INFLUENCE OF SHORT TERM CLIMATIC FLUCTUATIONS ON THE AGRICULTURAL LAND USE IN KERALA

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By

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APRIL 1997

DECLARATION

I hereby declare that this thesis entitled **INFLUENCE OF SHORT TERM CLIMATIC FLUCTUATIONS ON THE AGRICULTURAL LAND USE IN KERALA** is genuine record of research work carried out by me during the period 1991 to 1996, under the supervision and guidance of Dr.H.S. Ram Mohan, at the Department of Atmospheric Sciences, School of Marine Sciences, Cochin University of Science and Technology, and no part of this thesis has been previously submitted to any University or Institution for the award of any degree or diploma.

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CERTIFICATE

I hereby certify that this thesis entitled **INFLUENCE OF SHORT TERM CLIMATIC FLUCTUATIONS ON THE AGRICULTURAL LAND USE IN KERALA** is an authentic record of genuine and bonafide research work carried out by Mr. Neelakantan.T., during the period 1991 to 1996, under my supervision and guidance, at the Department of Atmospheric Sciences, School of Marine Sciences, Cochin University of Science and Technology, and no part of this thesis has been previously submitted to any University or Institution for the award of any degree or diploma.

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CHAPTER 1
INTRODUCTION

Any one familiar with the panoramic landscape of Kerala with its evergreen forests, backwaters and scenic splendour of the majestic ghats, would agree that the God who created this should have green fingers. It is a land where nature in all its pristine beauty still holds her own inspite of industrialisation, urbanisation and related population expansion. The State hailed as 'God's own country', lies in the south-western part of India along the West Coast. The State supports a population of 29,098,518 (Census of India, 1991), which is about 3.44% of the country's population, though it occupies only 1.18% of the total geographical area. The high population density (749 persons per sq.km.) and the resultant demand on the three natural resources - land, water and atmosphere - of the State has increased the need for proper planning and management for their judicious exploitation. There exists close inter-relationships among these basic resources, as is evident from the fact that the water supplies over the land comes from the atmosphere. Therefore it is necessary that these inter-relationships are properly understood before embarking on planning any developmental projects for the region.

The State of Kerala is essentially agriculture based with the cultivated area (including the fallow lands) being more than 60 % of the total geographical area. However, the land area of the State is limited and confined to a narrow strip bounded between the steep slopes of Western Ghats and the Arabian Sea. Such a physiography is one of the dominant causes of the abundant rainfall received by the State during the southwest monsoon season. It is also a constraint for exploitation of available water resources for agriculture and other land use.

A variety of climates is observed over the State due to the diversity of physical features. The most dominant factor of the climate is the South West Monsoon along with all its vagaries and spatial and temporal variations. In fact, the monsoon is the dominant control of agriculture of the State. The inter-annual and intra-annual variability of the rainfall influences the water budget components of the region, which in turn influences the land use of the State in general and agricultural land use in particular.

The land use pattern of any region is dependent on a variety of factors, many of them physical and some of them socio-economic. Therefore, for planning an optimum land use pattern for a region, a detailed study of the climate and physiographic features of the area are essential. In this context, a study of the climatological features of the region along with an appraisal of the water balance of the State becomes relevant and necessary. The derived parameters of water balance project vital information necessary in agricultural planning, such as choice of crops, scheduling of farming operations, assessing of irrigation potentials as well as irrigation scheduling.

Fluctuations of rainfall affect agricultural production adversely to varying degrees depending on the intensity, timing and duration of these fluctuations, even though irrigation facilities, where ever available, deduce its risk in agricultural operations. Prolonged deficits in rainfall and associated droughts affect the irrigation system itself. A detailed study of the fluctuations in rainfall and the variations in the water budget of different areas is, therefore, necessary and relevant. Fluctuations in rainfall and hence in other hydrometeorological parameters could affect production and yield of crops grown in the region. This would lead to changes in cropping pattern and crop combination resulting in changes in the agricultural economy of the region. Hence a detailed study of the agricultural land use and its variations over the State due to fluctuations in rainfall is also a pre- requisite in agricultural planning.

In the present study, the land use over Kerala State and its spatial and temporal variations, spatio-temporal variations of water budget elements, climatic shifts, incidence of droughts and the influence of inter-annual fluctuations of rainfall on area. production and yield of selected crops, have been studied in detail. The thesis consists of seven chapters including the introduction. The first section of the Second Chapter deals with the importance of agroclimatological studies in general and its application in agricultural land use in particular. It also gives an overview of the short term climatic fluctuations, water balance studies, crop weather relationships, land use patterns and various agricultural indices. This includes a detailed review of available literature in this field. The basic concepts. data used and the methodology adopted in the study forms, the second section of this Chapter.

The Third Chapter gives the details of the physical features of the State such as the relief, geology, geomorphology. soils, drainage, and vegetation.

The agroclimatology of the State is discussed in detail in Chapter Four. The first Section presents annual and seasonal variations of temperature and rainfall of the State along with a discussion on the water balance of the State. The second

Section of this Chapter deals with the influence of rainfall and water balance elements on various crops.

The district-wise general land use pattern of the State and its spatio-temporal variations are discussed in Chapter Five.

The first Section of Chapter Six gives an overview of the agricultural land use pattern of the State, cropping patterns, cropping intensity, crop combination and their spatio-temporal variations. The inter-annual variability of water balances of various stations of the State computed using the method of Thornthwaite (1948) and Thornthwaite & Mather (1955) is presented in the second Section of Chapter Six. This also includes a discussion of how the climatic shifts have occurred over the State and the influence of variations of climatic and water balance elements on the crops.

The Seventh Chapter gives the summary of the work carried out and the results obtained from the study. Interpretations of the results, conclusions and suggestions made, based on the observations of the study are incorporated in this Chapter.

CHAPTER 2

LITERATURE REVIEW, MATERIALS AND METHODS

Climatic variability is the result of the variation in the rotation of the earth, changes in the axis of its inclination, unequal distribution of land and water and unevenness of its surface. The most direct influence of climate is reflected in crop cultivation. Since each crop requires certain specific climatic requirements, any variations in this would adversely affect the growth and output. Crop failure due to variations in climate could be disastrous in a country where agriculture is the backbone of its economy. This necessitates the need for an understanding of climatic variations at the regional level, especially of short-term variations. This would help take proper remedial measures so that the impact is minimised.

Other major factors that determine the cropping pattern and agricultural output are the local terrain, soil types, technological support, etc..

A brief review of major studies carriedout in the field of land use, impact of climatic variations on crop production, application of water balance approach and agricultural regionalisation are given in the first Section of this Chapter. The second Section gives the details of materials and methods adopted in this study.

2.1 REVIEW OF LITERATURE

2.1.1.GENERAL LAND USE.

The term 'land use' means the different ways by which a piece of land is put to use over a period of time or at a point of time. Campbell (1987) defines land use as "use of land by humans, usually with emphasis on the functional role of land in economic activities'. It forms an abstraction, not always directly observable. The term 'land cover' is often used in synonym with land use, which refers to the natural vegetation, water bodies, rocks and man-made land cover resulting due to land reforms. The land use of a region is dependent on many factors such as the topography, soil, climate, socio-economic conditions and reflect the interaction between society and environment.

Land use information is of much significance to the governmental administration. Since there are wide spatial variations of economic activities, it is essential to have a comprehensive land use plan which would help prevent uncontrolled distribution of economic activities from damaging environmental and human resources, and from disrupting efficient functioning of local economies.

The ever increasing pressure of population on land and demand for food focuses the need for scientific and judicious use of every piece of land. This could be achieved only through the understanding of existing land use pattern and changes that have taken place in concerned regions.

The pioneer among the researchers who studied land use was Sir Dudley Stamp. He was instrumental in the first land use survey of Britain conducted during the thirties. With the help of volunteers, Stamp mapped the entire land areas of England, Wales and Scotland on the Ordinance Survey topographic maps. "At the time the entire country was covered by a map series at 1:10,560 (six inches to the mile). Each sheet represented six square miles, and depicted field boundaries, buildings and other cultural details".(Campbell,1987.). Stamp used the following classification scheme for the land use mapping.

1. Forest and wood lands
   a). High forest (specified as coniferous, deciduous or mixed)
   b). Coppice
   c). Scrub
   d). Forest cut and not replanted.
2. Meadowland Permanent Grass.
3. Arable or Tilled land, Fallow land.
4. Heathland, Moorland, Commons, Rough Hill Pasture
5. Gardens.
6. Land Agriculturally Unproductive, Buildings, Yards, Mines, Ponds.

Being the first land use survey, Stamp's methodology formed a precedent and model for subsequent surveys. Coleman (1961) conducted the Second Land Utilisation Survey in England. This survey was more detailed in respect to both cartographic and taxonomic details, but was analogous in many other respects to the Stamp's methods.

The Lisbon Conference of International Geographical Congress (April, 1949) made a proposal to map the entire land area of the earth using a common map base and legend. The project was primarily intended for providing land use information for economic development for the Third World Countries. Even though considerable effort was made in establishing an administrative framework for guiding and co-ordinating the work, with help of IGU and UNESCO, the World

Land Use Survey failed because of lack of proper co-ordination among various nations and financial support.

Using remote sensing data, the United States Geological Survey (USGS) prepared land use and land cover maps of the United States(1976) on scales 1:250,000 and 1:100,000. After careful examination of the existing land use patterns, the USGS adopted a hierarchical classification scheme (Table 2.1). Levels I and II are appropriate for mapping coarse levels of details while the Level III could be developed depending on the local needs.

In India nascent work was done by Chatterjee(1953), Prakasa Rao(1956), and Shafi(1960), following the methodology of Stamp. Other major works carried out on regional basis are those of Ameen(1956), Sen(1957), Bharadwaj(1961), Raina(1962) and Learmonth(1962). This was followed by number of works ranging from simple inventories of land use survey to topical descriptions using many quantitative and cartographic techniques.

In India till 1949-1950, the land area was classified into five categories. They were

1.Forests
2.Area not available for cultivation
3.Other uncultivated land excluding the current fallow
4.Fallow lands, and
5.Net sown area

LEVEL I	LEVEL II	
1. Urban or Built-up Land	11.	Residential
	12.	Commercial and Services.
	13.	Industrial.
	14.	Transportation,Communication and Utilities.
	15.	Industrial and Commercial Complexes.
	16.	Mixed Urban or Built-up Land
	17.	Other Urban or Built-up Land
2. Agricultural Land	21.	Cropland and Pasture.
	22.	Orchads, Groves, Vineyards, Nurseries and Ornamental Horticultural Areas.
3. Rangeland.	31.	Herbaceous Rangeland.
	32.	Shrub and Brush Rangeland.
	33.	Mixed rangeland.
4. Forest Land	41.	Deciduous Forest Land.
	42.	Evergreen Forest Land.
	43.	Mixed Forest Land.
5. Water	51.	Streams and Canals.
	52.	Lakes.
	53.	Reservoirs.
	54.	Bays and Estuaries.
6. Wetland.	61.	Forested Wetland.
	62.	Nonforested Wetland.
7. Barren Land.	71.	Dry Salt Flats.
	72	Beaches.
	73.	Sandy areas other than Beaches.
	74.	Bare Exposed Rocks.
	75.	Strip Mines, Quarries,and Gravel pits.
	76.	Transitional Areas.
	77.	Mixed Barren Lands.
8. Tundra	81.	Shrub and Brush Tundra.
	82.	Herbaceous Tundra.
	83.	Bare Ground Tundra.
	84.	Wet Tundra.
	85.	Mixed Tundra.
9. Perennial Snow or Ice.	91.	Perennial Snowfields.
	92.	Glaciers.

TABLE 2.1. THE USGS LAND USE AND LAND COVER CLASSIFICATION

Since this scheme was found to be a very broad outline of the land use in the country and not enough to meet the planning needs, the Government of India set up the Technical Committee on Co-ordination of Agricultural Statistics in 1948, by the Ministry of Food and Agriculture. The Committee recommended a nine fold classification scheme with standard concepts and definitions for each land use class, to be followed by all the States of the country. This nine fold classification is as follows. (ICAR, 1992)

1.Forests. : Including all lands classified as forest, private or public. This also includes all the wooded lands and area of crops raised within the forest and grazing lands inside the forest.

