AGROCLIMATOLOGICAL STUDIES OF KERALA STATE FOR APPLICATION IN LAND USE PLANNING

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By

E. SARAVANAN

CENTRE FOR EARTH SCIENCE STUDIES
THIRUVANANTHAPURAM-695 031, INDIA

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CERTIFICATE

I hereby certify that this thesis entitled "Agroclimatological studies of Kerala State for application in land use planning" is an authentic record of genuine and bonafide research work carried out by Shri. E . Saravanan, under my supervision and guidance at the Centre for Earth Science Studies, Thiruvananthapuram, and that no part of this thesis has been previously submitted to any University or Institution for the award of any degree or diploma.

H. S. Ram Mohan 12/12/94

Kochi - 16,
December, 1994.

H . S . Ram Mohan
(Supervising Teacher)
Professor
Physical Oceanography &
Meteorology Division
Cochin University of
Science and Technology
Kochi, Kerala.

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CHAPTER 1

INTRODUCTION

The State of Kerala also known as "Gods own country" lies in the south western part of Peninsular India. The area of the state is only 1.18% of the total area of the country, but supports about 3.7% of its total population. The high population density and the resultant high demand for food has increased the need for judicious exploitation of the available natural resources- land, water and atmosphere. That there exists close interrelationships among these three basic resources is evident from the fact that all the water supplies over the land come from the atmospheric moisture. It is imperative that these interrelationships are properly understood and the knowledge effectively applied in any developmental programme of the region.

The land area of the state is limited and combined to a narrow belt bounded by the steep slopes of the Western Ghats on the east and the Arabian Sea on the west. This unique topographic feature is one of the dominant causative factors for the abundant rainfall received during the south west monsoon season. However, it is also constraint in the water resources available for exploitation for agricultural and other landuse.

With in a short distance of 120 km from coast line to the Western Ghats, a variety of climates is observed due to the diversity of physiographic features. The vagaries of the south west monsoon, which is the major contributor to the annual rain fall of the State, controls predominantly the agricultural income of the region. The intrannual variability of the rainfall and hence of the water budget components over the

State influences the landuse of the State in general and the agricultural landuse in particular. Droughts and floods are considered to be two sides of the same coin of rainfall variability, but in a high rainfall area it is the water deficiency that is more important and critical.

For efficient control and management of the available natural resources, a detailed study of the climatology of the area with particular reference to availability of water for agricultural use are essential. In this context, study of the water balance of the State becomes relevant and necessary. Derived parameters of water balance project essential information useful for agricultural planning, such as choice of crops, and scheduling of farming operations. Fluctuations in rainfall effect agricultural production adversely. Eventhough irrigation facilities reduce the risk in agricultural operations, prolonged drought conditions effect the irrigation system itself.

The land use pattern of any area is dependent on a variety of factors, some physical others social. However, an optimum landuse pattern can be defined and delineated using rational parameters such as climate, soil. physiography geomorphology and vegetation. The areas which are suitable for agricultural landuse can be further classified for the different cropping patterns and crop combinations. This can lead to effective use of the agricultural potential of the areas so that the maximum agricultural development is achieved as a sustainable basis. The present study attempts to apply the agroclimatological information to Kerala State for the purpose of landuse planning. The thesis consists of seven chapters including the introduction.

The first Section of the second Chapter discusses the importance of agrolcimatological studies in general and their applications in landuse planning in particular. This includes a review of the available literature in this field. The basic concepts, the data used and the methods employed in this study form the second Section of this Chapter.

The third Chapter deals with the different geographical features of the region under study- the physiography, drainage, soil types, geomorphology and vegetation.

An overview of the agro-climatology of Kerala forms the first section of the Chapter Four. Section Two of this Chapter includes the inter annual variability of the water budget elements over the State computed using the models of Thornthwaite (1948) and Thornthwaite and Mather (1955).

Detailed analysis of the spatio-temporal variation of the landuse patterns forms the first Section of the fifth Chapter. The second Section focuses on the spatio-temporal variation of agricultural landuse the cropping pattern, cropping intensity and crop combination regions.

The first Section of the sixth Chapter presents the delineation of the different agroclimatic zones of Kerala State based on climate, soil, physiography, geomorphology and vegetation. An optimum landuse pattern for Kerala State is proposed in the next Section This includes better crop combinations and different cropping patterns based on the effective agricultural potentials of the areas, so that sustainable agricultural development of the region is achieved.

The seventh Chapter gives the summary of the work carried out based on the results obtained from the study. It also incorporates the conclusions drawn and the suggestions made based on the results of the investigations.

CHAPTER 2

LITERATURE REVIEW, MATERIALS AND METHODS

A brief review of agroclimatological studies and their importance in land use planning is given in the first section of this chapter. The methodology adopted in the present study along with the sources of data is presented in the second section.

2.1 LITERATURE REVIEW

The climatic elements exercise a very strong and direct influence on the development and distribution of soil, crops and livestock. Since all crops have a specific range of moisture and heat requirements, climatic variations rigorously control the distribution of crops. On the other hand, the micro-climate itself is very much affected by the nature of relief, natural vegetation and other land cover.

The world's land resources are under increasing pressure for food and fibre production. It is due to rising population. It is important that land use is judiciously planned using appropriate agroclimatic information. Such planning is of utmost importance for agricultural development in developing countries, where there are greater stresses on the meagre resources.

Agroclimatology is defined as the study of meteorological climatological and hydrological conditions which are significant for agriculture owing to their interaction with the objects and process of agriculture production. Early workers on agroclimatology were from West European countries The beginning of micro-meteorology is usually traced towards the end of 19th century with the works of Theodor Honie'n from Finland and Gregor Kraus from Germany (Geiger, 1960). Others developed the fundamentals of micro meteorological studies, particularly, from Germany and Austria. Gregor Kraus (1845-1925) published a book on soil and climate in 1911, and he is considered the father of micro-climatology. Geiger, the German meteorologist, was the first to work extensively in this direction after 1920 for systematic investigations of climatic variations that occur horizontally and vertically within a short distance from the surface of the ground. Ramdas (1934) soon followed similar investigations in India after 1932. Such studies gave birth to the science of micro-meteorology and then to micro-climatology for crops. It was only in 1956 that for the first time the workers in micro-climatology and micro-meteorology were brought together by Thom from Holland by forming an International Society of Bio-Climatology and Bio-meteorology through which the agroclimatology received recognition as a separate and important division of climatology. The works of Whyte (1960) and Nuttonson (1955) are commendable for investigating crop production and environment relations. Nuttonson even developed and described agro-climatic analogies for North America and other parts of the world. All these attempts of some macro-meteorologists have focused attention to agroclimatology as a separate branch by 1950.

The rapid advances in evapotranspiration research starting with H.L. Penman (1948) in Britain and C.W. Thornthwaite in U.S.A. in 1948 helped further for applying climatic data for agricultural studies. Identification and classification of agroclimates are the primary requirement for rational application of climatic data for crop planning. On one side it is linked up with maximization of crop production using resource inputs while on the other it is concerned with conservation of the natural environment, so important for sustainability in crop production. The two seemingly contradictory requirements are to be blended for various soil and climatic conditions depending on each crop variety for sustenance of production levels.

Climatic classifications have been attempted with different objectives and the important applications are:

1. General agricultural suitability.
2. Choice of crops, their varieties as per growing season for rational agricultural crop location.
3. Delineation of homogeneous soil-climatic zones for crop planning and cropping system.
4. Flexible crop planning covering risks.
5. Improvement in crop productivity.
6. Assessment of potential productivity zones and
7. Exploitation of agroclimatic resources for specific problems of agroclimatic zoning.

Early attempts at agroclimatological zonation in India were made either by geographers or by agronomists using existing cropping patterns, relief, soils and annual rainfall. The climatic zones of the country therefore followed geographical patterns. Meteorologists divided the country for climatic features into 30 sub divisions only on rainfall base with reference to floods, droughts, date of establishment (onset) of S.W. monsoons and few important weather phenomena (Ramdas, 1950). Though rainfall is an important element for climatic classification, these meteorological sub-divisions are far from being homogeneous agroclimatologically since no consideration is given to soil types, temperature, cropping intensity and efficiency, and moisture deficiency or surplus. Later some attempts were made to utilise various climatic indices for regrouping geographer's sub-divisions with agricultural suitability.

The indices tried for such a classification are Potential Evapotranspiration (P.E) index, drought index, aridity index, biologically dry day, moisture index etc. Indices based on P.E. are much closer to the objective. Carter (1954) first gave the climatic patterns of India based on Thornthwaite's P.E. index. This and other indices were used by Indian workers to classify the country (or part of it) into crop regions or agroclimatic zones (Subramaniam 1966, Jagannathan 1964, Krishnan 1968 and Anon 1964).

There are many ways to classify climates of any region. These aspects have been discussed by Burgos (1958). Climate classification is the method of arranging various data of climatic parameters, singly or grouped into sets so as to simplify them to identify analogies and demarcate a country or region into homogeneous zones. But the classification should fulfil the specific agricultural needs as stressed by Burgos (1958).

Meyer (1926) suggested precipitation/saturation deficit ratio index (P/s.d) where s.d. is calculated from temperature and relative humidity. This is called Meyer's Index and it was used in India by Hosking (1936) for preparing climatic map with limited humidity data. Moisture or Humidity index of Thornthwaite (1931 and 1938) was the outcome of such attempts. Thornthwaite's modified P.E index was used in India (Subrahmanyam 1956). The other indices are Padmanabhamurthy's Agroclimatic index of (1968), Palmer's Drought index and Hargreave's moisture availability index (1977). A number of agroclimatic indices have been discussed in a review by Hayhoe (1975). Identification of suitable methods for the computation of classificatory agro-climatic variables and the comparison of those obtained using standard methods (Troll, 1968, Cocheme and Franquin 1967; Hargreaves, 1971, 1975). In Canada, an agroclimatic resource index has been developed (Williams 1983). This index was useful in providing input to the land use planning process and in emphasising the need to protect critical land resource areas.

In this section the work done to classify the Indian climate in relation to agricultural development is described. Most Indian workers have adopted the classification strategies based on techniques developed by Koeppen (1936), Thornthwaite (1931, 1948), Thornthwaite and Mather (1955), Gaussen (1954), Troll (1965), Cochevne and Franquien (1967), Papadakis (1970), Hargreave (1971) for delineation of climate using quantitative averages of climatic parameters.

Using Koeppen's classification, Bharucha and Shanbhag (1957) determined the climatic types for 104 stations in Indian sub continent. Subrahmanyam et al (1965) also employed this technique for regionalisation of Indian climates. Both the studies have emphasised on thermal factors than on moisture factor and the parameters used were mean annual temperature and mean annual precipitation. Thornthwaite classification has been widely used by Shanbhag (1956); Bharucha and Shanbhag (1957); Subrhmanyam (1957, 1963, 1965); Subrahmanyam and Murthy (1968), Murthy (1968); Subrahmanyam and Sastry (1969); and Krishnan (1969).

Other workers such as Krishnan and Thanvi (1972); Subramaniam and Umadevi (1979); Subramaniam and Vinayak (1982); Bora (1983); have applied Thornthwaite (1948) method in one form or the other for defining the agroclimates of various regions of India. Krishnan and Singh (1968) using moisture and thermal index and super-imposing them on soil maps have divided India into 64 soil climatic zones.

Sarkar and Biswas (1986) modified Hargreave's technique (1971) to suit dry farming tract of Indian subcontinent using two productivity levels of moisture adequacy index and agroclimatic zoning was performed on weekly basis as against monthly by Hargreaves. Sarkar and Biswas (1988) worked out agroclimatic classification for entire India.

Raman and Murthy (1971) worked out water availability periods for 200 Indian stations using Cocheme and Franquine (1967) method. Subramaniam and Umadevi (1983) and Subramaniam and Raju (1986) have also used this method to designate water availability periods for a few stations in Orissa and Andhra Pradesh.

International Crop Research Institute for Semi-Arid Tropics (ICRISAT) used Troll's technique (1965) for the classification of semi-arid tropics of India. Chaudhary and Sarwade (1982) made some refinements in the method and demarcated various homoclines in the country. De Martonnes method (1926) was used by Pramanik et al (1952) and Krishnan and Shankarnarayan (1964) for classification of the climate for Rajasthan. National Agricultural Commission (1976) used monthly rainfall as the parameter and identified five climatic types in India. Planning Commission has adopted the agroclimatic regions as basis for agricultural planning. Soil characteristics, physical conditions, topography, rainfall and water availability, cropping pattern, climate and status of development of irrigation have been the principal characteristics used for regionalisation (Alag 1988).

The National Bureau of Soil Survey and Land use Planning (NBSS&LUP) has divided India into agro-ecological regions based on climatic and ecological conditions (Murthy and Panday 1978). The same organisation has now updated and divided India into agro-ecological regions based on physiography, soil, climate and length of growing period (Sehgal et al; 1990).

Many studies have been conducted on agroclimatic aspects on regional scales in India. To mention a few significant studies are the water balance approach in drought studies done by Subrahmanyam and Ram Mohan (1979, 1984), Bora (1976), Ram Mohan (1978), Ram Mohan et al (1986), Ram Mohan and Nair (1986a, 1986b) Ram Mohan and James (1989), Vinayak (1991), Lekha (1992).

Nair (1973), delineated thirteen agroclimatic zones and identified cropping patterns in Kerala State based on rainfall, altitude, topographical features and soil characteristics. Kerala state Agricultural University under the National Agricultural Research Project has brought out status report of five agroclimatic zones in the year 1984 and another report in the year 1989 based on physiography and climate for broad agricultural planning.

Information on the agroclimatology of Kerala is scanty. Murthy (1982) and Vinayak (1992) have made a beginning in this direction on Kerala. Still the application of agroclimatology in crop land use study in Kerala has not been carried out. Thus, the present study is aimed at to fulfil this requirement by studying the cropping pattern, cropping intensity, crop diversification and concentration, crop combination and finally to delineate the agroclimatic regions of Kerala. This study will form as a basic resource inventory/document for the State and will provide a sound basis for broad crop land use planning and developing agriculture on a sustainable basis.

2.1.1 Application of agroclimatology in Landuse Planning

Among the land resources, agricultural land resources has played a vital role since time immemorial engaging the largest percentage of the inhabitants of the world. Owing to increasing pressure of population on land and the ever growing demand for food and raw materials, there is a dire need to use every piece of land properly, which calls for scientific, rational and judicious planning for use of land resources without disturbing the ecological or socio-economic balances of the area. This calls for an exhaustive land use survey together with a study of decisive socio-economic factors of land utilisation. (Dzewonski, 1956) in order to visualise existing use and misuse; the planners should know what and how it should be done and also where it shall be done (Prakasha Rao, 1956). This information when analysed lead to a better understanding of existing use of land and possibilities for its future development.

Thus keeping importance of land use surveys in view, various countries of the world have conducted them on different lines depending upon their physical economic and social conditions.

Dudley Stamp was the pioneer in this work under whose direction landuse surveys of Britain was conducted in the thirties. The surveys included crop land use and provided first hand factual information by recording the facts in the map. This approach of land use was followed by Coleman (1961) in conducting second land use survey of Britain. Dziewonski (1959) and Kostrowicki (1953) followed the same method with some variation in the landuse survey of Poland in 1953.

Similar studies have been conducted in different parts of the world (Barmes, 1929, De Vries, 1928; James and Jones 1954, and Mc Murthy 1936). Landuse survey of China was conducted in 1929 by Buck which was considered as an extensive array of facts in all aspects of land use (Buck 1937, and Gressey 1939). Landuse surveys on similar line have been carried out in various parts of India (Shafi 1960, 1966 and Mohammed 1979).

Josbir Singh (1974) in his agricultural atlas of India brought out a series of maps on crop land use, cropping pattern, crop association and crop combinations. Sadasivan (1967) in his study suggested an alternative plan of crop pattern in Kerala State using different types of soil and returns from various crops. Bishnoi and Ram Singh (1981) using soil climatic zones identified judiciously crops and cropping patterns for Hariyana.

In 1964 the Planning Commission of India had classified India into fifteen regions and sixty one divisions (sub-region). In delineating the regions and divisions the Planning Commission considered such bases as geological conditions, climate, topography, soils land utilisation, irrigation and cropping pattern (Mammoira 1975). I.C.A.R (1972) proposed a new classification of the agricultural regions of India, and identified four broad zones for each of the most common crops.

Scott (1957), in his attempt to delineate the agricultural regions of Tasmania tried to define the regions from a statistical point of view. In his work, he had applied the idea of crop combination developed by Weaver (1954) with slight modification and developed his regions on the basis of combinations of crop, livestock and landuse.

The work of Dikshit (1973) on Maharashtra State brought out that crop pattern is a significant variable in differentiating agricultural landscape into a set of regions.

The study of crop combination region constitute a significant aspect, as it provides a good basis for regional planning. The delineation of crop regions would help in the regional framework of agricultural activities and specialisation of crops in any region. The patterns of crop combination regions that will emerge from the delineation might also serve the purpose in a balanced regional planning of agriculture.

In order to obtain the crop combination regions, it is essential to have a standard statistical basis so as to study the dominance of the specific crops in an area and their association. Weaver (1954), pioneer in this field of study, brought out crop combination regions in the Middle west of USA in a series of thematic maps. Later Thomas (1962) modified weaver's method and brought out crop Combination regions of Wales. Rafiullah (1965) also modified the Weavers method and simplified the crop association and helped in the designation of agricultural regions (Husain, 1972).

Another modification of Weaver's method put forward by Kikukazi Doi (1959) on deriving crop combinations for different regions (Siddiqui, 1975; Mohammed, 1975; Majid, 1978; and Khan 1973), with Doi's method it was found that the results are more realistic in comparison to other methods.

In delineating agricultural regions an approach of agroclimatic regionalisation has adopted (Papadakis 1966) since the climatic elements are most significant factor in influencing the growth of crops. Similarly Phillips (1967) has devised an elaborate system of ecological regions for the tropics, based on vegetation types and climate. The assumption is that these are good indicators of agricultural potential Benett (1960) has constructed a world map of food-crop climates which seeks to differentiate climates according to their relative hospitality to production of major food crops.

The studies of cropping pattern and crop combination though many standard statistical techniques, ultimately delineate crop regions which fit exactly with the physical parameters including climate. Thus for any crop land use in any part of the world is being dealt with, climatic criteria are probably the best indicators of agricultural potential. An attempt is being made in this study to correlate the Agroclimate with that of the agricultural landuse for the State of Kerala, which will form the first such document for planning purposes.

2.1.2. Potential Evapotranspiration

Evapotranspiration represents the total exchange of moisture from the earth surface to the atmosphere through evaporation and transpiration. There are different factors which affect the rate of evapotranspiration such as external supply of energy, capacity of air to remove the water vapour, nature of vegetation, availability of water for evapotranspiration etc. Evapotranspiration varies from place to place and with time due to the variations in weather, landuse and soil management, plant growth etc.

Thornthwaite (1948) introduced the concept of Potential Evapotranspiration (PE). He defined it as the total water loss from large homogeneous vegetation covered area, which never suffers from lack of water. This is a function of climate and edifice controls. Attempts for the measurement of this parameter using modified lysimeters were unsatisfactory due to the difficulties in maintaining the ideal conditions during installation and maintenance of the instrument.

A number of methods have been developed to estimate PE and extensive literature has been generated on these methods, utility and limitations. Mather (1954) felt that Thornthwaite's PE values are underestimates in winter and overestimates in summer. Van Wijk and De Varies (1954) reported that Thornthwaite formula give good results in similar climates, where it is developed, but values obtained for semi-arid climates are very low. Thornthwaite's formula is fairly good for humid regions or seasons, but not suitable for dry conditions.

Eventhough these limitations to Thornthwaite's equation exist, it is widely accepted among the researchers in various fields. According to Penman (1956), Thornthwaite's formula is quite acceptable, considering its simplicity and limitations. All empirical formulae except Thornthwaite's require a number of parameters which are not easily available. On the other hand, Thornthwaite's formula requires only the mean monthly temperature of the station. He assumed that the air temperature has a positive correlation with net radiation which acts as the energy source for PE. The detailed instructions and tables to compute PE values using Thornthwaite method are given by Thornthwaite and Mather (1957) and Subrahmanyam (1982).

Field capability, the maximum amount of water that a soil can retain in the root zone against gravity depends upon the type of the soil and vegetation. Thornthwaite and Mather (1957) presented a table giving the values of water holding capacity corresponding to soils of different field capacities.

While precipitation and potential evapotranspiration are the two basic elements of water balance, actual evapotranspiration (AE), water deficiency (WD) and water surplus (SW) are the derived elements.

Actual Evapotranspiration is the amount of water that is actually available for evaporation and transpiration and depends on PE, precipitation and the actual moisture content of the sol. When there is sufficient amount of water it is equal to PE and in dry situations, it may be less than PE being equal to the sum of the amount of precipitation and moisture withdrawn from the soil.

Water deficiency is the amount by which precipitation and soil moisture together fail to meet the PE or in other words, the amount of water needed for supplemented irrigation in agriculture for the most efficient growth of crops.

Water surplus represents the excess of precipitation after meeting the demands for PE and the recharge of the soil storage. This factor is very important in the assessment of water resources for their maximum utilisation.

In the preset thesis water balance elements of Kerala have been worked out on a climatic basis, using the modified procedure of Thornthwaite and Mather (1955).

In order to work out the water balance of Kerala, it is essential to compute PE values for all the stations. However, for stations where temperature data were not available, an interpolation technique has been applied to monthly PE values (Ram

Mohan and James, 1989). For this, mean monthly temperature data for 11 stations in and around Kerala states has been used. Correlation between heights of the stations and monthly PE values were examined and since correlation coefficients were found to be statistically significant for all months, regress lines have been fitted (James, 1991). However, from the regression lines it was observed that the scatter was very large for high attitude stations, situated 1,500 metres above mean sea level and hence such stations were omitted. From the fitted regression lines, rates of decrease of PE with height (lapse rate of PE) have been found out for all months. Since a uniformity was observed in lapse rates of PE of different months of the same season, regression lines have been fitted for different seasons and average lapse rates of PE for the seasons have been evaluated and these values are given in Table 2.1.

Table 2.1: Correlation coefficients are lapse rates of PE for different seasons

Season	Correlation Coefficients (r)	Lapse rates of PE r PE mm/100m
Winter	-0.984	5.90
Pre-monsoon	-0.950	4.62
Monsoon	-0.991	5.72
Post-monsoon	-0.992	6.40

The stations for which computed values of PE are available are taken as base stations. Using the calculated values of seasonal lapse rates, PE values for all the 14 rain gauge stations have been estimated from PE values of suitable nearby base stations. The base stations is so chosen, that the height difference between it and the rainguage station is the least. If a base station has a height H1 m and Potential Evapotranspiration PE_1 mm, the Potential Evapotranspiration PE_2 mm of another station having height of H_2m, which is nearby to the base station and has almost the same type of climate is given by the equation.

$$Pe_2 = PE_1 - (H_2 - H_1)\ PE$$

Where $_{PE}$ is the lapse rate of P.E.

When the estimates of P.E values derived from the fitted lines were compared with the actual values (computed from temperature data), the differences were found to be less than 5% in 82% of cases and less than 8% in 92% of cases, white the maximum error was about 10%.

Using this procedure, P.E. values for all the stations which do not have the measured temperature data, have been interpolated on a monthly climatic basis. The seasons and annual value P.E. for one station have been calculated and plotted separately for spatial distribution studies.

2.2. CONCEPTS OF WATER BALANCE

Water balance is a basic concept in the modern climatology and has been gaining importance in various fields of study. It is a comparative study of rainfall and evapotranspiration and plays an important role in many fields of Earth Sciences, agriculture and water resources development.

The concept of book-keeping procedure of water balance was introduced by Thornthwaite (1948) to solve many soil moisture problems; he employed it as a basis of a new improved and national climatic classification Since then, further studies based on this approach have led to many revisions and extensions of the procedure itself and have resulted in numerous applications in various fields. The details of water balance computations have been explained by Thornthwaite and Mather (1955, 1957) and Subramanyam (1982).

Water balance or water budget is a monthly, weekly or daily comparison of water supply in the form of precipitation with the water demand or potential evapotranspiration (PE), where the soil moisture acts as a sort of reserve available for use to a limited extent for the purpose of evapotranspiration during periods of water shortage. The book-keeping procedure of water balance, based on such comparison provides comprehensive information on many parameters such as amount of water stored in the soil, actual evapotranspiration (AE), water surplus, water deficit etc at a place in quantitative manner. Since accurate measurements of these parameters especially AE and soil moisture, are not generally feasible on a continual basis due to technical difficulties, the book keeping procedure of water balance is extensively used in various fields. Subrahmanyam (1972, 1982) has described applicability of this approach in various aspects such as climatic classification, agriculture, hydrology etc. The derived parameters of the water balance, especially water surplus and water deficit, can give very essential information useful for various agricultural activities.

Water balances of more than 240 climatological stations in India and vicinity are worked out by Carter (1954). This concept of water balance was introduced in India by Subrahmanyam (1956a) who used the derived parameters of water balance for climatic classification of India. Subrahmanyam (1956 b) mapped the annual values of surplus and deficits over India using the modified book-keeping procedure. Subba Rao and Subrahmanyam (1961), Sastri (1969), Rama Sastri (1973), Sarma (1974), Bora (1976), Ram Mohan (1978), Ram Mohan et al(1986), Nair (1987) and James (1991) have carried out similar works on regional basis. Kayane (1971) presented distribution of water balance components over Monsoon Asia.

2.2.1 Applications of water balance in drought climatology

Drought is a short period of water deficiency while aridity is a prolonged and persistent deficiency of water for established use. In India 99 per cent of the famines that occur are due to droughts (Ray, 1901). Droughts, appear as periods of acute water shortage, have been sighted as a major scourge of mankind, since they are a menace to food production, mainly through agriculture (Subrahmanyam, 1967).

Droughts have been defined variously by different researchers (Tawnehill, 1947; Hoyt, 1938; Thornthwaite, 1948; Shantz 1927; Thornthwaite and Mathew 1955; Palwer 1967; Blair 1943; and Henry 1906). But, a completely satisfactory or definition of drought has not yet been possible. Depending upon the purpose of study and basic criteria chosen, droughts maybe grouped mainly into 4 categories - precipitation droughts, atmospheric droughts, agricultural droughts and hydrological droughts.

Just as there exists various definitions of droughts, approaches to drought studies are also varied. The different methods employed for the study of droughts may be categorized are

a) Statistical techniques (Walker, 1914; James, 1932; Ramdas, 1950; Foley, 1955; Majumdar, 1958; Naqvi, 1958; Mohan 1967; and Gibbs and Mathew, 1967).

b) Non-statistical techniques (Knochenhaver,1937 and Gaussen 9154).

c) Dynamic methods (Bond, 1960;p Troup, 1965; Namiar, 1966; Morris and Ratcliffe, 1976 and Green 1977) and

d) Water Balance methods (Thornthwaite, 1948; Van Bavel, 1953; Sapozhmikova, 1958; Plamer, 1956, 1957 and Rodda, 1965).

In India, the water balance approach was suggested for the aridity and droughts by Subramanyam (1956b). Subramanyam and his co-workers used the aridity index (Ia) to categories droughts of various intensities (Subrahmanyam and Subramaniam, 1964, 1965; Subrahmanyam and Sastri, 1967 and 1971. Subrahmaniam and Sarma, 1972; Sastri 1969; Ramasastri, 1973; Sarma, 1974; Bora 1976; Ram Mohan, 1978 and Ram Mohan 1984). All these studies project the Versatility of the water balance procedure as it enables a realistic quantitative evaluation water deficiency which is the root cause of all droughts.

In these studies and in the present investigation, the departures of yearly aridity index (Ia) values from the average is used as a measure of the intensity of drought. The yearly departures of aridity index from the median is graphically represented against the respective years. The standard deviation of aridity indices is used as a measure of departure, with the median as the base reference. Classification of drought years in the order of their intensity are given in Table 2.2.

Table 2.2: Classification of Drought years

Departure of Ia from median	Drought Integrity
Less than 1/2 σ	Moderate (M)
Between 1/2 σ and σ	Large (L)
Between σ and 2 σ	Severe (S)
More than 2 σ	Disastrous (D)

The number of drought years of each category in each decade is presented graphically to project the decennial intensity of droughts.

2.2.2 Climatic shifts

Another aspect of special study in this investigation, is the occurrence of climatic shifts of the annual water balance of entrain stations may be of such magnitude that their very climatic types could be shifted by one or more categories in the drier or the water direction. Such temporary shifts of climate, are of great interest to the agroclimatologists, for their frequency and magnitude reflect the conservation of climate and determine the progressive improvement, stability or deterioration in the climatological potentialities of a region for development. Accordingly, the moisture index (Im) values for individual years were plotted and years of extreme dryness and wetness were identified. Monthly water balances of the stations in such extreme years were also studied and compared graphically with that of the normal year.

2.3. MATERIALS AND METHODS

Brief description of the methodology adopted for computation of various parameters used for agroclimatology and crop land use is presented. The period of study, length of data availability and source of apart from the methods used.

2.3.1. Rainfall Study

From 1901-89 rainfall data for about 80 rain gauge stations in Kerala have been collected from India Meterological Department (IMD). This includes monthly and yearly rainfall of the state. Based on that series of thematic maps of south west monsoon, north east monsoon and other season have been prepared adopting the standard statistical techniques.

2.3.2. Climatic water balance

The most important climatic water balances of 14 stations were calculated adopting the modified scheme of Thomthwaithe (1948) and Thornthwaite Mather (1955) which involves a book keeping procedure. This method requires mainly mean monthly temperatures and rainfall over longer period.

2.3.3. Crop combination

A number of statistical procedures have been introduced to demarcate the crop combination regions or sets of elements that play significant role in any particular system. A most valuable statistical formula of crop combinational analysis was advanced by Weaver (1954) in his study on the crop combination in the Middle West of USA. Weaver calculated deviation of real percentages for all the possible combinations in the unit considered against a theoritical standard. Weaver's method to determine the minimum deviations appears to be quite simple, but in practice, it requires much calculations work. Occasionally it also tends to produce highly generalised results.

Another modification of Weaver's method has been put forward by Kikukazi Doi (1951). This method substitutes $\Sigma d^2/n$ of Weaver's with the sum of squared differences (Σd^2). Thus the combinations having the smallest Σd^2 will be the combination formed by major crops only.

To prepare the combination regions 14 important crops of Kerala has been selected. Using the standard statistical technique (Doi's method), a map of crop combination regions of Kerala has been prepared.

Area and yield of 14 crops from two different periods (1976-1977; 1987-1992) will be compared and the spatio-temporal distribution will be discussed. The area and yield of the above crops will be depicted in the form of thematic maps.

CHAPTER 3

GEOGRAPHICAL FEATURES OF KERALA

3.1 LOCATION AND EXTENT

The State of Kerala extends from latitude $8^{o}18'N$ to $12^{o}48'N$ and longitudes $74^{o}52'$ E to $77^{o}22'E$ along the south-western coast of Indian subcontinent. The State is bounded by Karnataka in the north, Tamil Nadu in the east and south and the Lakshadweep sea in the west. With an area of 38,863 km^2 the population stood at as per 1991 census.

Table 3.1: Districts along with area and population in Kerala state.

District	Area in km^2	Population
1. Kasaragod	1,992	1,071,508
2. Kannur	2,966	2,251,727
3. Wayanad	2,131	672,128
4. Kozhikode	2,344	2,619,941
5. Malappuram	3,550	3,096,330
6. Palakkad	4,480	2,382,235
7. Thrissur	3,032	2,737,311
8. Ernakulam	2,407	2,817,236
9. Idukki	5,019	1,078,066
10.Kottayam	2,203	1,828,271
11.Alappuzha	1,414	2,001,217
12.Pathanamthitta	2,642	1,188,332
13.Kollam	2,491	2,407,566
14.Trivandrum	2,192	2,946,650

The State come into existence on 1st November, 1956 as a result of the re-organisation of Indian States with 9 districts and 55 taluks. Further re-organisation within the State in subsequent years has resulted in the present setup of 14 districts and 61 taluks. The names of the districts, their area and population as given in 1991 Census Report are given in Table 3.1.

3.2. PHYSIOGRAPHY

The State extends over a distance of 560 km along the west coast its width varying from 15 to 120 km. Within a limited area of 38,863 km^2, it presents a vary wide variation in its physical features.

Figure 3.1 shows the physiographic regions of Kerala. The inset map shows the generalised altitudinal zones (adapted from the Public Works Department of Kerala). The Lakshadweep sea in the west and a long range of mountains called the Sahyadris (a part of Western Ghats) in the east bound the State. A major part of this range is dissected by numerous west-flowing rivers resulting in varied land forms. The mountains are essentially plateau remnants of two or three altitudinal ranges, approximately around 1,800 m, 1200 m, and 600 m called planation surfaces. These plateau remnants are considered to be the result of periodic uplift of this part of the Western Ghats. Wayanad plateau, Kunda hills, Nelliampathi plateau, Periyar plateau and Agasthya malai are all parts of this range at different elevations. Several peaks in this range exceed 2000m in height Anamudi (2695m) being the highest peak in Peninsular India.

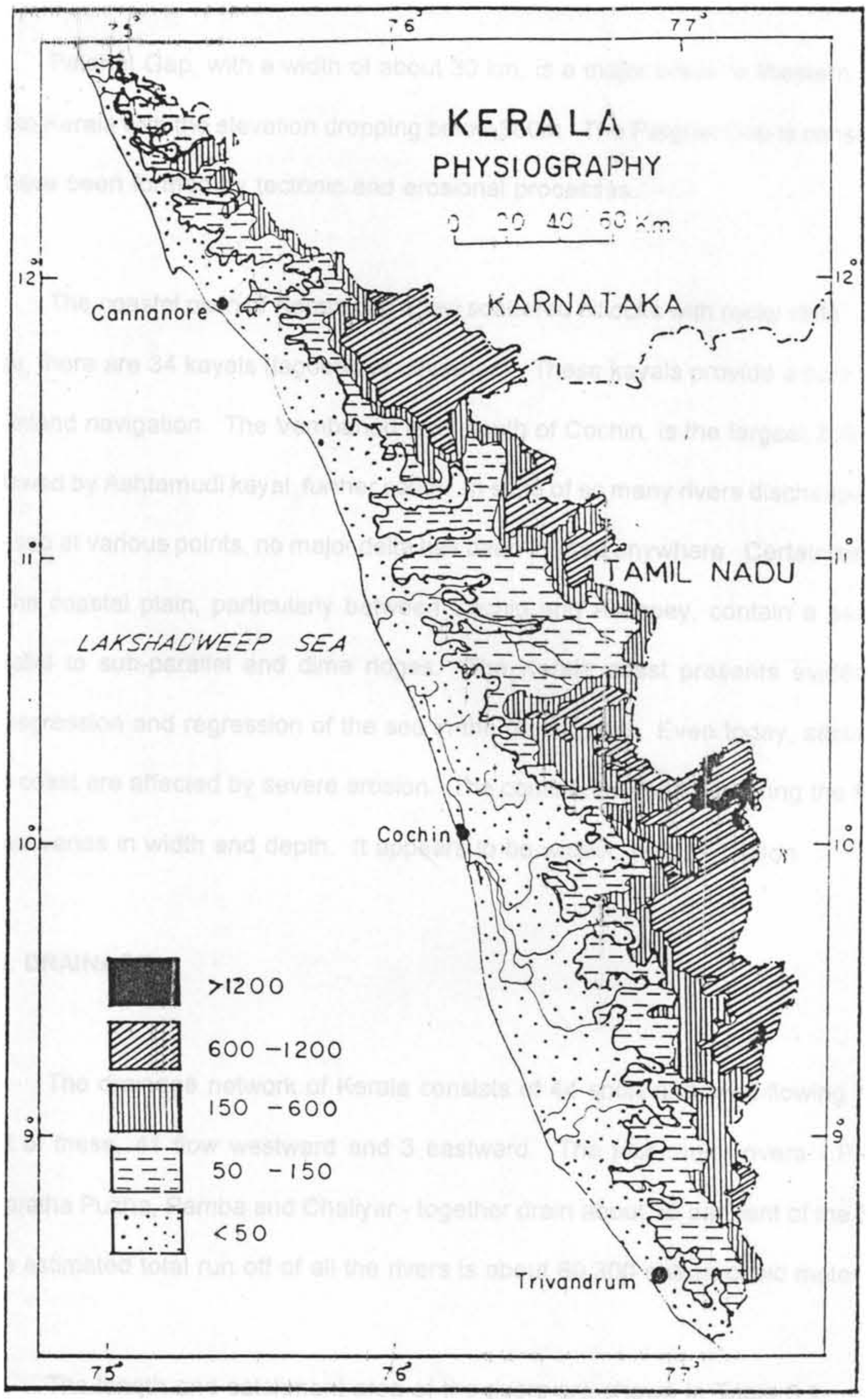

Fig 3.1: Physiography of Kerala

Palghat Gap, with a width of about 30 km, is a major break in Western Ghats within Kerala with the elevation dropping below 300m. The Palghat Gap is considered to have been formed by tectonic and erosional processes.

The coastal plain of Kerala has a few scattered hillocks with rocky cliffs. In this area, there are 34 kayals (lagoons or estuaries). These kayals provide ample scope for inland navigation. The Vembanad lake, south of Cochin, is the largest 205 km^2), followed by Ashtamudi kayal, further south. In spite of so many rivers discharging into the sea at various points, no major delta has been formed anywhere. Certain sections of the coastal plain, particularly between Cochin and Alleppey, contain a series of parallel to sub-parallel and dime ridges. The Kerala coast presents evidence of transgression and regression of the sea in the recent past. Even today, sections of this coast are affected by severe erosion. The continental shelf bordering the Kerala coast varies in width and depth. It appears to be widest, west of Quilon.

3.3. DRAINAGE

The drainage network of Kerala consists of 44 short and swift-flowing rivers. Out of these, 41 flow westward and 3 eastward. The four major rivers - Periyar, Bharatha Puzha, Pamba and Chaliyar - together drain about 35 per cent of the State. The estimated total run off of all the rivers is about 80,300 million cubic meters.

The length and catchment area of the rivers are shown in Table 3.2.

Table 3.2: Length and catchment area of rivers in Kerala

Sl. No.	River Basin	Length (km)	Catchment area (Inside Kerala) (sq km)	Annual Yield in Kerala) (Mm^3)	Annual utilisable Yield (In (Mm^3)	Irrigation water requirements (Mm^3)
1.	Manjeswar	16	90	-	-	-
2.	Uppala	50	76	309	106	149
3.	Shiriya	67	290	620	358	187
4.	Moryal	34	132	1718	1218	507
5.	Chandragiri	25	145	-	-	-
6.	Chittari	25	570	-	-	81
7.	Nileshwar	46	190	1356	937	329
8.	Karingote	64	429	-	-	-
9.	Kavvayi	31	143	-	-	-
10.	Peruvamba	51	300	1143	603	-
11.	Ramapuram	19	52	-	-	-
12.	Kuppam	82	469	1236	786	203
13.	Valapatnam	110	1321	1784	1823	331
14.	Anjarakkandy	48	412	986	503	89
15.	Tellicherry	28	132	251	122	81
16.	Mahe	54	394	803	445	194
17.	Kuttyadi	74	583	1626	1015	352
18.	Korapuzha	40	624	-	-	-
19.	Kallayi	22	96	7135	2616	3541
20.	Chaliyar	169	1735	-	-	-
21.	Kadalundi	130	1122	-	-	-
22.	Tirur	48	117	1165	60	221
23.	Bharatapuzha	209	4400	6540	3349	4684
24.	Keecheri	51	401	1024	345	822
25.	Puzhkkal	29	234	-	-	-
26.	Karuvannur	48	1054	1887	963	970
27.	Chalakudy	130	1404	2591	1539	1093
28.	Periyar	244	5284	11391	8004	1999
29.	Muvattupuzha	121	1554	3814	1812	2141
30.	Meenachil	78	1272	2849	1110	1180
31.	Manimala	90	847	1829	1108	402
32.	Pamba	176	2235	4641	3164	1732
33.	Achenkovil	128	1484	2287	1249	889
34.	Pallikkal	42	220	-	-	-
35.	Kallada	121	1699	2270	1368	1162
36.	Ithikkada	56	642	761	429	493
37.	Ayroor	17	66	-	-	-
38.	Vamanapuram	88	687	1324	889	755
39.	Mamom	27	114	-	-	-
40.	Karamana	68	702	836	462	466
41.	Neyyar	56	497	433	229	502
42.	Kabani	-	1920	4333	4333	2182
43.	Bhavani	-	562	1019	1019	476
44.	Pambar	-	384	384	708	298

(Source: Water Resources of Kerala 1974 Public Works Department, Government of Kerala)

The general drainage pattern of Kerala is dendritic. At places, it is subparallel and radial. Most of the rivers are structurally controlled and follow conspicuous lineaments, the general directions being NW-SE and NE-SW.

Study of gradients of some selected rivers indicates that the coastal plain extends far more eastward in the central part than in the northern and southern parts of Kerala. Extension of high gradients to a considerable length from the source of some rivers suggests their youthful stage. For example, Chalakudi and Periyar rivers have gradients of 1/250 or more for three-fourths of their course. The reduction in discharge of water in the rivers during summer months not only makes navigation difficult but also increases the salinity of the river water. Consequently, the drinking water wells and crops in the lowland, near water bodies are also affected. A number of canals, interconnecting kayals, were excavated for navigation purposes.

3.4 GEOMORPHOLOGY

The six geomorphic units identified here approximately correspond to the physiographic zones and are described below: Figure 3.2 shows the general geomorphology of Kerala.

