditions in this region were found favourable for rubber cultivation. These areas record very high rainfall compared to other parts of the zone.

A relatively wider base in rainfall was noticed when entire central zone was considered as a whole with moisture availability over a longer period during the year. However, in addition to the moisture availability, the other aspects also should be considered before planning proper cropping systems. In valleys, paddy is grown during summer with almost no risk of drought succeptibility. Moisture is fairly adequate to grow summer rice in many areas with modest risk. Otherwise during summer months quick growing vegetables or pulse crops can be grown safely.

On the lower reaches of the paddy lands which have been generally developed in the valleys, a third crop of paddy could be taken with no irrigation. This is possible in regions like Muvattupuzha, Kothamangalam and Mannarkkad.

There is scope for growing intercrops in the eastern parts of the zone except the Palakkad and Chittur area. Since moisture availability is relatively more in this region, crops with marked preference for moisture such as plantains, tubers like yams and dioscorea could be grown as intercrops among the main crops of arecanut and coconut on the slopes. If perennial crops are the choice for intercropping, then pepper, nutmeg, cinnamon and cocoa offer scope. In choosing crops for intercropping, the crop characteristics like moisture requirements especially the tolerance towards drought during summer should be considered. The main principle is that the main crop and intercrop should not compete for moisture, sunlight and nutrients. By appending the above suggestion a viable cropping pattern for the central zone can be evolved. It is felt that the results of the present work will give suitable information in this regard.

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AGROCLIMATOLOGY IN CROP PLANNING FOR CENTRAL ZONE OF KERALA

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ABSTRACT OF A THESIS

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ABSTRACT

A study was undertaken to determine weekly index of moisture adequacy (IMA) and water availability periods for various locations in the central zone of Kerala and to examine the viability of important crops.

Daily rainfall data for the period 1978-97 were collected from 26 stations in the central zone. Daily data on maximum and minimum temperature, wind speed, maximum and minimum relative humidity and bright sunshine hours for Kochi, Palakkad, Pattambi and Vellanikkara were collected. Soil data and crop data were also collected for the zone. Mean weekly, monthly, seasonal & annual rainfall and coefficient of variation for all stations were worked out. Spatial variation of mean rainfall and coefficient of variation during the different seasons were studied. Monthly dependable rainfall at 75 per cent and 90 per cent were calculated using the ranking method suggested by Frere and Papov, and its spatial variation over the zone was studied. Initial and conditional probabilities of receiving 30 mm or more rainfall per week following Markov chain model for all the rain gauge stations were worked out and discussed. Water balance elements were computed for the 26 stations following book-keeping method of Thornthwaite. PET was computed following the modified Penman method as suggested by Doorenbos and Pruitt.

Annually, the actual evapotranspiration (AET) varied from <400 mm in the eastern region of the zone to >700 mm in the southern part of the zone. The lowest AET of 311 mm was observed at Parambikulam and a highest of 779 mm at Piravom. A gradual increase of AET can be observed from northern part to southern part. The midland and of the central part of the zone had higher values of water deficit (WD)

compared to the northern and southern parts i.e., more than 1300 mm. Parambikulam had highest value for WD i.e., 1606 mm. Almost all the coastal region and midland of the northern and southern parts were found to have lesser WD value (< 1300 mm.)

Water surplus (WS) was high in the midland and coastal areas of the zone. The highest value of WS, 913 mm was observed at Wadakkancherry followed by Kunnamkulam (614 mm) both in the coastal region. Almost all stations in the coastal region were found to have higher values of WS, i.e., more than 400 mm except a small patch around Kochi.

Water availability periods were identified comparing the AET and PET. It was found that water availability periods followed the same pattern for most of the stations in the central zone. It was characterised by a 1st sub humid period followed by a humid period and a 2nd subhumid period. The highest number of moist days was recorded at Piravom (203) followed by Aluva and Perumbavoor(188). At this station the humid period extended for 170 days which is also the highest value compared to all other stations. The least number of moist days was observed at Parambikulam (82). At this station there is a break in the humid period which gave way to a sub humid period. Most of the stations have total number of moist days more than 150. Generally, the water availability period starts in the 2nd week of June and extends up to 3rd week of November.

The cropping system of the central zone of Kerala was analysed and it was found that the cropping patterns fall under three major categories (1) mainly paddy (2) mainly coconut and (3) plantations other than coconut. The viability of these cropping patterns based on water availability periods and soil information are discussed.