2.Land Put to Non-Agricultural Uses. : This category includes all the built-up areas used for residential, commercial, industrial, administrative, transportation and recreational purposes. Also included in this category are the areas under water bodies like lakes, rivers and ponds.

3.Barren and Uncultivable Lands. : Includes all barren and uncultivable lands like mountains, deserts, etc., which cannot be brought under cultivation, except at high cost.

4.Permanent Pastures and other Grazing lands. : Includes all pasture lands, grazing lands and village meadows.

5.Land under Miscellaneous Tree Crops. : This category include all the cultivated areas not included in the net sown area, but are put to some agricultural uses. Lands under bamboo bushes, thatching grass, casurina trees and other groves are included in this category.

6.Cultivable Waste Lands. : Cultivable waste lands include the lands once cultivated, but not cultivated for the past five years in succession. Such lands either may be fallow or covered with shrubs or jungles which are not put to any use.

7. Fallow other than Current Fallow. : These are lands which were put to cultivation once, but are temporarily out of cultivation for period not less than one year but not more than five years.

8.Current Fallow. : This category includes all those lands which are kept fallow during the current year only. For example, if any seedling area is not cropped again in the same year, they are treated as current fallow.

9.Net Area Sown. : This includes all those cultivated areas, counting area sown more than once in the same year only once.

Following the USGS scheme of classification, the National Remote Sensing Agency, under the Department of Space, Government of India, developed the National Land Use / Land Cover Classification System (NRSA,1989) to suit the Indian conditions.(Table 2.2).

Raghavaswamy(1983) described the structural inter-relationships between land capability classes, land use pattern and population distribution in Visakhapatnam tract.

Using the remote sensing data Mohan and Gupta(1985) classified the land use types around Jaipur.

Aerial photographs of 1:50,000 scale were made use of by Natarajan et.al.(1986), in their study of land use Mewat area in Haryana. They identified four major physiographic units and the land use was studied in relation to the physiographic units.

"The changes in land use implies the changes in the areas devoted for different purposes like and recreation" (Chauhan, 1966). The changes in land use may involve a shift from one type to another or within the same class. For example, the area under paddy may change to

LEVEL I		LEVEL II
1. Built-up Land.	1.1	Built-up Land
2. Agricultural Land	2.1	Crop Land i). Kharif. ii). Rabi. iii). Kharif + Rabi.
	2.2	Fallows
	2.3	Plantations
3. Forests	3.1	Evergreen /semi evergreen forest
	3.2	Deciduous forest
	3.4	Forest blank
	3.5	Forest plantations
	3.6	Mangroves
4. Wastelands	4.1	Salt affected land
	4.2	Waterlogged land
	4.3	Marshy / swampy land
	4.4	Gullied / ravinous land
	4.5	Land with or without scrub
	4.6	Sandy areas(coastal and desertic)
	4.7	Barren rocky / stony waste, sheet rock area.
5. Water bodies	5.1	Rivers / streams
	5.2	Lake / reservoir / tank / canal
6. Others	6.1	Shifting cultivation
	6.2	Grassland / grazing land
	6.3	Snow covered / glacial area

Table.2.2. THE NATIONAL LAND USE AND LAND COVER CLASSIFICATION SYSTEM OF NRSA.(1989)

coconut area, or the change may involve transfer of agricultural land to non-agricultural uses.

Sen(1986) indicated how the land use pattern of the hills of Uttar Pradesh disrupted and destroyed the ecosystem. He also emphasised the need for change in the existing land use pattern.

Other major studies in this field include that of Mohammed(1978), and Sharma(1991).

2.1.2.AGRICULTURAL LAND USE

The term 'agricultural land use implies the different ways by which the land devoted for agriculture is used such as for the cultivation of various crops, animal husbandry, poultry and other related activities.

Agricultural land use is most dynamic and changes with the fluctuations in the climate. The impact of short-term variations of climate is immediately felt on the agricultural land use.

Within the broad agricultural system regional variations occur in cropping pattern, cropping intensity and crop combination, because of variations in climatic conditions and the socio-economic conditions of the population.

Various statistical and cartographic models are available for the assessment of crop land use, crop combination, intensity of cropping and overall agricultural performance.

Weaver(1954) proposed a statistical technique to identify crop combination involving both qualitative and quantitative aspects of crop production. Weaver's technique compares the actual percentage of cropped area occupied by various crops with the theoretical distribution in which the cropped area is equally divided among the component crops in different regions.

This procedure designates the crop combinations which are in close resemblance to the actual percentage with the theoretical distribution. Weaver used the standard deviation technique to compare the actual percentages and the theoretical distribution.

It has been proved by many studies that the Weaver's technique of crop combination analysis will be of little help in regions where the share of several crops are quite close to one another. Doi(1959) modified this technique by substituting Weaver's least standard deviation method with that of sum of squared deviations. The combination having least squared deviation is assumed as the combination for that particular region.

Thomas(1963) made a modification to the Weaver's technique. He selected all the crops in the region instead of limiting it to certain crops based on their cropland occupancy, as done by Weaver. The Thomas technique finds out the deviation of actual percentage areas of crops with the theoretical values. The squared values of deviations are added and divided by the number of crops considered. The lowest value of squared deviation divided by number of crops is assumed as the combination of that region.

Coppock(1964) suggested that the division of sum of squared deviations by number of crops is an additional calculation without bringing about any further improvement in the results. He suggested that the lowest sum of squared deviations can be taken as the combination for that particular region.

Many commendable studies have been done in India in the field of agricultural geography particularly at the regional level. "The primary purpose of agricultural geography is to undertake a geographical enquiry into the regional differences and spatial variations in agricultural formations and geographic association, and it lends itself to a greater quantification in the description of regional distributions"(Singh and Dhillon,1994).

Singh(1994) demonstrates the comparative use of these techniquesin the Kurukshetra District of Haryana. Vidyanath (1986), Ramanaiah and .Reddy(1986), Shafi(1984) and Saravanan(1994) also followed the Weaver's and Doi's techniques in their studies.

Agriculture is dependent on many factors, especially the climate. Variations of climate over different parts of the world result in variations in agricultural systems. Typically in a vast country such as India, there are many agricultural systems. This spatial variations necessitate a thorough understanding of various agricultural systems, its cropping patterns and crop productivity. In order to overcome agricultural backwardness, achieve self sufficiency and eliminate regional imbalances in agricultural output, it is necessary to regionalize the agriculture, so that through proper planning these drawbacks can be expunged. "Agricultural regionalization is the process of dividing an area into territorial units of complexes of uniformities and is the result of a set of processes.(Singh,1994).

A number of studies have been done in various parts of the country using different agricultural regionalisation methods. Location Quotient method proposed by Bhatia(1965) is widely used for analysing the regional concentration of particular crop. He derived the location quotient values indicating the regional concentration of particular crop, through dividing the area under a particular crop in the component aerial unit by the total cropped area in the same aerial unit. The resultant value is performance as a concept, means the degree to which the economic, cultural, technical, and organisational variables (ie.manmade frame) are able to exploit the abiotic resources of the area for agricultural production". (Singh, 1994)

Several techniques are used for assessing the levels of agricultural productivity. The ranking coefficient method developed by Kendall in 1939 uses the hectare-yield of crops to asses the efficiency of agriculture. Shafi(1960) adopted this technique to determine the agricultural efficiency of Uttar Pradesh.

Bhatia(1967)assumed that the hectare-yield of a particular crop can be considered as the result of influence of physical and human factors connected with crop production. According to him, the agricultural efficiency would be the overall performance of all crops with regard to their yield per hectare. The contribution of each crop to the agricultural efficiency of the regions would be corresponding to the share of cropland. Bhatia's yield index, which takes into account both the hectare yield of each crop and its aerial extent, is considered to be one of the better indices of agricultural efficiency.

Enyedi (1964) proposed a new technique for determining the productivity index. He had taken into consideration the production of selected crop in the concerned aerial unit and the production of the same crop at the regional or national level and the total cropped area at the unit and national level. One major draw back of this technique is that it does not consider that in certain cases the productivity index is influenced by the magnitude of area under particular crop. Also, when the district yield is less than the State yield or National yield, its productivity index is higher than that of the state or nation.

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Hussain and Sahu(1982) identified regional concentration of rice in Assam using this technique. Other major studies include that of Das(1982), Kunyal(1987) and Singh(1994).

In places where extensive cultivation is not possible because of limitation of availability of land, intensification of cultivation, through multiple cropping, is practised. Hence, cropping intensity is considered as one of the indicators of agricultural development. Many studies have been done at the national and regional levels on the intensity of cultivation. Sohal(1993) described the changes in the intensity of cropping in Punjab.

The ever increasing population and corresponding demand for food is a major challenge facing the world today, especially in the under-developed and developing countries. The shortage in food production is mainly due to the insufficient production of food grains, even after the best efforts to enhance them. This is mainly due to unfavourable weather conditions, lack of mobilisation among farmers, primitive way of farming etc. This results in regional imbalance in the level of agricultural productivity. "The level of agricultural productivity or performance as a concept, means the degree to which the economic, cultural, technical, and organisational variables (ie.manmade frame) are able to exploit the abiotic resources of the area for agricultural production". (Singh, 1994)

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Shafi(1972) modified the Enyedi's technique where the productivity coefficient is considered to be in conformity with lower or higher yield of a particular crop at the unit areal level relative to regional or national level.

The weighted composite level of the agricultural performance propounded by Singh et.al. (1990) takes into consideration both the cropland occupancy and productivity of crops to assess the level of agricultural efficiency. This technique helps identify the weaker areas of agricultural performance which would help in proper planning for future agricultural development.

Other notable studies on the agricultural land use in different parts of the country include that of Singh (1982), Khan (1982), Srivastava (1983), Sawant and Gadgil (1983), Sharma and Coutinho (1983), Ramakrishna and Yadav (1984), Mohammad and Amani (1985), Dhillon et.al(1986), and Sharma (1987)

2.1.3. THE HYDROLOGIC CYCLE

The constant redistribution of water between the earth and the atmosphere, which is called as the hydrologic cycle, is well known to geographers, meteorologists, hydrologists, agriculturists and others concerned with water utilisation and management. The hydrologic cycle involves evaporation of water from the oceans, lakes, rivers, ponds and other water bodies, transpiration from plants, condensation of water vapour from clouds, precipitation in different forms under different conditions, movement and accumulation of water in the soil and ultimately evaporation once again back to the atmosphere. The application of 'principle of conservation of mass', often referred as the continuity equation in hydrology, would lead to the study of water balance . The continuity equation states that, for any arbitrary volume of water during any given period of time, the difference between the total input and output will be balanced by the change of water storage within the volume.

2.1.4. CONCEPT OF WATER BALANCE

Water balance or water budget is a monthly or daily comparison of water supply in the form of precipitation with the water demand or PE., where the soil moisture acts as a sort of reserve available for use to a limited extent for the purpose of evapotranspiration during the periods of water shortage. The book-keeping procedure of water balance, put forwarded by Thornthwaite(1948), based on such a comparison, provides comprehensive information on many parameters such as the amount of water stored in the soil, actual evapotranspiration, water surplus, water deficit, surface flow and underground flow in a quantitative manner.

Whenever precipitation (P) exceeds Potential Evapotranspiration (PE), the soil moisture gets recharged and when the soil moisture storage exceeds the field capacity of the soil, Water Surplus (WS) occurs. The water surplus either percolates downwards and adds to the groundwater storage, produces subsurface flow and underground flow or produces surface runoff from that area, which adds to streams, rivers and finally, to the oceans. In such cases, when precipitation equals or exceeds PE., evapotranspiration attains its potential rate, which implies that A.E. and P.E. are equal. However, when P.E. exceeds precipitation, evapotranspiration cannot be at the potential rate, the stored soil moisture gets depleted and there

will be deficiency of water. When the water deficiency becomes large with respect to the water need, the climate becomes progressively drier or more arid. On the other hand, the climate becomes more humid when large amounts of water surplus occurs. When precipitation equals P.E., the water is available for use just as needed :
there is neither water deficiency nor water surplus.