Steep to very steep hills ranges

This unit corresponds to the physiographic zones of the Sahyadris and adjoining midland, having are altitude of more than 300m. The dissected segments and high

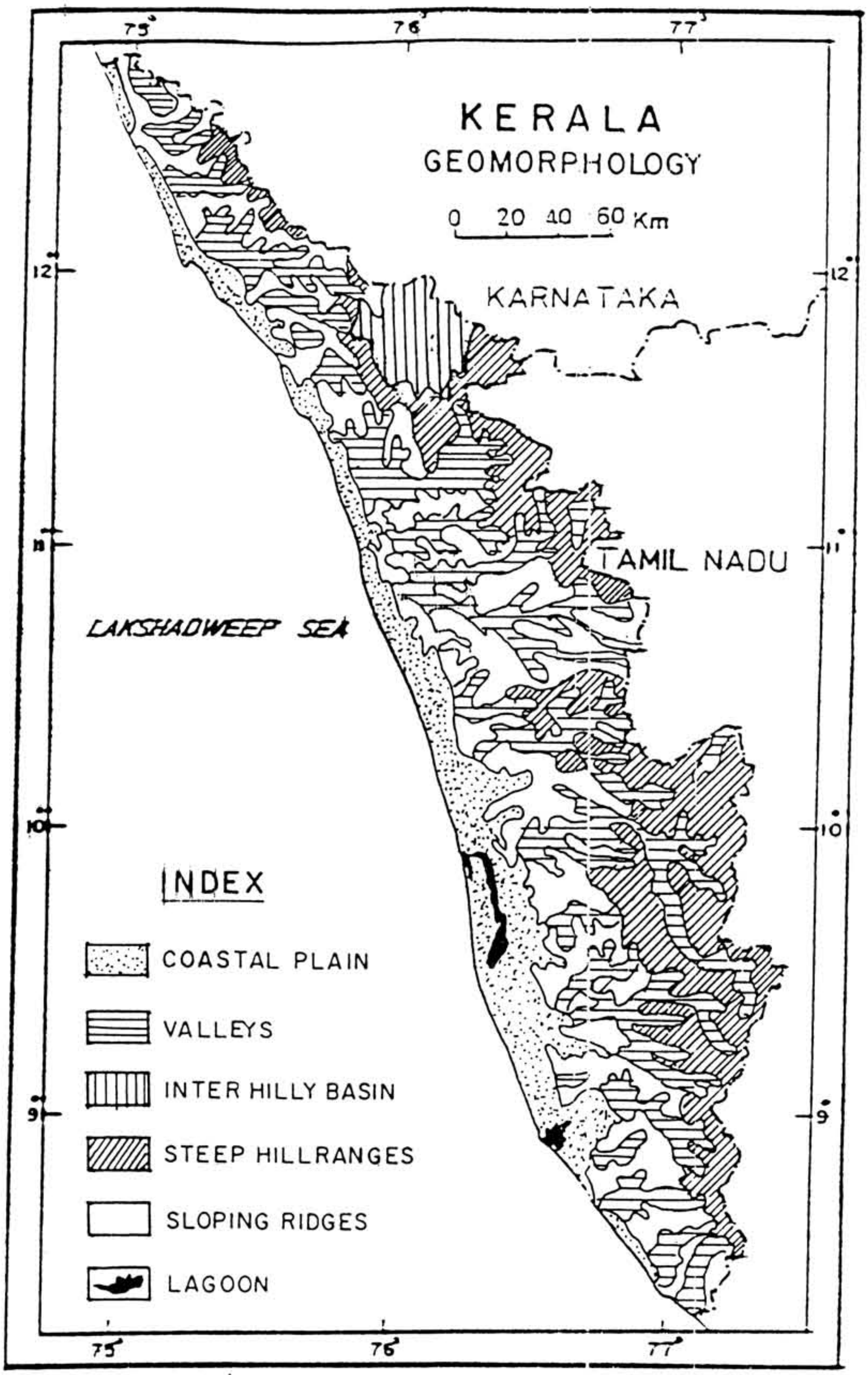

Fig. 3.2: Geomorphology of Kerala

level plateaus (>600m) of Western Ghats exhibit this slope range. Plateau edges are highly indented having 80 to 100 per cent slope. The Palghat Gap interrupts the continuity of this unit. The southern part of this unit, stretching between the Nelliampathi plateau and the Agasthya malai, is encircled by steep slopes on the west and east.

Moderately to steeply sloping ridges

This unit corresponds to the upland zone having an altitudinal range of 50 to 300 m. The slope ranges from 55 to 60 per cent. The topography is highly dissected due to intensive fluvial action. The valleys are deep and narrow. The interfluve area is occupied by ridges. In the northern part, these ridges have flat tops with laterite capping. The change in slope from the first type to this region is evident from the knickpoints observable in the profiles of rivers.

Greatly to moderately sloping spurs

This unit lies between the uplands and coastal plains. This is presumed to be a transitional zone between degradational and upgradational plains and is characterised by a slope range to 10 to 20 per cent. Isolated hillocks are observed, surrounding which the slope has steep gradient. In the northern part, the area appears to be hummocks. The interfluve areas occupied by these spurs usually have lateritic flat top surfaces.

***Gently to moderately sloping inter-hilly basins*:**

this unit representing the Wayanad plateau is an extension of the Mysore plateau. This plateau with easterly gradient is characterised by gentle to moderate slopes ranging from 10 to 20 per cent. Interlocking spurs. isolated hills etc are common.

Nearly level to very gently sloping coastal plains

This unit falls between the coastline and the 10 m contour. This is the youngest planation surface, mostly depositional, developed by fluviale as well as marine action. Features like alluvial plains, lagoons, coastal dumes, and mudflats indicate the broad aggradational character of this unit in contrast to the degradational character of the other geomorphic units.

***Valleys-gently sloping to flat bottom*:**

This unit is identified along the river courses where the bed level is less than 50 m. Here the valley sections are broad and mostly `U' shaped, with extensive development of river terraces. The valleys have gentle slopes of 3 to 5 per cent and gradually merge with the coastal plain.

3.5 GEOLOGY

Kerala region has four major rock formations namely Quaternary sediments, Laterite developed on Crystalline and Sedimentary rocks, Sedimentary rocks (cenozoic) and Crystalline rocks (Precambrian).

The crystalline rocks consists chiefly charnockite, khondalites, granitic gneisses, Dharwar schists and granites traversed by pegmatites and basic dykes. The charnockites are characterised by the presence of a rhyombic pyroxene-hypersthene. The charnockites are with narrow bands of pyroxene granulite, magnetite-quartzite and calc granulite form the most widespread group in the State. Many of the hornblende and biotite gneisses are considered to be the retrogradec equivalents of charnockites.

The khondalites include a group of light coloured, fine to medium grained, foliate/granulitic rocks comprising garnet-sillimanite gneiss with or without graphite, garnet-biotite gneiss, garnet-quartzofelspathic gneiss predominant rock types in south Kerala. They are also found in Palghat district. Lenticular bands of crystalline limestone associated with calc granulite are seen in these rocks. A narrow zone of codierite gneiss is seen around Konni, Thiruvalla and Kottayam.

The quartz-mica schist, quartz schist, fuchsite quartzite and tremolite-chlorite talc schist constitute the narrow belt of Dharwar Schists covering parts of Kasaragod, Cannanore and Wayanad districts. There are numerous dolerite and gabbro dykes traversing the crystallines. Bodies of granites, gramophyres, syenites, anorthosites and pyroxenites are also recorded.

Occurrence of sedimentary rocks belonging to Cenozoic age is found as discontinuous outcrops along coastal Kerala. This include, the `Quilon' and `Warkalli beds' (Mio-pliocene). These are found to extend to the off shore part of Kerala. Quaternary is represented by laterite, soil alluvium etc.

Minerals:

Rich concentrations of beach placers containing ilmenite, monazite, rutile and zircon occur in the deposits near Neendakara, Chavara and Kolithottam in Quilon district. Good quality china clay, fire clay and ball clay are seen in all the districts. This is a major mineral resource in the State which has high potential for development. The glass-sand deposit found between Shertallai and alleppey along the coast. Limestone, especially cement grade and calc-granulites are noted in many parts in the State particularly, in Palghat districts. Graphite deposits are seen with the khondalite group of rocks. The occurrences in Kottayam, Ernakulam and Idukki districts are promising Vein type graphite is seen in Trivandrum district.

Iron ore occurrences are found in Kozhikode and Malappuram districts. Primary lodes of gold have been recorded from parts of Calicut, Malappuram and Cannanore districts. Gem quality chrysoberyl and associated semi-precious stones are known to occur as accessory minerals in pegmatites traversing the khondalite group of rocks in

Trivandrum district. Bauxite associated with laterites is found in parts of Cannanore, Quilon and Trivandrum districts.

Recent studies by Oil and Natural Gas Commission have indicated promising source, reservoir and cap rock situations conducive for petroleum prospects in the offshore part of Kerala.

3.6. HYDROGEOLOGY

Ninety per cent of the total geographic area of the State is occupied by Precambrian crystalline rocks and the rest by sedimentary formations. In general, crystalline rocks are poor acquifers. Among the crystallines, the charnockites and associated gneisses in the midland region yield 10 to 15 litres of water per minute, suitable for the development of domestic wells from its average weathering profile of about 8 m. The weathered horizon in the khondalite terrain of south Kerala is deeper and can sustain wells with yield upto 120 litres per minute. Granite and related gneisses are poor acquifers. Narrow valley portions and deep weathered horizon in crystallines are more potential for ground water development. The fracture zones in crystallines can support very high yielding wells.

Ground water in the sedimentary rocks occurs in both water table and confined conditions. Water table in Cenozoic sediments of Quilon and Trivandrum districts go down to 30-50 m below ground level, whereas in Quarternary sediments, it is on an average 10m. Cenozoic confined acquifers in the deeper horizons in the south and middle coastal plains support medium and heavy duty wells yielding about 510 to 2580 liters per minutes.

The water obtained from the cenozoic aquifers in generally potable. Pollution due to direct recharge from kayals and canals is common in the areas between Shertallai and Cochin and north of Ponnani.

It is estimated that the Cenozoic acquifer system is capable of transmitting 1,68,000 cubic metres of water supply per day, whereas the draft from these for water supply purposes is just over 50,000 cubic meters per day. this would indicate that the system could be developed further for water supply and irrigation purposes. However, any local development should be planned, in such a way as to prevent possible contamination of the fresh water bearing coastal acquifers by way of sea water encroachment and other pollution.

3.7. SOIL

Based on the physico-chemical properties and morphological features the soil of the sea has been classified into ten broad groups which could be identified with thirteen "Great groups" of soil taxonomy. The Figure 3.3 - shows the soil types of Kerala.

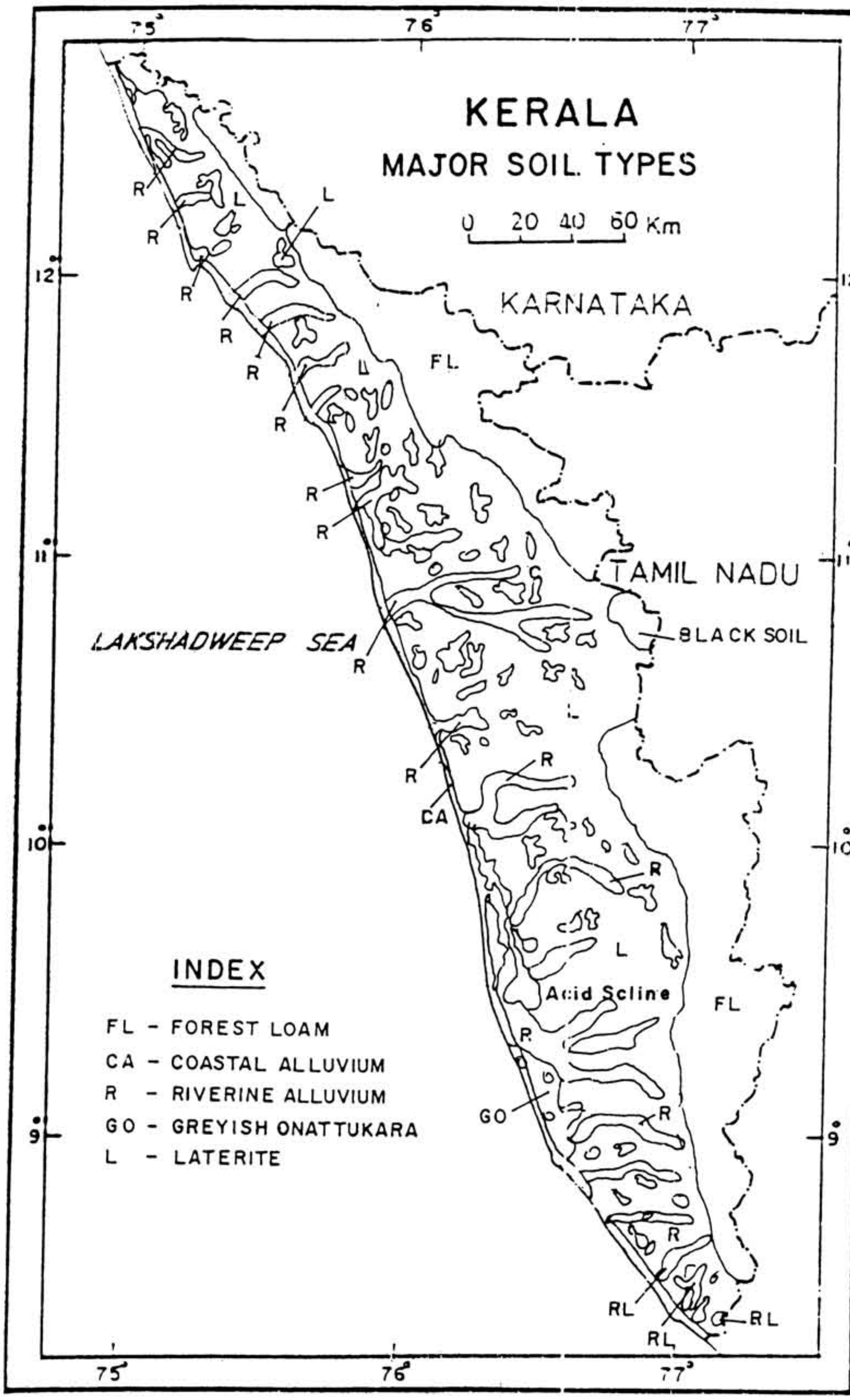

Fig. 3.3: Distribution of different soil types in Kerala

Coastal Alluvium

The soil has originated from recent deposits, predominantly marine, with some fluvial sediments along the coast line. The soil is immature with high sand content and low water holding capacity with pH values less than 6.5 in most of the areas:

Riverine Alluvium

This type of soil, developed along river valleys, occurs throughout the State cutting across the extensive laterite soils. The soil is very deep with surface texture ranging from sandy loam to clay. It is very fertile having high water holding capacity and plant nutrients which are regularly replenished during floods. It supports cultivation of paddy arecanut, pepper, tapioca and wide variety of vegetables.

Red Loam

This occurs mainly as colluvial deposits in isolated patches in foothills and hillocks being associated with laterites. The red colour is due to the presence of iron oxides. The soil being highly porous and friable is not fertile.

Lateritic Soil

This soil, a typical weathering product under humid tropical conditions, occurs throughout the State. It shows the development of AB(c) profiles, which are deep to very deep. The B horizon is well developed in the most cases with abundant ferruginous and quartz gravels. Though this soil, in general, is acidic and poor in available nitrogen, phosphorus, potash and organic matter, it is well drained, widely cultivated and responds to management practices. A variety of crops like coconut, tapioca, rubber, arecanut, pepper, cashew etc can be successfully grown by the proper application of fertilizers and irrigation.

***Grayish Onattukara*:**

This soil with its characteristic grey colour occurs in the districts of Alleppey and Quilon. It is generally coarse grained, highly porous with limited capacity for retaining water and fertilisers. These soils are acidic and are extremely deficient in major plant nutrients. Additions of sufficient organic matter and irrigation facilities improve the water holding capacity for cultivation of paddy, tapioca and other seasonal crops in addition to coconut.

Acid Saline

This soil is found mainly in Kuttanad region. Developed under hydromorphic conditions, these include the kari soil (black soil with high organic content developed in low lying water logged areas), Kayal soil (soil in reclaimed areas with high clay content) and Karappadam soil (soil along river courses with high silt content). Salinity and waterlogging have put limitations to crop culture but with careful management, these soils can sustain good crop production. Paddy is successfully grown in this soil.

Brown Hydromorphic soil

This is commonly found in areas of wetlands. They are moderately rich in organic matter, nitrogen and potash and deficient in lime and phosphate. Acidity is a problem in some places. For poorly drained areas, provision for drainage is essential.

The saline soil of this group is observed along the coastal strip where inundation by sea causes salinity. The problem of acidity is also observed within this soil group in some areas.

Black Soils

Black soil is found in the north eastern part of Palghat district adjacent to Combater district of Tamil Nadu. This soil is dark in colour, low in organic matter, calcareous, moderately alkaline and high in clay content. The higher proportion of clay makes it sticky and plastic in character. The shrinking - swelling capacity is also high. As this soil promotes cotton cultivation, it is often referred to as black cotton soil. Due t low organic matter and high clay percentage, it is found suitable for a limited variety of crop.

Forest Loam

This soil is developed in the eastern part of the State within forest area on the weathered crystalline rocks. The upper layer is highly enriched with organic matter derived from the decomposed leaves. Due to the presence of excessive organic matter, the soil is dark reddish brown to black in colour. It is rich in nitrogen, but poor in bases. The soil is quite fertile under forest cover and promotes prolific undergrowth. In denuded areas, protection against soil erosion is recommended.

3.8. CLIMATE

The State falls in the region of tropical climate. The coastal location of the State and a high variation in relief from the coast to the Western Ghats influence the climatic characteristics to a large extent. While most of the areas are under tropical dry and wet conditions with high maritime influence, certain areas in the eastern parts experience subtropical type of climate.

Temperature

Five attributes of temperature variations, namely, the highest temperature, mean maximum, mean monthly, mean minimum and the lowest temperature have been shown in the map. It is observed from the graph that the period, March - May,is the hottest when temperature reaches a maximum >32^{O}). From June, it gradually comes down due to heavy monsoon. Again, an increasing trend is noticed in October and

November, followed by lower temperatures (<27^{O}) in the months of December and January.

The seasonal and diurnal variations of temperature are not uniform throughout the State. The stations located near the coast are influenced by land and sea breezes and here the seasonal and diurnal variations of temperature are almost of the same range 5^{O} to 7^{O}). At Palghat, the mean seasonal variation is less than the diurnal variation, but in the high ranges, which are typically sub-tropical, the diurnal variation is very high (>15^{O} in some months) - a typical example of a tropical climate remarkably modified by the higher altitude.

Rainfall

Kerala State receives high rainfall amounting to an annual precipitation of about 300 cm. Analysing the rainfall trend, the following three seasons are identified:

Winter	- January - February
Pre-monsoon	- March - May
Monsoon	- June - September
Post-monsoon	- October - December

Rainfall - Annual

The annual rainfall varies from less than 100 cm (around Chinnar and north Maraiyur) to more than 500 cm (around Neriyamangalam). The yearly rainfall pattern records a change from north to south. The stations in the northern part mark a single peak corresponding to the month of July. The southern part extending form Ponnani to Trivandrum with the sole exception of Devikulam shows two peaks in the months of June - July and October corresponding to the two monsoon seasons. Most of the northern stations experience a dry spell in the month of January and in some places like Irikkur the dry spell extends upto March.

It reveals that, in general rainfall increases from the coast to he foothills and then decreases on the hill tops. This general trend is partially disrupted in the Palghat region. The rainfall distribution in the State is controlled by orography.

South-West Monsoon

Nearly 60 per cent of the annual rainfall is during this season. The pattern of rainfall distribution in south-west monsoon is akin to the annual rainfall pattern. The foothill zones of the Wayanad plateau and Pirmed-Neriyamanagalam stretch towards west of the Periyar plateau receive high rainfall (>300 cm). It is observed that the Malabar coast receives more rainfall compared to the Cochin-Quilon coast. Southern and eastern parts of the State (along the Western Ghats ridge) receive very low rainfall.

North-east Monsoon:

The distributional pattern of rain in this season is quite different from that of the other seasons, though the basic trend of higher rainfall in foothill zone prevails. In general, the northern part receives less amount of rain compared to the south in this season. The maximum raifall (> 100 cm) is recorded in Neriyamangalam. It gradually decreases towards east and west.

Other than Monsoon

The rainfall, in general, is scattered. Rainfall exceeding 50 cm is recorded around Hosdurg, Kozhikode, north of Cochin and in the foothills of Periyar plateau.

Rainfall variability

It is observed that general variability in the State is 20 to 40 per cent. During south-west monsoon, variability of more than 50 per cent in recorded in 8 scattered areas of which 5 are located in the southern part of the State. The high variability zones shift entirely to the coast and adjoining midlands during north-east monsoon. Variability of annual rainfall indicates that the comparatively low variability zones are concentrated in the southern part where seasonal rainfall is high. The northern part, particularly, Cannanore district experiences high variability (> 50 per cent) in the day season.

The variability of rainfall affects the traditional acquacultural practices in the States. Though a high rainfall region, the State has been experiencing problems due to erratic monsoon, characteristic of tropical areas.

3.9. VEGETATION

The Figure 3.4 depicts the vegetation types identified by the Forest Department through forest resource surveys. Distribution of different types of vegetation confined to parts of highland and midland zones falling within the Western Ghats and to foothills. The five main types of vegetation are Wet Evergreen and Semi-Evergreen, Moist Deciduous, Dry Deciduous, Montane sub-tropical and temperate, and Planations and others.

Isolated patches of evergreen forests are marked in rugs slopes of Western Ghats. Wet-evergreen, semi-evergreen and moist deciduous forests are located in the rainfall zone of 200-300 cm with temperature more than 20^{o} and elevation above 300 meters.

Trees in the moist deciduous type of forests remain leafless during the period December to June. Several commercially valuable trees are included in this group.

Subtropical broad leaved hill forests are confined to small areas in the eastern border of Idukki, Palghat and Wayanad districts.

Montane wet temperate forests known as temperature shola, occur in the valleys of the higher ranges.

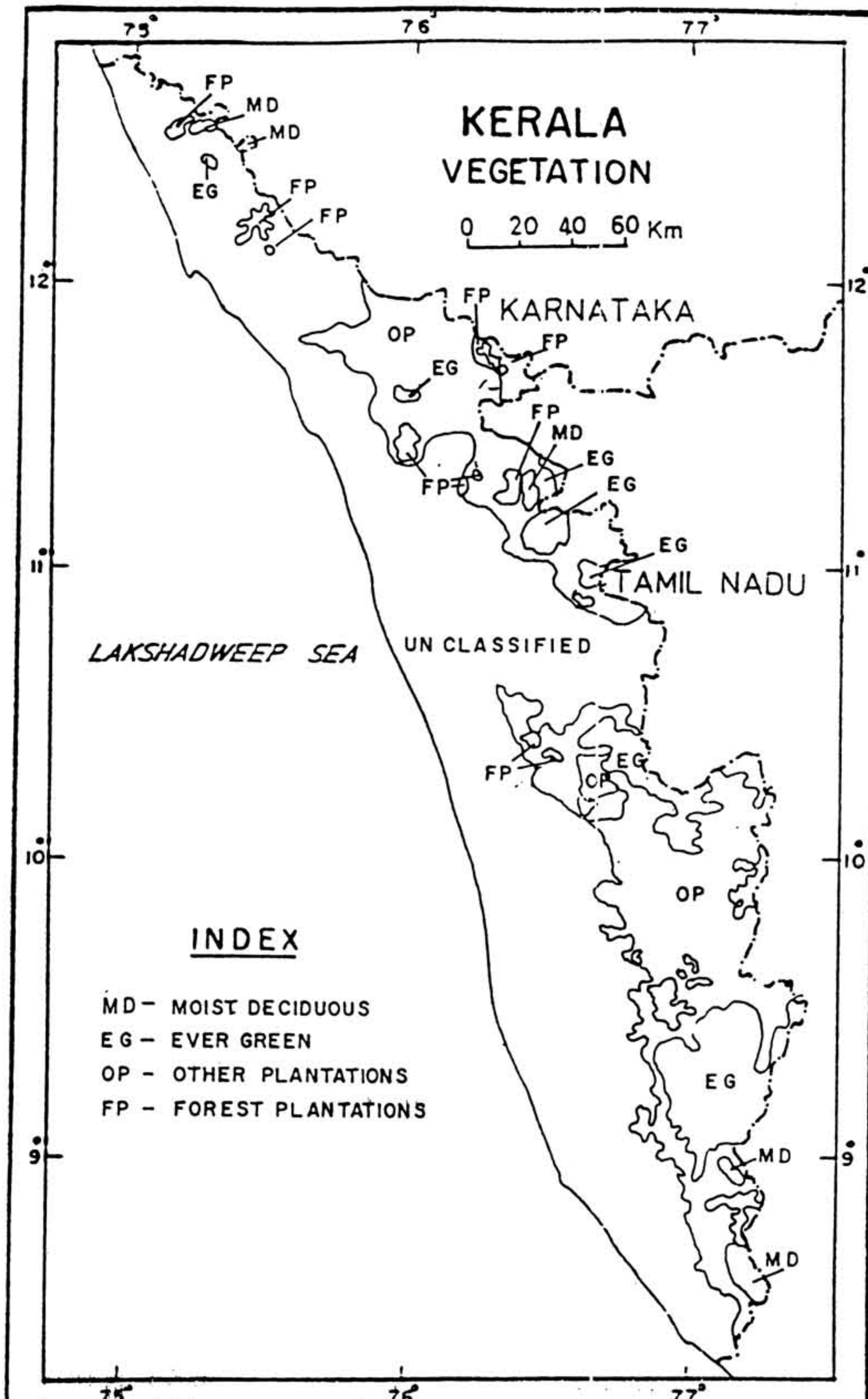

Fig 3.4: Vegetation map of Kerala

3.10.LAND USE

The land use types are distinctly governed by physiography and climate of the State. There are mainly five broad categories of land use distributed unevenly. It is observed that arable land forms a continuous stretch along the entire State spanning from the coast to the inland upto 100 m above mean sea level and further east only along the river valleys. Both irrigated and unirrigated lands are included in this category. The next important group is the forest land, the western limit of which can roughly be marked by 300 m contour The entire eastern part of the State, except in the vicinity of Palghat Gap is forest land. Many plantations have been developed within the forests. While the high altitude plantations in Periyar and Wayanad plateaus are mainly tea, coffee and cardamom, the plantations along the western fringe of the forest are mostly rubber. Grasslands are marked throughout the State in isolated patches. Extensive waste lands, formed of hard crust laterite, unsuitable for cultivation are found in the northern part of the State.

3.11. AGRICULTURE

Agriculture is the chief source of livelihood of the people and the most important sector in the economy of the State. The abundance of rainfall and natural fertility of the soil have made the State an essentially agricultural region. Agriculture accounts for about 50 per cent of the State income and absorbs about 50 per cent of the work force. About 56 per cent of the total area of the State is under cultivation. There is a diversity of crops which give good yields and characterised by the higher intensity of cropping. Coconut, paddy, arecanut, sugar cane and banana are the important crops grown in the coastal region Main crops in the midland region are tapioca, pepper, cashew, coconut, ginger, pulses, oilseeds, coffee and rubber and those in the hills are rubber, coffee, tea and cardamom. Many of these products help the State to earn foreign currency too.

Important seasonal crops are paddy, pulses, ragi, seasmum, sugar-cane, tapioca, groundnut, ginger, turmeric and cotton. About 10 per cent of the cropped area is irrigated, mainly for the cultivation of paddy and sugar cane.

The most important seasonal crop is paddy. It has three important crop seasons. They are (1) Autumn (Virippu) crop corresponding to the southwest monsoon (2) Winter (Mundakom) crop corresponding to Northeast monsoon and (3) Summer (Punja) crop. The present level of production can, however, meet only 50 per cent of the States requirements.

CHAPTER 4

AGROCLIMATOLOGY OF KERALA AND ITS INTERANNUAL VARIABILITY

In this chapter an attempt is made to understand the agroclimatology of Kerala State to the extent that it influences the landuse of the region. In the second Section, the inter-annual variability of the various agroclimatological parameters studied in particular the shifts that are caused in the climates of different stations due to variations in rainfall and temperature have been highlighted. Large variations in rainfall amounts and in its distribution cause significant changes in landuse patterns. One of the important effects of deficient and irregular distribution of rainfall is the occurrence of droughts of different magnitudes. The drought climatology of representative stations in the State is also therefore, presented.

As a consequence of wide variations in rainfall, the water budgets show large inter-annual fluctuations. A critical examination of the comparative values of the water budget elements in extreme dry and wet years has been made in comparison to the climatic water balance of each station. Such a study of the effects of extreme climatic shifts on the water balances is of immense practical value in landuse planning.

4.1 AGROCLIMATOLOGY OF KERALA

The State falls in the region of tropical climate. The coastal location of the State and a high variation in relief from the coast to the Western Ghats influence the climatic characteristics to a large extent. While most of the areas are under tropical dry and wet conditions with high maritime influence, certain areas in the eastern parts experience subtropical type of climate.

4.1.1. Temperature

Five attributes of temperature variations, namely, the highest temperature, mean maximum, mean monthly, mean minimum and the lowest temperature have been shown in figure 4.1 It is observed from the graph that the period, March - May, is the hottest when temperature reaches a maximum >32°C). From June, it gradually comes down due to the monsoon. Again, an increasing trend is noticed in October and November, followed by lower temperatures (<27°C) in the months of December and January.

The seasonal and diurnal variations of temperature are not uniform throughout the State. The stations located near the coast are influenced by land and sea breezes and here the seasonal and diurnal variations of temperature are almost of the same range (5°C to 7°C. At Palghat, the mean seasonal variation is less than the diurnal variation, but in the high ranges, which are typically subtropical, the diurnal variation is very high (>15°C in some months) - a typical example of a tropical climate remarkably modified by the higher altitude.

Based on the climatic conditions over the State, the year is divided into four seasons.

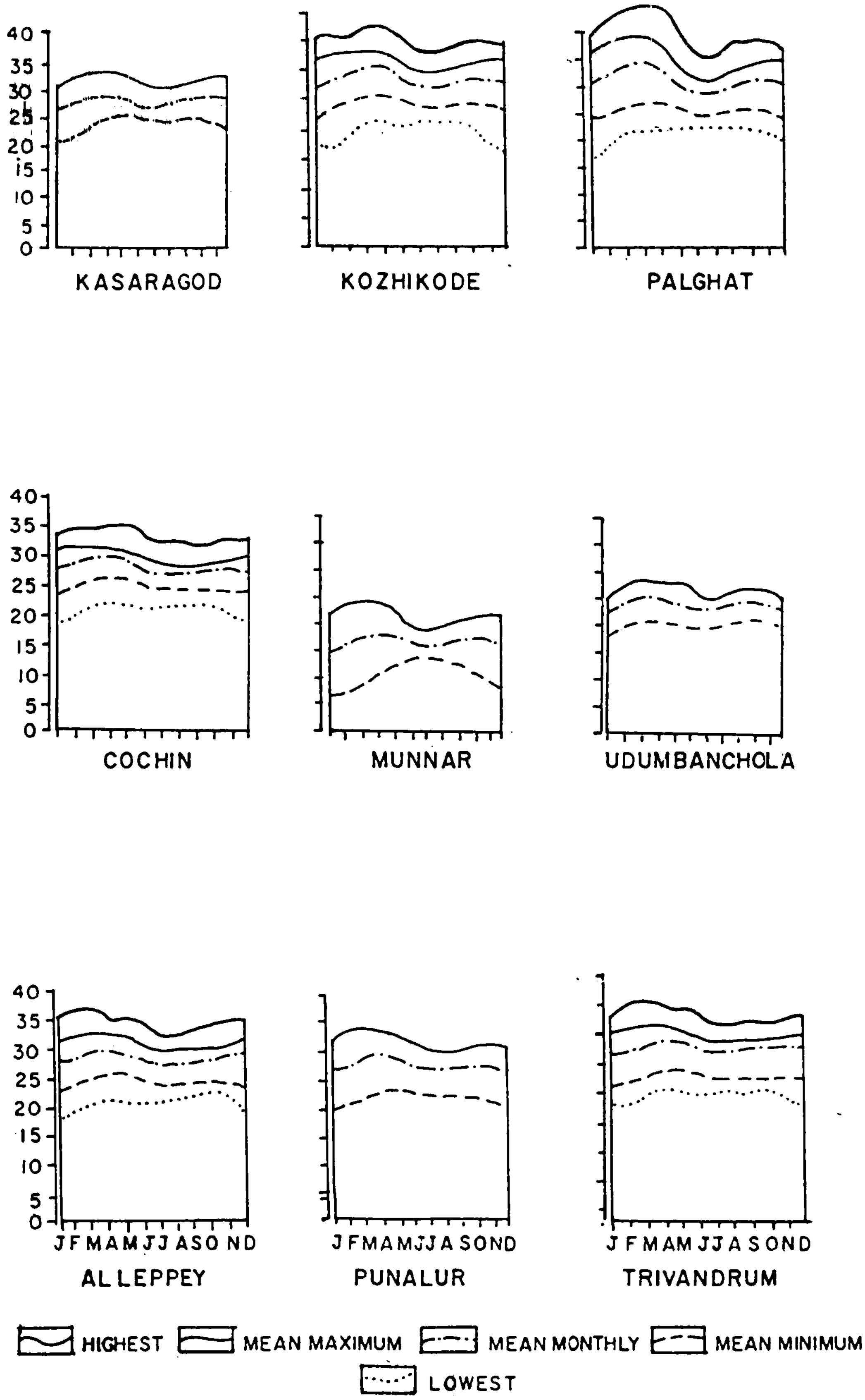

Fig. 4.1. Temperature variation

Winter	- January - February
Pre-monsoon	- March - May
South-west monsoon	- June - September
Post-monsoon	- October - December

4.1.2. Rainfall

Kerala receives the highest annual rainfall among the States of India - about 300 cm in a year which is three times the average rainfall of India. The State receives rainfall for almost ten months in an year from both monsoons and local systems though most of the rainfall occurs during the southwest monsoon period. (Fig. 4.2)

Annual rainfall increases along the west coast form 15o cm in the south to more than 350 cm across the eastern side of the Ghats and the isohyets follow a predominant north-south orientation in their vicinity. There exist two pockets of heavy rainfall, around Pirmed (491 cm) and Kanjirappally (410cm) in the south and around Vythiri (437 cm) and Kuttiyadi (435 cm) in the north. The highest rainfall in Kerala (683 cm) was recorded at Pirmed in 1911. Also, Kuttiyadi reported 615 cm of rainfall in 1924. It is interesting to note that the station Chinnar which records the lowest amount of rainfall (61 cm) in the State lies close to Pirmed. Chinnar recorded its lowest rainfall of 11 cm in 1926 and its highest rainfall (172 cm) in 1922.

Pre-monsoon Season

The maximum rainfall during the pre-monsoon season (Fig. 4.3) is received at Kanjirappally (100 cm), accounting for 24% of its annual rainfall (Fig. 4.4). From this pocket, the rainfall decreases towards south and north. Trivandrum and Kasargod districts get about 30 cm of rainfall, the seasonal rainfall being about 20% and 10% of the annual respectively. However, Chinnar in Idukki district receives only 9 cm of rainfall in this season, which is 10% of the annual.

The rainfall distribution during the southwest monsoon season is similar to that of the annual pattern. Rainfall increases from 85 cm in the south (50% of annual) to 290 cm in the north (80% of annual). Pockets of heavy rainfall are observed around Pirmed (328 cm), Munnar (288 cm), Vythiri (355 cm) and Kuttiayadi (325 cm). A low rainfall region is observed around Chinnar (15 cm). At Chinnar, only 28% of the annual rainfall is received in this season, while at the nearby Munnar, it is 78%. On the leeward side (eastern side) of the Ghats, rainfall sharply decreases to about 10 cm (20% of annual).

Northeast monsoon is the period during which the eastern slopes of the Ghats also receive fairly good amounts of rainfall, comparable to the western sides. The Ghats region receives about 30 cm to 40 cm of rainfall in this season, accounting for 20% of the annual rainfall. Once again, a pocket of comparatively heavy rainfall is observed around Kanjirappally (87 cm) and Pirmed (81 cm), with values decreasing towards north and south, with Chinnar (31 cm) receiving the lowest amount. Northern

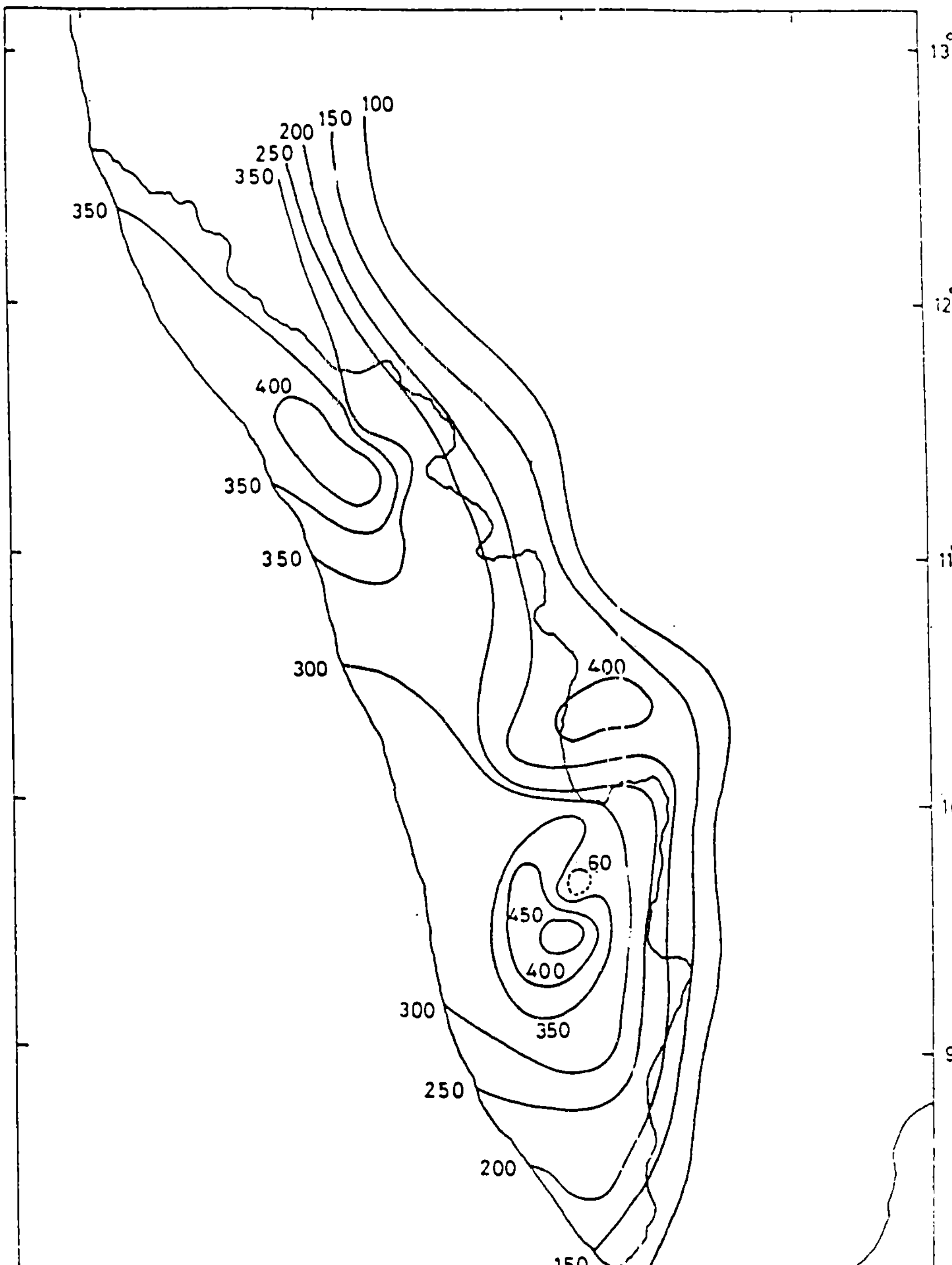

Fig. 4. 2. Annual rainfall over Kerala

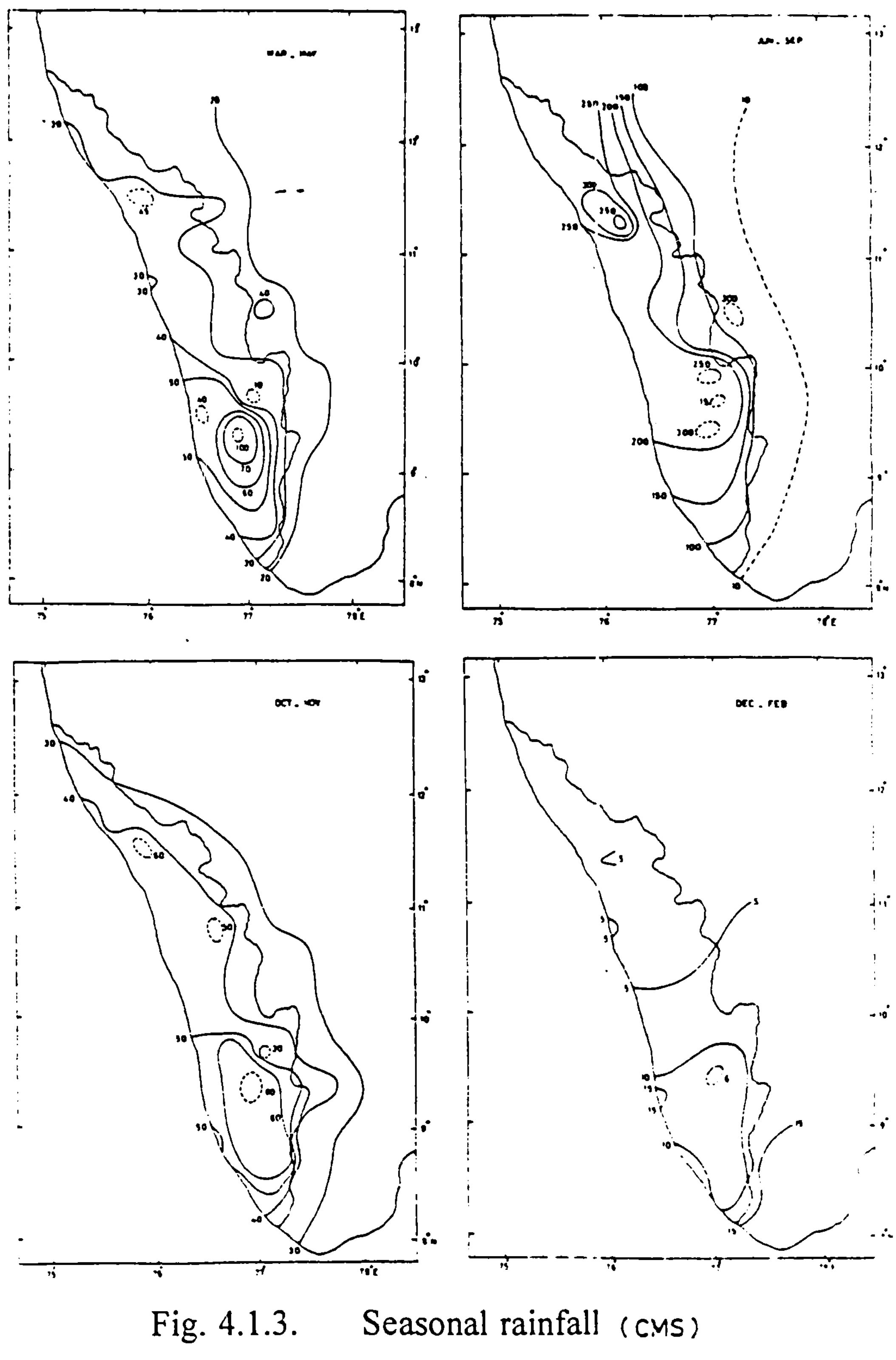

Fig. 4.1.3. Seasonal rainfall (CMS)

districts get less than 10% of their annual rainfall in this period while the southern districts get 25% and adjoining Tamil Nadu, about 50%.

Winter is a period of very low rainfall for the whole State. Rainfall decreases from less than 15 cm over Trivandrum district to less than 5 cm in the northern districts. Alleppey receives the highest amount (15 cm) which is 5% of the annual while Chinnar receives 6 cm accounting for 17% of its annual rainfall. The adjoining Tamil Nadu areas receive 20% of the annual rainfall during this season.

Rainfall variability

It is observed that general variability in the State is 20 to 40 per cent. During the south-west monsoon, seasonal variability of more than 50% is recorded in 8 scattered areas of which 5 are located in the southern parts of the State. The high variability zones shift entirely to the coast and adjoining midlands during northeast monsoon. Variability of annual rainfall indicates that the comparatively low variability zones are concentrated in the southern part where seasonal rainfall is high. The northern part, particularly, Cannanore district experiences high variability (> 50 per cent) in a dry season.