Many commendable studies have been carried out in India using Thornthwaite's book-keeping procedure of water balance by many researchers. The pioneer among them was Subrahmanyam(1956). The detailed procedures for calculating the water balance using the book-keeping procedure and its applications in various fields are given by Subrahmanyam (1982).

2.1.4a CLIMATIC CLASSIFICATION.

The major application of water balance is in the field of climatic classification. The fundamental idea of any climatic classification is to provide a concise description of various climatic types. Koeppen (1900) made a major advance in climatic classification. He used the vegetation types as an index for classifying climate. But his classification lacked the rational basis for limiting values of temperature and precipitation. Thornthwaite (1948) used the efficiency of temperature and effectiveness of precipitation for the growth and development of natural vegetation as the indices for climatic classification. He evaluated the dryness and wetness of stations by comparing the the water deficit and water surplus with the water need, through the Aridity index and Humidity index.

By definition

Aridity Index I_a (%) = (WD ÷ PE) X 100

Humidity Index I_h (%) = (WS ÷ PE) X 100

Another parameter, the Moisture Index was also developed by Thornthwaite,modified by Thornthwaite and Mather (1955), by incorporating the water surplus and water deficit in relation to the water need as

$$\text{Moisture Index} \quad I_m = I_h - I_a$$

He used the moisture index values for classifying climates. Various limiting values have been assigned for different climatic types. Negative values of moisture index indicate dry climates and positive values moist climate. Mather and Carter (1966) modified the limiting values for dry climates.

Subrahmanyam (1958) compared the climatic types of India, classified using the Thornthwaite scheme, with the natural vegetation as reported by Champion (1936). Using the Index of Moisture adequacy, which is the ratio between AE and PE (AE ÷ PE), Subrahmanyam and Ram Mohan(1980) delineated the monsoon climates of the world in general and India in particular. Ram Mohan and Maria Juliet (1986) classified the monsoon climates of the world using the modified criteria. The climate of the State of Madhya Pradesh has been studied using the water balance approach by Subramaniam and Srimannarayana (1991).

2.1.4b DROUGHT CLIMATOLOGY.

Droughts remain as one of the most disastrous natural hazards to man even in this modern world of advanced technology. In countries where agriculture is the main source of the national income, droughts can cause havoc in their economy. The term 'drought' has different implications in different contexts. Until recently, the criteria for defining drought was the deficiency of rainfall alone. "A clear understanding and better appreciation of the problems of droughts and aridity became available after the water balance approach was put forth by Thornthwaite and Mather in 1955" (Subrahmanyam, 1982). Subrahmanyam and Subramniam (1964), Subrahmanyam (1967), Subrahmanyam and Sastri (1968) used water balance approach for the drought studies

Sastri.et.al(1982) used the Thornthwaite's technique for assessing the probabilities of occurrence of droughts in the Guhiya catchment of Rajasthan. The utility of water balance approach has been amply described by Ram Mohan and Subrahmanyam(1983). Using the water balance approach Subrahmanyam and Ram Mohan(1984) explained the droughts and agricultural land use in India, Pakistan and Bangladesh. Ram Mohan et.al.(1984) used the Index of moisture availability as the criterion for studying droughts.

Rao and Kalavathi (1985) demonstrate the relationship between the derived elements of water balance and crop concentration. The usefulness of water balance studies in agriculture has been explained by Pandey and Gupta(1991).

In Kerala, major studies have been done by Nair(1987) and James(1991). Saravanan(1994) and Haseena Raghavan(1996) also used the water balance approach in their studies.

2.1.5. IMPACT OF CLIMATIC FLUCTUATIONS ON AGRICULTURE

2.1.5a.CROP-CLIMATE AND CROP-WEATHER MODELS

The influence of climatic or weather elements on agriculture is well established through various studies in different parts of the world. Meteorologists and agriculturists have developed a number of crop-climate and crop-weather models which describe the influence of weather and climate on different crops. The influence of various weather elements on agriculture vary from region to region. In higher latitudes, for example, temperature is a limiting factor in agriculture, while in the lower latitudes rainfall is the major limiting factor. "Millions of people all over the world depend directly on rainfall as their only accessible source of water. In the absence of monsoons that bring adequate rain, lifestyles can be seriously and sometimes irreversibly disrupted. The first effect of the insufficient rain is the crop yield reduction or crop death." (Swaminathan, 1987)

Climate-agriculture relationship is basically studied using the climate impact and climate interaction models. The impact approach assumes a direct cause and effect relationship between climate and agriculture.(Virmani, 1991). Various types of models used include empirical statistical models and simulation models. Rao (1983) used the crop-climate models to assess the influence of climate and technology on wheat yield in Punjab. Jain et.al.,(1980) described the effect of climatic variables on rice yield at different stages of crop growth. Venkataraman and Rahi (1983), Subramaniam and Raju (1987) and Mavi et.al., (1993) also used crop-climate models in their studies.

A number of studies have been done which depict the influence of weather parameters on agricultural output. Venkitaraman and Krishnan (1992) gave a detailed description of the various principles of crop-weather relationship. Parry and Carter (1988) described the features of current public strategies for combating the impact of rainfall variability on agriculture in India and indicate the scope for making fuller use of the agroclimatic environment and the farmer's resource base for improving and sustaining agricultural productivity in the dry tropics, through different case studies.

Swaminathan (1987) in his study explained the impact of abnormal monsoons on the Indian economy. He is of the opinion that "with the help of science and technology, human insecurity and endeavour can convert calamities into opportunities for progress. Through concurrent advances in weather forecasting, prediction of climatic trends, and abnormal monsoon management, humankind can be insulated from hardships caused by droughts and floods to a much greater extent than has been considered possible until now".

Long-term climatic trends and their influence on agriculture can be predicted fairly accurately and proper measures can be adopted for enhanced production. But the year to year fluctuation of climate is often difficult to predict though its influence on agriculture would be large. Oram (1985) indicates a number of potentially desirable areas for action in this regard and suggests that "several of these would be beneficial both as a buffer against short term effects of variability and as a means of combating climatic changes"

.Saha and .Mooley (1988) observe that there is no significant periodicities in the long term trends in Indian monsoons. Their study of Chanda and Ratnapuri districts of Maharashtra state reveals that there is significant correlation between crop yield and monsoon rainfall variation.

Using the Weather Index approach, .Chaudhury and .Rao (1978) explain the climatic fluctuations and their impact on wheat yield in Punjab and Haryana States.

Rasmidatta (1978) on his study in Thailand reveals the influence of climatic fluctuation on corn production. He is of the opinion that conditions for corn production in Thailand are highly favourable provided proper attention is given, by way of proper use of fertilizers, cultural practices, use of insecticides, crop-weather calendars and weather modifications.

Recently food production in Sri Lanka was adversely affected by weather failures. Gooneratne (1978) analysed the pattern of rice production in Sri Lanka and the influence of weather failures on rice production. Another study of similar nature on Sri Lanka was done by Domrös (1978).

Superimposing the isohyetal map of annual rainfall and rice yield map of Bangladesh, Mowla (1978) described the relationship between rainfall and rice yield. This proves that areas having higher annual rainfall give better rice yields than areas having lower annual rainfall.

The crop-weather models usually use simple regression analysis technique to establish their inter-relations and to forecast the yield. Das et.al., (1971) used the regression model to predict the paddy yield in the Mysore State. Gupta and Singh (1988) developed a multiple linear regression model to estimate sugarcane yield. Thompson (1986) used regression analysis technique to determine the influence of variability of climate and weather on the corn yield in the States of Illinois, Indiana, Iowa, Missouri and Ohio of the United States of America.

Tanaka (1978) studied the relationship between inter-annual fluctuation of rice yield and the local and large scale climatic fluctuations over Monsoon Asia.

Commenting on the predictions of climatic fluctuations by Global Circulation Models used so far in various parts of the world, Gadgil (1995) is of the opinion that the impact of year to year variations of the Monsoon will continue to be dominant over long period changes even in the presence of global warming. She also stresses the need for a detailed study on climatic components of agricultural productivity of various crops at the district level.

2.2. MATERIALS AND METHODS

2.2.1.GENERAL LAND USE:

The district level land use data , published annually as 'Agricultural Statistics of Kerala', 'Seasons and Crop Report' and 'Statistics For Planning' by the Directorate of Economics and Statistics, Government of Kerala, have been collected for the period from 1961 to 1994. The data were collected for all the individual districts and for the State as a whole, for the above period.

For the purpose of general understanding Shafi (1984) grouped the twelve categories of land use of Uttar Pradesh into five categories viz .1). Waste land which included the barren and uncultivable land and the land put to non-agricultural uses, 2). cultivable waste land - including cultivable waste land, pastures and other grazing lands and the land under miscellaneous tree crops, 3). fallow lands, 4). net area sown and 5). total cropped area.

Since the areas under permanent pastures and grazing lands, barren and uncultivable lands and area under miscellaneous tree crops in Kerala are very few, the land use categories of the State are grouped into the following five categories in this study.

1. Forests
2. Land put to Non-Agricultural Uses (including barren and uncultivable lands)
3. Pastures(including grazing lands and miscellaneous tree crops)
4. Fallow lands (including cultivable waste lands fallow other than current fallow and current fallow).
5. Net area sown.

The inter-annual variability of each category of land use was calculated. Decadal variations of land use categories at the district level were calculated for the periods 1961 - 1971 (first decade) 1971 - 1981 (second decade) and 1981 -1991 (third decade). Since an increase in area under one category of land use will be compensated by the decrease in another category, the separate totals of all increases and decreases would be the same. This percentage is taken as the overall change for the decade, as suggested by Weaver (1954) and adopted by Sharma (1991). The following formula has been used for calculating the overall change.

$$\text{Overall change} = X \div Y$$

where X is the difference of percentages of land use categories of increases, and Y is the difference in percentages of land use categories of decreases for different periods.

2.2.2. AGRICULTURAL LAND USE.

Agricultural statistics for all the individual districts and for the State as a whole were collected for the above periods. Crops were selected for this study on the basis of their share in the total cropped area (TCA). All those crops which occupy more than 5% of the TCA are taken into consideration. In most of the districts, only major crops like paddy, coconut, tapioca and rubber have more than 5% of TCA and they together account for more than 80% of TCA. In addition to these four major crops, pepper, cardamom, tea and coffee in Idukki district, groundnut in Palakkad district ,coffee and pepper in Wayanad district, arecanut and pepper in Kannur and Kasargod districts are included since these crops occupy more than 5% of TCA.

The annual yield index was calculated for all the crops at the district level using the Bhatia's method. Yield index may be expressed as

$$I_{ya} = Y_c \div Y_r$$

where 'I_{ya}' is the yield index, 'Y_c' is the hectare yield of crop 'a' in the component aerial unit and 'Y_r' is the hectare yield of crop 'a' in the entire region.

The regional concentration of crops was calculated using Bhatia's Index of Concentration method. The location quotient was found out using the following formula

$$Ic = \frac{A_r}{TCA} \div \frac{A_{rc}}{TCA_n}$$

where

I_c is the index of concentration

A_r is the area of particular crop in the concerned aerial unit.

Arc is the area of particular crop in the entire region or country

TC is the Total Cropped area of the given areal unit

TCn is the total cropped area of the region/country

Regional variations in the levels of agricultural performance were calculated using the methodology of Singh et.al.(1990). It takes into account both cropland occupancy and crop production. The formula for calculating the levels of agricultural performance is

$$V_w = \frac{Y_{ae}}{Y_{ar}} \times \frac{P_{ae}}{P_{ar}} + \frac{Y_{be}}{Y_{br}} \times \frac{P_{be}}{P_{br}} + \frac{Y_{ce}}{Y_{cr}} \times \frac{P_{ce}}{P_{cr}} \qquad + N = \frac{\Sigma Lqs}{N}$$

where

V_w - is the Weighted Composite Level of regional inequality

Y - is the crop yield in kg / hectare.