The variability of rainfall affects the traditional agricultural practices in the States. Though a high rainfall region, the State has been experiencing problems due to erratic monsoons, and other system characteristic of tropical areas.

4.1.3 Water balance of kerala

The hydrological potentialities of a region cannot be assessed by the study of precipitation alone, even though it is the only source of water supply to any region. The transport of water from the earth back to the atmosphere, variously known as water loss, consumptive use, evapotranspiration etc has also to be considered simultaneously. Evapotranspiration, thus, represents an important mass transfer from ground to atmosphere, the reverse of precipitation in the hydrologic cycle. A comparative study of precipitation and potential evapotranspiration - measured or computed - gives a good idea of the water balance of the region.

Potential Evapotranspiration (P.E.)

Potential evapotranspiration or the water need is the amount of water that would evaporate from the soil and transpire from the vegetation when there is no water deficiency. Seasonally (Fig. 4.14) during March - May, P.E. values range from 45 cm to 50 cm in the State, increasing to more than 50 cm during the southwest monsoon season. Water need of about 25 cm to 28 cm is experienced during October - November. However, during December - February, P.E. values are higher - more than 40 cm at all stations inside the State. During all the seasons, the elevated regions over the Ghats (some beyond the boundaries of the State) experience much lower water needs compared to the plains inside Kerala State.

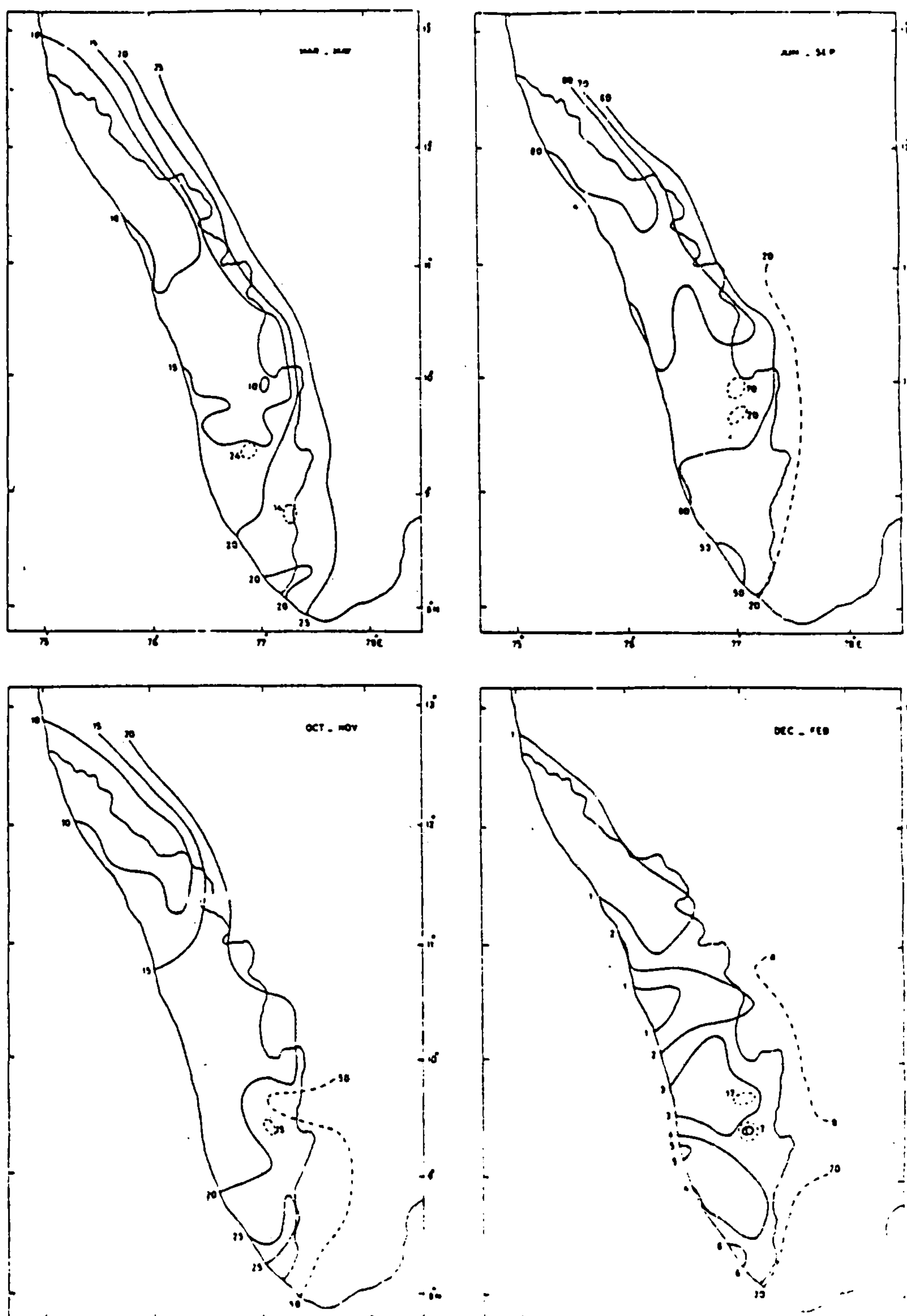

Fig. 4.1.4. Seasonal rainfall as percentage of annual

Actual Evapotranspiration (A.E.)

For the development and management of water resources, the actual mount of water that evaporates and transpires (A.E.) is more important than the P.E. Actual Evapotranspiration is an approximate index of water used by plants and hence of plant growth (Muller, 1972).

In Kerala, the annual values of P.E. vary from 150 cm around Alleppey and Cochin to 130 cm towards the Ghats region. Seasonally (Fig. 4. 6), the .E. values during March - May increase from 25 cm in the north to more than 45 cm in the south. During the southwest monsoon season, the values decrease from more than 55 cm along the west coast to 50 cm around the eastern boundary of the State. The A.E. values vary from 25 cm to 30 cm over the entire State in the other two season. Decrease in A.E. is noticeable on the leeward side of the Ghats. (Fig. 4.7)

Water Deficit (W.D.)

Water deficit is a measure of the additional water required for any region to meet the full demands and hence, is a basic criteria for the development of water resources. It provides information on the total volume of water needed at any time and gives a definite measure of droughts.

As stated earlier. annual water deficit of 25 cm to 35 cm occurs over the State. Seasonally, there exists water deficiency only during the pre-monsoon and winter months and distribution for these periods alone are presented (Fig. 4. 8). During the pre-monsoon period, northern parts of Kerala exhibit a water deficiency (W.D.) of

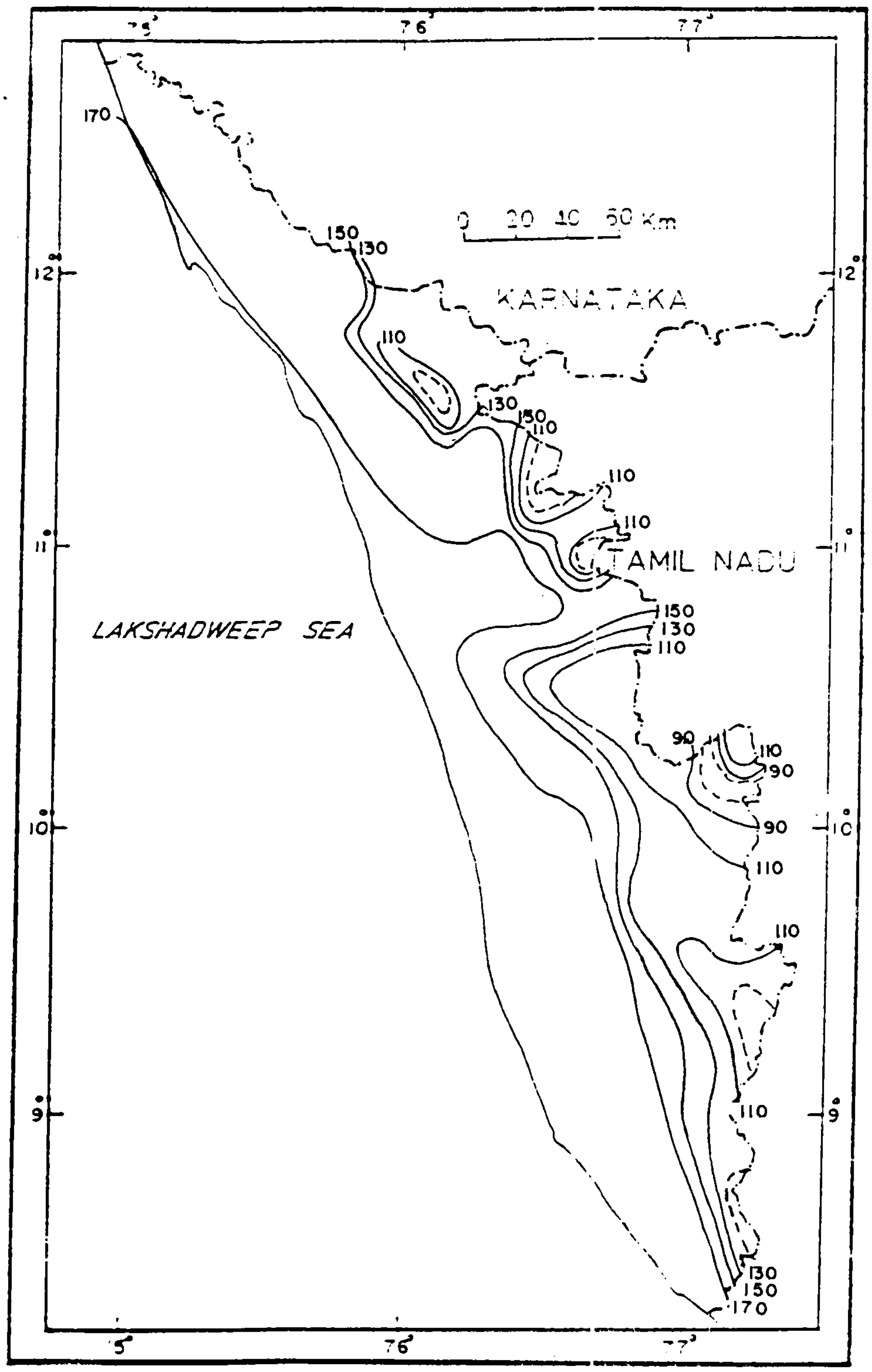

Fig. 4. 5. Spatial distribution of annual P.E over Kerala (cm)

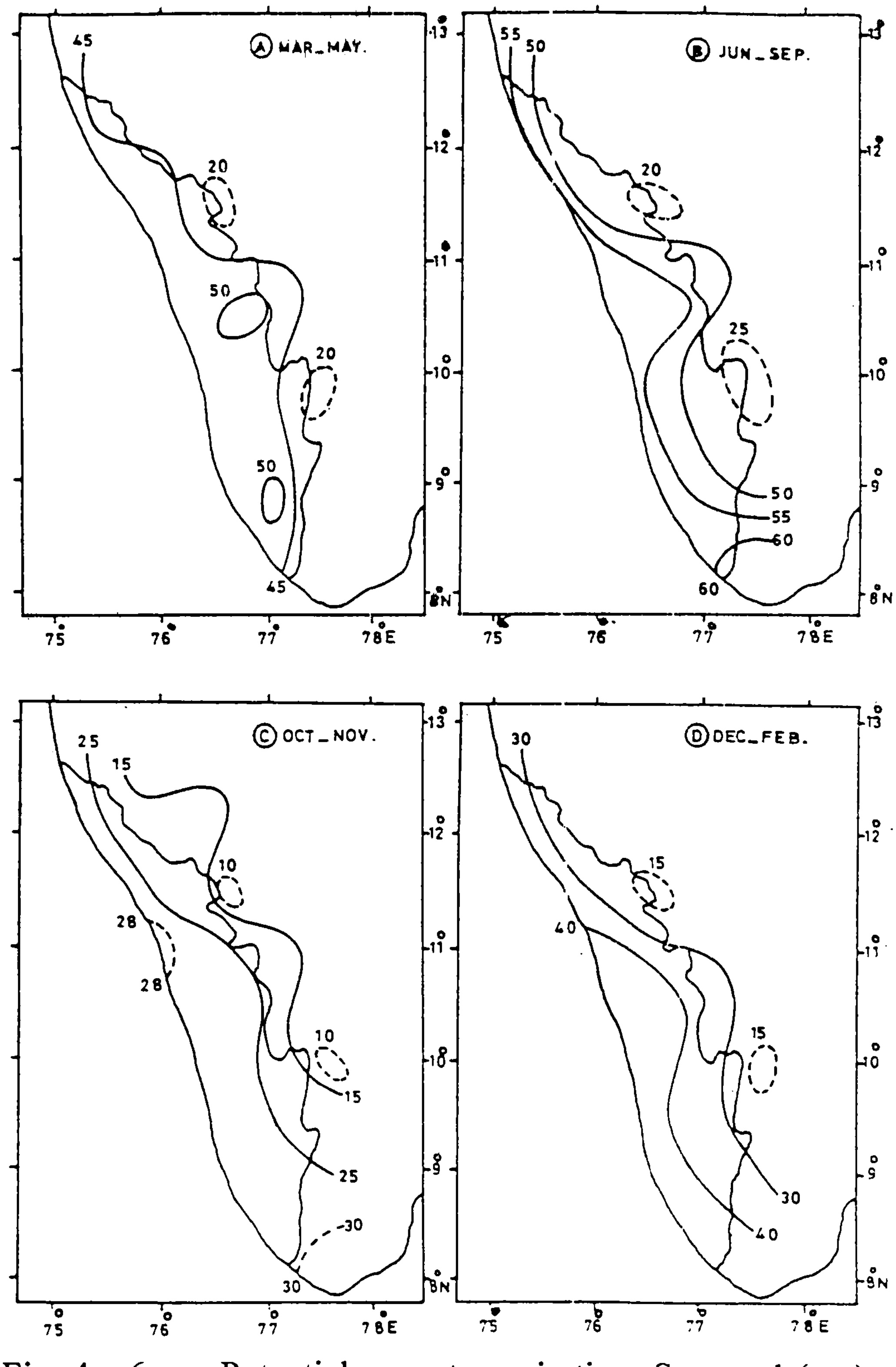

Fig. 4. 6. Potential evapotranspiration -Seasonal (cm)

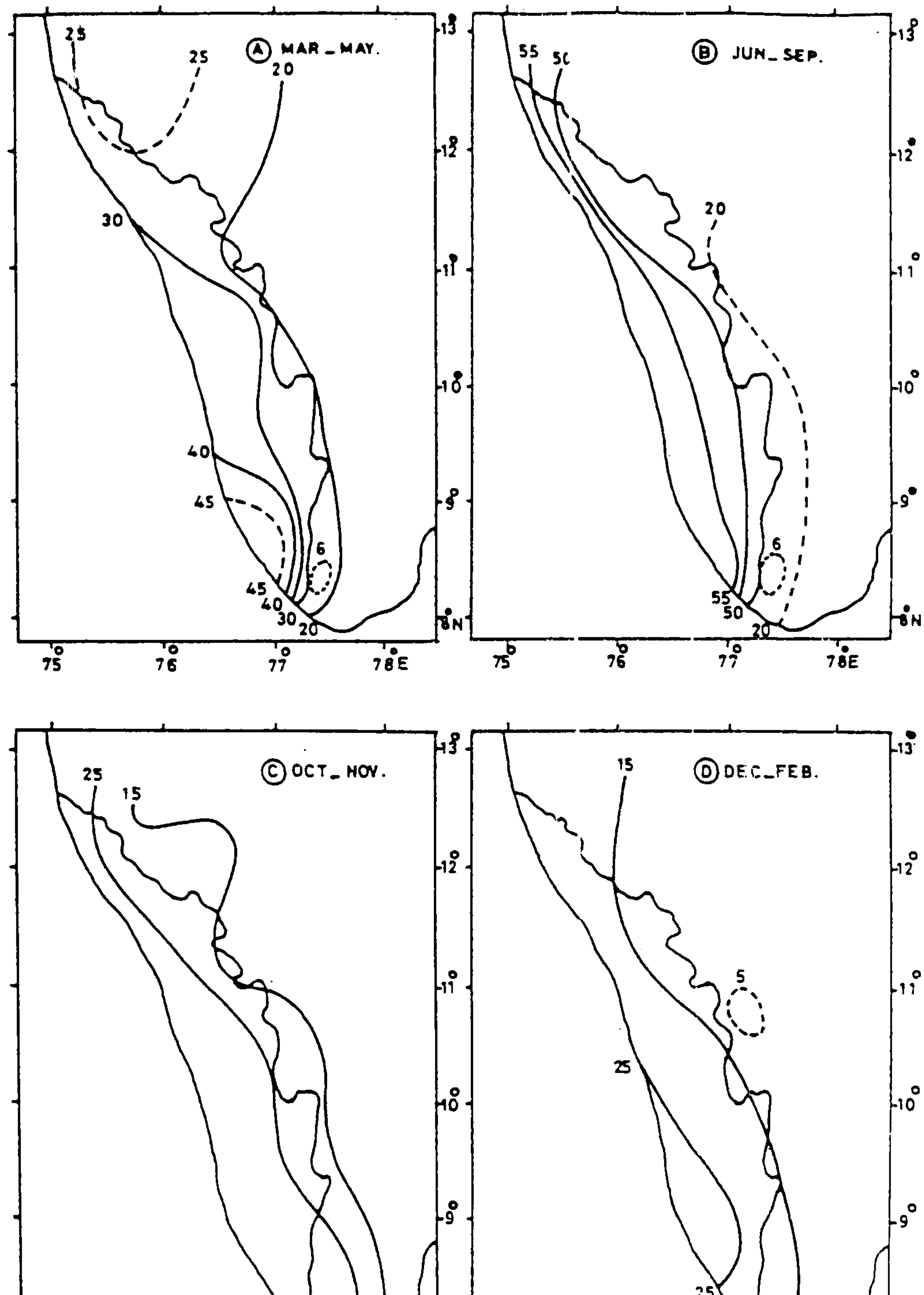

Fig. 4. 7. Actual evapotranspiration-Seasonal (cm)

around 15 cm. Southward, the values decrease to less than 10 cm especially over the coastal areas. Over the extreme south, deficit again increases to 20 cm. Around 15 cm of water deficit is observed over the whole State in the pre-monsoon months. Eastern side of the Ghats have more water deficiency during these seasons.

Water Surplus (W.S)

Water surplus represents the excess of rainfall after the demands of water need (P.E.) and that needed to field capacity have been met. This is the water available for runoff and stream flow. By definition, water surplus is the amount of water which does not remain in the surface soil layers but which is available either for overland or surface flow or for deep percolation to the water table contributing to groundwater and subsurface flow.

Annual water surpluses vary from 50 cm around Trivandrum, 150 cm around Punalur to more than 200 cm in the northern portion of the State. Figures showing seasonal distribution of water surplus (Fig. 4.9) are presented only for the periods June - September and October - November as no water surplus is observed in the State during other two seasons, except at Alleppey, where a surplus of 8 cm occurs in the pre-monsoon season. More than 75% of the annual water surplus occurs in the southwest monsoon season. The surplus values vary form 35 cm around Trivandrum and 100 cm in Quilon district to nearly 200 cm in the extreme north of the State. During October - November months, more surplus occurs in the southern coastal portion of the State (20 cm) than in the north (10 cm). However, Alleppey exhibits a water surplus of around 30 cm.

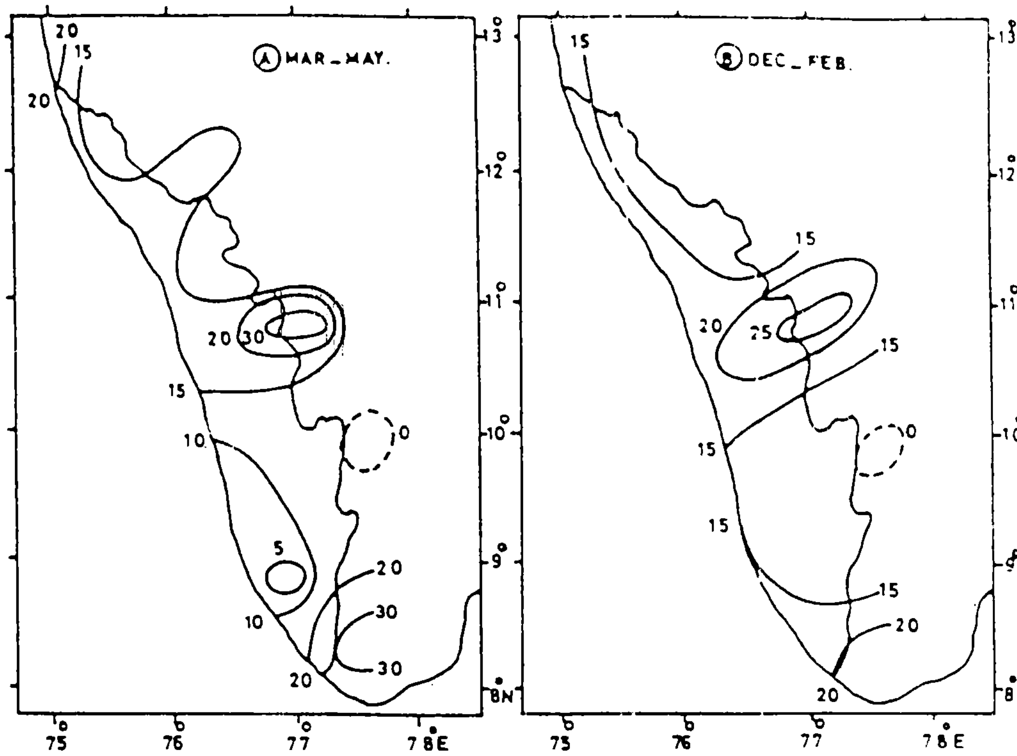

Fig. 4. 8. Water deficit-seasonal (cm)

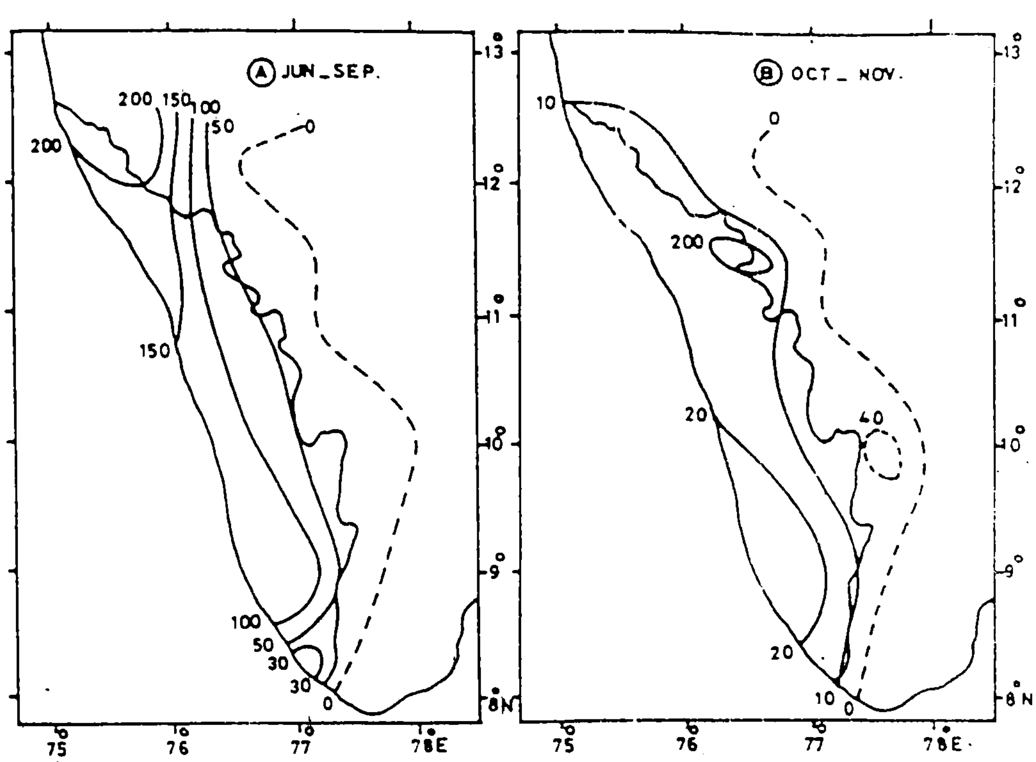

Fig. 4. 9. Water surplus-seasonal (cm)

4.2. INTERANNUAL VARIABILITY

4.2.1. Climatic shifts

As a result of wide fluctuations of water budget parameters - both water deficiency and water surplus it is quite likely that the normal climatic regimes are occasionally shifted into more humid or less humid categories. Such occurrences are of great academic interest as these may provide clues to secular or periodic changes in climate. In order to study this aspect, climatic shifts have been studied by plotting the inter-annual variations of moisture index (I_m) for all station.s

Table 4.2.1

Stations	B4	B3	B2	B1	C2	Total
1. Kasargod	8	7	5	-	-	20
2. Payyanur	8	5	7	-	-	20
3. Peermade	-	-	-	-	-	nil

Of the stations studied three belong to the perhumid category. Kasargod ha a total number of 20 shifts into the other climatic types. Of these, 20 were to th humid climates of different categories and one to the moist subhumid type. Payyanu on the other hand, shifted on 20 occasions to the humid category. Peermade however, had no climatic shift as such into any drier climatic type, because its climatic moisture index value in above 310%. However, the moisture index values were below the climatic value on 32 occasions.

Among the humid stations Cannanore had the largest number of shifts (46) of which 23 were to the more humid category. Trichur and Kottayam had 45 shifts each while, Calicut, Cochin and Alleppey had 44, 43 and 41, respectively.

All these five stations had larger number of climatic shifts into the drier categories of the humid climate. In addition, Kottayam had two shifts into the moist subhumid climate while Trichur and Alleppey had one each.

Punalur, the only station belonging to the B3 humid category, had a total of 43 shifts, of which six were to the perhumid category. Kayamkulam (B2) had as many as 46 shifts into a wide spectrum of climates ranging from per humid to semi arid. It experienced 4 shifts into the perhumid type, 6 to the B4 and 12 to the B3 (all wetter categories). Further, 7 shifts to moist subhumid and 2 each to the dry subhumid and semiarid categories were also noted.

Palghat and Quilon both B1 humid Stations, had 41 and 39 shifts respectively during the study period. Of the 41 shifts at Palghat 30 were on to the drier side 22 to moist subhumid and 8 to dry subhumid. Quilon, on the other hand, had more shifts to the wetter side of which were to the perhumid category.

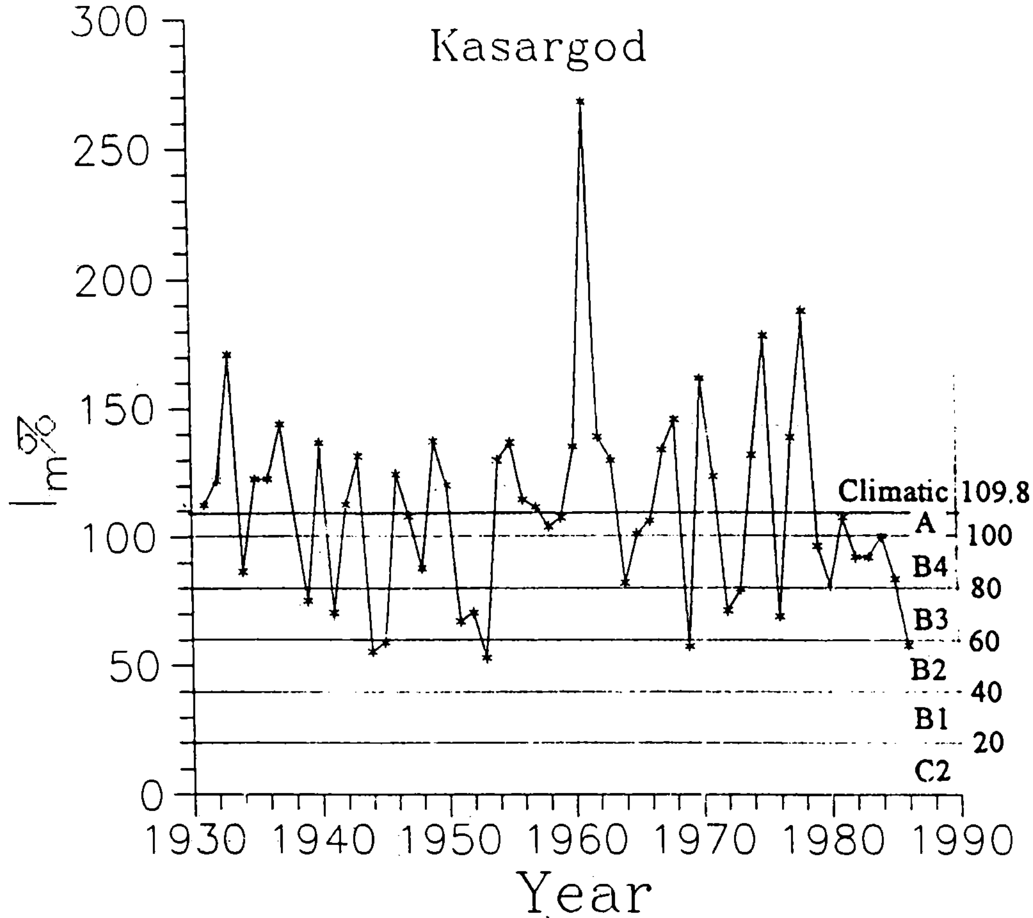

Fig. 4. (a) Climatic shifts

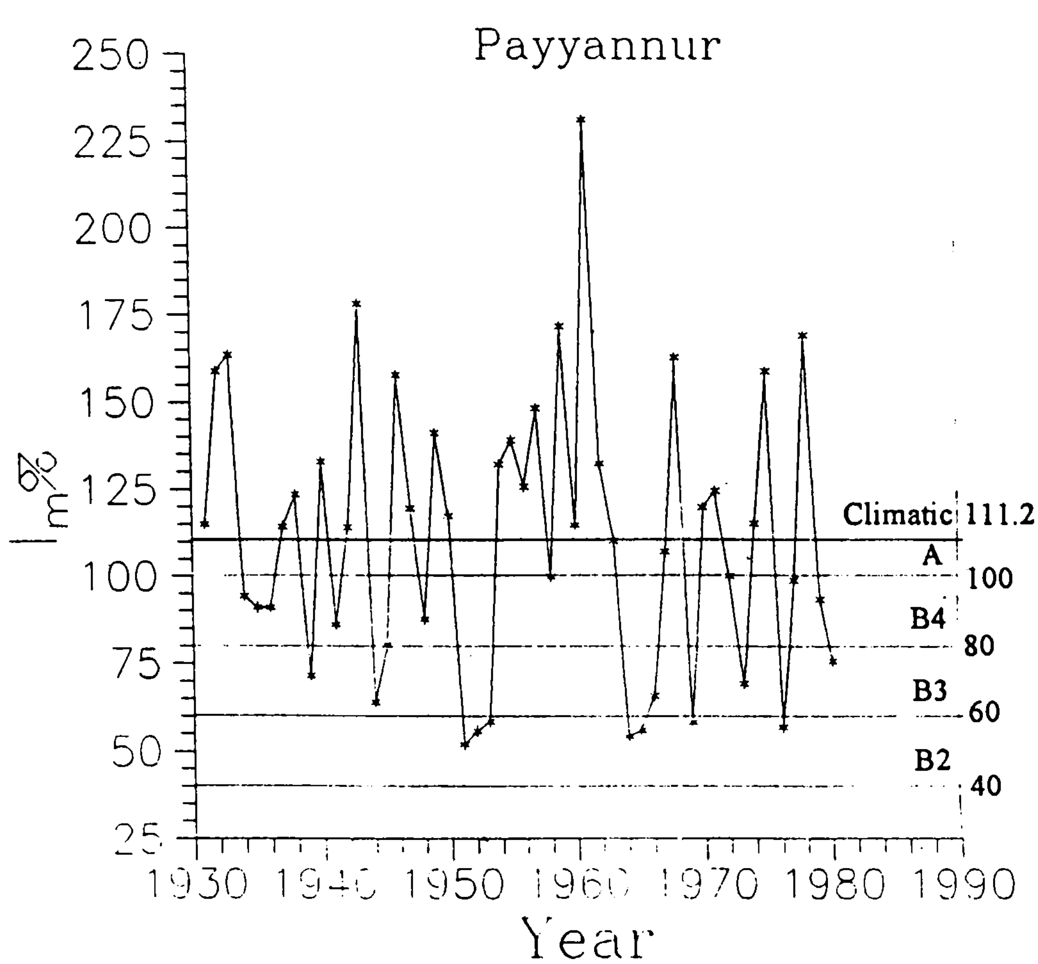

Fig. 4. (b) Climatic shifts

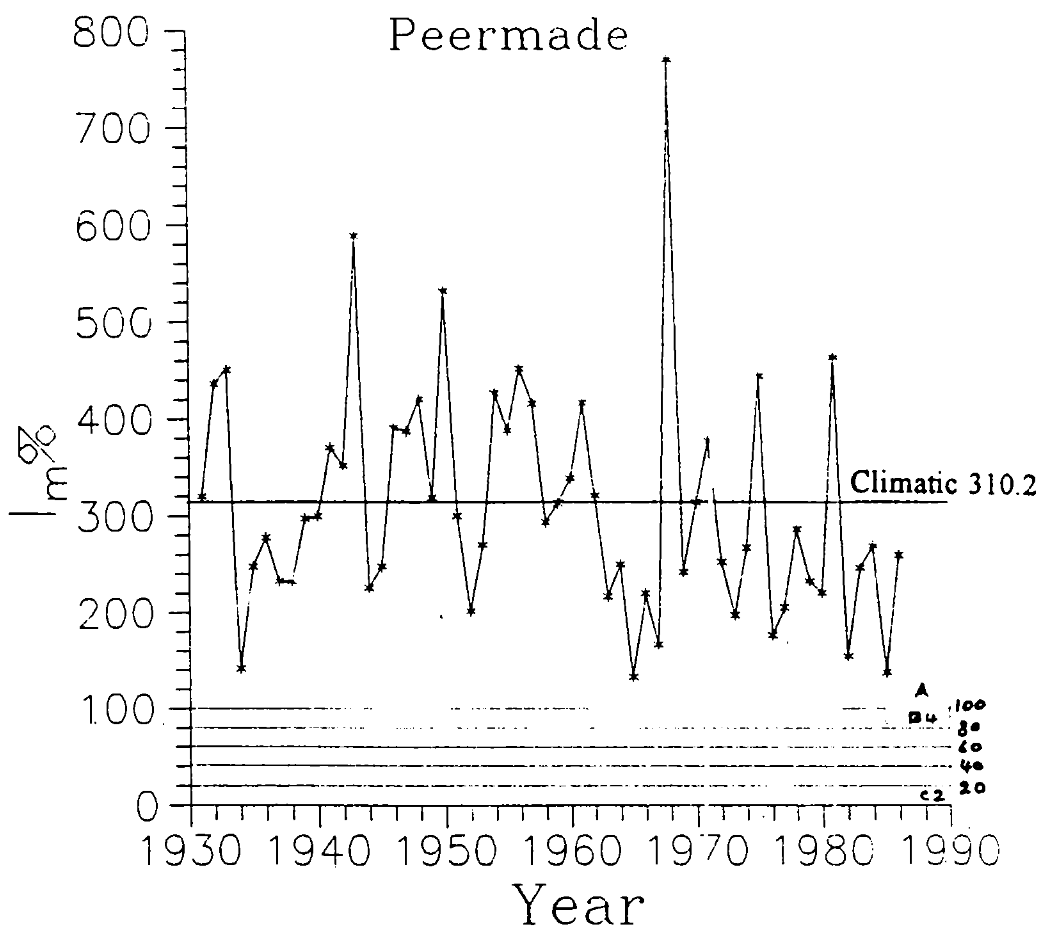

Fig. 4. (c) Climatic shifts

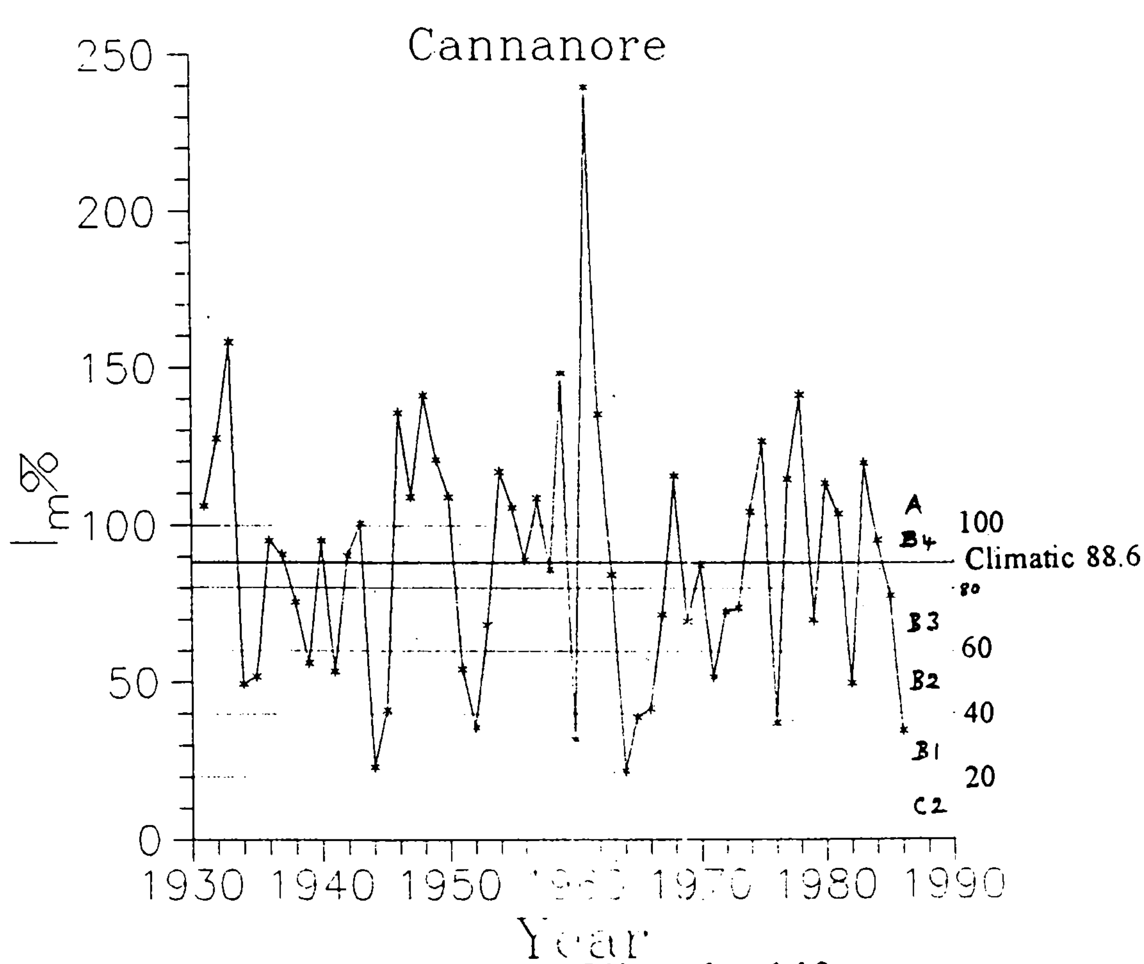

Fig. 4. (d) Climatic shifts

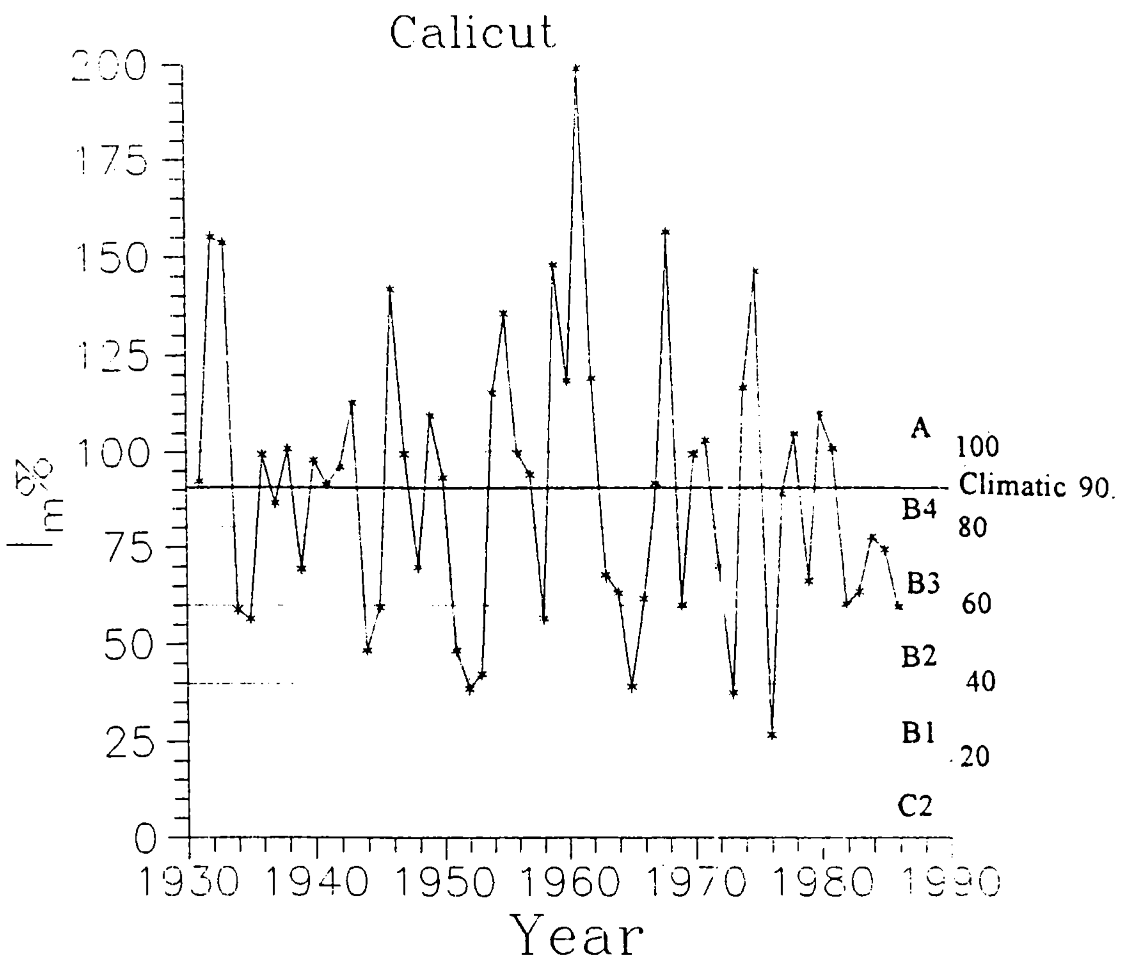

Fig. 4. (e) Climatic shifts

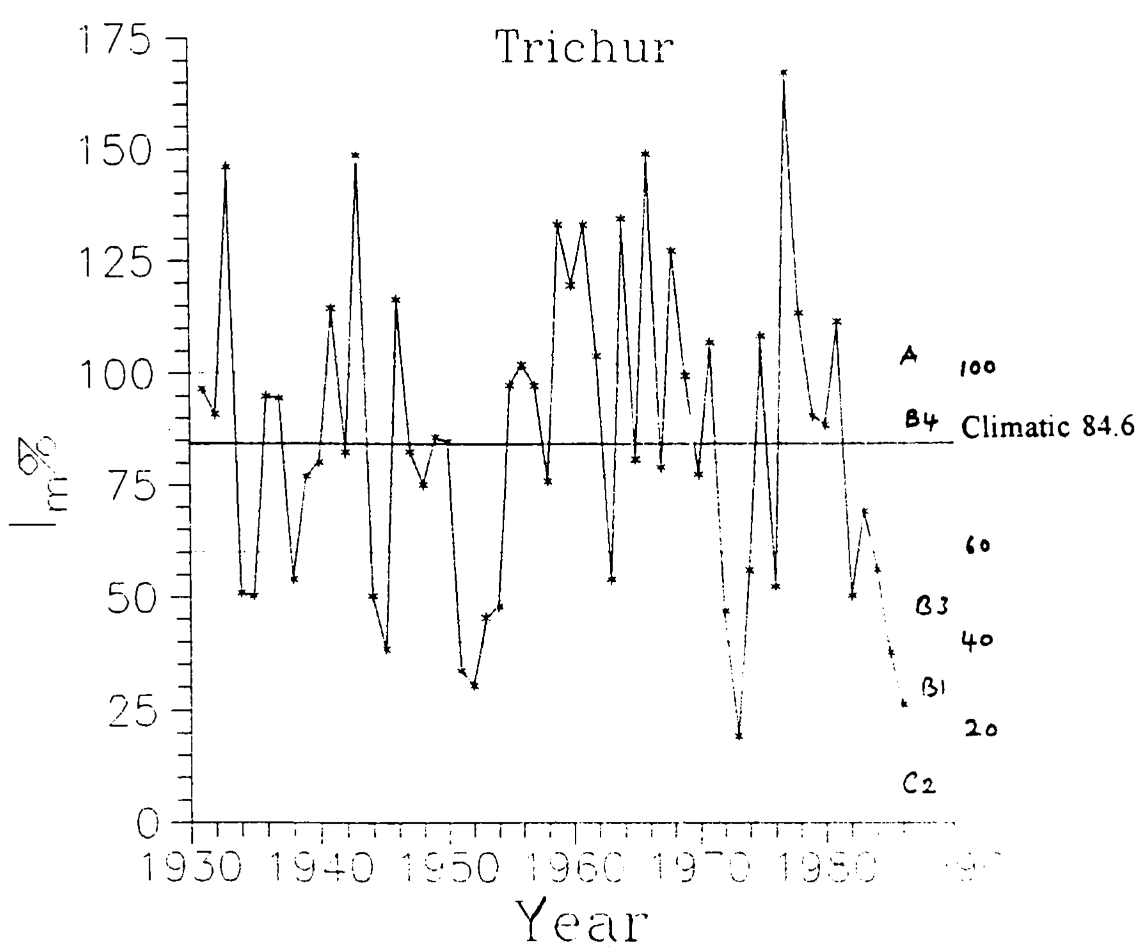

Fig. 4. (f) Climatic shifts

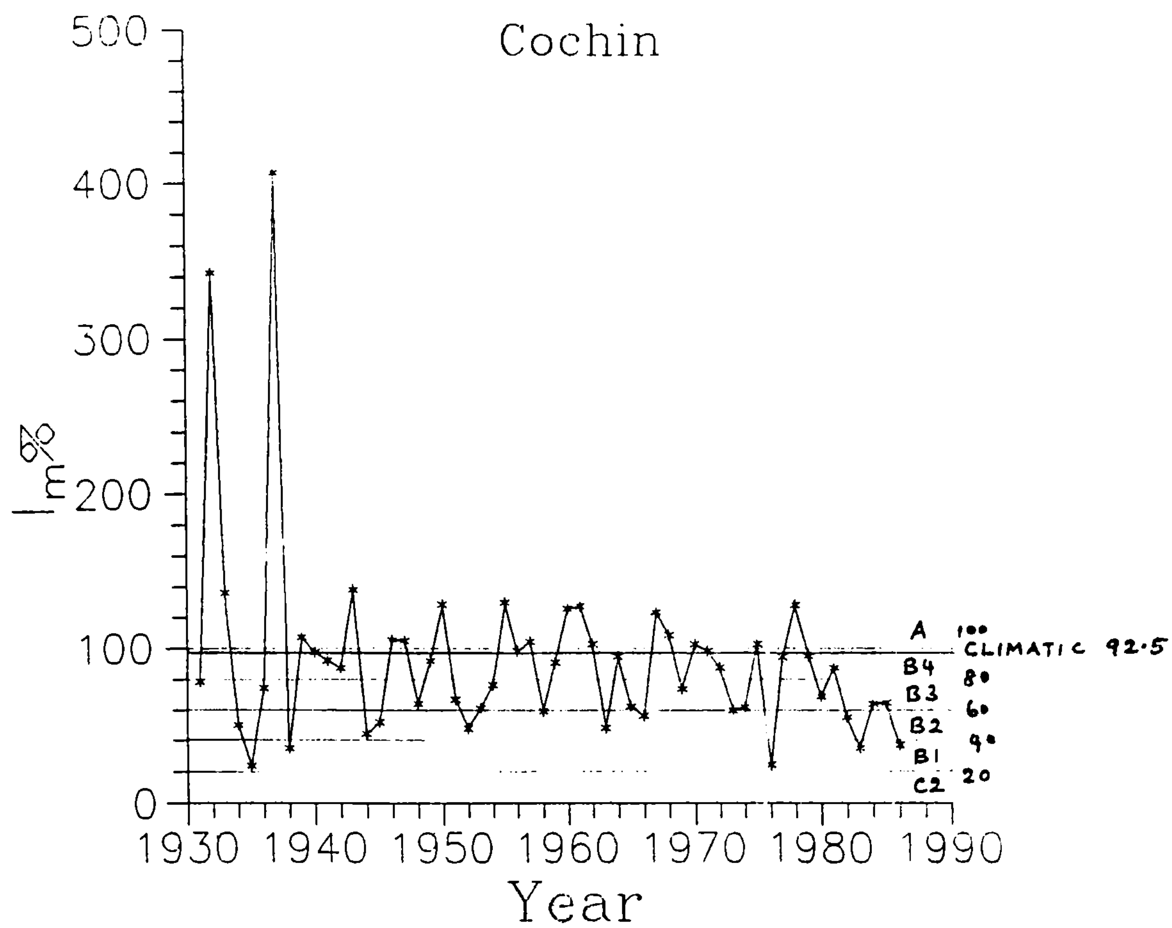

Fig. 4.10.(g) Climatic shifts

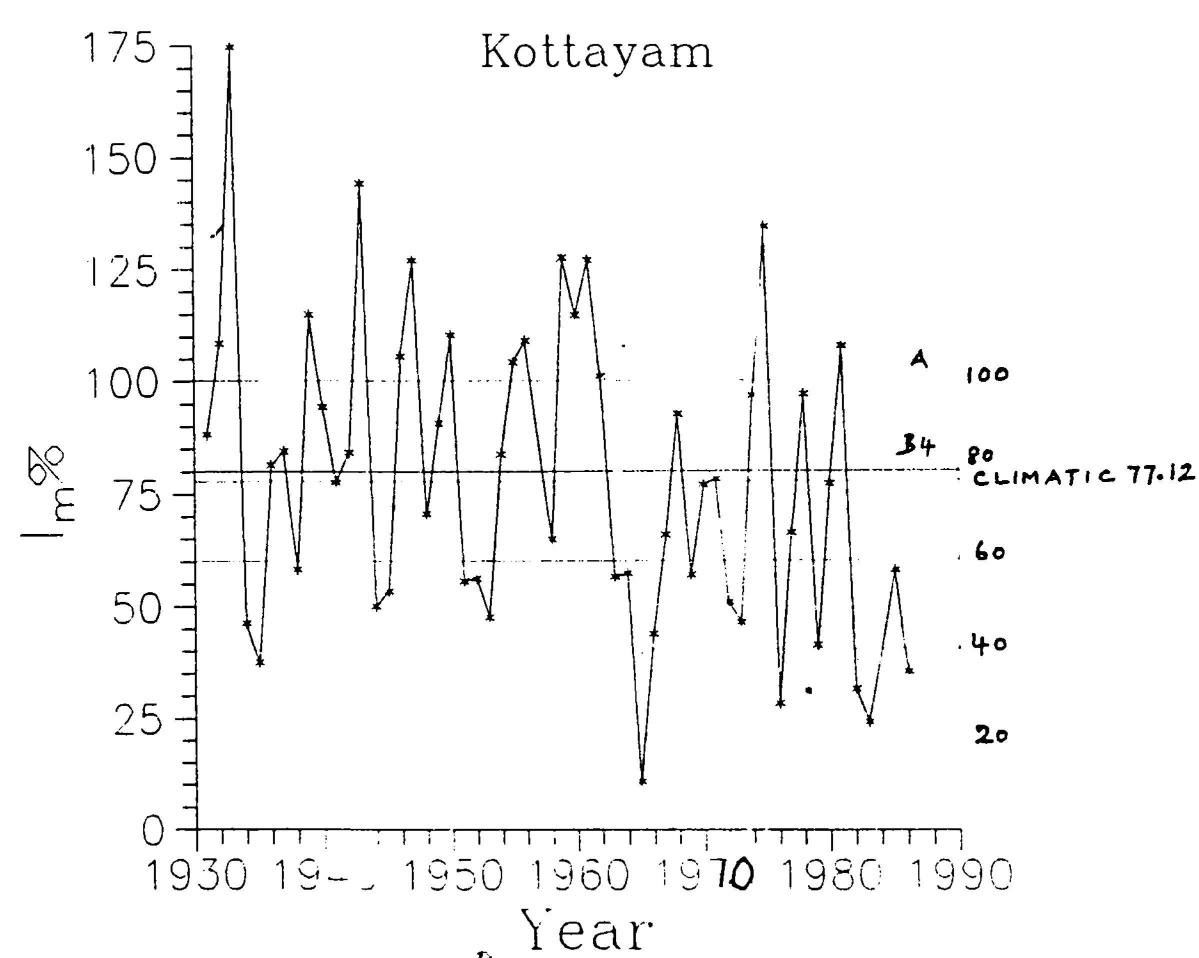

Fig. 4.10 (h) Climatic shifts

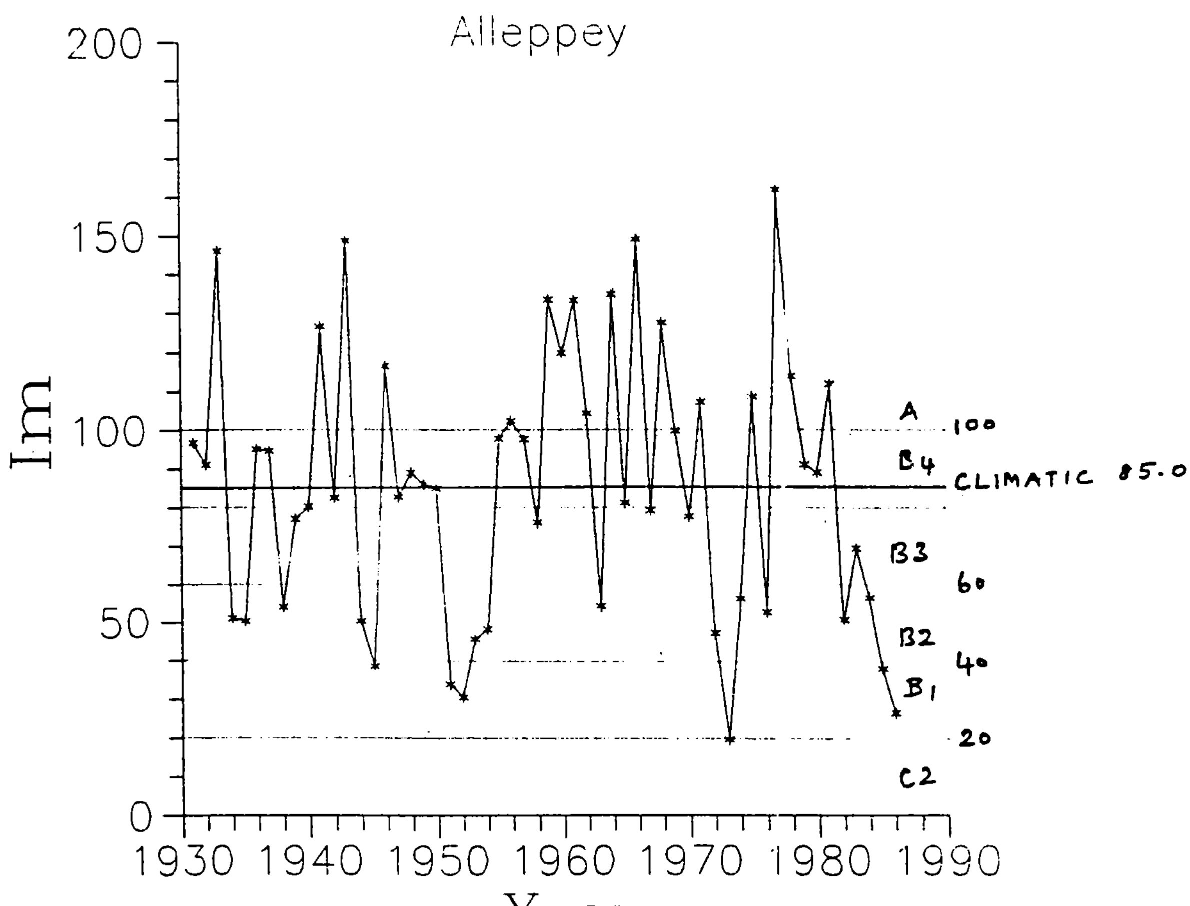

Fig. 4.10 (i) Climatic shifts

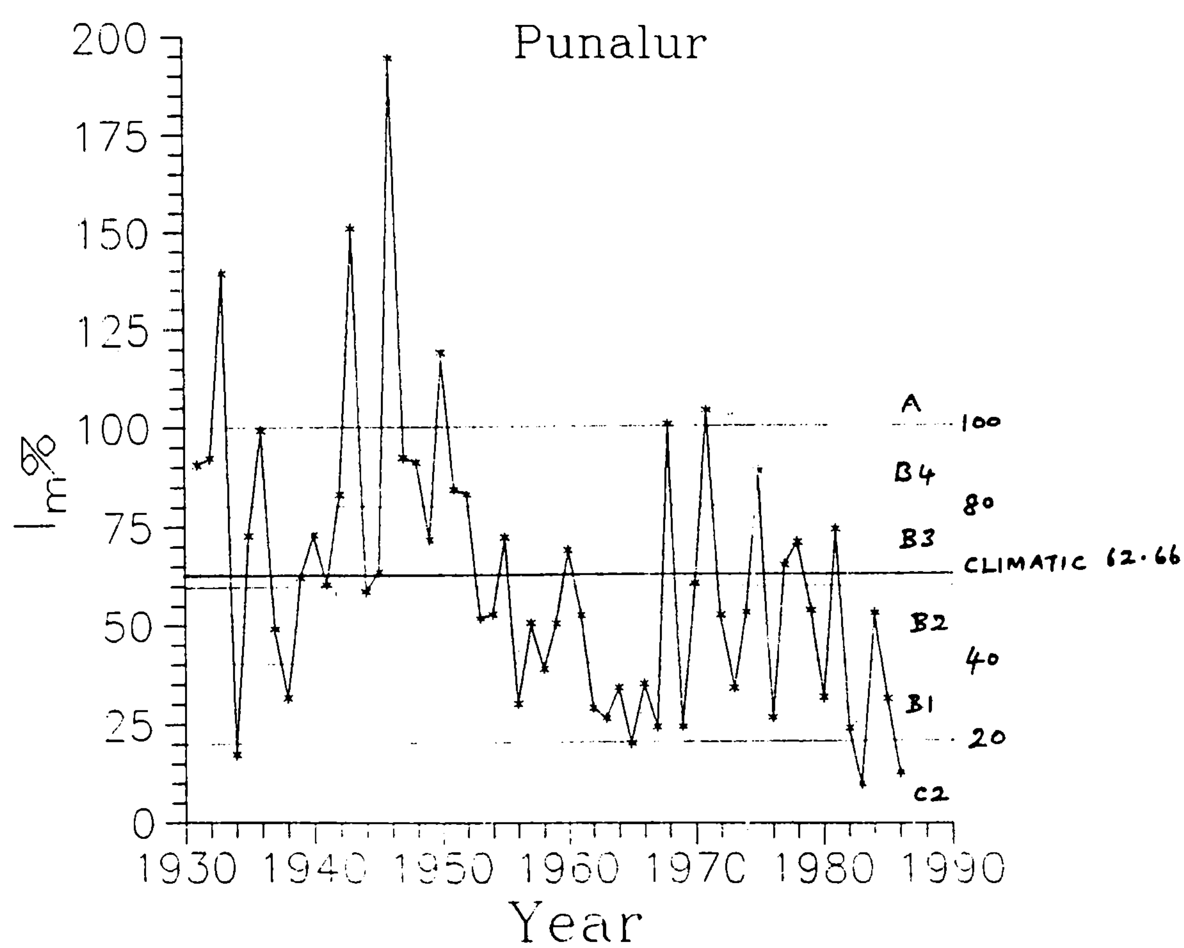

Fig. 4.10 (j) Climatic shifts

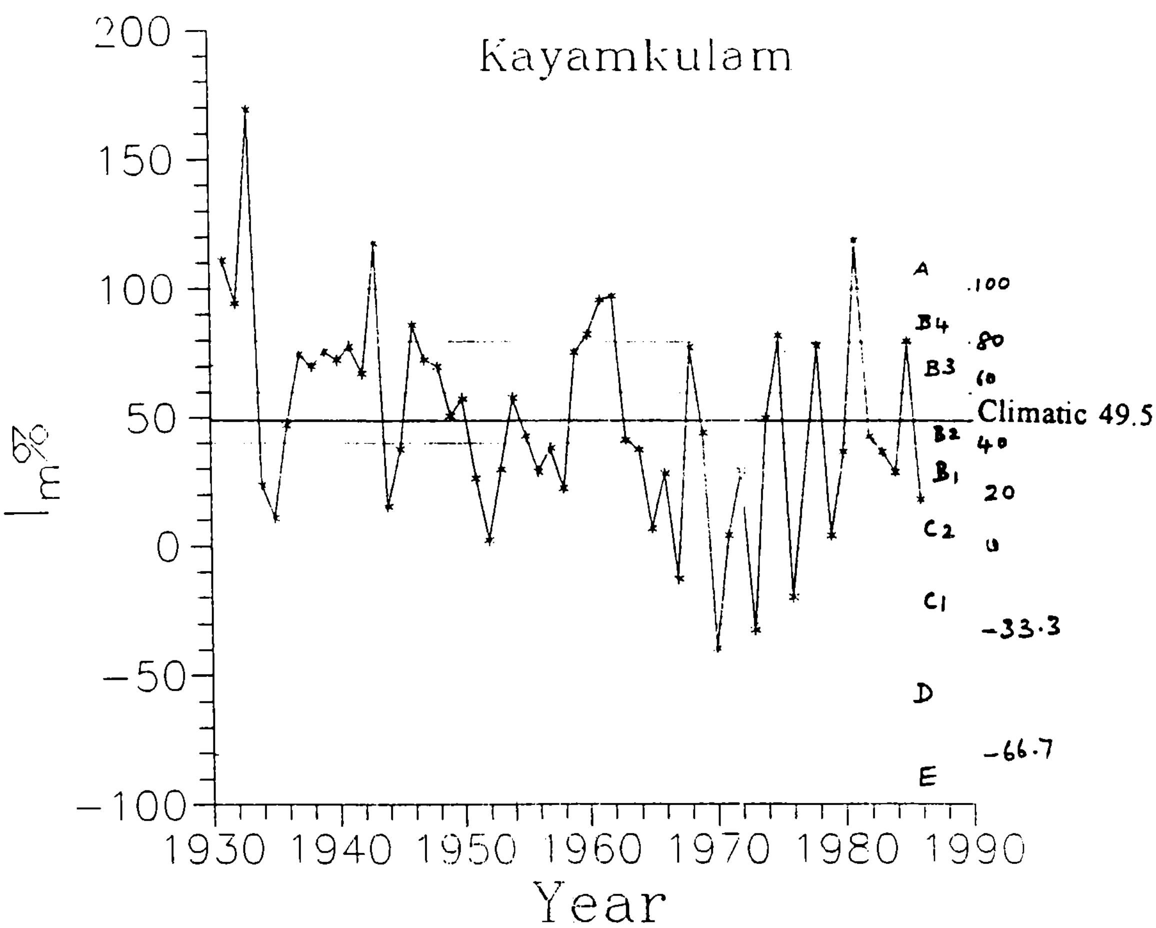

Fig. 4.10. (k) Climatic shifts

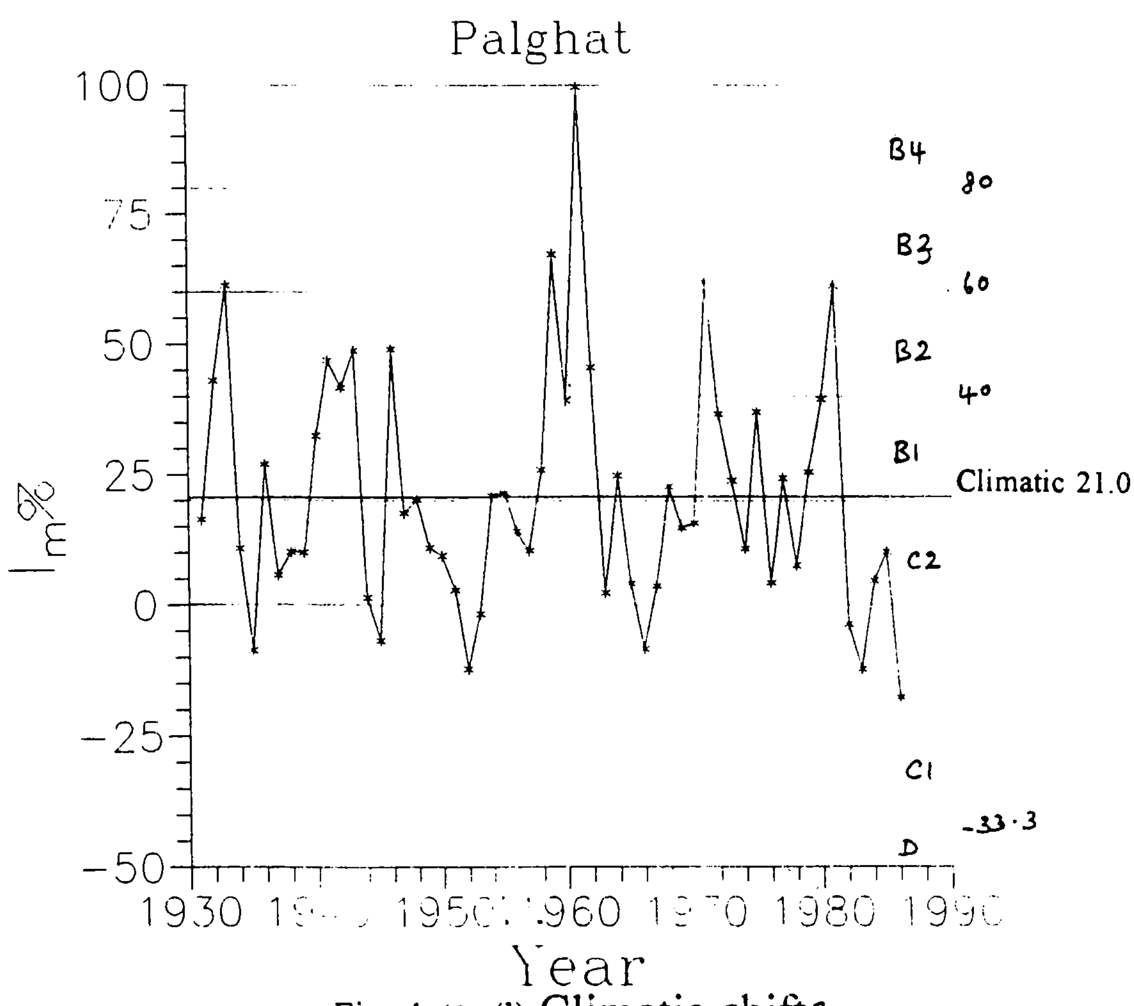

Fig. 4.10. (l) Climatic shifts

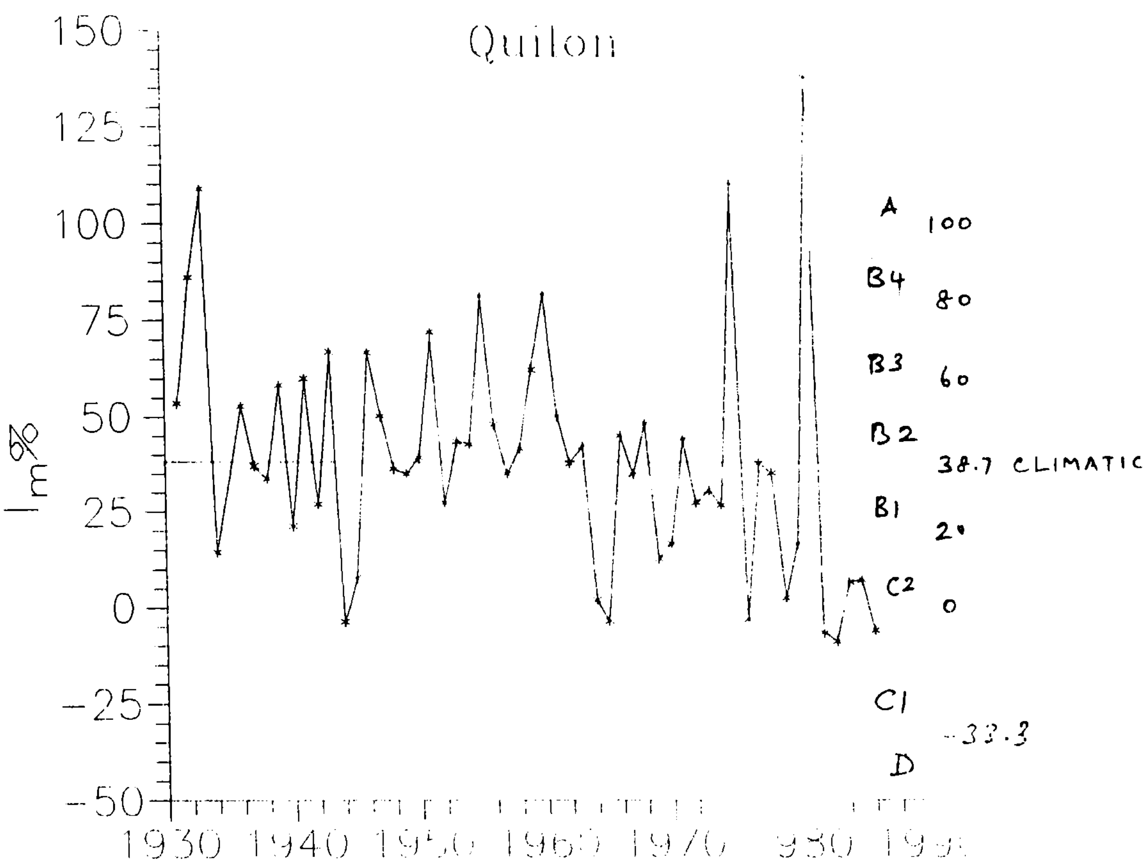

Fig. 4.10. (m) Climatic shifts

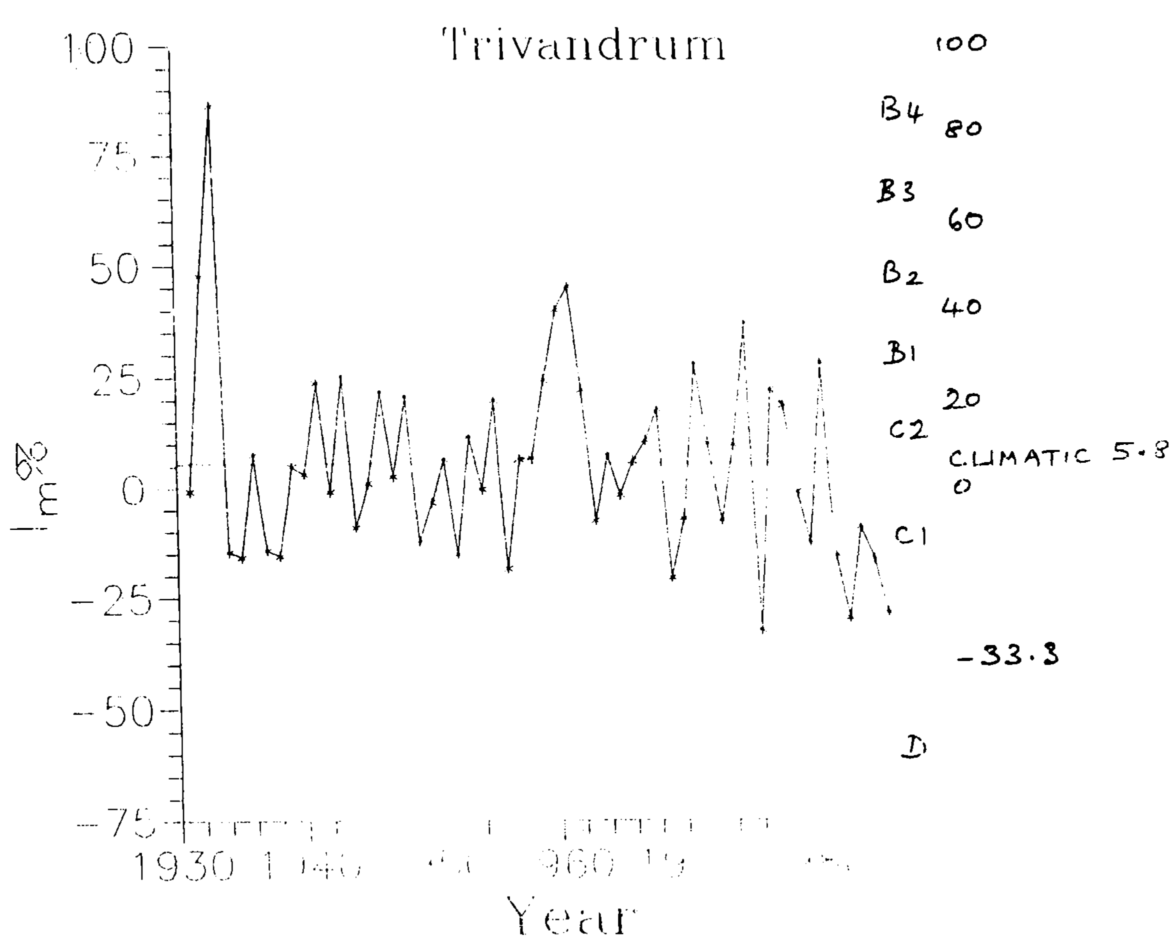

Fig. 4.10. (n) Climatic shifts

Trivandrum, the only moist subhumid station studied have had a total of 39 shifts of which 23 were to the dry subhumid and 1 to the semi arid category.

4.2.2. Study of drought and aridity

Table 4.3 has been prepared from the march of aridity Index of each station and gives the number and categories of the drought years. As already mentioned, all stations have a study period of 56 years (1931-86) except Payyanur where the period of study is limited to 50 years (1931-80).

Among the perhumid stations Peermade had the maximum number of droughts (28), while Payyanur had 26 in a limited data set of 50 years. While Payyanur had 2 disastrous and 5 severe droughts, Peermade has 3 disastrous and 2 severe droughts. Kasargode experienced 28 droughts of which 2 were disastrous and 4 severed. In all the three cases, the number of large and moderate droughts were expectedly higher than the more severe categories.

All the nine humid stations (B4, B3, and B1) experienced between 23 to 28 droughts within the study period. Of these Calicut and Palghat experienced 3 disastrous droughts while Cochin, Kottayam and Alleppey experienced 2 each. Further Trichur, Kottayam and Punalur experienced the minimum number of severe droughts (6) while Palghat and Cannanore the maximum (9). Droughts of large and moderate categories were higher in number at all stations except at Trichur which

Table 4.2.2: Number and categories of droughts

Station	D	S	L	M	Total
A Kasargode	1968,86	1952,79, 82,83	1945,53, 54,64,71, 73,75	1934,35,39, 46,49,50,55, 62,69,72,74, 76,81,85	27
	(2)	(4)	(7)	(14)	
A Payyannur	1953,79	1934,35, 50,52,80	1937,45, 49,55,68, 69,70,71, 74	1931,39,43, 51,64,67,72, 73,75,78	26
	(2)	(5)	(9)	(10)	
B4 Peermade	1964, 82,83	1974,86	1956,73, 76,77,78, 79,80,81	1931,34,43, 45,49,53,59, 60,61,63,65, 67,68,72,75	28
	(3)	(2)	(8)	(15)	
B4 Cannanore	1970	1934,35, 45,53,63, 67,74,81, 82	1952,64, 66,69,78, 86	1937,39,56, 57,72,73,75, 77	24
	(1)	(9)	(6)	(8)	
B4 Calicut	1935, 53,83	1957,59, 64,71,73, 74,78,86	1940,50, 58,68,79, 82	1931,39,52, 61,65,72,76, 80,85	26
	(3)	(8)	(6)	(9)	
B4 Trichur	1935	1945,74, 82,83,84, 85	1934,57, 63,71	1948,49,50, 51,52,55,69, 72,73,78,79, 80,81,86	25
	(1)	(6)	(4)	(14)	
B4 Cochin	1935, 83	1961,62, 71,76,79, 80,82	1931,32, 36,38,45, 48,49,51, 57,59,63, 64,66,69	1953,72	25
	(2)	(7)	(14)	(2)	

contd....

Station	D	S	L	M	Total
B4 Kottayam	1979, 83 (2)	1935,45, 49,53,71, 82 (6)	1936,40, 62,64,65, 72,80 (7)	1931,42,48, 50,52,56,66, 69,70,73,86 (11)	26
B4 Alleppey	1982, 83 (2)	1940,45, 49,65,66, 67,69 (7)	1935,36, 51,76,86 (5)	1952,53,58, 59,60,62,72, 73,74 (9)	23
B3 Punalur	1983 (1)	1939,40, 59,61,80, 82 (6)	1931,49, 53,56,60, 65,67,69 (8)	1941,45,57, 62,64,70,73, 74,75,76,77, 79,86 (13)	28
B1 Palghat	1952, 74,86 (3)	1931,35, 45,50,53, 67,78,82, 83 (9)	1964,84, 85 (3)	1934,46,49, 57,65,69,73 75 (8)	23
B1 Quilon	1981 (1)	1944,60, 61,79,80, 83,85 (7)	1967,69, 76,77,78, 82,86 (7)	1931,34,35, 38,39,48,58, 59,64 (9)	24
C2 Trivan-drum	1976, 83 (2)	1935,53, 66,82,86 (5)	1931,44, 49,52,64, 67,68,74, 85 (10)	1936,39,45, 48,51,58,57, 61,65,69.79 (11)	28

D = Disasterous; S = Severe; L = Large; M = Moderate.

experienced only 4 large droughts. Palghat 3 large droughts and Cochin only 2 moderate droughts during the study period.(Fig. 4.11).

The only moist subhumid station, Trivandrum, experienced a total of 28 droughts of which 2 were disastrous 5 severe, 10 large and 11 moderate droughts. A general comparison of the number and categories of the drought year at different stations reveals no evidence of any spatial coherence. In other words, droughts do not always occur at the same time or with the same intensity in different parts of the State. Expectedly, disastrous droughts were least common while moderate droughts were most frequent.

A detailed comparison of the years in which droughts occurred at various stations and the years in which there were climatic shifts of significant magnitudes reveals interesting facts. During many of the y ears when the climate shifted to the drier side stations experienced droughts of one or the other categories. However, during some years many stations did not experience droughts even though shifts in the climate to the drier classes were observed. There have also been occasions when even severe or disastrous droughts have been observed when there have been increases in the moisture index (I_m) values (shifts in the wetter direction).

At some stations droughts have occurred even when there was no perceptible climatic shifts. For example Peermade did not experience any climatic shift but was affected by as many as 28 droughts. These results highlight the greater ecological importance of optimum (appropriate) rainfall distribution than of rainfall totals. It is possible for the crops or vegetation to experience droughts during certain periods of