P - is the cropland occupancy in percentage to TCA

$_{a,b,c}$ - denotes the crops considered

$_{e,r}$ - denotes the enumeration unit and the entire region respectively

N - denotes number of crops considered and

LQ - means location quotient

The summed up LQs were divided by the number of crops considered and multiplied by 100 to obtain Weighted Composite Level of Agricultural Performance.

$$WCLAP = \frac{\Sigma LQs}{N} \times 100$$

The crop combination was calculated using the Coppock's (1964) method. This is a modified version of Weaver's technique. In this technique, the crops are arranged in descending order in terms its occupancy in the total cropped area. The difference between actual and theoretical percentages are calculated starting with monoculture. It is assumed that one crop occupies 100% of the TCA in monoculture. 2, 3, 4, 5 combinations are progressively foundout, assuming its crop land occupancy to be 50, 33.33, 25 and 20 percentage respectively. The best fit combination is determined by the least-square method. Here, the difference between the actual and theoretical percentages are squared and summed up. The lowest sum of least-square is taken as the best fit.

In order to assess the regional differences in crop productivity Singh's (1976) methodology has been adopted in this study. In this technique, the yield index and concentration index are ranked separately for all the districts. The yield index and concentration index are found out taking the mean data for two time periods- 1961 to 1971 and 1981 to 1991. The yield and concentration indices ranks of individual crops are added and there after divided by 2. This gives the Crop Yield and concentration Indices ranking coefficient. The lower the coefficient values, the higher will be the productivity levels.

2.2.3. WATER BALANCE

Thornthwaite (1948) and Thornthwaite and Mather(1955) methods were followed to calculate the annual water balance of 19 selected stations of Kerala. The monthly temperature and rainfall data for these stations were obtained from IMD for the period 1950 to 1986. The annual water surplus and water deficit for all the stations have been workedout. From this the relative dryness and wetness of the stations have been evaluated using the aridity (I_a) and humidity (I_h) indices, calculated using the following formulae.

$$I_a = WD \div PE \times 100$$

$$I_h = WS \div PE \times 100$$

In order to findout the climatic type of individual stations the moisture index was calculated using the formula

$$I_m = I_h - I_a$$

The different climatic types and their limits of I_m values are given in Table 2.3.

CLIMATIC TYPES			MOISTURE INDEX (%)
Humid climates			
	Perhumid	A	100 and above
	Humid	B_4	80 - 100
		B_3	60 - 80
		B_2	40 - 60
		B_1	20 - 40
	Moist sub-humid	C_2	0 - 20
Dry climates			
	Dry sub-humid	C_1	-33.3 to- 0
	Semi-arid	D	-66.6 to -33.3
	Arid	E	below - 66.6

Table.2.3 MOISTURE INDEX LIMITS AND CLIMATIC TYPES

{ After Carter and Mather, 1966 }

Inter-annual variability of various water balance parameters were determined. Identification of climatic shifts, droughts and categorisation of droughts were done.

In order to asses the trend in the annual rainfall, water surplus, water deficiency, potential evapotranspiration and actual evapotranspiration linear regression trend lines have been fitted on the individual graphs showing the annual values. This was done using the MICROSOFT EXCEL software. All the diagrams have also been prepared using this software.

Categorisation of droughts have been done following the methodology of Subrahmanyam and Subramaniam(1965) The departure of Ia from median values of all the individual stations were calculated and the percentage departures were plotted on a graph. Table 2.4 gives the different categories of droughts

Departure of I_a from median	Drought Intensity
$< 1/2\ \sigma$	Moderate
$1/2\ \sigma$ to σ	Large
σ to $2\ \sigma$	Severe
$> 2\ \sigma$	Disastrous.

Table.2.4. CATEGORISATION OF DROUGHTS

The choropleth technique is used to represent various themes on maps. These maps are prepared using the Geographical Information Systems (GIS) software MAP MAKER. The outline map of Kerala was first scanned in the 'tiff' format and later converted to 'dra' format in the software, by polygonizing all the individual districts. After assigning different symbols to each polygon, it was then converted to 'map' format to produce the final map.

To asses the influence of climatic fluctuations on agriculture, coefficient correlation and regression models were used. The coefficient of variabilities of area, production and yield of major crops for selected districts have been calculated using the following formula.

$$\text{Coefficient of Variability} = \text{Standard deviation} \div \text{Mean} \times 100$$

The Coefficient of Determination (R^2) was calculated through the regression analysis. The R^2 values have been calculated for the annual rainfall and crop area, rainfall and crop production, and rainfall and crop yield of paddy, tapioca, coconut and rubber, for selected stations. These stations Have been selected assuming that they represent the concerned districts in which they are located. The R^2 values would give the degree of dependence of area, production and yield of major crops on rainfall.

CHAPTER 3

PHYSICAL FEATURES OF KERALA

3.1 LOCATION

Kerala is a narrow strip of land on the southwestern corner of the Indian Union. It extends between the latitudes 8°18'N and 12°48'N and longitudes 74°52'E and 77°22'E. The State has a total geographical area of 38863 Sq.kms which is 1.18% of the total area of India. It has a long coastline of 590 kms. The width of the State varies from 30 kms. to 130 kms. It is narrower in the North and South, and broader in the central portion. The State is bounded by the Lakshadweep sea on the West and the Sahyadris in the East. North and North-East of the State is bordered by Karnataka State and South and South-East by the State of Tamil Nadu (Fig.3.1).

3.1.1 ADMINISTRATIVE DIVISIONS.

Consequent to the reorganisation of the States, Kerala was formed on 1st November 1956 by merging the erstwhile princely States of Travancore, Cochin and Malabar. Various reorganisations within the State resulted in the formation of 9 districts by 1958. They were Thiruvananthapuram, Kollam, Alappuzha, Kottayam, Ernakulam, Thrissur, Palakkad, Kozhikode and Kannur. Subsequently 5 more districts viz. Malappuram, Idukki, Wayanad, Pathanamthitta and Kasargode were formed during the period from 1969 to 1984. Thus the State now has 14 revenue districts, 61 taluks and 1452 villages. This also includes 990 panchayats, 59 municipalities, 3 corporations and 1 township.

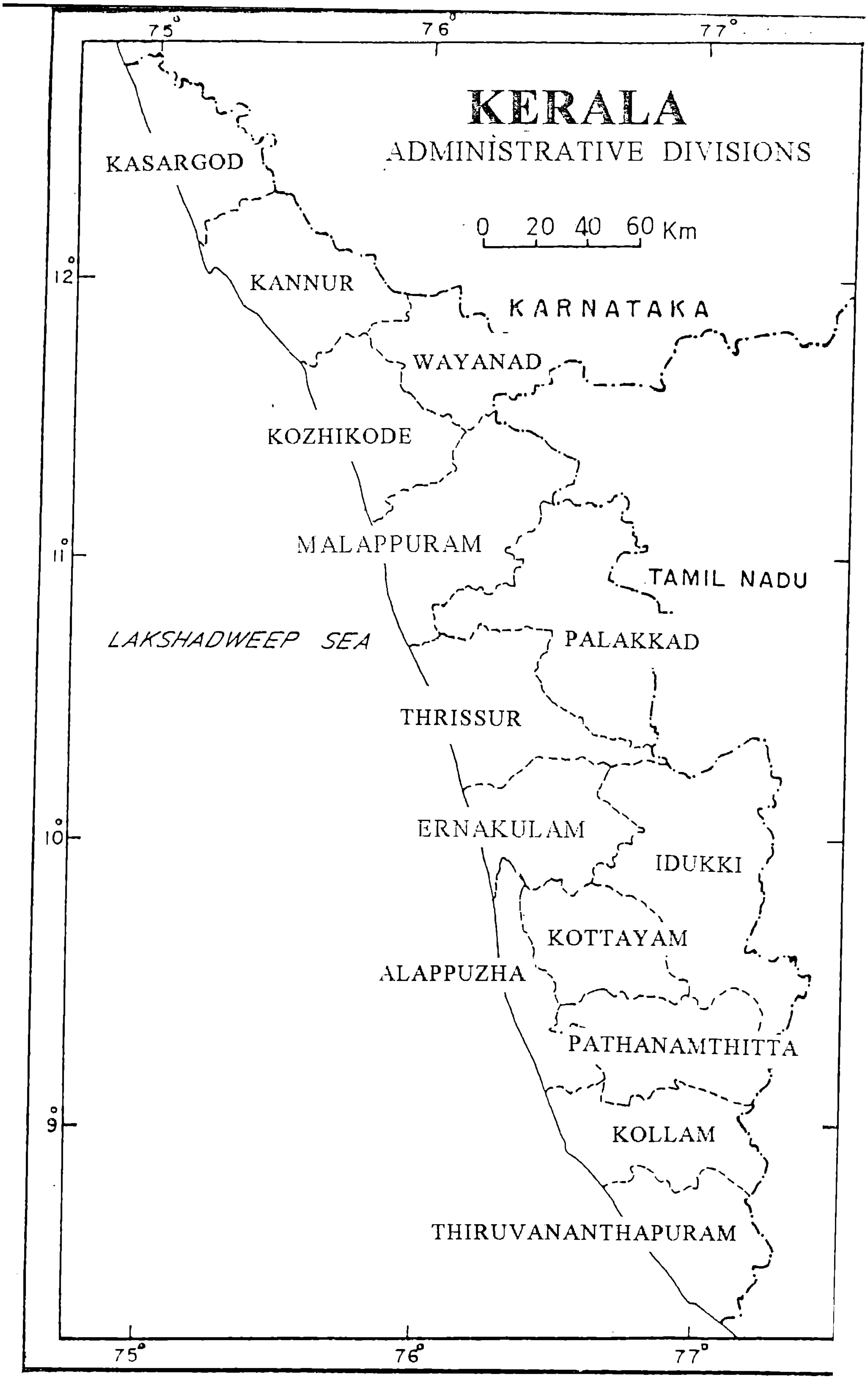


Fig. 3.1. KERALA ADMINISRATIVE DIVISIONS

3.2. PHYSIOGRAPHY :

Kerala has varied physiographic features that are the result of complex geological processes. The Public Works Department of Kerala divides the State into 3 major physiographic divisions, according to their elevation from the mean sea level (MSL). They are (i).Highlands with altitude above 75m of MSL, (ii). Midlands with altitude of 7.5m to 75m above MSL and (iii). Lowlands with altitude of less than 7.5m above MSL.(Fig.3.2)

3.2.1. HIGHLANDS

Highlands are the most conspicuous feature of Kerala and has an area of 18654 sq.km which is 48% of the total geographical area of the State. They are known as Sahyadris and are part of the Western Ghats. The Sahyadris include the Nilgiris, Anamalai, Palani and Vershanad. Andipatti ranges with arching projections into Tamilnadu. Innumerable rivers dissect these ranges resulting in varied landforms. These mountains are mostly the remnants of old plateaus with three distinctive planation surfaces at 1800m, 1200m, and 600m. They are the result of periodic upliftment of the Western Ghats. Wayanad Plateau in Wayanad district, Kunda hills in Malappuram district, Nelliampathy Plateau in Palakkad district, Periyar Plateau in Idukki district and Agasthyamalai in Thiruvananthapuram district are all parts of this extensive range. The highest peak of the Western Ghats, Anamudi (2694m) which is also the highest peak, south of Himalayas is located in Idukki district.

The continuous and extensive upland terrains of the Sahyadris have a major break in the Palakkad area known as the PALAKKAD GAP. This gap has a width of about 30km.It is

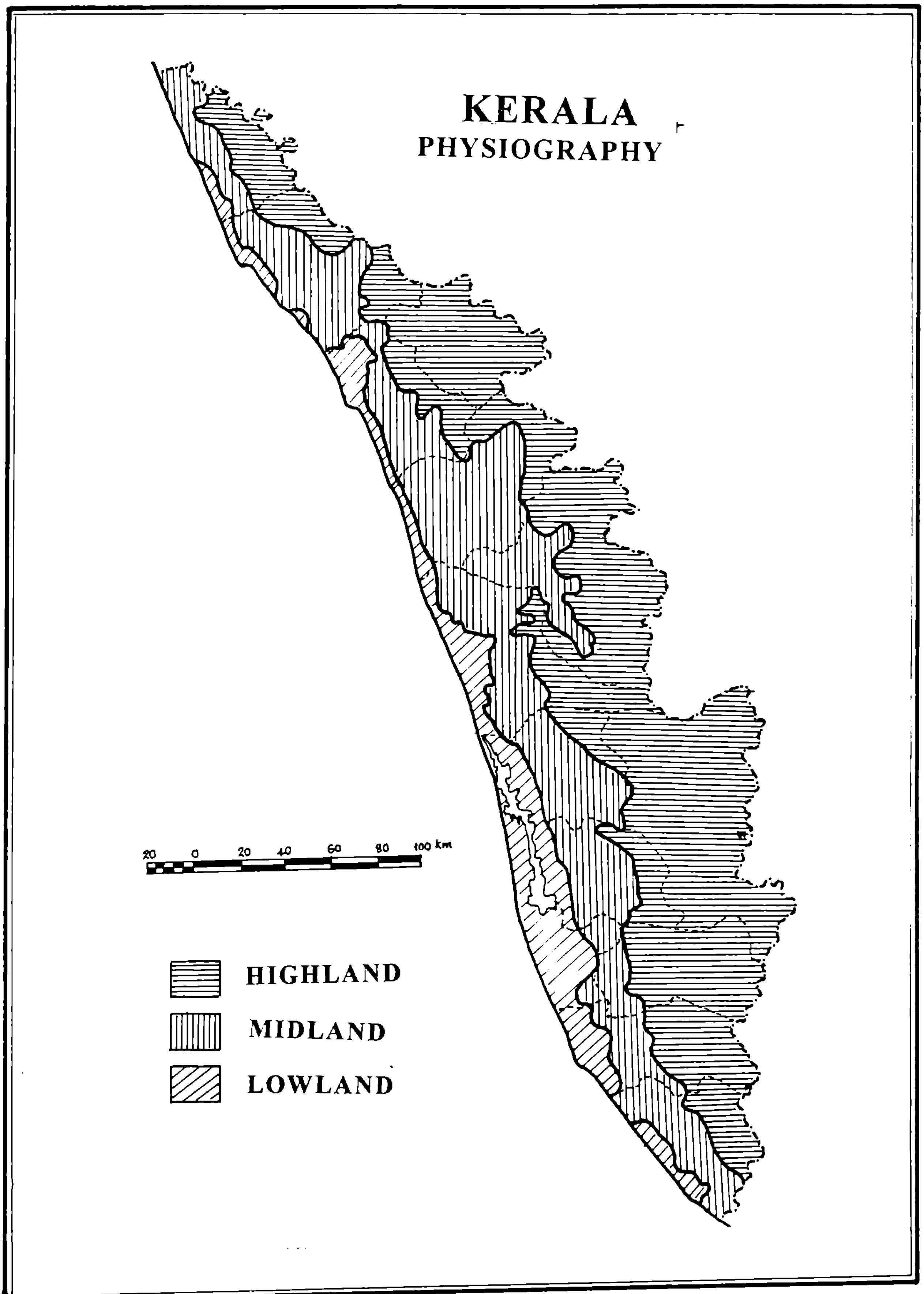


Fig. 3.2. KERALA - PHYSIOGRAPHY

bounded in the north and south by lofty hills with altitude of 1100 to 2000m. The Sahyadris also have some minor gaps south of Palakkad gap. They are the Aryankavu or Chenkotta gap in Kollam district; Kumily gap, Kombanmedu pass and Munnar pass in Idukki district. All these gaps connect Kerala and Tamilnadu and are major trade routes.

3.2.2 MIDLANDS

Midlands have an area of 16231 sq.kms, which is 41.8% of the total geographical area.They have rocky spurs protruding towards the west from the Sahyadris. In most places it extends eastwards right upto a few metres to the seashore. In the southern districts, these secondary ridges produce undulating topography with wide valleys. North of Cardamom Hills, excepting the Palakkad Gap , long spurs and extensive ravines of ghat mountains are seen to merge westward into gentler slopes, rolling down and gradually widening valleys which end themselves abruptly in cliffs giving way to lowlands.(Kerala State Gazetteer.1986).

3.2.3. LOWLANDS

Lowlands ranging in width from 20km to 100km consist of peneplains, flood plains, rock cut terraces, colluvium and coastal plains. Coastal plains are low in relief ranging from 4 to 6 m. It is characterised by the presence of numerous beach dune ridges which run parallel to the present shoreline. There are about 34 lagoons or estuaries, locally known as Kayals, in this zone. These kayals have been created in depressions formed in between the old beach dune ridges. The lowlands occupy 10.2% of the geographical area (3979 sq.km) of the State.

3.3. DRAINAGE

Kerala is blessed with 44 short and swift flowing rivers. Of these 41 are west flowing and 3 are east flowing.(Fig.3.3). Unlike other peninsular rivers, the rivers of Kerala do not form deltas because of their short distances from their sources to the mouth. The general drainage patterns of the State is dendritic. In some places it is sub parallel and radial. Most of these rivers are structurally controlled and follow the general direction of NW-SE and NE-SW of prominent lineaments. Table 3.1 gives details of the drainage systems of the State.

NAME OF RIVER	LENGTH IN KM.	CATCHMENT AREA IN SQ.KM. (IN KERALA)
WEST FLOWING		
1. MANJESWAR	16	90
2. UPPALA	50	76
3. SHIRIYA	67	290
4. MORYAL	34	132
5. CHANDRAGIRI	25	145
6. CHITTARI	25	570
7. NILESWAR	46	190
8. KARINGOTE	64	429
9. KAVVAI	31	143
10. PERUVEMBA	51	300
11. RAMAPURAM	19	52
12. KUPPAM	82	469
13. VALAPATANAM	110	1321
14. ANJARAKKANDY	48	412
15. TELLICHERY	28	132
16. MAHE	54	394
17. KUTTYADI	74	583
18. KORAPUZHA	40	624
19. KALLAI	22	96

20. CHALIYAR	169	1735
21. KADALUNDI	130	1122
22. TIRUR	48	117
23.BHARATHAPUZHA	209	4400
24. KEECHERI	51	401
25. PUZHIKKAL	29	234
26. KARUVANNUR	48	1054
27. CHALAKKUDY	130	1404
28. PERIYAR	244	5284
29. MUVATTUPUZHA	121	1554
30. MEENACHIL	78	1272
31. MANIMALA	90	847
32. PAMBA	176	2235
33. ACHENKOVIL	128	1484
34. PALLIKKAL	42	220
35. KALLADA	121	1699
36. ITHIKKARA	56	642
37. AYOOR	17	66
38. VAMANAPURAM	88	687
39. MAMOM	27	114
40. KARAMANA	68	702
41. NEYYAR	56	497
EAST FLOWING		
42. KABANI	-	1920
43. BHAVANI	-	562
44. PAMBAR	-	384

Table.3.1. RIVERS OF KERALA

3.4. GEOLOGY

Kerala is part of the Indian Peninsular shield and is composed of four major rock types.

1. Crystalline rocks of the Precambrian which are 600 to 3800 million years old

2. Sedimentary rocks of Tertiary (Cenozoic) which are younger than 65 million years.

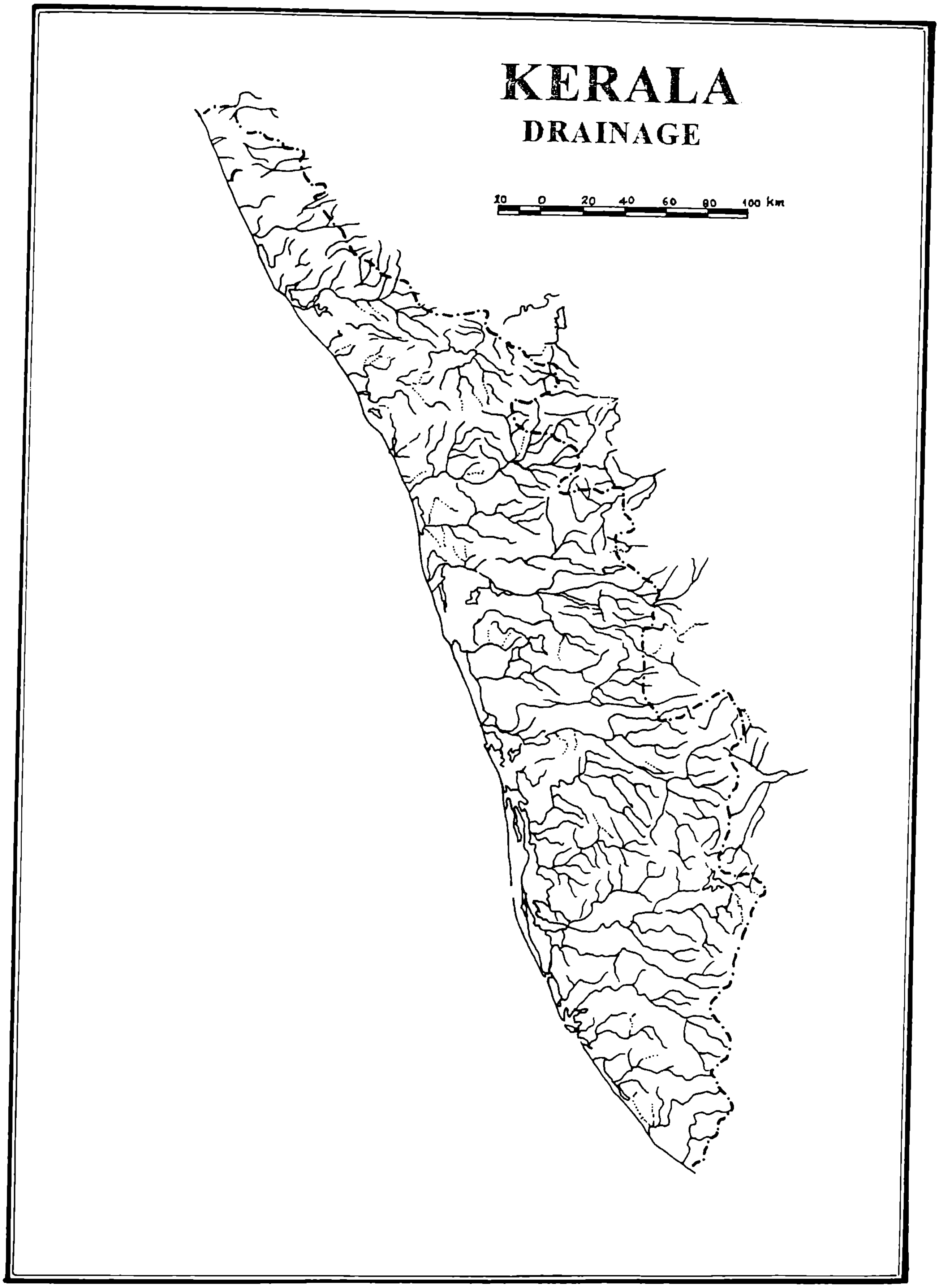


Fig. 3.3. KERALA - DRAINAGE

3.Laterite developed due to chemical weathering mostly during the Pleistocene occur over crystalline and sedimentary rocks.

4.Recent to sub recent rocks, 10,000 yrs old occupy low-lying areas of river valleys.

The crystalline rocks are mainly igneous and metamorphic igneous. They are mostly exposed in the Sahyadris and their foothills and to a lesser extent in the midlands. They mainly consist of Charnokite,
Khondalities, Granite gneisses, Dharwar Schists and Granites traversed by Pegmatities and basic dykes.

The Khondalitic group includes fine to medium grained and light coloured granite-sillimanite biotic gneiss and garnet-biotic gneiss. There are seen extensively in the Southern districts of Kerala. They are also found in Idukki and Palakkad districts.