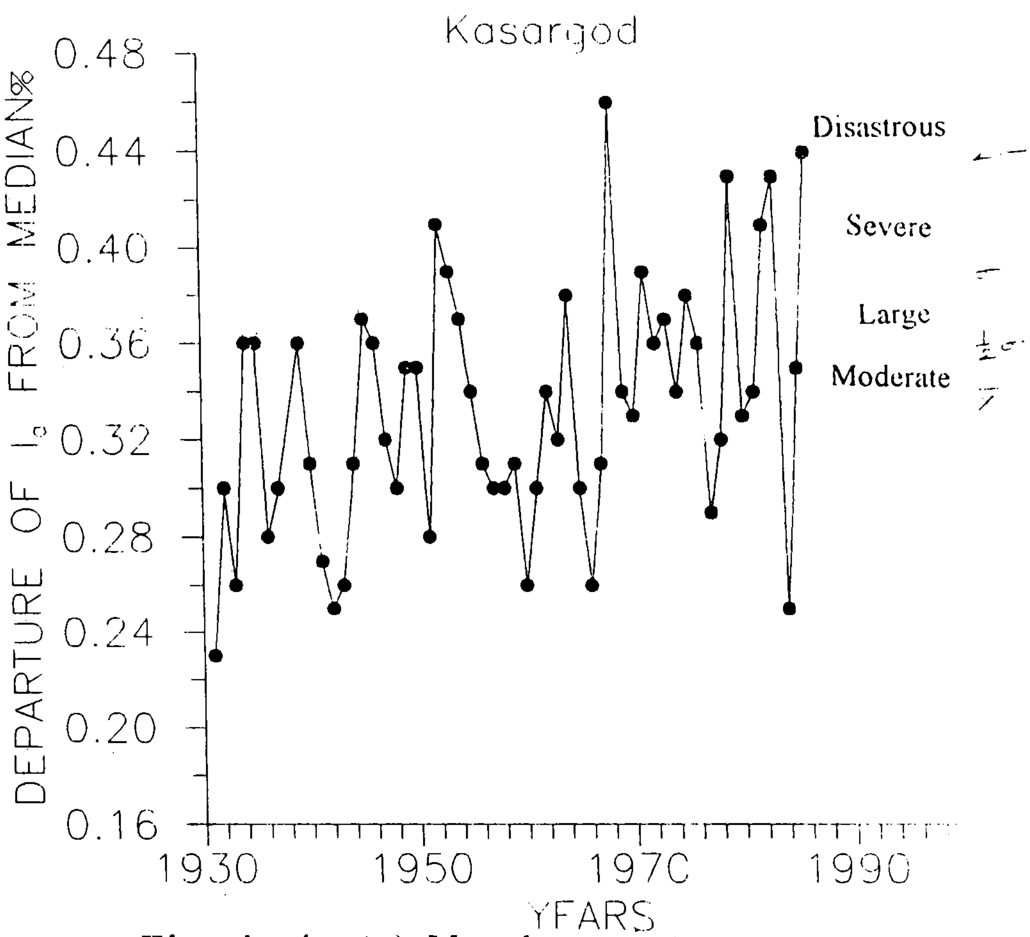

Fig. 4. 11. (a) Yearly march of aridity index

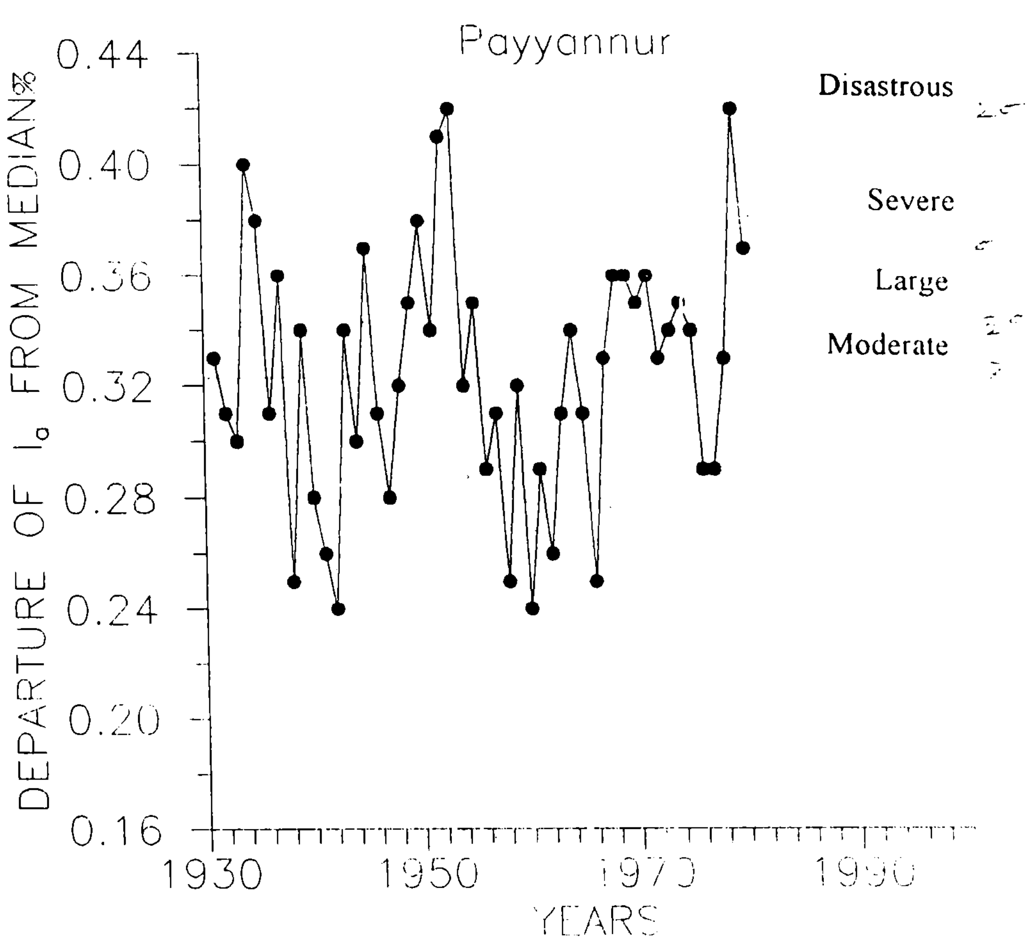

Fig. 4. 11. (b) Yearly march of aridity index

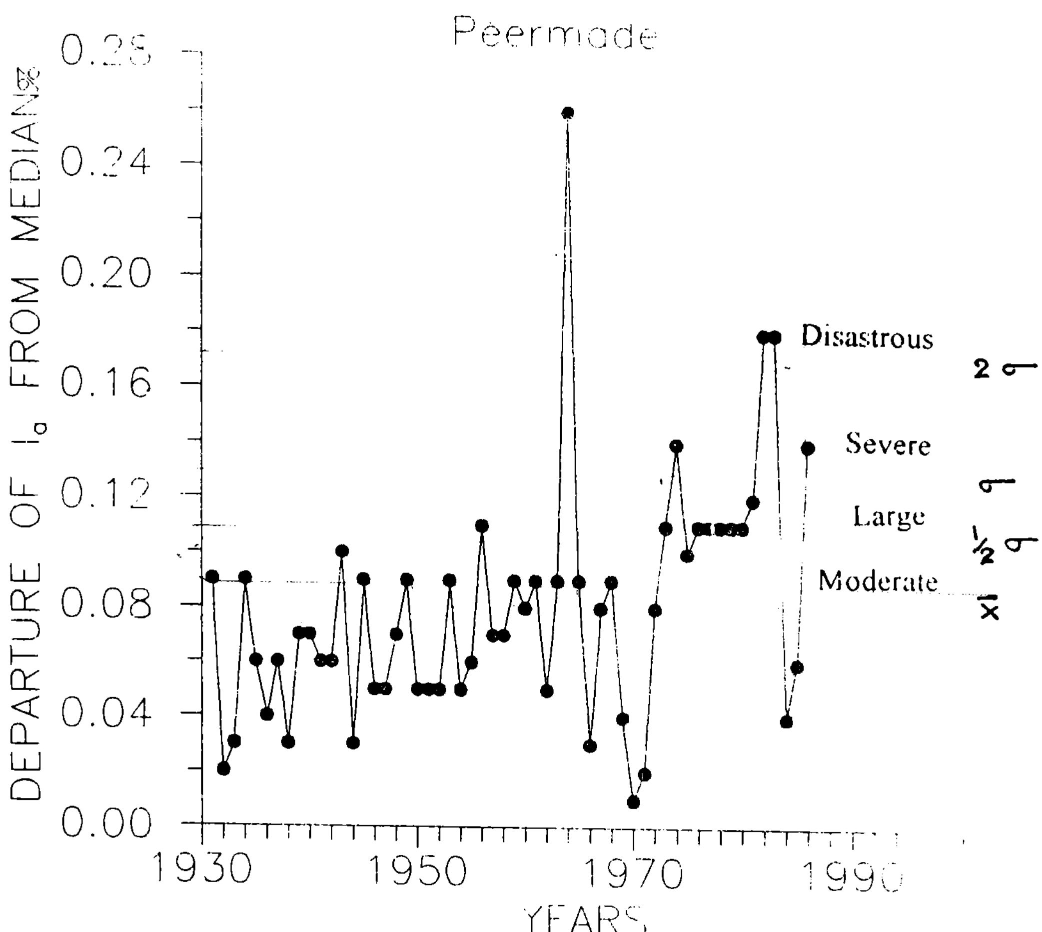

Fig. 4. 11 . (c) Yearly march of aridity index

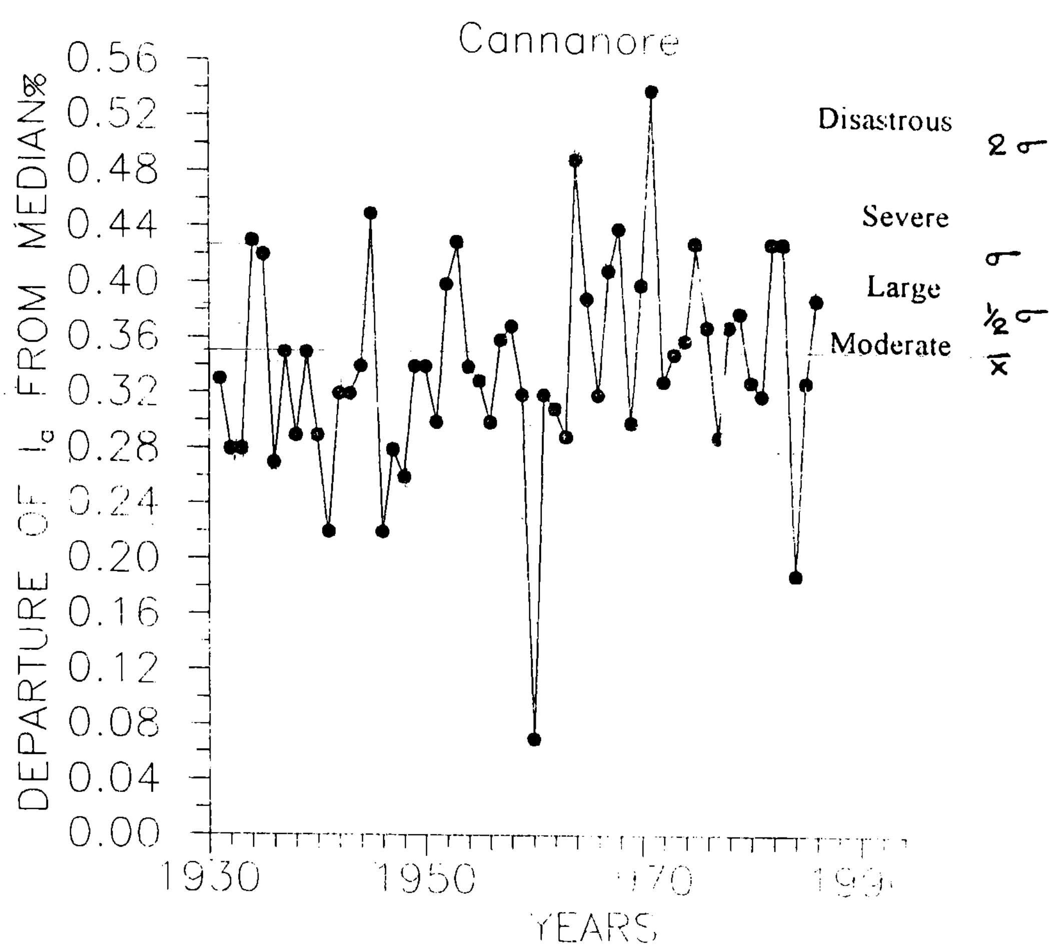

Fig. 4. 11.. (d) Yearly march of aridity index

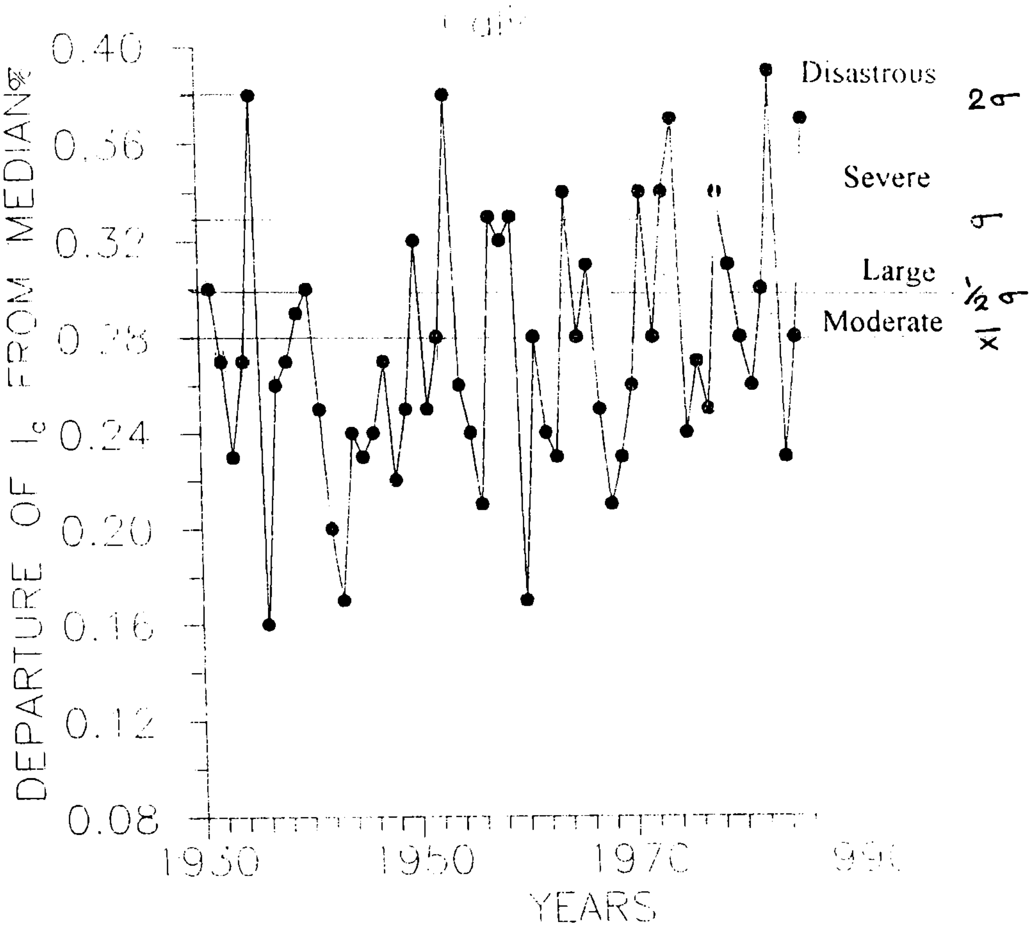

Fig. 4.II . (e) Yearly march of aridity index

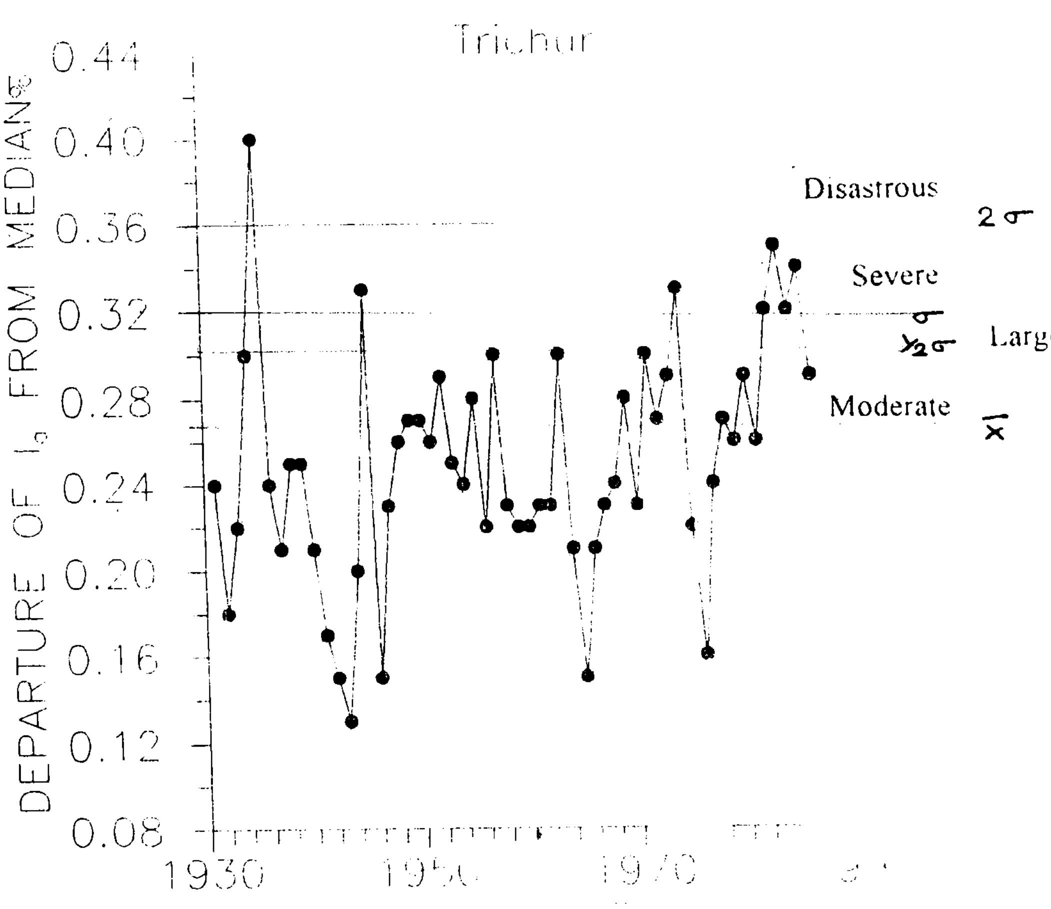

Fig. 4.II. . (f) Yearly march of aridity index

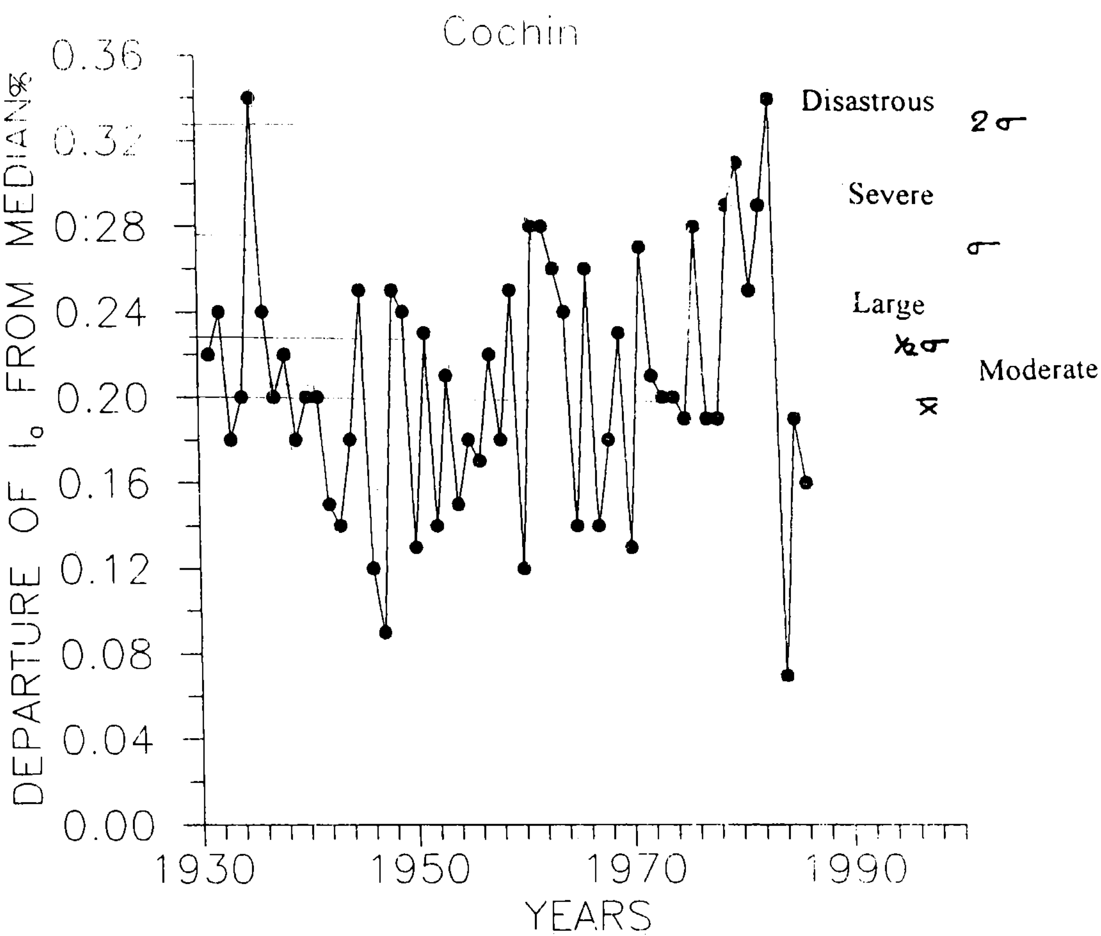

Fig. 4. 11.. (g) Yearly march of aridity index

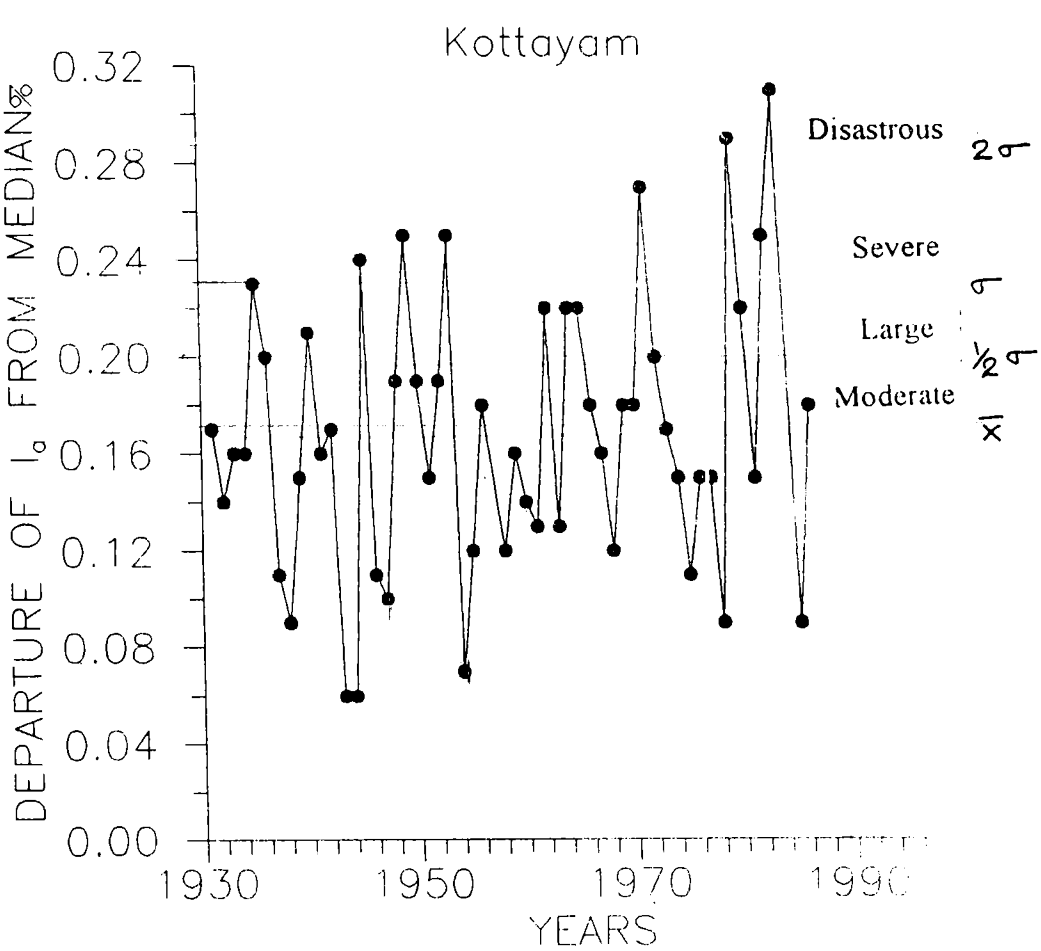

Fig. 4..11.. (h) Yearly march of aridity index

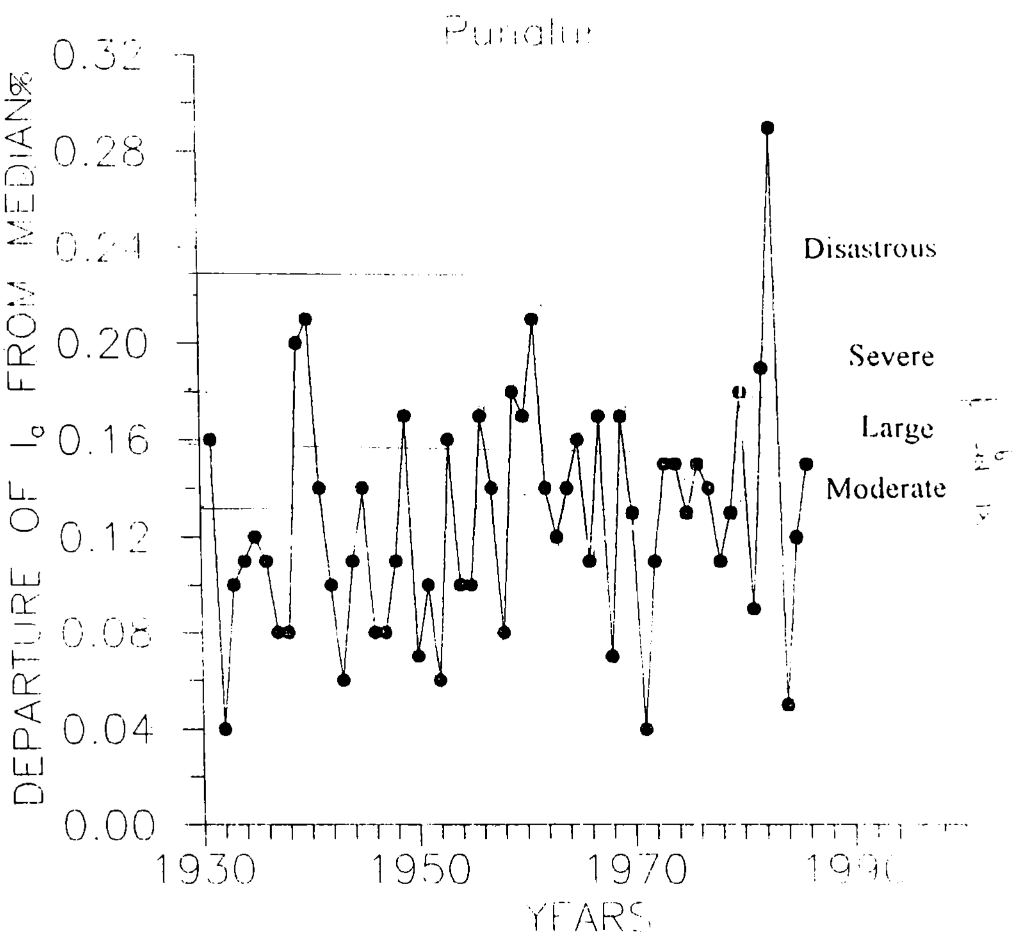

Fig. 4.11. (i) Yearly march of aridity index

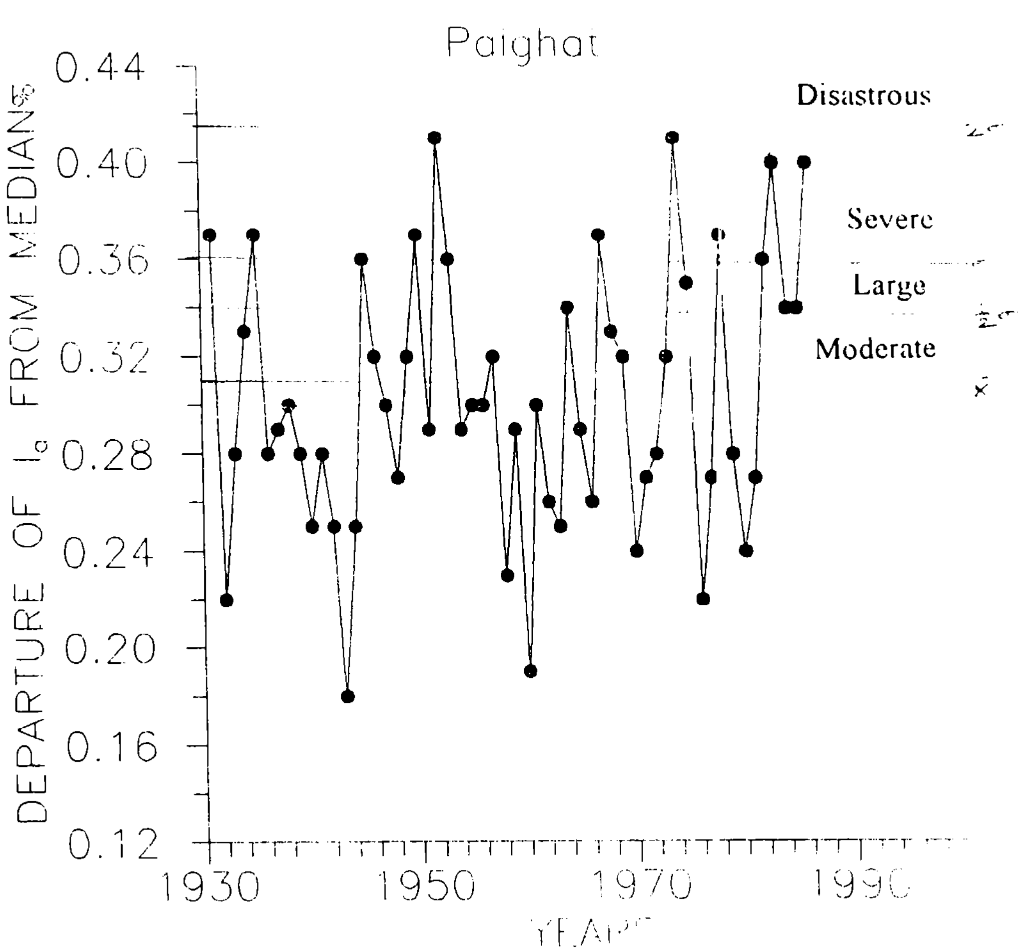

Fig. 4.11: (j) Yearly march of aridity index

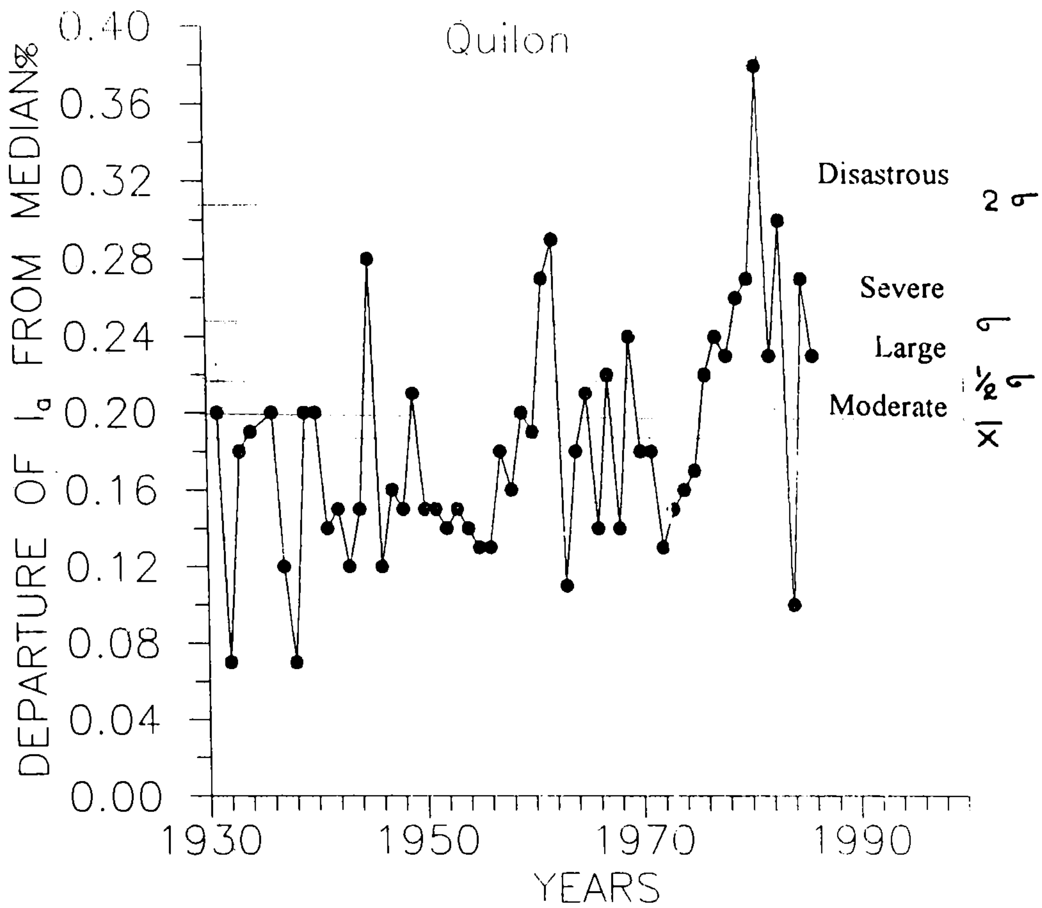

Fig. 4.11. (k) Yearly march of aridity index

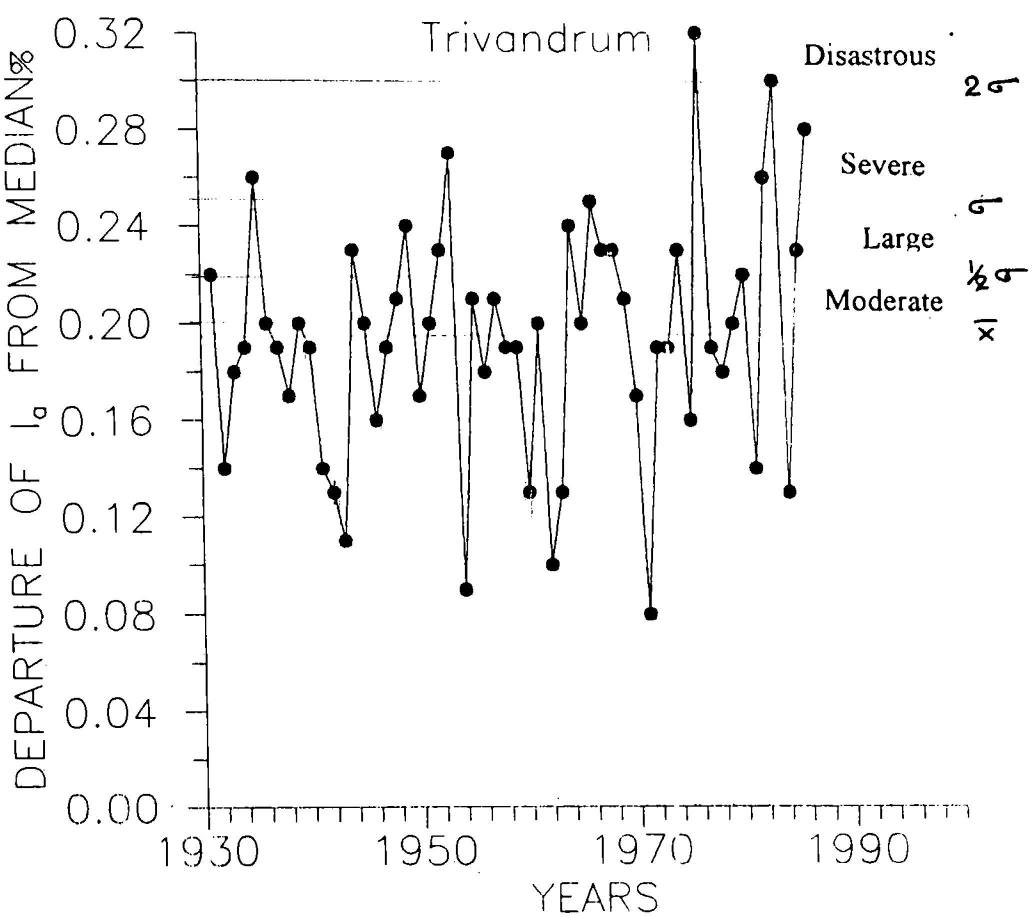

Fig. 4. 11. (l) Yearly march of aridity index

the years even when there is excessive rainfall during other periods. In fact floods during one season and droughts during others have been observed at some stations.

In the present study, the effects of rainfall increases in certain years has not been investigated as in a high rainfall region, it is the variabilities towards the lower side that is ecologically important.

4.2.3. Study of water budget elements

A critical examination of the comparative values of the elements of water balance in years of extreme climatic shifts in relation to the normal values reveals useful information that can be applied to landuse planning exercises. Hence, water balance of 9 stations (table 4.4) in the years of maximum climatic shifts both on the humid and dry sides were critically examined in relation to their respective normal climatic water balances.

During a normal year at Kasargode the precipitation is about 361 cm. Water deficit is about 57 cm while the water surplus mainly during the monsoon months is 447 cm. During the wettest year (1961) however, the rainfall exceeded normal values by about 70% while water surplus was more than double the climatic value. However, water deficit was almost equal to the climatic value. During 1938 the driest year rainfall was very low and water surplus were very close to normal values but the water deficiency was around 420% the climatic value. The climate shifted to B3 humid category from the normal perhumid class. At Peermade annual rainfall of 414 cm is

Table 4.2.3: Elements of Water Budget

Category of Year	Water Need (cms)	Rainfall (cms)	Water Deficit (cms)	Water Surplus (cms)	Moisture Index	
		KASARGODE				
Normal Year		360.9	56.60	246.9	109.8	A
Wet Year (1961)	167.6	613.1	50.36	500.0	468.3	A
Dry Year (1938)	169.3	358.1	239.30	238.8	075.6	B3
		PEERMADE				
Normal Year	106.0	413.9	8.10	320.8	310.2	A
Wet Year (1968)	107.5	440.1	12.70	355.8	769.8	A
Dry Year (1965)	109.9	327.9	9.10	227.2	132.8	A
		CANNANORE				
Normal Year	170.0	320.9	47.70	198.7	88.6	B4
Wet Year (1961)	167.5	566.1	53.40	454.8	239.7	A
Dry Year (1964)	166.8	202.4	81.20	117.9	22.0	B1
		CALICUT				
Normal Year	172.0	324.4	46.90	200.2	90.1	B4
Wet Year (1961)	167.9	495.2	47.50	381.4	198.8	A
Dry Year (1976)	171.4	216.3	46.10	91.9	26.7	B1
		COCHIN				
Normal Year	171.1	311.3	31.00	167.0	92.5	B4
Wet Year (1937)	168.3	314.2	34.00	178.1	85.6	B3
Dry Year (1976)	174.3	217.0	48.80	91.4	24.45	B1

contd....

Category of Year	Water Need (cms)	Rainfall (cms)	Water Deficit (cms)	Water Surplus (cms)	Moisture Index	
		ALLEPPEY				
Normal Year	171.8	310.0	21.70	160.0	85.0	B4
Wet Year (1977)	177.6	364.7	21.50	208.9	105.5	A
Dry Year (1973)	173.3	289.2	30.10	152.6	70.70	B3
		PUNALUR				
Normal Year	168.0	298.9	16.60	135.8	62.6	B3
Wet Year (1948)	172.6	335.7	19.50	177.3	91.0	B4
Dry Year (1983)	182.9	210.0	53.00	71.9	10.3	C2
		PALGHAT				
Normal Year	174.3	209.1	42.60	77.6	21.0	C2
Wet Year (1961)	169.8	333.0	50.50	219.3	99.6	B4
Dry Year (1986)	178.6	145.3	72.00	40.5	17.6	C1
		TRIVANDRUM				
Normal Year	171.9	183.9	29.90	51.9		
Wet Year (1933)	164.4	303.6	29.70	171.9	86.5	B4
Dry Year (1976)	172.3	112.7	55.60	0.00	32.25	B1

experienced of which 320 cm appears as water surplus. Water deficiency negligible at 8 cm. Rainfall in 1968 the wettest year was about 6% higher than normal and water surplus exceeded the climatic value by about 10% water deficiency was marginally higher at 12.7 cm. During the driest year 1965 rainfall was only 80% of the normal, but deficiency continued to be very insignificant. However, the water surplus was only 70% of the normal values.

The humid station Cannanore experiences an average rainfall of 320 cm, surplus of about 198 cm deficit of 48 cm. During 1961 rainfall was more than 175% of the climatic value and the water surplus exceeded the normal value by 130% making it the wettest year in the study period.

On the other hand precipitation was only 63% of the climatic value in 1964, the driest year and the deficiency was 70% higher. Water surplus was lower by about 60%. The climate shifted to the drier B1 humid category.

Calicut has a normal water surplus of about 200 cm since it has an annual rainfall of 354 cm. Water deficit experienced during the nonmonsoon months are moderate at 47 cm. In 1961 the wettest year the water surplus was about 190% the normal value caused by precipitation which exceeded the normal value by 53%. In the driest year (1976) rainfall was only two thirds of the normal value and surplus was down to 46%. Significantly in all the 3 cases the deficit did not show any appreciable change.

The normal rainfall at Alleppey is 310 cm of which about 160 cm appears as water surplus. Water deficiency of about 22 cm is also experienced in the normal year. In the wettest year 1977 the precipitation exceeded the normal by about 17% but the water surplus increased by 30% while the deficit was near normal. In 1973 rainfall was about 6% lower decreasing the surplus by about 5% but increasing the deficit to 30 cm.

At Punalur the annual rainfall is around 900 cm the deficit 130 cm and surplus 17 cm. Rainfall increased to 336 cm in 1948 and surplus to 177 cm making it the wettest year. The deficit also increased marginally while the climate shifted to the B4 category. In the driest year 1983 rainfall was only 70% of the normal value while surplus decreased to about 16%. The deficits however were about 320% of the normal value and the climate shifted to the moist subhumid category.

At Palghat a water surplus of about 78 cm resulting from a rainfall of 209 cm in the normal climatic year. But during the wettest year 1961 rainfall exceeded the normal by about 60% but caused an increase in surplus by over 180%. The water deficit in fact rose marginally during this year. In the driest year 1980 the rainfall was only 70% of the normal and surplus about 52% while the deficit rose by 67%. The climate shifted to the dry subhumid category.

At Trivandrum the only most subhumid station considered here the normal annual rainfall is about 184 cm, surplus 52 cm and deficit 30 cm. Precipitation shot up by 65% in 1933 the wettest year, increasing the surplus to about 230% of its normal value. The water deficit however stood at the normal value. During the driest year 1976 the rainfall was only 60% of its climatic value and caused a steep increase in water deficit to 56 cm. Significantly there was no water surplus during any month of this year while the climate shifted to the C1 category almost close to the semi arid boundary.

CHAPTER 5

LANDUSE PATTERN

5.1.SPATIAL AND TEMPORAL VARIATION

The net area sown in Kerala rose from 19.24 lakhs ha in 1960-61 to 22.47 lakhs ha in 1991-92, an increase of about 15.5 per cent. In the case of total cropped area or gross cropped area, there was an increase of about 23 per cent during the two decades from 1960-61 to 1980-81. Significantly there is an increase of only 4.7 per cent during the decade 1980-81 to 1991-92 from 28.85 lakhs ha it increased at 30.21 lakhs ha. This was mostly due to the increase in the cropping intensity from 122 to 132 per cent during the period 1960-61 to 1980-81. Whereas, the cropping intensity stood at 134 per cent during 91-92 a marginal increase from 80-81 figure. This is obviously due to a very marginal increase of gross cropped area during the decade. The area under permanent pastures and other grazing land, land under miscellaneous tree crops, cultivable waste, fallow other than current fallow, and current fallow fell substantially during the period 1960-61 to 1991-92. However, during the last decade the area remained stable for all the above five categories (Table 5.1).

During the past 10 years, not much change has been visible in the area under forests. However, the usual interpretation of landsat images collected by the National Remote Sensing Agency (NRSA) reveal that the percentage of forest area in the State to the total geographical area in 1972-75 was 22.15 and that in 1980-81 the forest area reduced by about 3.17 per cent. This means that the actual forest area

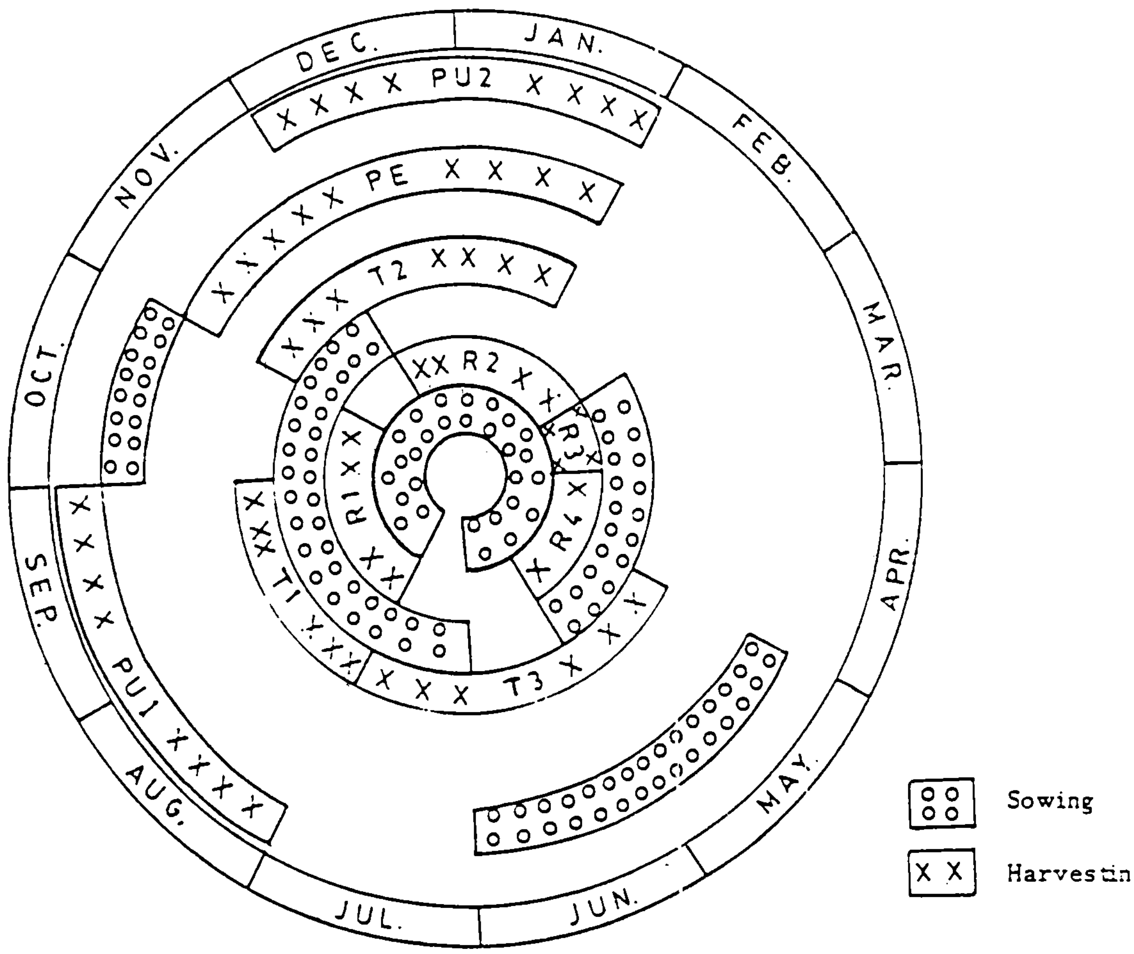

Figure 37 Crop calender of Kerala

R = Rice
T = Tapioca
PE = Pepper
PU = Pulses
1,2,3 denotes crop seasons

Fig 5.1: Crop calender of Kerala

Table 5.1: Per centage distribution of landuse pattern in Kerala (1991-1992)

DISTRICT	1	2	3	4	5	6	7	8	9	10	11
Trivandrum	22.81	9.50	0.50	0.12	0.05	0.29	0.26	0.35	66.21	26.30	92.52
Quilon	32.33	9.50	0.19	0.01	0.08	0.19	0.24	0.53	56.91	29.75	86.67
Pathanamthitta	57.74	4.08	0.24	0.00	0.04	0.16	0.21	0.46	37.04	10.41	46.47
Alleppey		17.47	0.21	0.00	0.15	1.56	1.06	2.19	77.34	44.65	122.00
Kottayam	3.71	9.96	0.83	0.01	0.09	0.44	0.98	1.42	82.55	24.81	107.38
Idukki	50.64	3.29	2.36	0.13	2.19	4.28	0.17	0.20	36.71	3.09	39.81
Ernakulam	3.45	14.61	0.76	0.04	0.30	1.35	0.87	1.19	77.42	27.41	104.84
Trichur	34.61	9.20	0.46	0.02	0.25	1.03	1.04	1.69	51.69	19.00	70.69
Palghat	31.04	7.49	2.16	0.02	1.60	5.19	1.18	1.83	49.48	28.74	78.22
Malappuram	28.47	6.03	1.37	0.04	0.55	2.80	1.20	2.05	57.50	16.55	74.05
Calicut	17.73	9.03	0.73	0.03	0.87	0.66	0.42	0.73	69.78	21.57	91.36
Wayanad	37.06	3.38	0.60	0.05	1.02	1.57	0.74	1.01	54.55	28.29	82.84
Cannanore	16.42	7.78	2.14	0.08	1.74	1.63	0.43	1.21	68.56	20.91	89.47
Kasargode	2.87	7.71	5.96	0.11	1.21	8.76	1.03	1.32	71.01	0.74	71.77
STATE	27.83	7.76	1.42	0.05	0.88	2.38	0.69	1.13	57.77	19.90	77.75

1 - Forest
2 - Land put to non-agri use
3 - Barren and uncultivable land
4 - Permenent pastures & other grazing land
5 - Land under misc. tree crops
7 - Fallow other than current fallow
8 - Current fallow
9 - Net area sown
10 - Area sown more than once
11 - Total cropped area

in Kerala is significantly lower than the estimation made through the conventional methods (Table 5.2) reflecting virtually the same figures for 1991-92.