The Charnokite group consists of Pyroxene granulite, Charnokite, Gneissic Charnokite Magnetite quartz etc. They are seen in almost all the districts of the State.

Granitic gneisses are found mainly in Wayanad and Kannur districts.

Dharwar Schist containing the quartz mica schist, quartz schist and tremotite chlorite talc schist is seen as a narrow belt in parts of Kasargod , Kannur and Wayanad districts.

Sedimentary rocks of Miocene age (Tertiary Sediments) known as Warkalli beds and Quilon beds are seen as a discontinuous cut crop along the Kerala Coast.

Laterite occurs as capping over crystalline and sedimentary rocks. They are seen extensively in the midland regions. They are the result of deep chemical weathering of rocks occurred during prolonged exposure of these rocks to tropical climate.

Recent to subrecent sediments are mainly coastal sands, silty alluvium, lagoonal alluvium and black clays. They are found in the low lying areas of Alappuzha and Kottayam districts.

3.5 SOILS

Soils of Kerala are mostly fertile and cultivable. It is dominated by lateritic and forest loam. The depth of the soil is considered to be moderately shallow when it ranges between 50cm to 75cm, moderately deep when it is 75 - 100cm. Soils are deep when the depth is between 100-150 cm, and it is very deep when the depth is over 150cm. 89% of the soils of Kerala are deep to very deep

The textures of surface layer of soils of Kerala vary from sandy to clayey. Nearly 59% of the soils are loamy in texture, 30 percent are clayey and about 4% sandy.

The capacity of the soil to hold moisture depends on the soil texture and depth. On the basis of the water holding capacity, expressed in mm.of water in 100cms.of soil or the entire soil column, if it is shallow,soils of Kerala can be grouped into the following categories.

About 72 % of the soils of Kerala are well drained. The soil survey unit of the Dept of Agriculture, Govt of Kerala classified the soils of Kerala into 10 broad categories based on the physio-chemical characteristics and morphological features.

WATER HOLDING CAPACITY	DEPTH IN mm.	AREA IN PERCENTAGE
1. VERY LOW	< 50	6
2. LOW	50-100	38
3. MEDIUM	100-150	14
4. HIGH	150-200	35

Table. 3.2 WATER HOLDING CAPACITY OF SOILS

1. COASTAL ALLUVIUM (Tropopsammonth -Tropofluvents)

This soil is predominantly marine in origin with some fluvial deposits and is found along the coastline. This soil is high in sand content and hence low in water holding capacity.

2.RIVERINEALLUVIUM(Tropofluvents-Eutropepts-Dystripepts)

This soil is developed along the river valleys and cut across the extensive laterites. The texture varies from sandy loam to clay and is usually very deep. This soil is highly fertile and has very good water holding capacity and hence supports wide variety of crops.

3. RED LOAM(Tropudalfs-Eutropepys)

Red loam occurs in isolated patches, in the foothills and hill locks associated with laterite as colluvial deposits. Its colour appears red because of the presence of high ferric oxide content. It is highly porous and friable and hence is not fertile.

4. LATERITE SOIL (Eutrorthox-Haplorthox-Dystropepts)

This is a major group of soil foind extensively throughout Kerala. Laterite show the development of deep to very deep AB(c) profile in some parts of the State.In most of the places, the B horizon is well developed.This soil is generally poor in potash, nitrogen, phospherous and organic matters. It is well drained and hence suitable for many crops such as coconut, arecanut, pepper, tapioca, rubber,etc.

5. GREYISH ONATTUKARA (Troporthents)

This soil is usually found in Kollam and Alappuzha diatricts.It has got the characteristic greyish colour.The texture is coarse and its water holding capacity is low.Highly deficient in plant nutrients and acidic in character,this soil is not suitable for cultivation

6. BROWN HYDROMORPHIC (Tropaquepts)

Usually found in wet lands, brown hydromorphic soil is rich in organic matter,nitrogen and potash. Lime and phosphate are deficit in this soil.

7. ACIDIC SALINE (Tropaquepts-Fluvaquepts)

Acidic Saline soil is found in the lowlying areas of Kuttanad regions. It is developed under hydromorphic conditions. This includes (i). Kari soil, which is black in colour with high organic content developed in the water logged areas (ii) Kayal soil, which is developed in the reclaimed areas and is high in clay content and (iii) Karappadam soil, which is developed along river courses. This soil is high In silt content and salinity is a major problem in many areas.

8. HYDROMORPHIC SALINE (Tropoqualfs)

This soil is found along the coastal strip, where inundation by sea causes high salinity.

9. BLACK SOIL (Chronuderts)

The black colour soil which is characterised by high clay content, is found in the North-eastern part of Palakkad district. It is low in organic content. Since the soil is highly suitable for cotton cultivation. It is also known as the Black Cotton soil.

10. FOREST LOAM (Hapludolts - Tropodalfs - Tropeptic - Eutrorthox)

This soil is highly enriched in humus content which gives it a dark reddish brown to black colour. It is developed in the forested areas of the eastern parts of the State. Highly rich in nitrogen and low in bases, this soil promote prolific undergrowth.

3.6. VEGETATION

The tropical humid climate of Kerala favours prolific growth of natural vegetation. Variations in climate from the coast to the highland within a short distance, results in various types of forests. The State has 11,223 sq.km of total forest area of which 9,400 sq.km are effective forest area. Forest plantations occupy about 1538 sq.km. The following table (Table 3.3) gives the classification of forest area of Kerala by Type and Legal status.

FOREST TYPES	AREA IN SQ.KM.	AREA IN %
1.TROPICAL WET EVERGREEN AND SEMI-EVERGREEN.	3480	37
2. TROPICAN MOIST DECIDUOUS	4100	44
3. TROPICAL DRY DECIDUOUS	94	1
4. MONTANE SUB-TROPICAL	188	2
5. FOREST PLANTATIONS	1538	16
TOTAL	**9400**	**100**
FOREDT BY LEGAL STATUS		
1. RESERVED FORESTS	9335	83
2. VARIED FORESTS	1888	17
TOTAL	**11223**	**100**

Table.3.3. CLASSIFICATION OF FORESTS OF KERALA

CHAPTER 4

AGRO-CLIMATOLOGY OF KERALA

4.1. CLIMATE.

Kerala experiences a wide variety of climate from perhumid to moist sub-humid type,because of the wide variations in relief from the coast to the Sahyadris. Such a climatic spectrum is capable of supporting enormous varieties of crops in the region. The important features of agroclimatology of the State are now briefly described.

4.1.1. TEMPERATURE.

Coastal regions experience more or less uniform day time temperature throughout the year, except during June, July, and August,when the temperature drops because of the overcast skies of the monsoon season.

Due to the influence of the South- West monsoon the maximum temperature is recorded in the pre-monsoon months. At the coastal stations the maximum temperature is often around 33^0C during April while the minimum temperature is around 22^0C during January. The interior stations have a higher maximum temperature (about 37^0C), and minimum temparature is usually less than that at the coastal stations.

The lowest mean monthly temperature at all stations in the State occur in July or August and the highest during the pre-monsoon months. "The zone with highest maximum temperature for the whole year (<27.5^0C) falls in the midland region; along the coast, temperature is moderate, whereas in the east it is low." (CESS, 1984).

4.1.2. RAINFALL.

The State receives abundant rainfall mainly from the South-West monsoon. The mean annual rainfall of the State is about 300cm. Based on the rainfall pattern there four seasons may be delineated :

1. Winter - January - February
2. Pre-monsoon - March - May
3. Monsoon - June - September
4. Post-monsoon - October - December

The annual rainfall of the State varies from less than 100cm in Chinnar to more than 400cm in Neriamangalam. The rainfall increases from South to North and from the coast to the Sahyadris. Most of the State has two peaks of rainfall, one during the South-West monsoon period and the other during the North-East monsoon period.

The South- West monsoon contributes about 66% of the total annual rainfall of the State. It is basically caused by the orographic lifting of moisture laden wind from the Arabian Sea. Normally the South-West monsoon sets over Kerala by the end of May or early June. It is locally known as *Kalavarsham.* Since the onset period is by the middle of Malayalam month 'Edavam', it is also known as *Edavappathy.* The South-West monsoon also shows the same pattern as the annual rainfall ; it increases from south to north. "The monsoon rainfall is more than 80% of the annual rainfall in the extreme northern part of the State and gradually decreases to about 45% in the extreme south. The general pattern is disturbed over the low rainfall region around Chinnar and heavy rainfall pocket around Neriamangalam."(James,1991).

During the North-East monsoon season, which lasts from October to November, the State receives about 18% of the annual rainfall. This rainfall is locally known as *Thulavarsham*. The southern districts receive more rainfall during this season than the northern districts. About 30% of the annual rainfall of the southern districts is received during this period, while it contributes only 9% of the annual rainfall of the northern districts. This rainfall is usually associated with cyclonic activities and thunder storms.

Rainfall during the winter (December-February) season is meagre and contributs only 1% of the annual rainfall of the State. The southern districts have about 3% of the annual rainfall during this period.

The pre-monsoon season, which lasts from March to May, contributes about 15% of the annual rainfall of the State. The rainfall during this season is mainly from the convective processes associated with thunder showers.

4.1.3. RAINFALL VARIABILITY.

The rainfall variability for the State as a whole is low ; it ranges from 15% in the northern districts to 30% in the southern districts. During the monsoon season, the variability is generally higher; during the month of June and July, variability is 30-40%, in August it is 40-60% and in September, 50 to 60%. The variability during the pre-monsoon and post monsoon periods are relatively higher and range from over 80% in the northern districts to 50-80% in the southern districts.

4.1.4. RELATIVE HUMIDITY.

Being located on the coast, the relative humidity of the State is usually high. "The monsoon currents bring lot of moisture from the Arabian Sea and it is found that the precipitable water vapour over Kerala increase from 3 to 3.5 gms. in winter months to about 5 gms. in the monsoon months.(Ananthakrishnan et.al.,1965). The relative humidity decreases from west to east. During the winter months the relative humidity decreases with altitude. The average relative humidity in the coastal region is about 77%. A maximum of around 88% occurs during monsoon months, while the minimum is about 66%, experienced during January.

4.1.5.WINDS.

The winds blown over most parts of the State is thermally driven. This thermo-dynamism is due to the differential heating and cooling of the land and water bodies.The resultant land and sea breezes have a westerly component during day time and easterly component during night and early morning throught out the year. These winds are usually strong during afternoons and weak during nights.

4.2. AGRO-CLIMATIC ZONES

The climatic conditions and soil types of a region play a dominant role in determining the agricultural landuse pattern and crop yields. Understanding of these two elements is a pre-requisite for planning and maximising agricultural production for sustainable development

According to FAO, an agro-climatic zone is a land unit interim of major climate and growing period which is climatically suitable for a certain range of crops and cultivation.

Based on the mid term approvals of the VIIth Five Year Plan (1985-1990) the Planning Commission divided India into 15 broad agro-climatic zones based on physiography and climate.

Zone 1 - Western Himalayan Regions
" 2 - Eastern Himalayan Regions
" 3 - Lower Gangetic Plains
" 4 - Middle Gangetic Plains
" 5 - Upper Gangetic Plains
" 6 - Trans Gangetic Plains
" 7 - Eastern Plain & Hill Regions
" 8 - Central Plain & Hill Regions
" 9 - Western Plain & Hill Regions
" 10 - Southern Plain& Hill Regions
" 11 - East coast Plain&Hill Regions
" 12 - West coast Plain&Hill Regions
" 13 - Gujarath Plain &Hill Regions
" 14 - Western dry Regions
" 15 - The Island Regions

Subsequently under the National Agricultural Research Project (NARP), the State Agricultural Universities were asked to divide the States into major sub zones based on rainfall, existing cropping pattern and administration division.

Consequently Kerala State was divided into the following five agro-climatic zones.(Fig.4.2.1).

1. Northern Zone: Comprises of Kasargode, Kannur, Kozhicode and Malappuram districts .This zone has a 293 km of coastline.

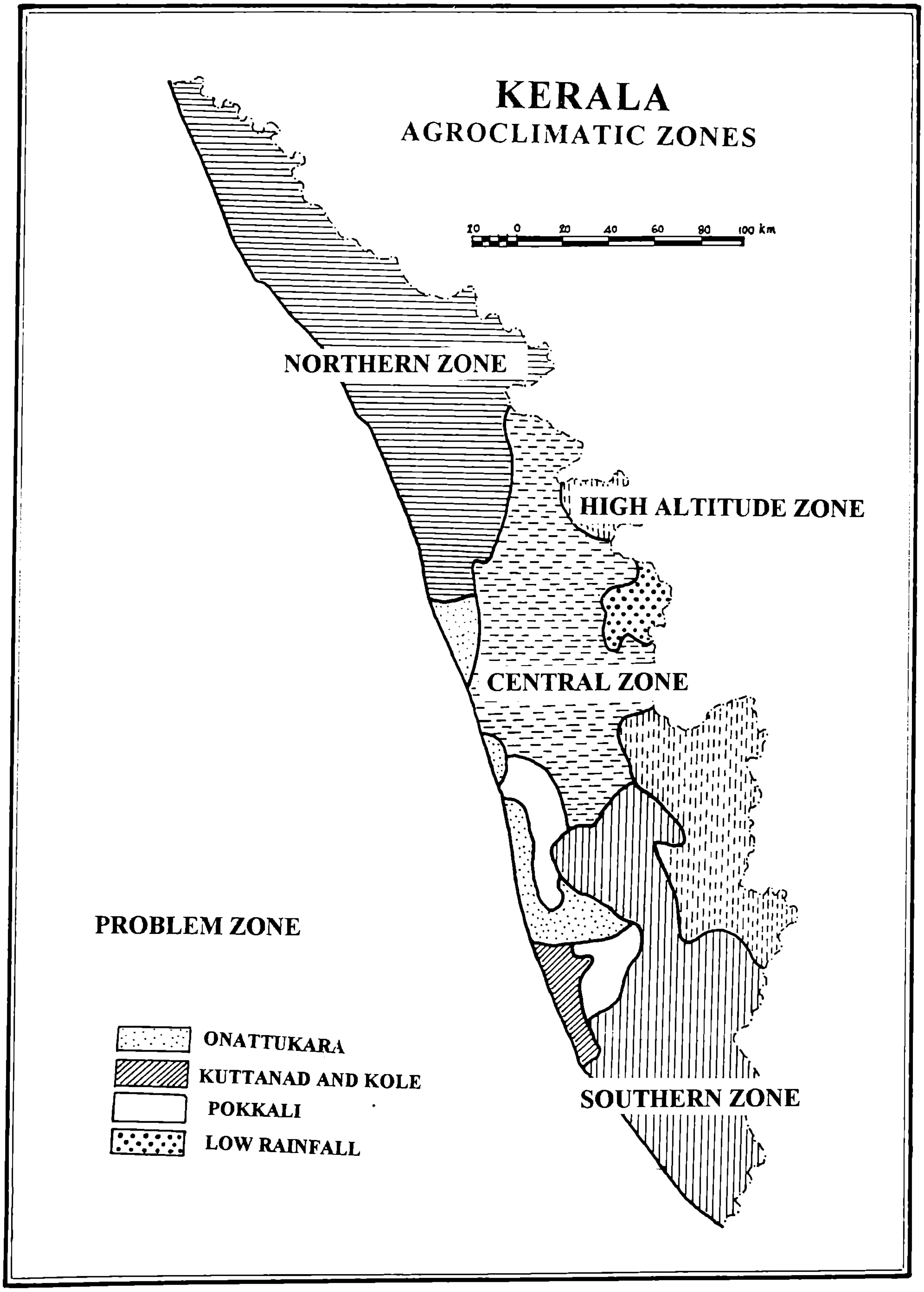


Fig. 4.21. KERALA : AGRO - CLIMATIC ZONES

The highland comprises of about 300 sq.kms. and midland about 400 sq.kms.

2. Central Zone: This zone includes all the areas of the State excluding the high ranges, Coastal zone and Kole lands of Ernakulam, Thrissur and Palakkad districts.

3.Southern Zone: Consists of Kottayam, Alappuzha , Patthanamthitta, Kollam and Thiruvananthapuram districts.

4. High Altitude Zone : This encompasses the high ranges with an elevation above 750m of Wayanad, Palakkad, Idukki, Kollam and Thiruvananthapuram districts. It has a total geographical area of 11140 sq.km.

5.Problem Area Zone : This include the lowland areas, Onattukara, Kuttanad and Kole lands, Pokkali and low rainfall areas of Malappuram, Thrissur, Ernakulam, Kottayam and Alappuzha.

Earlier, understanding the need for a rational classification of agro-climatic zones, the Govt. of Kerala appointed a committee to delineate the State into various climatic zones. The committee in its report, (1974) divided the State in 13 agro-climatic zones.(Table.4.1). Here the development blocks were taken as the lowest units.

4.3. AGRO-CLIMATOLOGY OF KERALA

In order to have proper agricultural planning, it is essential to have a detailed understanding of the water need, water loss, water surplus and water deficiency of the particular region. These elements of water balance calculated using the Thornthwaite (1948) method, gives a vivid picture of the agro-climatic situation of the particular region.

In this Section a detailed analysis of annual rainfall, Potential Evapotranspiration (PE), Actual Evapotranspiration (AE), Water Surplus(WS), Water Deficiency (WD), the climatic shifts and incidence of droughts are given for the selected 19 stations (Fig.4.3) of Kerala.

Sl.No	ZONES	AREA (Sq.Km)
1	ONATUKARA	519
2	COASTAL SANDY	1564
3	SOUTHERN MIDLAND	3224
4	CENTRAL MIDLAND	2666
5	NORTHERN MIDLAND	3765
6	NORTHERN MIDLAND (MALAPPURAM)	4524
7	HIGHLAND	8861
8	PALAKKAD	1280
9	RED LOAM	317
10	CHITTOOR BLOCK	508
11	KUTTANAD	284
12	RIVER BANK ALLUVIUM	
13	HIGHRANGES	5140

(Source : Report of the committee on agro-climatic zones, 1974)

Table.4.1. AGRO-CLIMATIC ZONES OF KERALA

A. NORTHERN ZONE

4.3.1. KASARGOD

Located at $12^0 31'$ N and 74^0 $55'$ E, Kasargod receives 3632 mm. annual rainfall. The rainfall pattern shows a slight declining trend.(Fig.4.3.1a).The highest rainfall recorded at Kasargod was 6134 mm. 1961.

A slight increasing trend in PE and decreasing trend in AE is evident from Fig.4.3.1b.