Table 5.2. Satellite remote sensing data on forest cover

	1972-75	1980-82	Change in %
Total area under forest as % of Total Geographical area	22.15	18.98	-3.17
Closed forest	19.84	16.15	-3.69
Open/degraded forests	2.32	2.82	+0.50

From the above it is to be inferred that the actual tree clad area for the period 1980-82 (18.98%) is significantly lower than the figures reported earlier. The possible causes of deforestation and encroachment, unauthorised felling of trees, submergence of forest area for hydroelectric projects/other projects, shifting cultivation, erosion, forest fires, forest diseases etc.

The suitability of the land and climate for a number of crops has tempted the farmers to cultivate a host of crops in the same field of land in mined stands. The overall intensity of cropping in Kerala is fairly high with the ratio between Gross Cropped Area and the Net Area Sown (NAS) is 1.34 during 1991-92. But this parameter, in the context of Kerala is deceptive because 45 per cent the NAS is under perennial crops.

Table 5.3: Per centage distribution of land in each district of Kerala according to different use (1976-1977).

DISTRICT	1	2	3	4	5	6	7	8	9	10	11
Trivandrum	22.81	7.78	0.66	0.02	0.16	0.47	0.76	0.54	66.80	43.75	110.55
Quilon	49.77	5.12	0.70	0.02	0.12	0.29	0.27	0.35	43.36	27.49	70.85
Alleppey	0.28	15.28	0.46	0.02	0.16	1.14	0.35	1.11	81.20	43.00	124.00
Kottayam	3.73	8.05	1.01	0.13	0.36	0.88	0.73	0.84	84.27	33.40	117.67
Idukki	50.67	2.60	3.37	1.60	3.85	7.06	0.20	0.26	30.39	0.24	30.62
Ernakulam	3.45	12.49	0.66	0.20	1.03	2.26	0.59	1.73	77.06	23.95	100.01
Trichur	34.61	6.34	1.39	0.11	0.60	1.66	0.46	1.36	53.47	24.21	77.68
Palghat	31.03	7.20	2.57	0.36	1.89	4.19	0.97	1.58	50.21	21.20	70.41
Malappuram	28.47	3.90	1.91	0.20	0.82	3.62	0.78	1.54	58.76	19.22	77.98
Calicut	24.48	5.79	1.35	0.17	2.38	1.78	0.26	0.43	63.36	12.14	75.50
Cannanore	14.74	7.85	4.35	0.65	4.67	4.31	0.80	1.16	61.47	3.79	65.26
STATE	27.85	6.69	2.03	0.41	1.88	2.96	0.57	0.95	56.66	18.86	75.50

1 - Forest
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3 - Barren and uncultivable land
4 - Permenent pastures & other land
5 - Mixed tree crops
6 - Cutivable waste
7 - Fallow otherthan current fallow
8 - Current fallow
9 - Net sown area
10 - Area sown more than once
11 - Total cropped area

Percentage Distribution of Landuse in each District

From the table 5.3, it can be seen that Kottayam district occupies the highest position in respect to Net Area Sown (NAS) with a per centage of 84.27 during 1976-77 and 82.55 during 1991-92. This is significantly higher than Net Area Sown in Quilon district (56%) . Quilon occupies 6.47% of the TGA where is Kottayam occupies over 5.64% of the TGA of the State. Another significant feature of the landause pattern in visible in Idukki, it occupying 13.23% of the TGA, with only percentage of 30.39 in respect to NAS. Idukki district being in the highland region, only cash plantation crops are grown here constituting only a minor fraction to the NAS.

Also it is quite discernible from the TCA of Trivandrum district that there is marked decrease in the TCA from 110.75% (76.77) to 92.52% in 1991-92. May be due to the fact that paddy fields are converted to house sites in the district.

With regard to percentage distribution of land put to non-agricultural use, Alleppey district occupies the highest position with 15.28% followed by Ernakulam district with 12.49%. Idukki the biggest district of the State as the least per centage of land in this category with a figure of 2.6 %. It is also interesting to note that the Idukki district has the highest percentage of 3.37 with regard to Barren and Uncultivable land and also Cultivable waste land with a figure of 7.06%.

The other factor to be mentioned in this context is the reduction in the forest area of Quilon district form 49.77% in 1976-77 to 32.33% during 1991-92.

Table 5.4: Per centage distribution of landuse in Kerala (1987-1988)

DISTRICT	1	2	3	4	5	6	7	8	9	10	11
Trivandrum	22.81	8.63	0.79	0.01	0.11	0.78	0.59	0.61	65.67	29.96	95.63
Quilon	32.34	9.20	0.26	0.01	0.08	0.26	0.29	0.49	57.07	30.28	87.35
Pathanamthitta	57.75	3.40	0.31	0.00	0.05	0.18	0.25	0.47	37.61	6.68	44.29
Alleppey		18.27	0.25	0.00	0.07	1.70	0.85	1.70	77.16	41.67	118.82
Kottayam	3.71	9.57	1.01	0.01	0.09	0.52	0.93	1.45	82.71	28.07	110.78
Idukki	50.67	2.75	3.34	0.34	2.05	5.60	0.23	0.43	34.59	7.03	41.62
Ernakulam	3.45	14.69	0.79	0.04	0.35	1.94	0.97	1.29	76.48	33.10	109.58
Trichur	34.61	8.09	0.57	0.03	0.38	1.51	0.99	1.77	52.05	19.90	71.95
Palghat	31.04	6.90	2.73	0.04	2.00	5.44	1.29	1.80	18.76	22.36	71.12
Malappuram	28.47	5.76	1.75	0.06	0.65	3.70	1.25	2.58	55.78	9.63	65.41
Calicut	17.74	8.69	0.86	0.04	1.03	1.02	0.48	0.89	69.25	20.14	89.39
Wayanad	37.07	3.00	0.87	0.04	1.41	2.64	0.69	1.04	53.24	14.25	67.49
Cannanore	16.42	4.45	3.41	0.09	2.20	2.00	0.79	1.48	66.16	8.84	75.00
Kasargode	2.87	7.56	6.95	0.12	2.12	10.12	0.69	0.91	68.66	0.12	68.78
STATE	27.83	7.33	1.86	0.08	1.05	2.97	0.74	1.24	58.91	17.72	74.63

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8 - Current fallow
9 - Net area sown
10 - Area sown more than once
11 - Total cropped area

With respect to the Area sown more than once, Alleppey district is in the leading status with a considerably high percent of 43.00 showing marginal increase to 44.00% during 1991-92.

Whereas in the case of Trivandrum district in the southern most part of the State, there appears to be a considerable decrease from 43.75% in 1976-77 to 29.96 in 1987-88 (table 5.4) to a further slide down to 26.30% during 1991-92.

Under the Net Sown Area category, Kottayam district occupies the first position with high percentage value of 84.27 closely followed by Alleppey district. There is only marginal decrease during the period from 1976-77 to 1991-92 in case of both the adjoining districts.

A very negligible fraction of the land is put to use in almost in all the districts towards the miscellaneous tree crops category.

Palakkad district occupies the top slot in the cultivable waste category with 4.19% with marginal increase to 5.19 during 1991-92.

It can be mentioned from the observation of the land use pattern in the State during 1976-77 through 1987-88 to 1991-92, not many significant changes are effected during the period. If at all, there is a decline in the forest cover area and also the TCA of the Trivandrum district in a big way.

May be suitable changes in the landuse pattern can be suggested taking into view the influence of agroclimatic factors under study.

5.2 Cropping pattern

Cropping pattern means the proportion of area under various crops at a point of time. The crop statistics are used to denote the cropping pattern. It is however, a dynamic concept as no cropping pattern can be good and ideal for all times to come. The cropping pattern differ from macro to micro region, both in space and time and governed largely by the physical, cultural and technological factors. For the purpose of agricultural regionalisation and planning, it is necessary to divide any areal unit homogeneous regions on some well defined basis. There can be number of physical, climatological, and agronomic criteria on which cropping pattern can be made. For example, the climatic index and soil groups can be taken into consideration as these are more or less fixed entities.

In India, the cropping patterns followed are based mainly on the traditional system of subsistence farming in which every farmer attempts to produce everything his family consumes. Such a cropping pattern, in fact, is based on utilisation of the inherent fertility of the soil without the use of modern agricultural technology. The need for adoption of suitable cropping patterns in a developing country such as India, where the frontier of arable land has almost been pushed to the limit, cannot be over emphasized. The rational use of the land and increasing the productivity per unit of time by changing the subsistence farming into market orientated cropping pattern is necessary to solve food problem and improve the standard of nutrition. The change in the cropping pattern and introduction of new crops, ideally suited to the prevalent agroclimatic conditions can go a long way in providing higher standard of diet and nutrition to the rapidly increasing population.

5.2.1 Cropping Pattern of Kerala (1987-92)

For the study of cropping pattern of Kerala, average values of crop landause statistics for the period 1987 - 92 (tables 5.5a and 5.5b) have been used. Fourteen important crops have been identified and the areas under each crop and their average yields have been shown in the form of maps. Further, the cropping pattern for the year, 1976-77 has also been studied in order to obtain the spatio-temporal variation of the major crops on a district wise basis.

Crops and Crop season

The crops grown in the State are food crops such as paddy, pulses, mango, jack, cashew nut, tapioca and banana and spices such as pepper, cardamom, nutmeg, cereals, oilseeds such as coconut, groundnut and gingelly and plantation crops such as tea, coffee, rubber, cocoa etc.

The period of sowing various crops are mainly in the rainy season. Post monsoon cool weather season (winter), monsoon are the seasons for the paddy, the staple food of the people of Kerala. The figure 5.1 shows the crop calendar for some crops of Kerala. But the most of the seasonal crops are sown well before the south

Table 5.5a: Per centage distribution of area under important crops in Kerala (1987-1992).

DISTRICT	Rice	Coconut	Tapioca	Rubber	Cashew	Pepper	Betel nut	Coffee	Other Plantain ains	Pulses	Tea	Seasa-mum	Banana	Sugar
Trivandrum	10.28	40.49	17.67	9.94	2.08	2.11	1.02	0.66	2.24	11.25	0.49	0.01	0.34	0.22
Quilon	13.20	34.76	41.66	14.08	3.13	3.59	0.93	0.10	1.53	0.53	0.54	0.67	0.52	0.07
Pathanamthitta	11.09	22.96	8.98	31.75	1.70	4.17	1.15	0.06	1.79	0.17	0.12	0.08	1.04	1.13
Alleppey	36.42	36.59	4.74	1.89	3.26	1.54	1.04	0.01	1.26	0.28		1.90	0.27	0.46
Kottayam	11.41	19.82	5.65	43.33	0.47	4.27	0.65	0.42	1.36	0.87	0.83	0.03	0.81	0.23
Idukki	2.39	7.96	3.24	16.54	0.43	16.93	0.84	4.29	0.90	0.49	11.10	0.06	0.18	1.19
Ernakulam	27.68	26.37	2.89	22.85	1.13	2.83	1.65	0.09	1.26	0.81	0.00	0.63	0.10	0.13
Trichur	35.55	36.25	1.89	3.66	2.75	2.44	2.72	0.01	1.94	0.71	0.21	0.39	0.81	0.32
Palghat	44.26	11.18	3.26	6.46	3.03	0.76	0.78	0.70	1.07	2.24	0.21	0.26	0.78	2.76
Malappuram	20.78	34.89	4.74	6.84	6.49	2.61	3.59		1.22	0.37	0.07	0.82	1.32	0.62
Calicut	4.94	56.01	1.74	6.25	1.87	7.03	2.65		1.27	0.42		0.01	0.22	0.16
Wayanad	13.19	2.91	1.18	2.88	0.53	15.71	1.01	38.53	0.87	0.22	3.44	0.10	0.75	0.17
Cannanore	8.49	33.47	2.67	8.59	13.34	9.83	4.06		1.25	1.04		0.03	0.66	0.09
Kasargode	8.91	30.37	1.84	11.24	18.35	5.53	8.00		1.27	0.67		0.03	0.52	0.07
STATE	19.20	20.02	5.30	13.22	4.00	5.47	2.11	2.45	1.36	0.81	1.16	0.36	0.70	0.62
Min.	2.39	2.91	1.18	1.89	0.43	0.76	0.78		0.87	0.17		0.01	0.18	0.07
Max.	44.26	40.49	41.66	43.33	18.35	16.93	8.00	38.53	2.24	2.24	11.10	1.90	1.32	2.72

Table 5.5b: Average yield of important crops in Kerala (1987-1992).

DISTRICT	Rice Kg/ha	Coconut No.nuts/ ha	Tapioca Kg/ha	Rubber Kg/ha	Cashew Kg/ha	Pepper Kg/ha	Betel nut In'000s	Coffee Kg/ha	Other Plantains Kg/ha	Pulses Kg/ha	Tea Kg/ha	Seasa Kg/ha	Banana Kg/ha	Sugar Kg/ha
Trivandrum	1714.70	5535.59	16930.45	660.17	720.84	240.59	126.59		5322.72	229.32	701.38	218.75	13204.73	126.04
Quilon	1785.19	4615.90	6272.22	862.73	919.50	356.65	171.35		4593.49	1010.93	294.48	383.48	12410.33	4384.80
Pathanamthitta	2308.75	4706.00	2081.52	648.15	679.31	344.00	317.90		6556.41	774.01	275.59	405.98	13926.58	6797.07
Alleppey	2088.93	4539.51	18301.20	1089.37	367.98	203.11	103.12		4267.42	867.54		164.42	13251.82	5156.05
Kottayam	2278.90	4232.96	23264.69	507.75	382.10	155.00	150.49		5826.66	876.40	75.07	207.83	14240.46	1849.39
Idukki	2076.42	3987.26	26880.89	625.00	525.46	431.22	251.45	438.75	7401.42	827.43	2089.91	319.05	16558.29	5944.76
Ernakulam	1635.30	5479.17	20589.56	515.40	441.35	181.09	195.35		4705.20	716.14		266.68	13714.73	546.52
Trichur	1657.93	6264.17	16493.44	1198.20	428.80	181.58	218.15		2941.07	714.79	3382.76	218.67	13339.83	26.39
Palghat	2117.51	3020.51	19079.50	588.08	440.61	130.61	121.86	557.26	3270.30	754.59	2348.35	251.90	12865.24	2263.12
Malappuram	1509.56	4634.36	17683.23	941.59	549.87	199.25	209.40		4076.38	741.96	111.49	161.49	11620.91	39.51
Calicut	1461.77	5413.23	14143.27	1215.99	563.26	170.70	169.74		6194.96	759.70		208.86	20250.05	85.86
Wayanad	1988.67	1337.57	29545.96	495.21	43.68	138.30	194.36	352.66	5734.42	763.11	1735.95	258.71	14176.38	174.08
Cannanore	1562.07	4991.14	17933.44	716.66	1317.89	301.90	225.77		3316.22	780.48		183.33	13367.81	363.80
Kasargode	2122.31	4757.40	13469.13	679.00	839.97	239.93	214.62		4041.88	779.78		91.29	13867.51	413.00
STATE	1861.02	4971.55	18860.05	674.79	842.28	295.42	191.67	362.75	4509.12	247.65	1818.96	226.52	13177.48	2778.00

west monsoon sets in the State. Though perennial crops dominate the agriculture sector of the State, intensive mixed cropping is the general pattern of cultivation.

5.2.2 Distribution of crops

Diversity of agroclimatic conditions are well exemplified in the distribution of crops. The agriculture department has identified as many as 38 crops throughout the State. Out of these, 14 crops have been selected to map their distribution. The crops along with percentage share of the total cropped area (Annual average for 1987-92) are listed in Table.

The selected 14 crops together 87 per cent of the total copped area. The remaining area is covered by crops like jowar, ragi, tur, chilly, ginger, turmeric, mango, citrus fruit, other fruits, sweet potato, onion, ground nut, caster, cotton, tobacco, fodder crops, green manure crops, other fibre crops, other narcotics, til, lemon grass etc

Rice -Area and yield (Fig. 5.2)

Out of the total cropped area of 2.98 million ha in the State, 0.57 million ha comes under rice which is cultivated in three seasons (Post monsoon, cool weather, monsoon). Rice cultivation in winter season accounts for higher acreage than during other two season. Acreage under rice cultivation varies from 2 per cent in Idukki to 44 per cent in Palghat. Palghat is followed by Alleppey (36 per cent), Trichur (35 per cent) and Ernakulam (27 per cent). The high coverage is attributed to alluvial soil found extensively in these districts. The Kuttanad area in Alleppey, Kole lands in

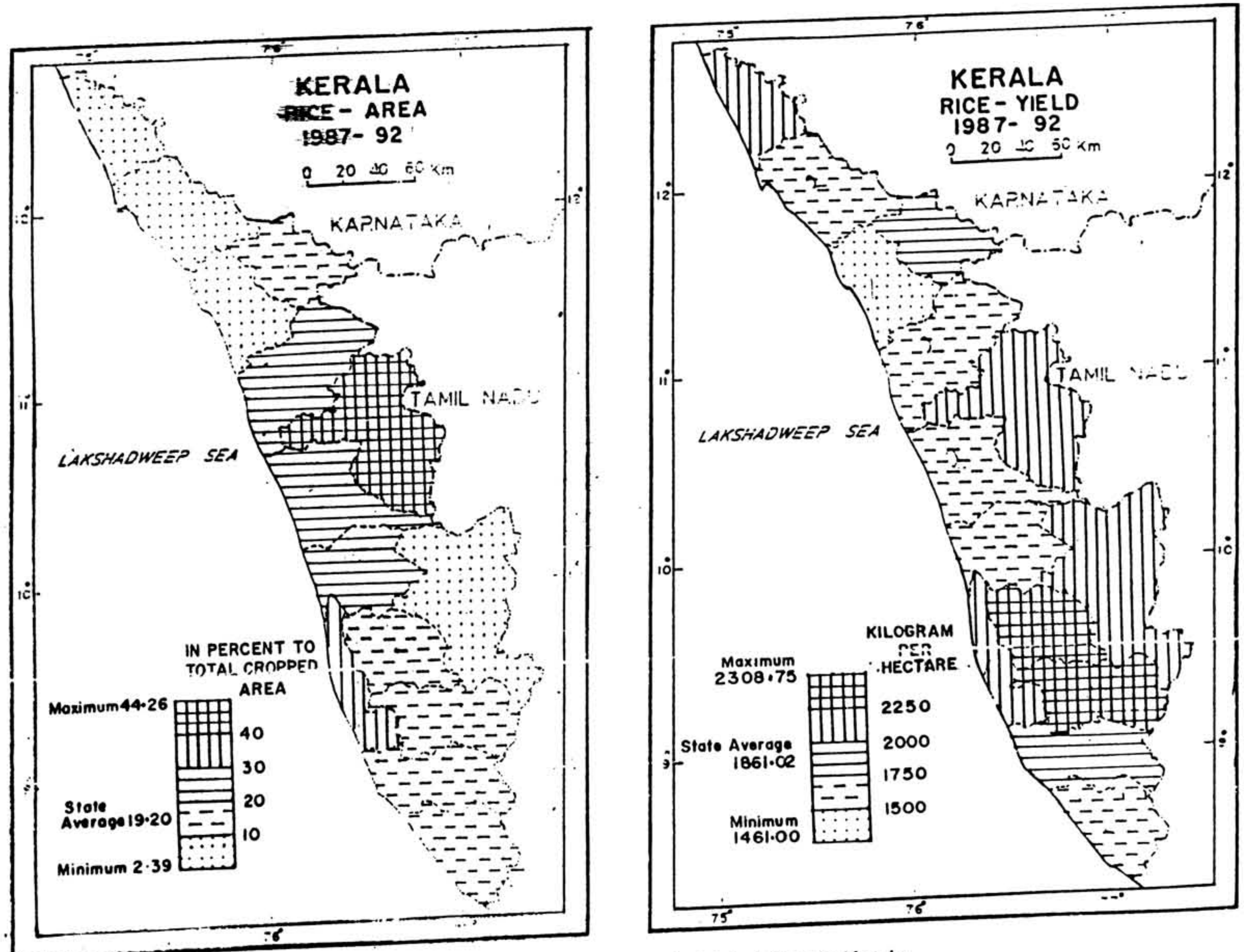


Fig 5.2: Map showing area and yield of Rice in Kerala

Trichur and Ernakulam are the most suitable areas for paddy cultivation. However. Pathanamthitta ranks first in the yield rate having an average yield of about 2308 kg/ha. Introduction of the high yielding varieties has considerably increased production.

Tapioca - Area and yield (Fig 5.3)

Tapioca is the fourth ranking crop in the State in terms of area coverage. This is most popular staple food after rise. Quilon, Trivandrum, Pathanamthitta and Kottayam have 41 per cent, 17 per cent, 9 per cent, and 5 per cent of their respective total cropped areas under this category. Wayanad has the lowest (1.18 per cent) area under tapioca. Regarding yield rate Idukki district stands significantly high with 26,880 kg/ha. The lowest yield rate of 2081 kg/ha is in Patharamthitta district.

Coconut - Area and yield (Fig 5.4)

Coconut is the first ranking crop in the State. The crop is very important for domestic and industrial uses. Kerala is the foremost among the States in exporting coconut products like coir. Kozhikode is the leading district having about 56 per cent of its total area under this crop followed by Trivandrum 40 per cent and Alleppey 36 per cent. Area under coconut is the lowest in Wayanad (2.91 per cent). Yield rate is maximum in the districts of Trichur (6264 nuts/ha), and minimum (1338 nuts/ha) in Wayanad. Coconut yield has declined considerably in recent years due to the incidence of root-wilt disease.

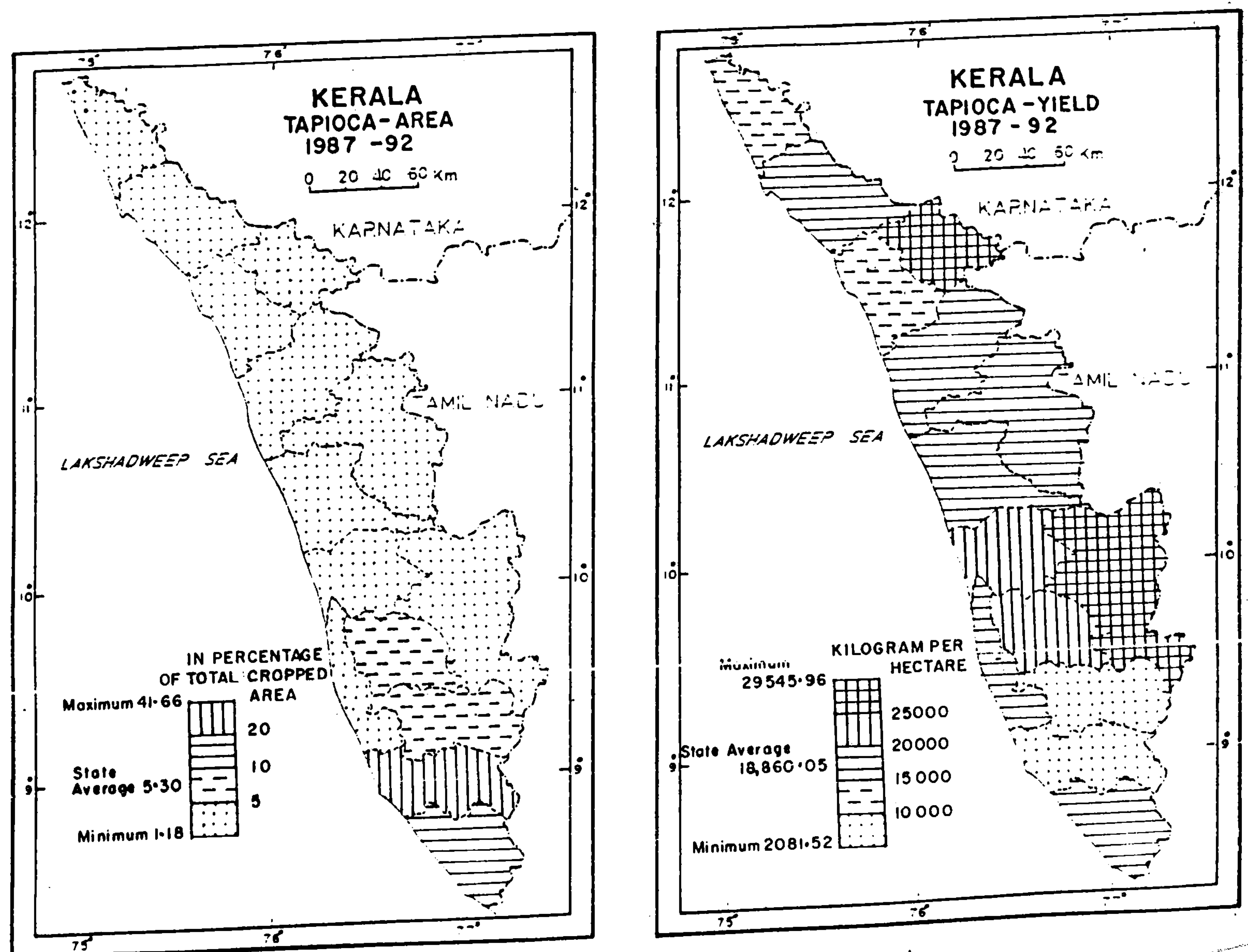


Fig 5.3: Map showing area and yield of Topioca in Kerala

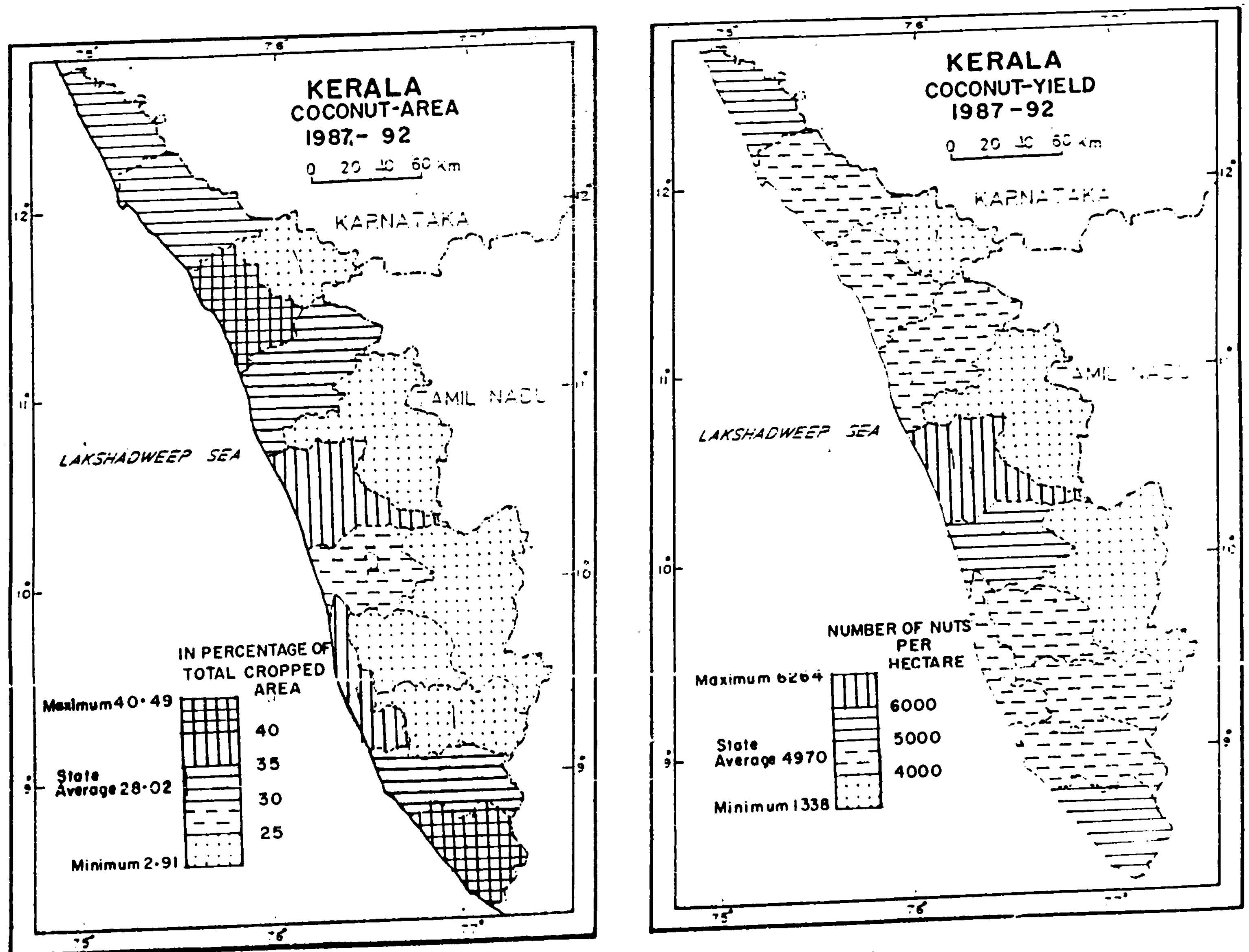


Fig 5.4: Map showing area and yield of Coconut in Kerala

Tea - Area and yield (1987-88) (Fig 5.5)

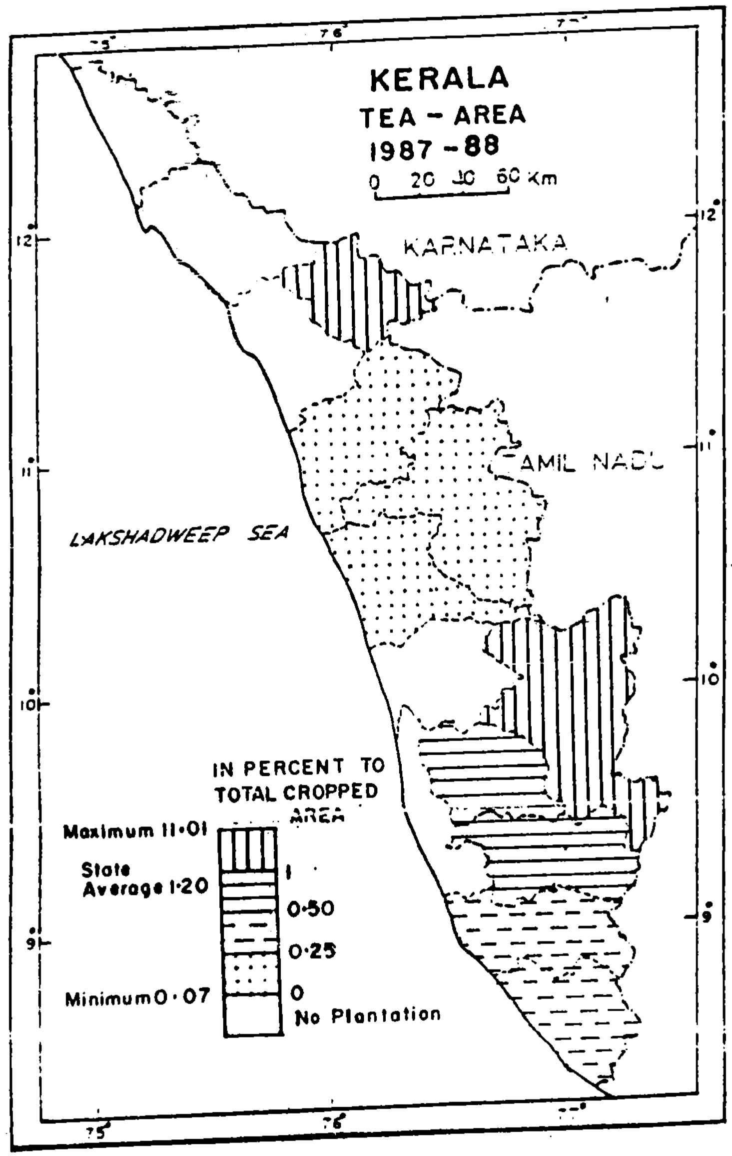
The area under tea accounts for 34,642 ha in the State which produces 51,592 tones of Tea per year. Kerala has 10 per cent of the total tea producing area in the country and contributes about 11 per cent of the total production. The importance of this crop in the State as well as in the national economy is well recognized. The district wise distribution reveals that the maximum area under tea plantation is in the district of Idukki, in the highland region. According Commodity Body estimates. The highest yield rate (39864 kg/ha) has been recorded in the district of Idukki followed by Wayanad (8776 kg/ha).

Coffee - Area and yield (Fig 5.6)

Kerala records nearly 3,58,957 ha of area under coffee plantation. It is more important than tea in the States economy, as much of it is domestically consumed. Kerala contribute 22 per cent of the total coffee production in the country. The district wise distribution shows that Wayanad has the maximum area (55,756 ha) under coffee plantation. The production of coffee is the highest in Wayanad district (15930 tones/year). The lowest production of is at the district of Alleppey (16 million tones).

Pepper - Area and Yield (Fig 5.7)

Kerala is the most important State for pepper production in the country accounting for 96 per cent of its total production. The district wise distribution shows that Idukki, Wayanad, Kollam, Pathanamthitta together account for 64% of the total pepper growing area. The maximum yield rate (431 kg/ha) is recorded in Idukki and the lowest 130 kg/ha in Palakkad.



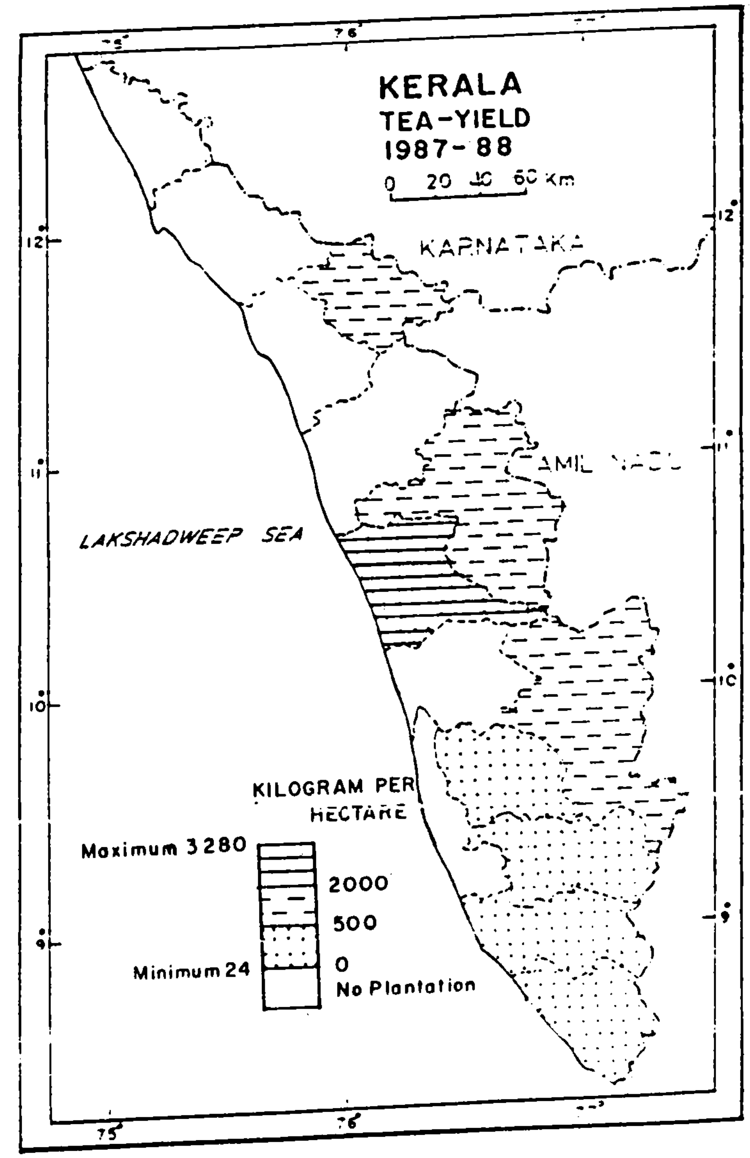


Fig 5.5: Map showing area and yield of Tea (1987-1988) in Kerala

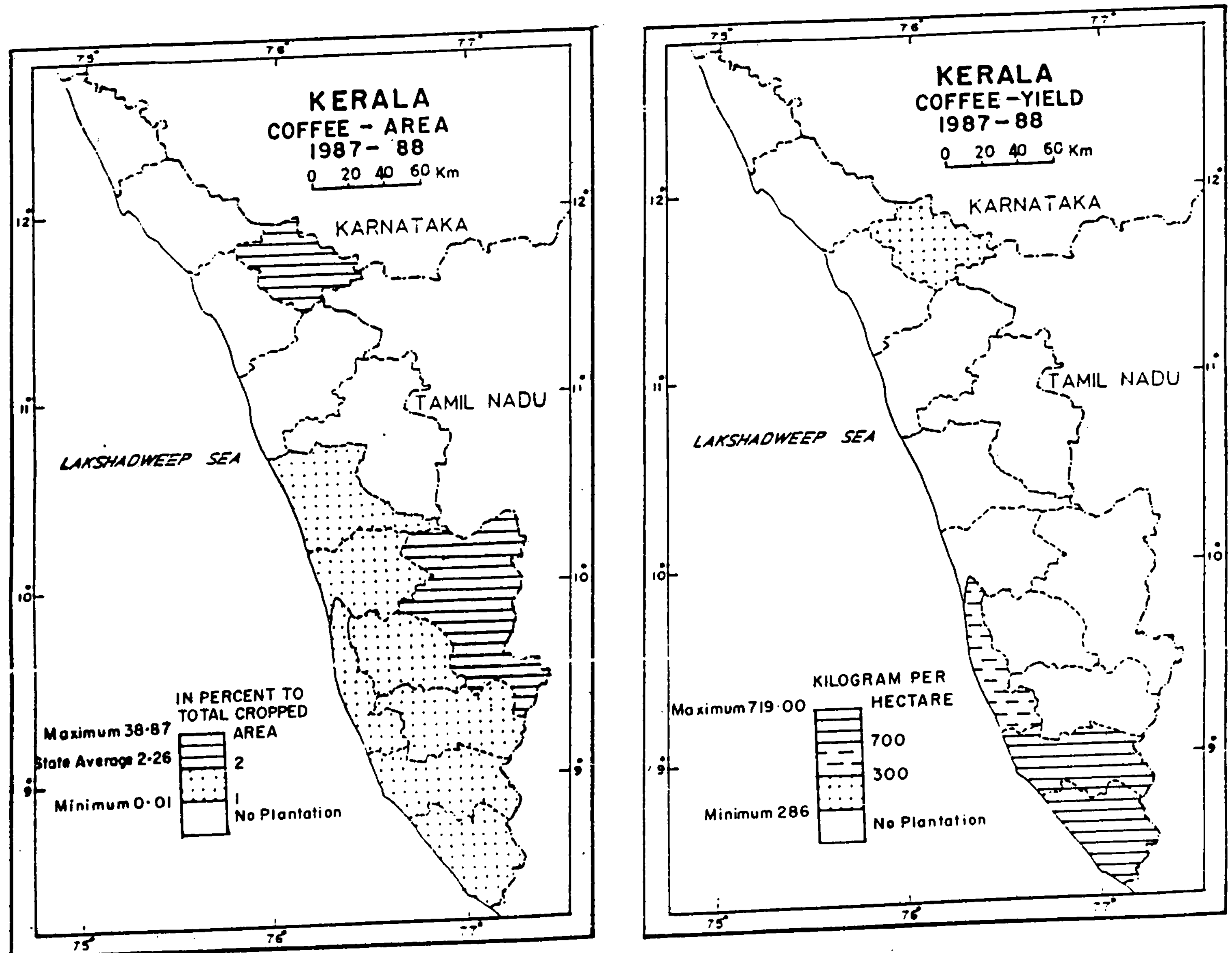


Fig 5.6: Map showing area and yield of Coffee (1987-1988) in Kerala

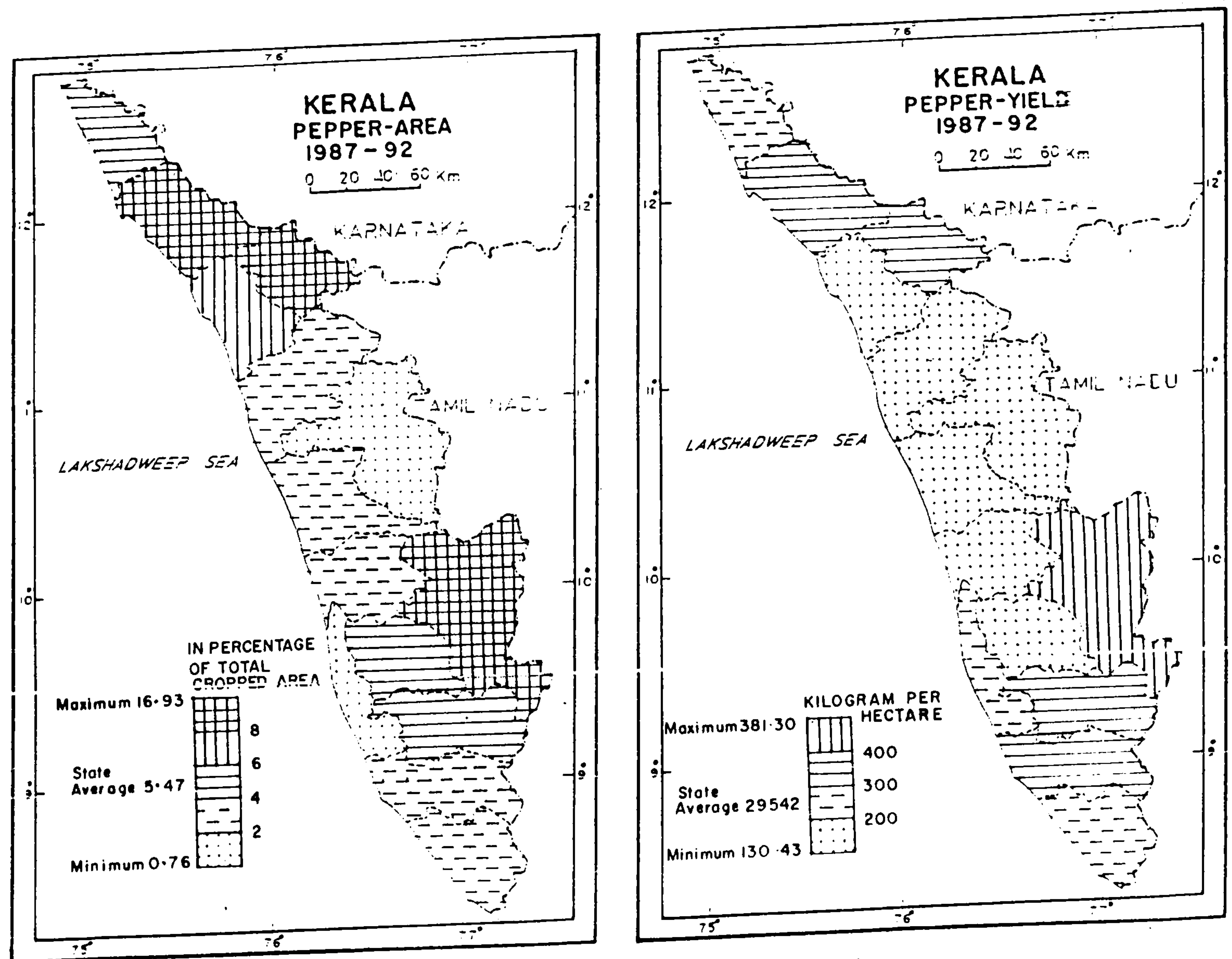


Fig 5.7: Map showing area and yield of Pepper in Kerala

Betelnut - Area and Yield (Fig 5.8)

Betelnut or arecanut is an important cash crop of the State. An area of 62,888 ha is utilised for growing betelnut while produces 12,050 million nuts annually. Fifty percent of the Betelnut producing area is concentrated in Idukki, Cannanore, Trichur Pathanamthitta districts. The highest yield rate (251,000 nuts/ha) is observed in Idukki district whereas Alleppey district records the lowest yield rate of 103000 nuts/ha.

Sesamum - Area and Yield (Fig 5.9)

Production of sesamum accounts for only 10 per cent of the domestic demand. The major constraint is the dearth of ecologically suitable area of cultivation of this crop. This crop covers 10,656 ha which is less than 1 per cent of the total cropped of the State. Alleppey, Quilon, Ernakulam and Malappuram are the main producers. The grayish Onattukara soil is most suitable for this crop. Pathanamthitta ranks highest in yield rate recording 405 kg/ha, Kasargod district marks the lowest yield rate 91 kg/ha.

Pulses - Area and Yield (Fig 5.10)

This is one of the essential food crops, the production of which in the State is far less than demand. The major constraints is the shortage of area suitable for pulses cultivation. The entire cultivation is then in small holdings. The district of Palakkad with silty clay loam soil is most suitable for this crop. Maximum area under pulses is recorded in Palakkad, Trivandrum and Cannanore district accounting for 56 per cent of the total area of pulses in the State. The yield rate is higher in Quilon district (1070 kg/ha) compared to the State average of (229 kg/ha).

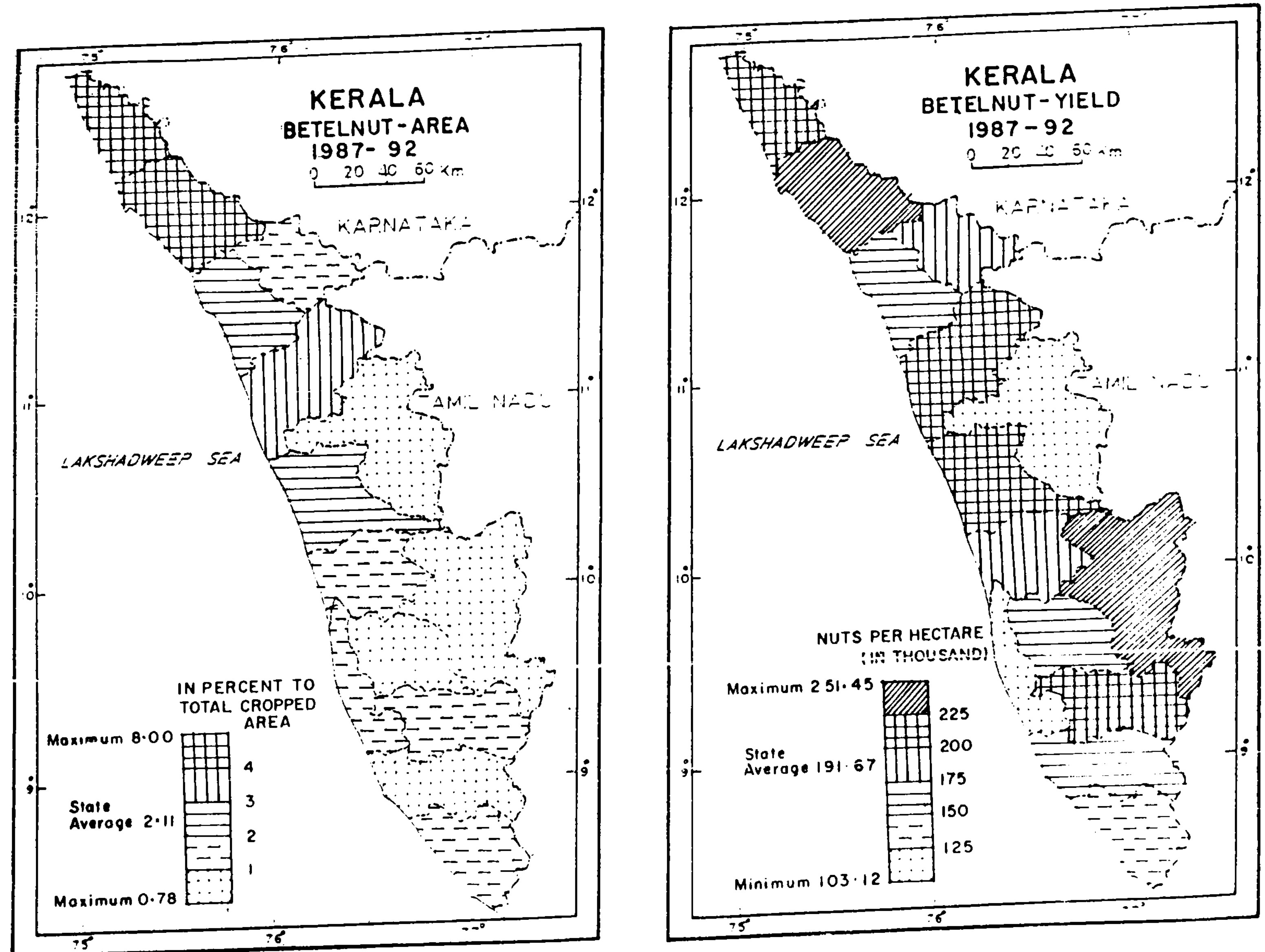
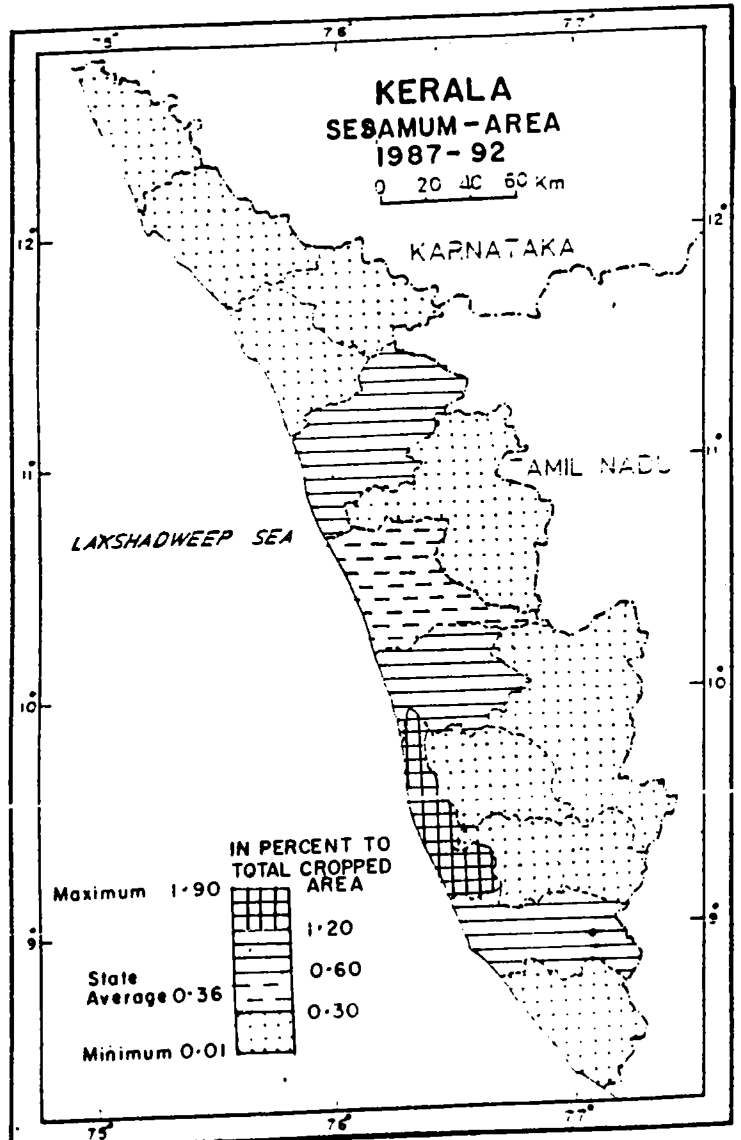


Fig 5.8: Map showing area and yield of Betelnut in Kerala



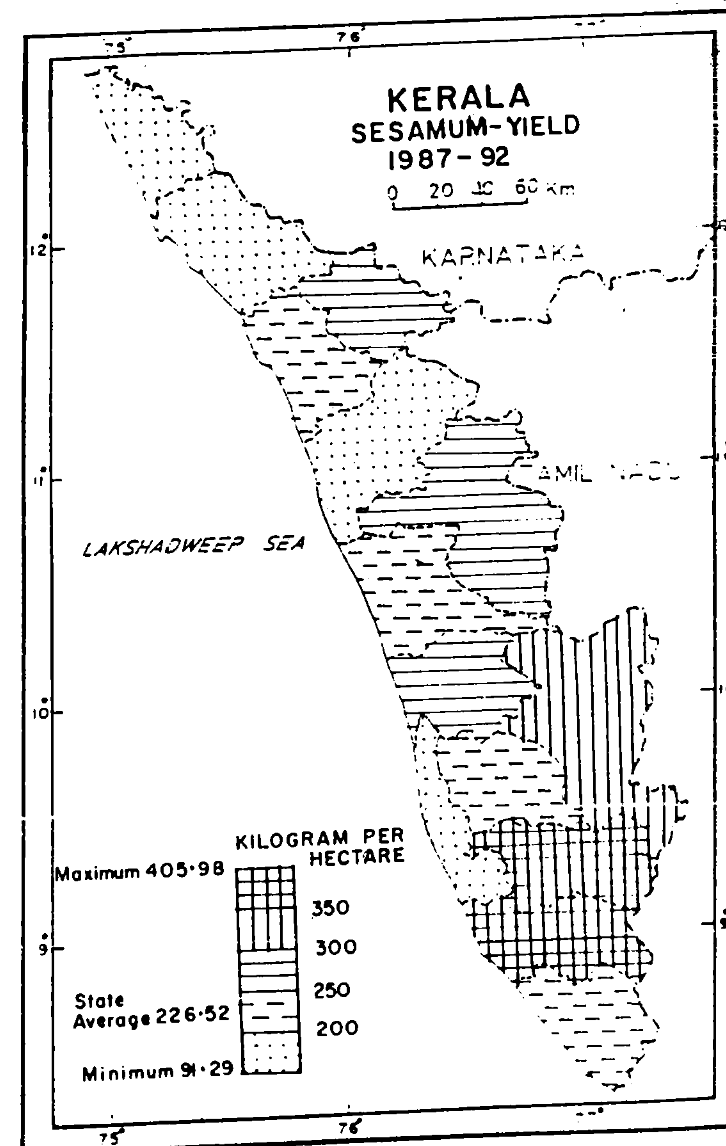
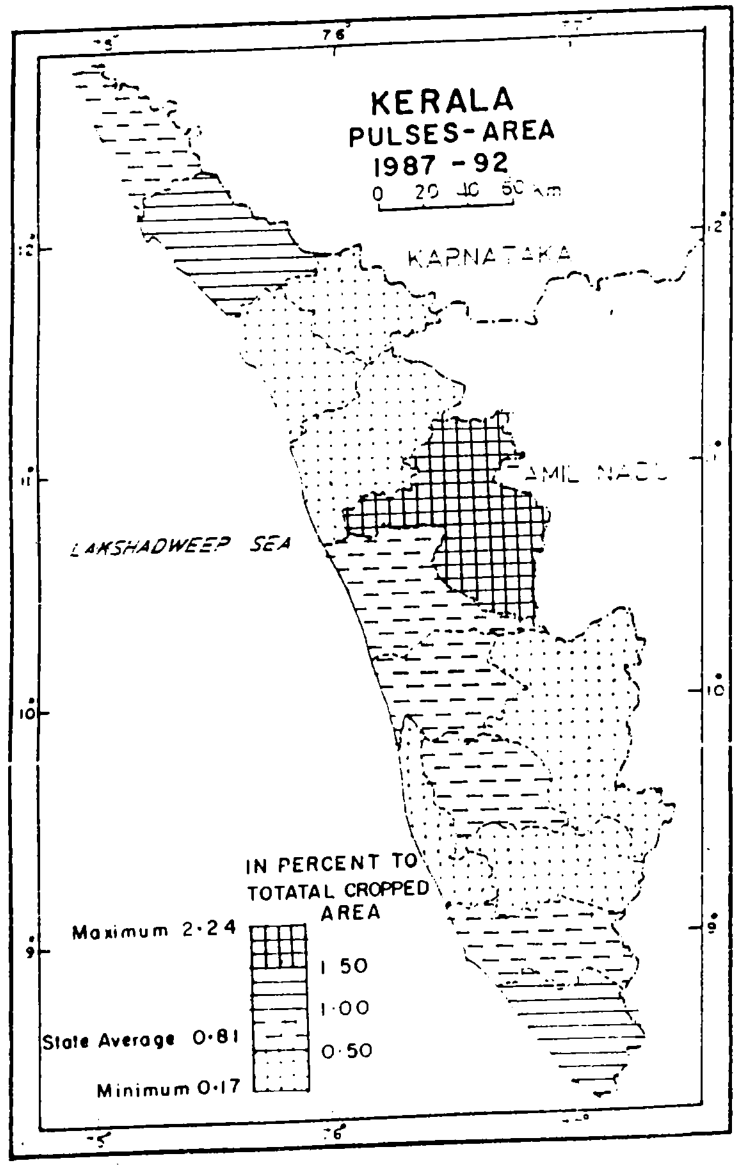


Fig 5.9: Map showing area and yield of Sesamum in Kerala



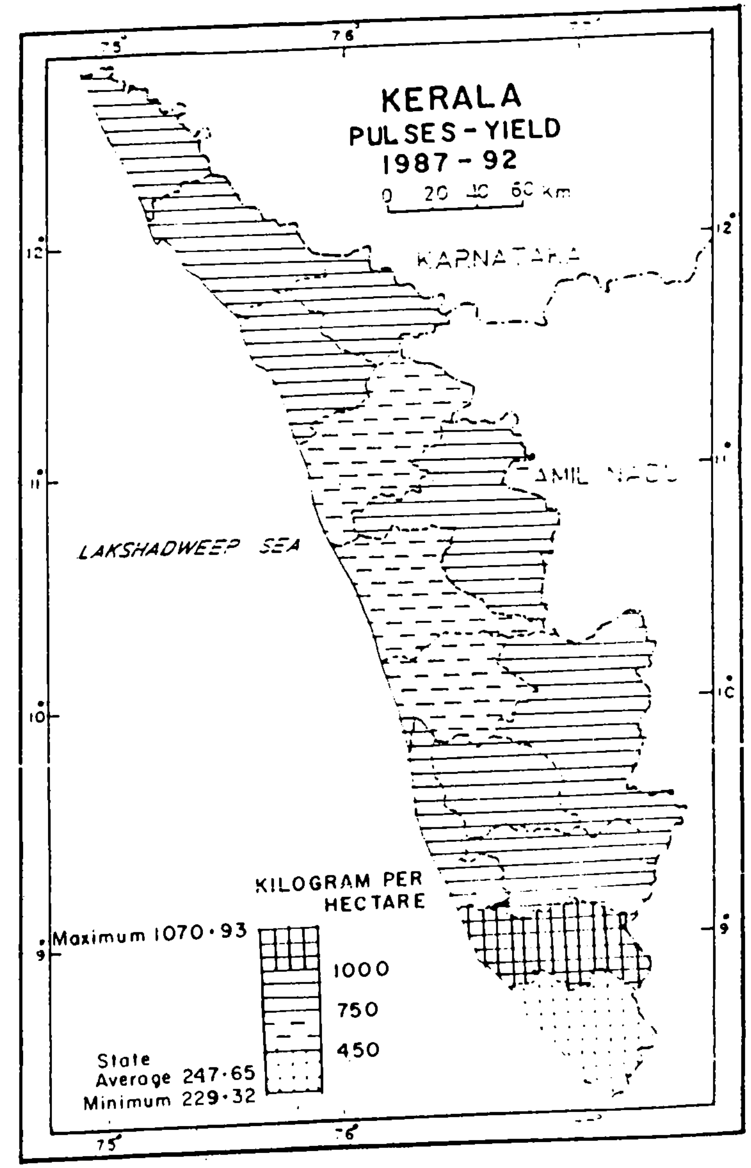


Fig 5.10: Map showing area and yield of Pulses in Kerala

Other plantain - Area and Yield (Fig 5.11)

Kerala is famous for its varieties of plantain and banana. Plantain occupies 40,510 ha or a little over 1 per cent of the total cropped area in the State. Low lying basin shape areas which are distributed through out State are most suitable for cultivation of this crop. Yield rate does not show much variation in different districts. The maximum (740 kg/ha) is in Idukki district and the minimum (2941 kg/ha) is in Trichur.

Sugar - Area and Yield (Fig 5.12)

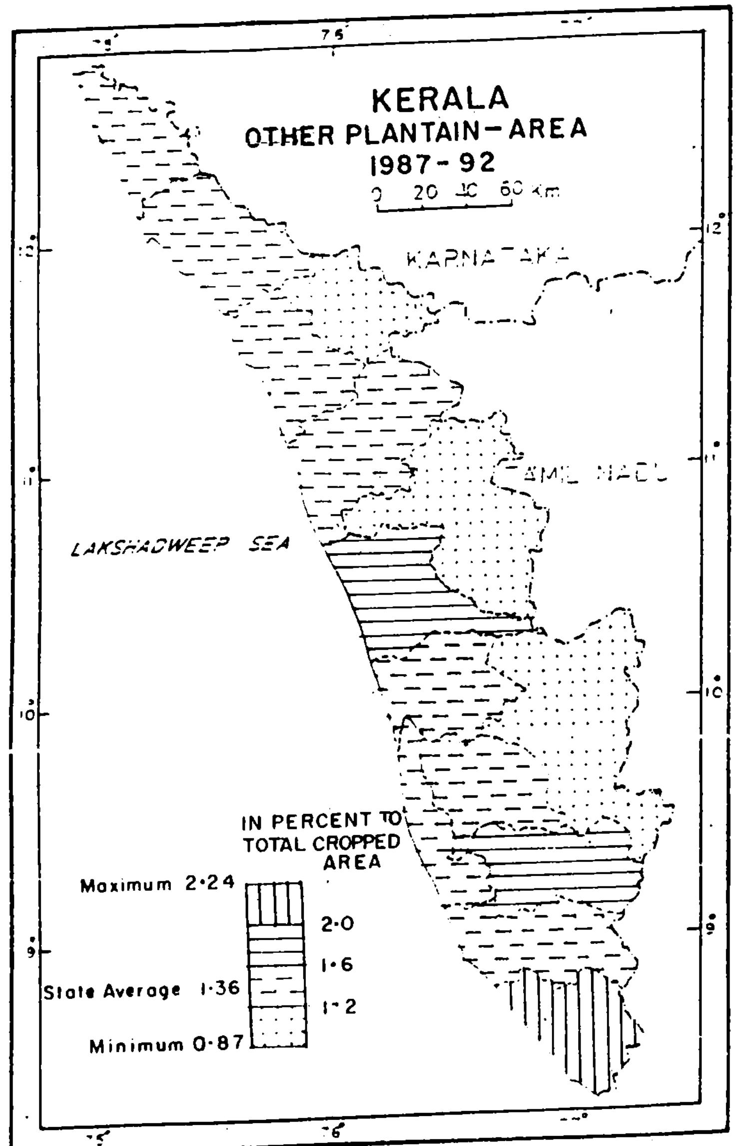
The acreage is very limited being only 1 per cent of total cropped area of the State. Palghat, Idukki, Pathanamthitta are the major producers having 80% of the State total sugar crop area. Yield rates varies from 26 kg/ha in Trivandrum to 6797 kg/ha in Pathanamthitta.

Banana - Area and Yield (Fig 5.13)

The area under this crop is almost less than 1 percent of total cropped area in all the districts. This distribution indicates that this crop withstand a wide range of agro-climatic variations. They are cultivated both as orchaid and garden crops. Yield rate varies from 11,620 kg/ha in Malappuram to 29,260 kg/ha is in Idukki district.

Rubber - Area and Yield (Fig 5.14)

This is a very important cash crop which contribute significantly to the economy of the State. Kerala contribute about 93 per cent of India's total production. Due to high market demand and environmental suitability, rubber is cultivated in almost all



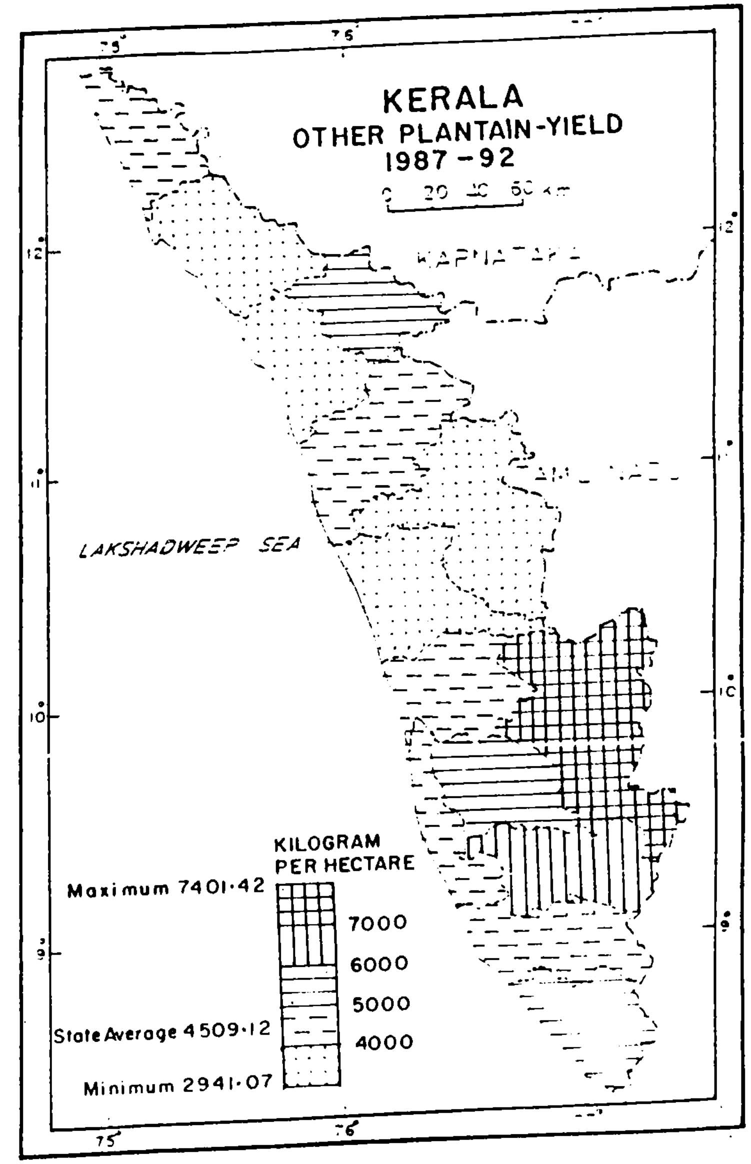


Fig 5.11: Map showing area and yield of other Plantain in Kerala

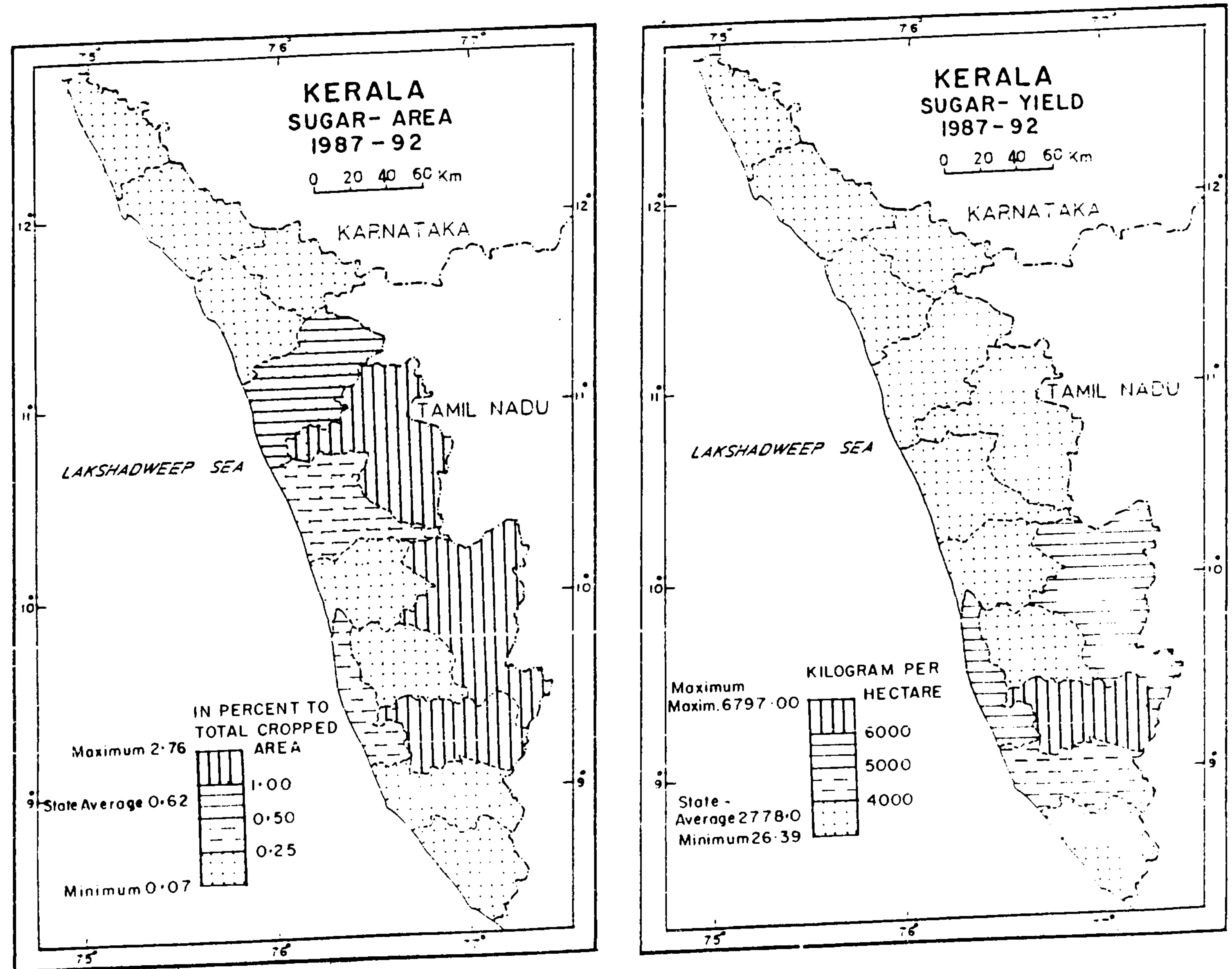
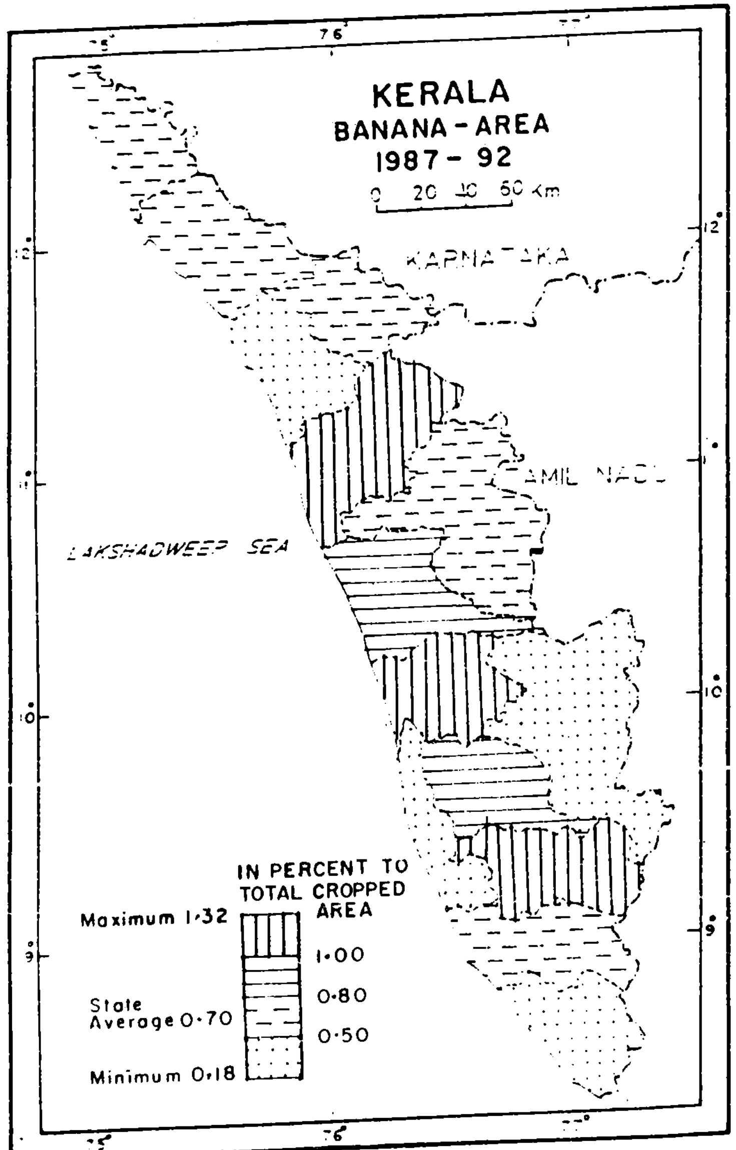


Fig 5.12: Map showing area and yield of Sugar in Kerala



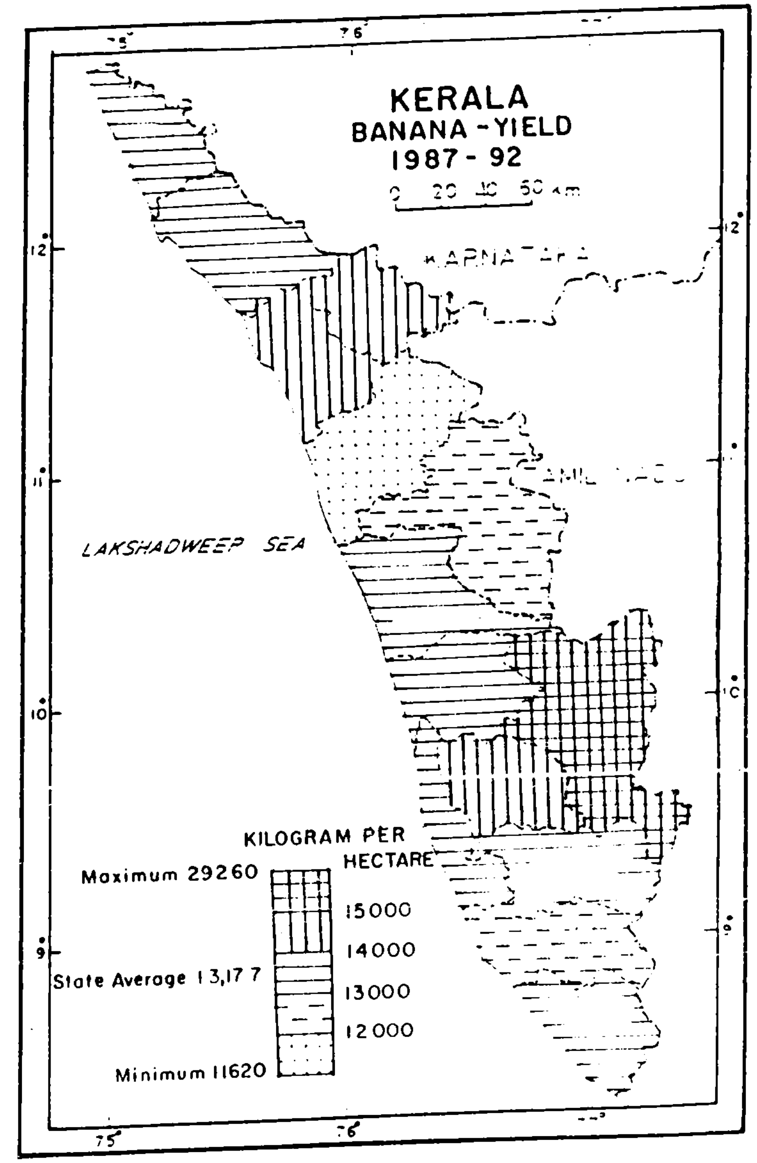


Fig 5.13: Map showing area and yield of Banana in Kerala

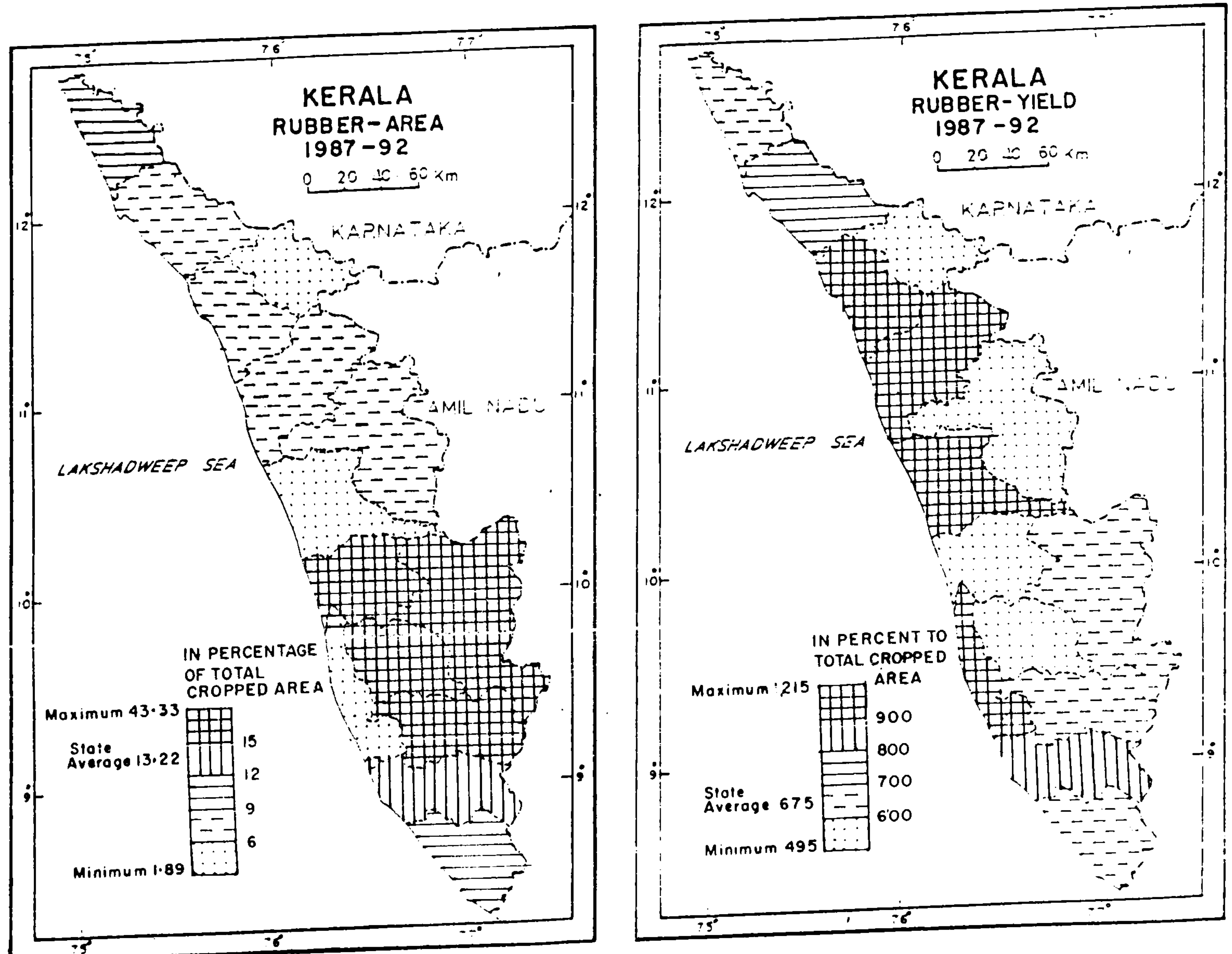


Fig 5.14: Map showing area and yield of Rubber in Kerala

possible areas except low lying flood prone areas. Nearly, 7 per cent of the total cropped area in the State comes under this crop. Maximum area under rubber cultivation is recorded (43 per cent) in Kottayam, and minimum is recorded (2 per cent) in Alleppey district. Though all the districts recorded rubber cultivation and have more than 2 per cent of their total cropped area under this crop. the leading district is Kottayam (>20 per cent). The maximum yield rate of rubber is recorded (1215 kg/ha) in Kozhikode district and minimum is recorded (495 kg/ha) in Wayanad district.

Cashew - Area and Yield (Fig. 5.15)

Area under cashew crop is maximum in Kasargod and Cannanore districts, minimum at Idukki and Kottayam districts. Yield rate is maximum in Cannanore district and minimum in Alleppey and Kottayam.

5.3 VARIATIONS IN CROPPING PATTERN

The agricultural landause pertaining to the year 1976-77 (table 5.6) has been compared to the existing landause discussed above. It is observed that certain corps have drastically reduced in their area under cultivation. Particularly, the area under rice in the State for the period 1976-77 was 29 per cent and has now come down to 19 percent. However, there is marked increase in the area under rise in Alleppey district form 13 per cent to 35 per cent. While in Palakkad it has increased from 20 per cent to 44 per cent. In other districts the area under rice decreased marginally.

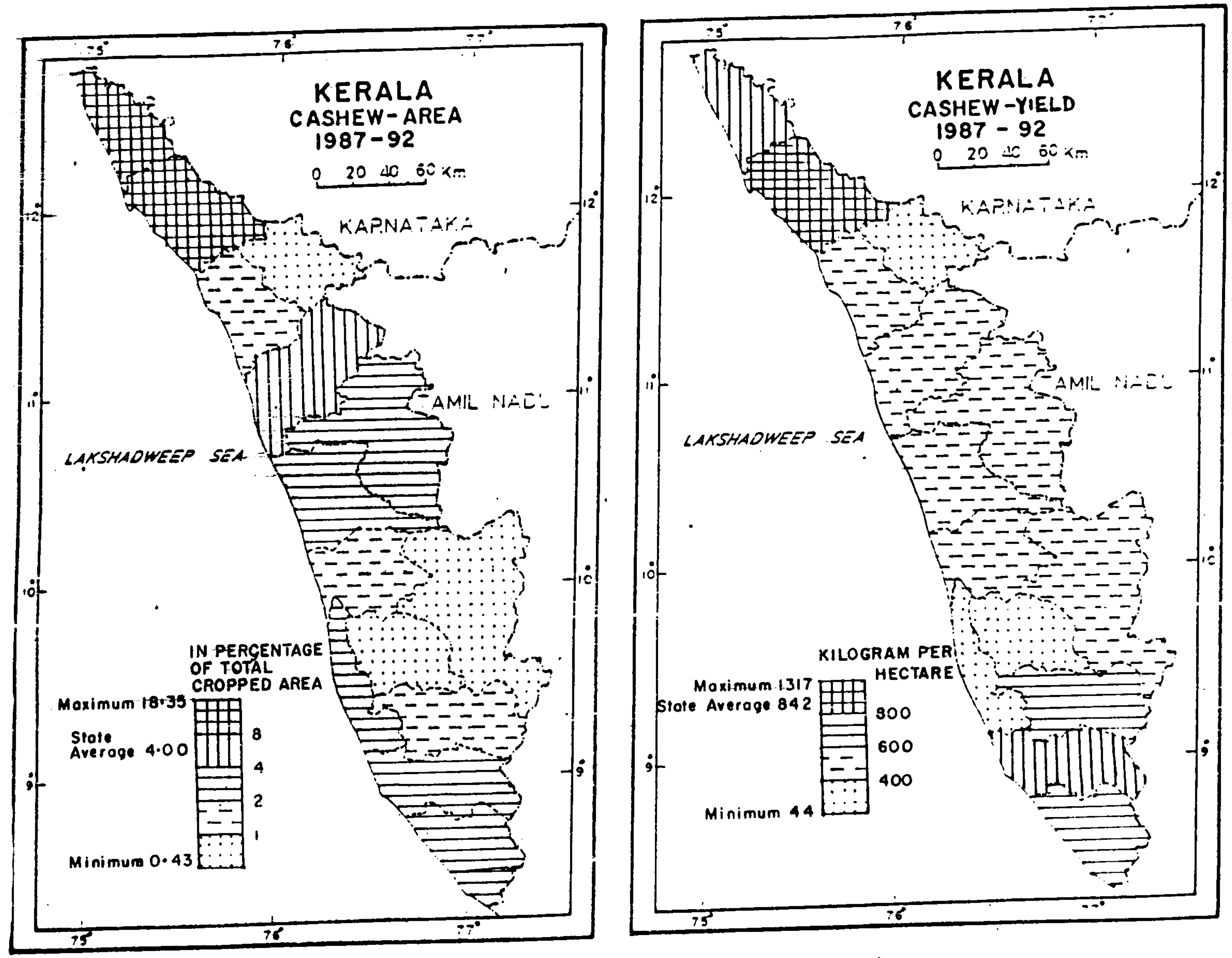


Fig 5.15: Map showing area and yield of Cashew in Kerala

Table 5.6: Per centage distribution of cropping patterns in Kerala (1976-1977).

DISTRICT	T.C.A	Rice	Pulses	Sugar	Condiments Spices	Tapioca	Fruits &Veg.	Oil Seeds	Pltn. Crops	Nonfood Crops
Trivandrum	241617	16.19	8.93	4.99	4.00	20.61	14.10	10.97	3.14	3.33
Quilon	336049	21.17	9.57	7.82	7.84	26.54	18.12	13.24	12.43	5.57
Alleppey	226393	37.97	2.23	9.95	3.41	8.87	26.42	9.73	1.35	3.41
Kottayam	258344	21.00	4.79	3.75	8.94	12.45	9.42	78.19	20.57	5.44
Idukki	157721	6.70	6.32	15.18	21.52	3.02	3.03	2.06	15.09	10.21
Ernakulam	237687	11.62	4.79	2.36	6.92	4.43	5.69	7.61	7.29	4.28
Trichur	232573	13.81	9.28	5.27	4.95	2.85	4.97	7.07	3.28	7.27
Palghat	309067	20.00	26.85	34.86	3.28	2.46	6.18	5.00	4.05	19.70
Malappuram	283237	10.70	6.62	10.05	7.10	9.07	10.89	9.39	6.19	11.86
Calicut	280222	6.05	5.08	4.66	12.24	2.64	5.81	14.36	21.98	5.15
Cannanore	370487	9.53	15.54	1.10	19.80	7.02	14.50	12.72	10.82	24.31
STATE	2933450	29.13	1.24	0.62	8.50	11.00	23.86	24.83	9.74	0.67

The area under pulses in all the districts has decreased during the study period pushing down the area under pulses in the State from 1 24 per cent to 0.82 per cent. Simultaneously, production of pulses was declining year by year (Season crop report 1987-88).

Similarly, the area under sugar has also reduced from 8228 to 8827 ha. The area under Condiments and spices in Idukki district has increased from 21 per cent to 40 per cent, whereas in Kozhikode district the area under this category has decreased from 12 per cent to 10 per cent. For the State as a whole it has increased from 8 per cent to 10 per cent.

The area under tapioca in all the districts has decreased resulting in a fall from 11 per cent to 5 per cent as a whole. Area under fruits and vegetables increased in Trichur, Idukki, Malappuram and Kozhikode districts and decreased in Trivandrum Quilon and Alleppey districts. For the State as a whole the decrease was from 23 per cent to 14 per cent.

The area under oil seeds has increased in all the districts of the State. The increase over the State was 24 per cent to 28 per cent of the total cropped area.

The under plantation crops has increased considerably in Kottayam, Idukki and Ernakulam districts. In the case of Kozhikode the area has been reduced from 10 per cent to 8 per cent. The increase in the area under the plantation crops over the State showed a raise from 9 per cent to 17 per cent.

Table 5.7: Cropping intensity in Kerala.

In percentage

DISTRICT	1976-77 T.C.A	1976-77 N.S.A	1976-77 C.I	1986-87 T.C.A	1986-87 N.S.A	1986-87 C.I	1991-92 T.C.A	1991-92 N.S.A	1991-92 C.I
Trivandrum	241670	146044	166	217605	144892	150	202255	144761	139
Quilon	336049	205671	163	220117	144581	152	218267	143338	152
Pathanamthitta	*	*	*	108287	101992	106	127563	99577	128
Alleppey	226393	148010	153	165602	101832	163	165993	105242	157
Kottayam	258344	185012	140	244180	183638	133	235741	181279	130
Idukki	157721	156499	101	199416	169551	118	204999	189107	108
Ernakulam	237687	181334	131	247415	178827	138	246720	182217	135
Trichur	232573	160082	145	214782	158338	136	211646	154774	136
Palghat	309067	220408	140	315835	217080	145	343372	217229	158
Malappuram	283237	213425	133	237165	203491	117	268971	208851	128
Calicut	280222	235165	119	199754	164694	121	213179	162840	131
Wayanad	*	*	*	148143	112777	131	176095	115956	152
Cannanore	370487	348962	106	214061	194854	110	265558	203497	130
Kasargode	*	*	*	1137952	130189	106	140757	139299	101
STATE	2933450	2200601	133	2870314	2206736	130	3021116	2247967	134

* District not formed

There is an increase in the area under other non food crops from 1 per cent to 2 per cent.

5.4 VARIATION OF CROPPING INTENSITY

The cropping intensity of a region is expressed in terms of the ratio between the total cropped area and net area sown. For the stucy of cropping intensity of the State the periods 1976-77, 1986-87 and 1991-92 have been considered in order to understand the temporal distribution of cropping intensity. It is observed that (table 5.7) the cropping intensity of the State changed from 133 per cent in 1976-77 to 130 per cent in 1986-87 and then to 134 per cent in 1991-92.

During the year 1976-77 maximum cropping intensity is recorded in Trivandrum district (166 per cent), while the minimum was in Idukki (101 per cent).

In the year 1986-87 the maximum cropping intensity was recorded in Trichur district (163 per cent), while the minimum was in Pathanamthitta district (106 per cent)

In the period 1991-92 the highest cropping intensity was in Palghat district (150 per cent) and the lowest was at Kasargod district (per cent) while the State cropping intensity was 134 per cent.

5.5. VARIATION OF CROP COMBINATION

Any study of crop landuse on regional scale must take into consideration the combinational analysis and the relative position of the crops. Such studies are fruitful in many ways; firstly they provide an adequate understanding of geography of an individual crops; secondly crop combination is in itself an integrative reality that demands definitions and distributional analysis; and lastly such regions are essential for the construction of still more complex structures of balid agricultural regions.

In this study a standard statistical procedure suggested by Weaver (1954) and modified by Doi to demarcate the crop combination regions of Kerala has been followed. This methodological part has already been discussed in chapter 2.

For the study on crop combination regions of Kerala, Doi's method has been used to demarcate the crop association regions district wise for the years (1987-92)

Table 5.8 : Crop combinations of Kerala (Doi's method)

1.	Trivandrum	O+T+F.V+P.C+R
2.	Quilon	O+T+F.V+P.C+R
3.	Pathanamthitta	P.C+O+F.V+R
4.	Kottayam	P.C+O+F.V
5.	Alleppey	O+R
6.	Ernakulam	R+O+P.C
7.	Idukki	C.S+P.C+O
8.	Trichur	O+R+F.V
9.	Palghat	R+O+F.V
10.	Malappuram	O+R+F.V
11.	Kozhikode	O+F.V+P.C
12.	Wayanad	P.C+C.S+R
13.	Cannanore	O+F.V+C.S
14.	Kasargod	O+F.V+C.S+P.C+R

R=Rice; T=Tapioca; F.V= Fruits and Vegetables; C.S=Condiments and Spices; P.C= Plantation crops; O=Oil seeds of the important crops. The following table shows the existing crop combinations in each district (Fig. 5.1 6)

It is evident that no single crop is dominating the agricultural scene of the state. The number of crops in each district varies from 2 to 5. Oil seeds and rice figure in the crop combination of all the districts. The crop combination to a major extent, depends on physico-climatic elements which transgress the district boundaries.

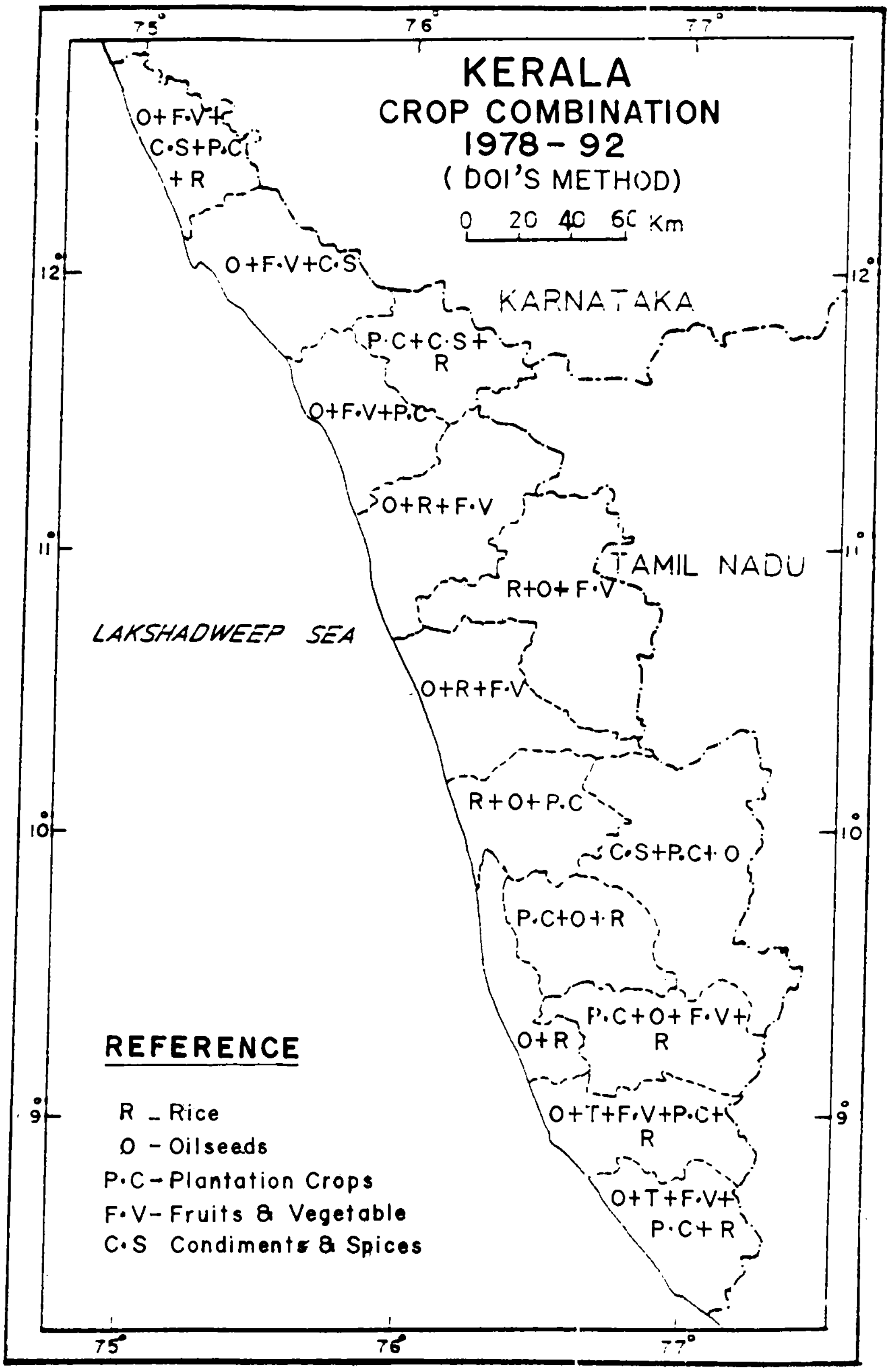
In the year 1978 crop combination regions for Kerala have been prepared (CESS, Resource Atlas, 1984) based on Weaver's method where the crop association varies from 4 to 10. The following table shows the spatial distribution of the crop combination regions of Kerala (Fig. 5.1 7).

Table 5.9 : Crop combinations of Kerala (Weaver's method)

1.	Trivandrum	O+T+R+F.V
2.	Quilon	O+T+R+F.V+P.C
3.	Kottayam	P.C+O+R+T+F.V
4.	Alleppey	R+O+F.V+T
5.	Ernakulam	R+O+F.V+P.C+C.S+T
6.	Idukki	C.S+P.C+O+R+F.V+T
7.	Trichur	R+O+F.V+P.C+C.S+T+P
8.	Palghat	R+F.V+O+N.F+T+P.C+P+S+C.S+C.M
9.	Malappuram	R+O+F.V+T
10.	Kozhikode	R+O+F.V+P.C+C.S
11.	Cannanore	O+F.V+R+C.S+P.C

R=Rice; T=Tapioca; F.V= Fruits and Vegetables; C.S=Condiments and Spices; P.C= Plantation crops; O=Oil seeds

Here the crop combinations are more since the least ranking crops are also taken into account in crop association (Weaver method). Thus the Palghat district has got the highest crop combinations (10).



KERALA
CROP COMBINATION
1978 - 92
(DOI'S METHOD)
0 20 40 60 Km
KARNATAKA
TAMIL NADU
LAKSHADWEEP SEA
O+F·V+C·S+P·C+R
O+F·V+C·S
P·C+C·S+R
O+F·V+P·C
O+R+F·V
R+O+F·V
O+R+F·V
R+O+P·C
C·S+P·C+O
P·C+O+R
P·C+O+F·V+R
O+R
O+T+F·V+P·C+R
O+T+F·V+P·C+R
REFERENCE
R _ Rice
O - Oilseeds
P·C - Plantation Crops
F·V - Fruits & Vegetable
C·S Condiments & Spices
75°
76°
77°
12°
11°
10°
9°

FIG. 5.16

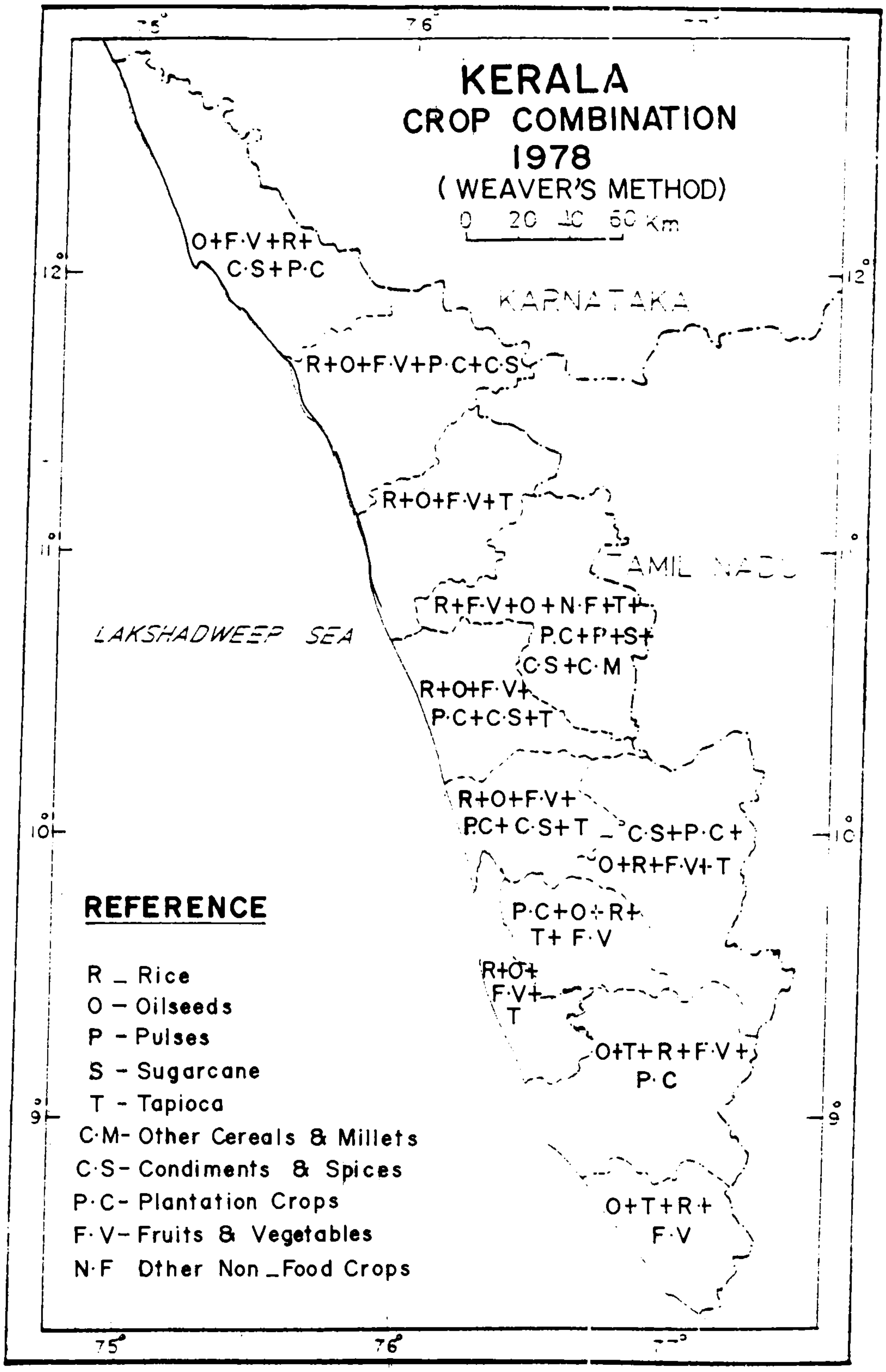

KERALA
CROP COMBINATION
1978
(WEAVER'S METHOD)
0 20 40 60 Km
KARNATAKA
TAMIL NADU
LAKSHADWEEP SEA
O+F·V+R+ C·S+P·C
R+O+F·V+P·C+C·S
R+O+F·V+T
R+F·V+O+N·F+T+ P.C+P+S+ C·S+C·M
R+O+F·V+ P·C+C·S+T
R+O+F·V+ P.C+C·S+T
C·S+P·C+ O+R+F·V+T
P·C+O+R+ T+F·V
R+O+ F·V+ T
O+T+R+F·V+ P·C
O+T+R+ F·V
REFERENCE
R – Rice
O – Oilseeds
P – Pulses
S – Sugarcane
T – Tapioca
C·M – Other Cereals & Millets
C·S – Condiments & Spices
P·C – Plantation Crops
F·V – Fruits & Vegetables
N·F Other Non–Food Crops

FIG. 5.17

From the comparison of the crop combinations during the two periods a reduction in the area under paddy is indicated . In the year 1978 half of the state (6 districts) has occupied by rice cultivation and ranked first; where as in the year 1987-92 area under oil seeds have occupied the positions of first rank and the area under rice took the second position. As explained in the case of cropping intensity crop combinations are also influenced by the physico-climatic features of the region

Thus the study of the crop combinations regions of Kerala constitutes a significant aspect of agricultural studies, as it provides a good basis for planning for the future of the sustainable development of the state.

In the previous chapter the impact of climatic shifts caused by rainfall variability on the water budgets of the different states was discussed. It was seen that during some years deficient rainfall led to the occurrences of droughts of different magnitudes. The agro-climatic features being a dominant factor in determining the success or otherwise of agriculture over the state would also seem to play an important part in the choice of the cropping pattern adopted during years of large shifts in climatic parameters. Though it has not been possible to segregate the exact influence of the inter annual variability on the cropping pattern from other factors, it is surmised that they play an important role. Future work in this regard to determine finite relationships between climatic shifts and temporal variations of agricultural landuse are necessary.

CHAPTER 6

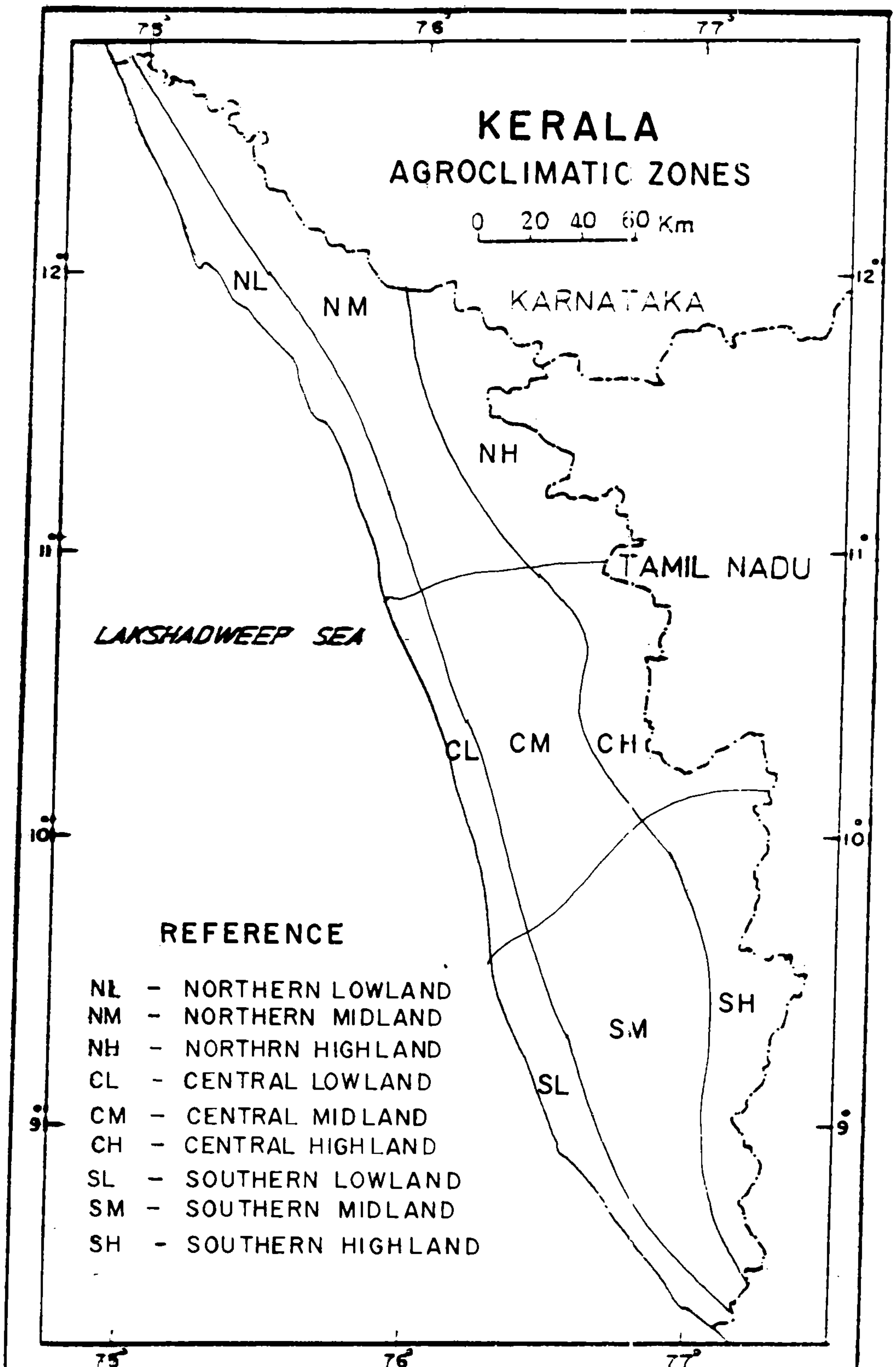
AGROCLIMATIC ZONES

6.1 INTRODUCTION

According to the FAO (1983), an Agroclimatic zone is a land unit in terms of major climate and is climatically suitable for a certain range of crops and clivations within such a zone. Local conditions may result in several subsystems each with its own climatic conditions. An agroclimatic zone, in fact, has a greater degree of commodity of the relevant basic features of soils, topography, climate and water resources. This fact form the basis for delineating the both agroclimatic regions presented here.

Superimposition of the spatial distribution maps depicting the different parameters has resulted in dividing State into nine agrolcimatic zones (Fig 6.1). The nine zones are

1. Northern low land
2. Northern midland
3. Northern highland
4. Central low land
5. Central midland
6. Central highland
7. Southern lowland



75°
76°
77°
KERALA
AGROCLIMATIC ZONES
0 20 40 60 Km
12°
11°
10°
9°
KARNATAKA
TAMIL NADU
LAKSHADWEEP SEA
NL
NM
NH
CL
CM
CH
SL
SM
SH
REFERENCE
NL - NORTHERN LOWLAND
NM - NORTHERN MIDLAND
NH - NORTHRN HIGHLAND
CL - CENTRAL LOWLAND
CM - CENTRAL MIDLAND
CH - CENTRAL HIGHLAND
SL - SOUTHERN LOWLAND
SM - SOUTHERN MIDLAND
SH - SOUTHERN HIGHLAND

FIG. 6.1

8. Southern midland

9. Southern highland

A brief description of each zone is presented here.

Northern low land

This zone consists of the western low land parts of the four northern districts of ~~KASG, CNR, K2N and SWM~~ Kasaragod, Cannanore, Kozhikode and Malappuram. This zone receives heavy rain during south west monsoon season and moderate RF during North East Monsoon. However, the during the months of December - May a prolonged dryness prevailed. During this period crops to experience the significant moisture stress. That affects their growth, development of yields. On the other hand, heavy rains during the peak south west monsoon months of June and July also pose a hazard at times due to water logging. In the coastal strip of Malappuram district, known as the kole lands salinity, acidity and poor drainage are characteristic features. Generally only one paddy crop is possible in the kole areas. As they are submerged during the other periods. In the entire zone coconut and rice are the principle crops.

Northern mid land

This zone occupies the midland parts of the four northern districts of Kasargod, Cannanore, Kozhicode and Malappuram. As in the previous case this zone II is endowed with plentiful rain fall during the monsoon but suffers from dryness for four to five months from December onwards. The midland region however gets more rainfall than the lowland regions. The soil in the zone is mainly lateritic. Rice, coconut, arecanut, pepper are the important crops.

Northern high land

This zone consists of the western parts of Malappuram, major part of Waynad and the extreme south east portions of Cannanore districts. The region receives heavy rain fall from June to September, and moderate rain fall in the pre-monsoon and the post monsoon months. The crops have to face the moisture stress from December to March. The soil type is forest loam characteristics by a surface layer of humus and other organic matter. Coffee is the most widely cultivated crop while pepper, cardamom, ginger and tea are the other plantation crops.

Central low land

This zone consists of the coastal belts of Trichur and Ernakulam districts. This zone is characterised by heavy rain fall during the south west monsoon season and moderate rain fall during the north east monsoon. A dry spell of six months from December to May is generally observed. The coastal strip of Trissur district is an extensive of the Kole area of the contiguous Malappuram district. As was already mentioned, acidity and salinity are characteristic of this region.

The marshy areas of Ernakulam district where salt water intrusion is a major problem are called Pokkali areas. The soils are acidic and saline only one rice crop is raised in these areas and the land is submerged during the monsoon months and frequently disturbed by seawater inundation due to tidal currents. Coconut and rice are the principal crops. In recent times prawn culture is also a prominent occupation.

Central mid land

This zone consists of mid land parts of Palghat, Trichur and Ernakulam districts. The rain fall pattern is similar to the previous zone. Soil type is mainly laterite and rice is the major crop of the region. Coconut and the arecanut are the other important crop.

Central high land

This zone consists of the high land regions of Palakkad and the northern most portions of Idukki districts. In this zone the main rainfall period is the south west monsoon. Forest loam and laterites are the main types of soils.

Southern low land

The coastal low lands of Trivandrum, Quilon, Alleppey districts form this zone. In this zone too the south west monsoon is dominant source of rainfall. In addition, north east monsoon is also significant. However, the annual average rain fall is lower than all the zones discussed above. The low lying lands and the backwater systems comprise the Kuttanad area and are interspersed with lakes. Lagoons and marshes. The main feature of this area is the flooding during the monsoon and the periodic seawater intrusion.

Southern mid land

The zone comprises the midland areas of Trivandrum, Quilon, Pathanamthitta, Alleppey and Ernakulam. The soils are mainly lateritic and the major crops are rice, coconut, pepper, cashew, rubber and arecanut.

Southern high land

This zone comprises of the high ranges of all the southern districts. Agriculture and animal husbandry are the main occupation of the people here. Very heavy rain fall occurs during south west monsoon period while it is very low between December to March. The highest mean rain fall of 507 cm is observed in Neriamanagalam. Strangely, the lowest rain fall in Kerala (60 cm) is observed at Chinnar, a station 35 km away on the boundary of Idukky district. Mainly two types of soils, forest loam and laterite are observed supporting plantation crops such as Tea, rubber, coconut arecanut and coffee.

6.2 OPTIMUM LANDUSE PATTERN FOR KERALA

After the delineation of agroclimatic zone in the previous section, an optimum landuse pattern for the State is proposed here. In order to arrive at the best possible landuse pattern the various maps of soil, physiography and geomorphology have been superimposed on the map depicting the agroclimatic zones. This overlay technique ensures that all the available physico-climatic parameters are considered in suggesting the most suitable landuse pattern for the State. As our main focus is an agricultural land use areas suitable for agriculture have been demarcated and presented in figure 6.2.

Based on the superimposition of the overlays of climate, vegetation, geomorphology, soil and physiography, a composite map has been derived (general trend of agroclimatic map). It is observed that the northern lowland consists of mixed

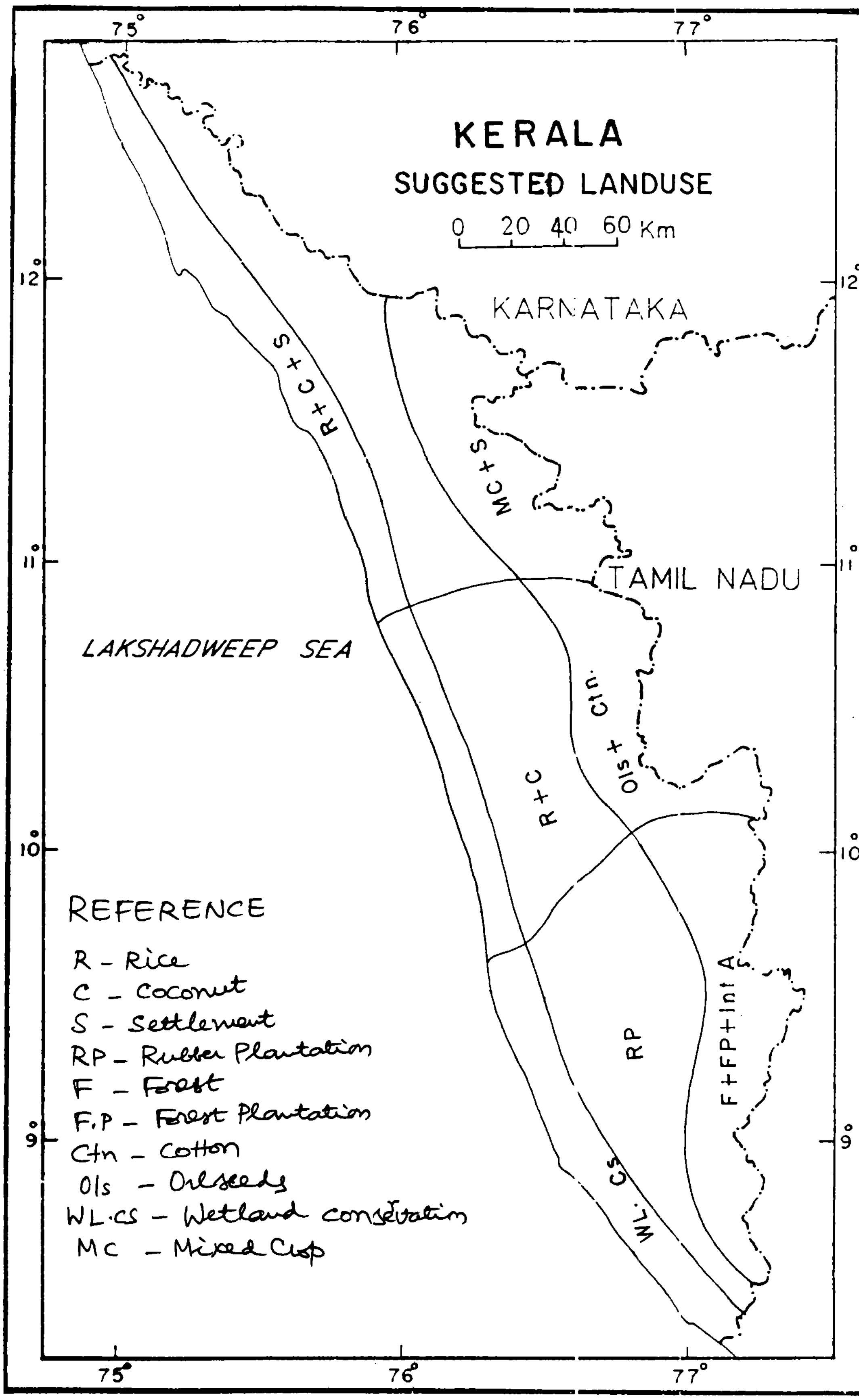

KERALA
SUGGESTED LANDUSE
0 20 40 60 Km
75°
76°
77°
12°
11°
10°
9°
KARNATAKA
TAMIL NADU
LAKSHADWEEP SEA
R + C + S
MC + S
R + C
Ols + Ctn.
RP
F + FP + Int A
WL. CS
REFERENCE
R - Rice
C - Coconut
S - Settlement
RP - Rubber Plantation
F - Forest
F.P - Forest Plantation
Ctn - Cotton
Ols - Oilseeds
WL.CS - Wetland conservation
MC - Mixed Crop

FIG. 6.2

crop like rice and coconut. In the northern midland region plantation and rubber are the main crop cultivated. In the northern highland region forest, other tree crops and pepper are the important ones found in this area. In the central lowland region rice and mixed crops are found. In the central midland region rubber and coconut are the other major crops. The central highland region is occupied with oil seeds and cotton. In the southern lowland region rice, coconut and mixed crops are found. The southern midland region consists of rubber plantation and mixed crop. The southern highland region consists of mixed tree crops and cardamon plantation. It is also important and necessary that the areas suitable for agricultural landuse are further studied in detail to evolve the optimum crop combination and cropping patterns so that the agricultural potentials of the areas are effectively harnessed. The physioclimatic feature of the areas suitable for agriculture have been examined in relation to the optimum physical requirements of the various crops in the different seasons. Such a procedure helps to suggest the most appropriate cropping patterns over the State, so that sustainable agriculture can be developed. Using this approach, most suitable land use pattern is suggested in the following,.

6.3 SUGGESTED CHANGES IN LANDUSE PATTERN FOR KERALA STATE

In order to increase the area under cultivation, it is essential to identify the waste lands, distributed through out Kerala State. For example the hard crust laterite formation that occupy more areas in the eastern part of the Cannanore and Kasargod district of Kerala could be exploited in a rational manner so as to cultivate crops that can withstands some aridity conditions. The laterite formation in the Northern part of

Kerala will be of immense help for the farmers to increase the cultivable area considerably.

Reclamation of the wetlands of Kerala is yet another approach to bring the marginal land under cultivation. Best suitable crops to be cultivated in reclaimed wet lands may be coconut, rubber etc. In some areas, tapioca is grown as pure crop, where some crop may be added as an inter crop in order to achieve maximum use of the land without affecting the environment.

Pulse varieties, such as cowpea, horsegram etc or oil seeds such as sesamum, ground nut etc can be intercropped with tapioca.

Nendran and red banana are high value crops widely grown as a pure crop in dry lands. Some suitable crops that can withstand dry period may be identified and suitable crop may be cultivated.

Identification of suitable intercrops for the partially shredded conditions in coconut gardens may be done in order to optimise the agriculture. Paddy fields remain fallow in many locations after harvest of the second crop of paddy. Short duration pulse varieties suitable for summer rise fallows may be identified.

Drought tolerant high yielding or improved varieties of vegetables suitable for fallow cropping may be attempted.

The interspace between coconut palms, can be utilised for growing pulses and oil seeds in addition to tapioca, banana and cocoa. Suitable shade tolerant varieties of pulses, oil seeds, rice and fodder had to be evolved.

By providing better irrigation facilities, third crop can be cultivated. The high cost of cultivation and comparatively low return on rice now a days had adversely affected both area and productivity of paddy.

Proper utilisation of cashew apple now being wasted, can generate 50% more income to the farmer.

Arecanut production can be improved by adopting proper management practices including irrigation.

It is expected that the above suggestions for the optimum landuse pattern suggested after an in depth study of all the important physiographic and agroclimatic features would be a positive step forward in developing the agricultural economy of the State.

CHAPTER 7

SUMMARY AND CONCLUSIONS

The detailed agroclimatic studies of Kerala State in relation to cropping patterns in this investigation has projected the rich diversity of the various physicoclimatic features which significantly influence the climate vegetation and the land use of the region. The most conspicuous features of the climate of the State is the rich abundance of water resources in the State due to the plentiful monsoon rains. However, the vagaries of the monsoon - the onset, active and weak phases, spatial and temporal variations and the withdrawal are all very complex.

For a State such as Kerala, which depends to a great extent on its agriculture for its welfare a detailed knowledge of the Agricultural potential of the region in relation to the climatology of the area is an essential requirement in agricultural planning. In recent decades the increasing population and the resultant higher demands for food have necessitated for optimal exploitation of the available natural resources, in particular, land and water. As the eastern boundary of Kerala is fully flanked by the Western Ghats, the entire State is under the dominant influence of its orography. This results in heavy monsoon rains and large water surplus during a part of the year. This feature combined with the variety of soil types, vegetation classes and geomorphological features result in a diversity of landuse patterns.

The economic progress for the State is largely linked to the exploitation of its agricultural potential which intern is influenced by the Agroclimatology of the region. Therefore a detailed study of the agroclimatology of the State is prerequisite for developmental planning of the region so that optimum utilisation of the available land is achieved. With this in view the present investigation attempts to apply agroclimatic information in landuse planning.

The thesis consists of seven chapters with a general introduction as the first one where the purpose and scope of the study are given. The first section of the 2nd chapter introduces the subject of agroclimatology and reviews the available literature in the field. In particular the application of agroclimatology in landuse planning is reviewed. In the 2nd section of this chapter the basic concepts of water balance and its applications are presented. The 3rd section consists of a description of the methods employed in the study and the data used.

The third chapter consists of a detailed discussion of all the important physicoclimatic features of Kerala State. This includes the location and extent, physiogrpahy, drainage, soil types slope, hydrogeology and vegetation over the State. An overview of the agroclimatology of Kerala forms the first section of the chapter four. This includes details about temperature, seasonal and annual distributions of rainfall over the State. The distribution of important water balance parameters such as PET, AE, WD and WS have also been discussed to point a broad picture of the agroclimatic background of the State. The second section of the chapter presents a detailed analysis of the inter annual variability of the water budget elements of the State computed using the models of Thornthwaite (1948), Thornthwaite and Mather (1955). This study includes analysis of the climatic shifts and a study of the droughts and aridity experienced over the State. A critical study of the comparative values of he water balance elements in the years of extreme climatic shifts in relation to the normal values has also been made. The salient results of the study are as follows:

Kerala receives the highest annual rain fall among all Indian States - about 300 cm which is about three times the average rain fall of India. There are two pockets of very heavy rain fall in the State, one in the south and the other in the north, having average rain fall of almost 500 cm. The highest mean rain fall is recorded at Neriamangalam (507 cm) and the lowest at Chinnar (60 cm). An interesting feature to be noted is that these stations are only 35 km apart.

The seasonal contributions to the average rain fall are 1%, 15%, 66% and 18% for the winter, pre-monsoon, monsoon and post-monsoon seasons respectively. Stations in the southern parts have their highest rain fall in June but in the northern parts the maximum occurs in July.

Isolines of PET are nearly parallel to the Western Ghats but there exists a few pockets of low annual values (< 90 cm). Correspond to hill stations. Average annual PE for the State is 160 cm 15% of which is in winter, 29% in pre monsoon, 32% in monsoon and 24% in post monsoon seasons. Annual and seasonal PE distributions are more uniform compared to precipitation distributions and important factor that determines the water balance of the State.

The mean annual AE distribution pattern resembles that of PE. However, during winter and pre-monsoon the distribution pattern are quite different. The non-uniform distribution of rain fall through the years causes seasonal water deficits ranging from 25 to 35 cm over the State. Seasonal deficits exist during on pre-monsoon and winter months. The annual water surpluses are observed during the south west monsoon and post monsoon seasons. They vary from 50 cm in Trivandrum district to 200 cm over Kasargod. Nariamangalam has a surplus of 358 cm while Chinnar does not register any. During winter season no station has any surplus. Almost all stations, except those in the southern heavy rain fall pocket, does not have any surplus during pre-monsoon season too. About 85% of surplus is during the monsoon month. Though the monsoon rain fall contributes only 66% to the annual total.

Studies of climatic shifts over the State show that this moisture regime of different areas and the State undergo wild fluctuations both in the drier and wetter directions. Very often the shifts cause the climatic regimes to more into more humid or less humid classes. As most of the station in the State belongs to the humid and perhumid categories, shifts in the wetter directions are not ecologically significant. In such humid climates it is the shifts into the drier categories because of deficient rain fall that is more critical in influencing the agricultural land use.

Rainfall deficiencies generally result in drought conditions of different severities. The drought climatology of different studied and present. Drought years have been delineated using the march of aridity index (Ia) at each station. A detailed analysis of the number and categories of the drought years at deferent stations reveals no evidence of any spatial coherence. In other words droughts do not always occur at the same time or with the same intensity in different parts of the State. Expectedly disastrous droughts were least common while moderate croughts here most frequent.

A comparison of the years in which droughts occurred at various stations and the years in which there were climate shifts of significant magnitude reveals interesting facts. During many of the years when the climate shifted to over side stations experienced droughts of one or the other categories. However, during some years many stations did not experience droughts even though shifts in the climate shifted to the drier classes were observed. There have also been occasions when even severe or disastrous droughts have been observed where there have increases in the moisture index (Im) values (shifts in the wetter direction). At some stations droughts have occurred even when there was no perceptible climatic shift. For example Peermade did not experience any climatic shifts but was affected by as many as 28 droughts. These results highlight the great ecological importance of optimum (appropriate) rain fall distribution than of rain fall totals. It is possible for the crops or the vegetation to experience droughts during certain period of the years even when there is excessive rainfall during other period.

The first section of the fifth chapter presents the existing landuse pattern over the State. In addition, the temporal variation in 1960-61 has also been discussed. The second section focuses on the spatio temporal variations of the agricultural landuse. The existing cropping pattern is discussed in detail by projecting the cropped area and yields of 14 selected crops which cover about 87% of the total cropped area. Further more the existing pattern has been compared to the pattern observed in the y ear 1976-77 in order to project the variation with time. The main finding of this study has been the production of the area under rice in the State from 29% to 19% of the total cropped area. Increase in the area under rice was, however, noted in Alleppey and Palghat districts. Similarly the area under pulses and sugar and tapioca decreased while the areas under oilseeds plantation crops and non-food crops showed an increase.

In the same manner the existing crop combination has been discussed in relation to the crop combination pertaining to the year (1978). From the analysis it is evident that no single crop is dominating the agricultural scene of the State. The number of crops varies from 2 to 5.

In the last part of this section are the variations in cropping intensity of the State for the 15 years has been discussed.

Delineation of the different agroclimatic zones of the Kerala State has been done by superposing the relevant maps of soil, topography and geomorphology with the appropriate agroclimatic maps of potential evapotranspiration, rain fall, water deficit and water surplus. Such a procedure has resulted in classifying the States into 9 agroclimatic zones.

The next section attempts to suggest an optimum landuse pattern for the State by overlaying physiographic map on the maps depicting agroclimatic zones. As a first steps the nine zones are sub divided into agricultural and nonagricultural areas. The area suitable for agriculture have been further analysed in detail to evolve the most suitable cropping pattern and crop combination. For this, the physioclimatic features of the different areas had been examined in relation to the optimum requirements of the various crops in the different seasons.

From an analysis of climatic shifts caused by the rain fall availability it was noted that agroclimatic features were influenced significantly which in turn affected the agriculture of the State. Agroclimatic features are also important inputs in the choice of appropriate cropping patterns though in this investigations in has not been entirely possible to quantify and segregate the exact influence of the winter annual climatic variability on the cropping pattern from other factors. It is surmised that they play a dominant role. Future work in this regard to determine finite relationships between climatic shifts and temporal variation of agricultural landuse are necessary. Towards this objective it is suggested that maps depicting the agroclimatic features in the years of extreme climatic shifts be superposed and the other maps of physical features to arrive at appropriate cropping pattern for such extreme years. This would be possible if geographical information systems (GIS) is employed. Such a step would be giant leap forward in planning appropriate strategy to compact drought or flood conditions over the State.

It is expected that the results of the present investigation would help in the judicious exploitation of the available natural resources of land, water and atmosphere at optimum levels. Needless to say this would enable effective planning for sustainable development of Kerala State.

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