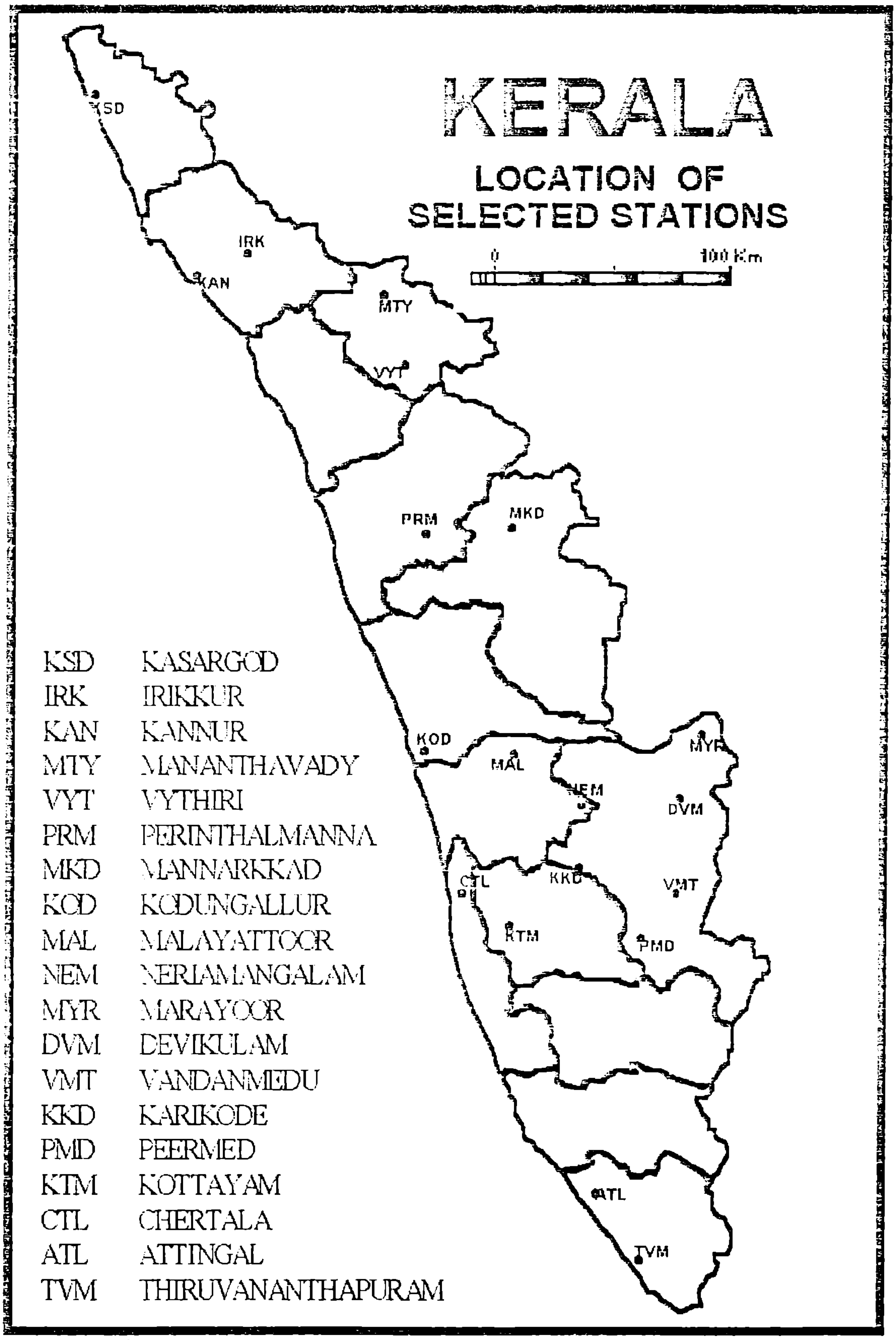


Fig. 4.3. KERALA - SELECTED STATIONS

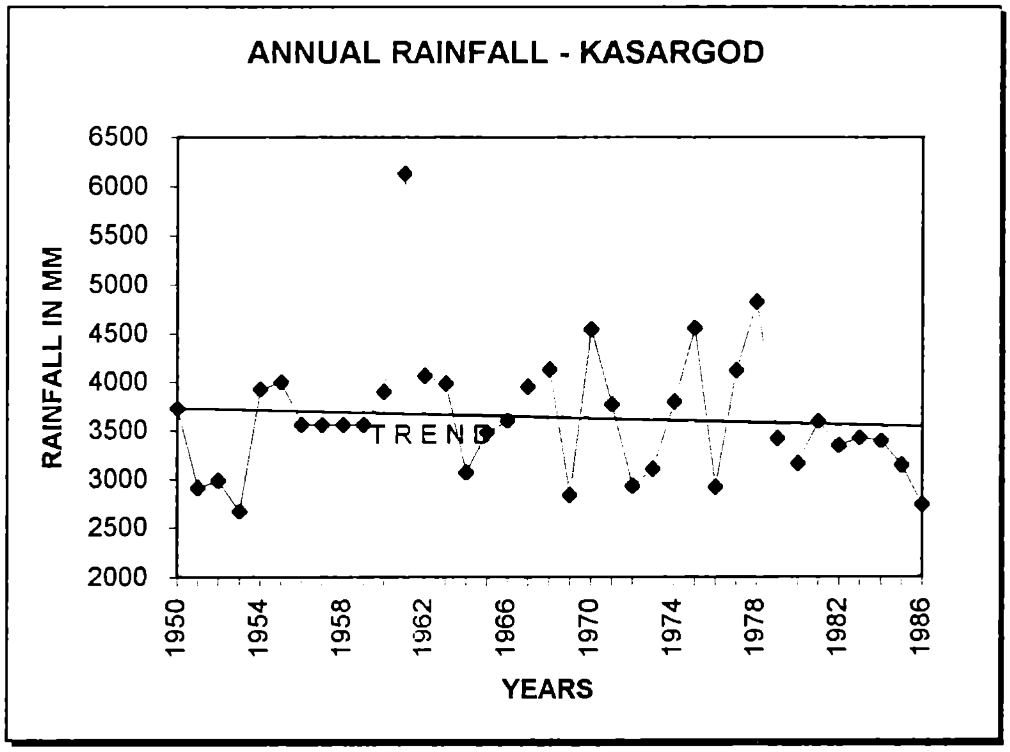


Fig. 4.3.1a. ANNUAL RAINFALL - KASARGOD

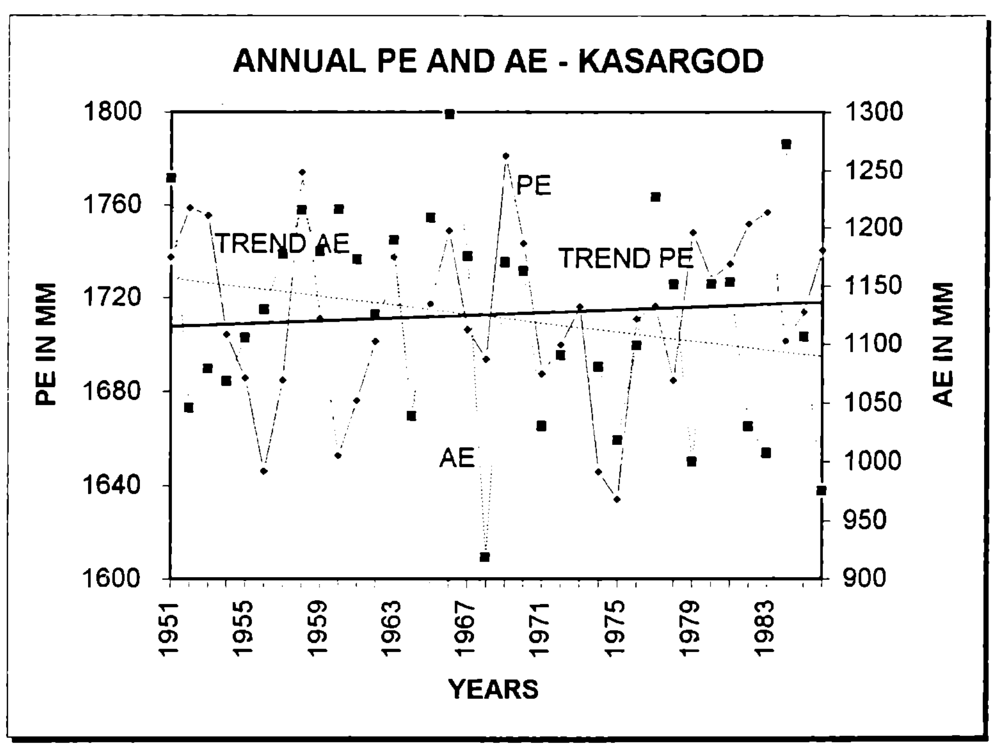


Fig. 4.3.1b. ANNUAL PE & AE - KASARGOD

A sharp increase in WD and decline in WS is the main feature of water balance of Kasargod. (Fig.4.3.1c).

Kasargod experiences a perhumid climate. There were no major shifts in climate. Most of the shifts were within the humid sub categories. (Fig.4.3.1d).

The absence of any disastrous droughts is the conspicuous feature of Kasargod. (Fig.4.3.1e). Twelve years within the period 1950-1986 had droughts, of which one was of severe magnitude, three were large and the remaining were of moderate category.

4.3.2. KANNUR

Kannur is located at $11^0 52'$N and $75^0 22'$ E. With a mean annual rainfall of 3220 mm., Kannur shows no trend in the rainfall pattern (Fig.4.3.2a). The highest annual rainfall was recorded at Kannur was 5661.mm in the year 1961, and the lowest was 2024 mm.in 1964.

Contrary to many other stations, Kannur shows an increasing trend in both PE and AE. (Fig.4.3.2b).

Similar to the rainfall pattern ,WS shows a declining trend and WD displays an increasing trend. (Fig.4.3.2c).

Kannur also experienced many of the climatic shifts within the humid category. (Fig.4.3.2d). The year 1964 witnessed a shift to C_1 type following the deficient rainfall that year. There were 15 drought years during the period 1950-1986, of which one was severe and one was disastrous. (Fig.4.3.2e).

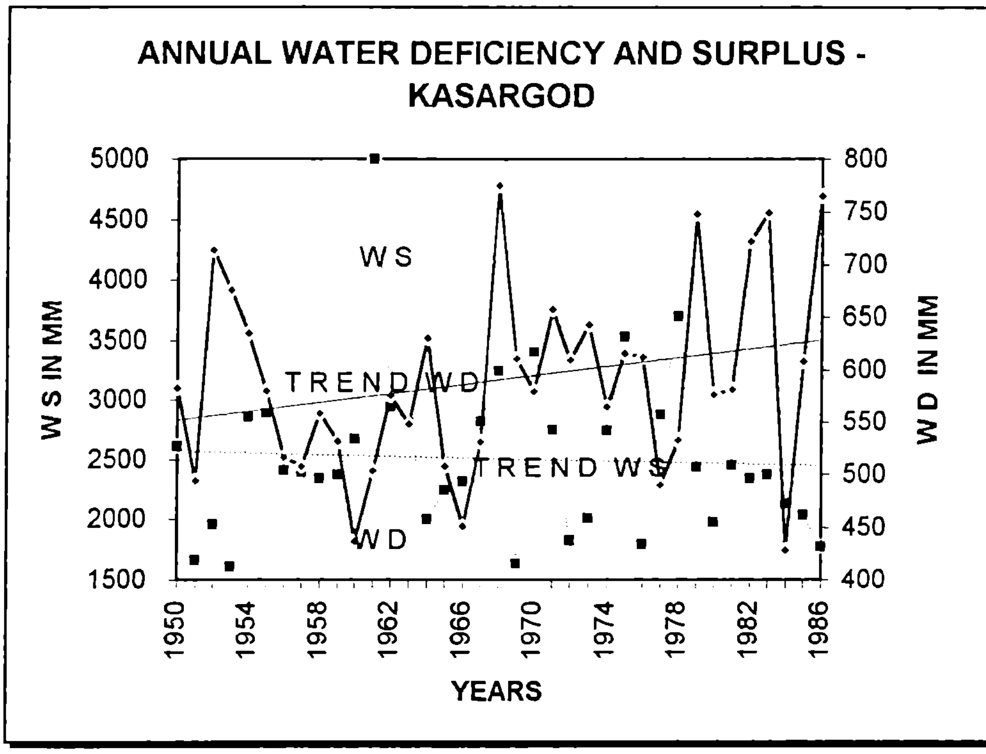


Fig. 4.3.1c. ANNUAL WD & WS - KASARGOD

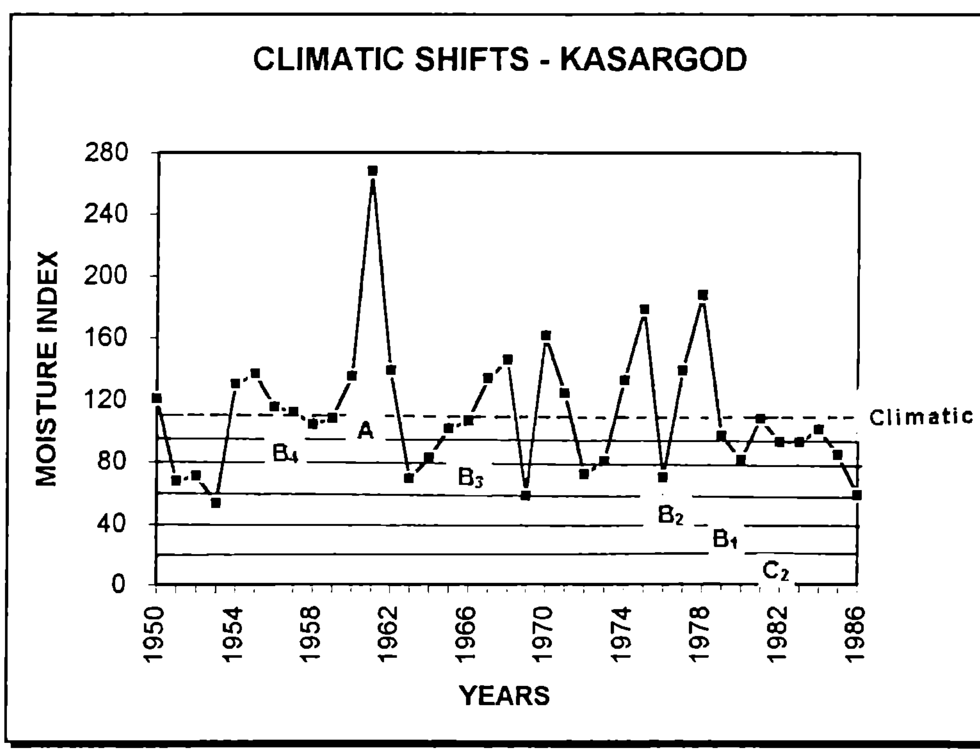


Fig. 4.3.1d. CLIMATIC SHIFTS - KASARGOD

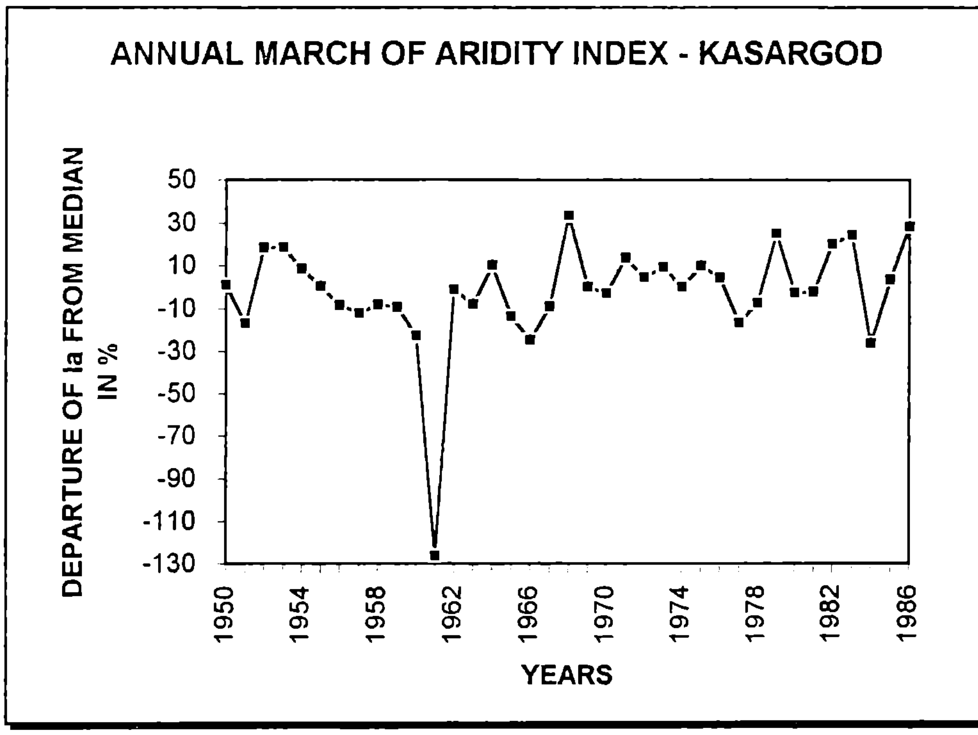


Fig. 4.3.1e. ANNUAL MARCH OF ARIDITY INDEX KASARGOD

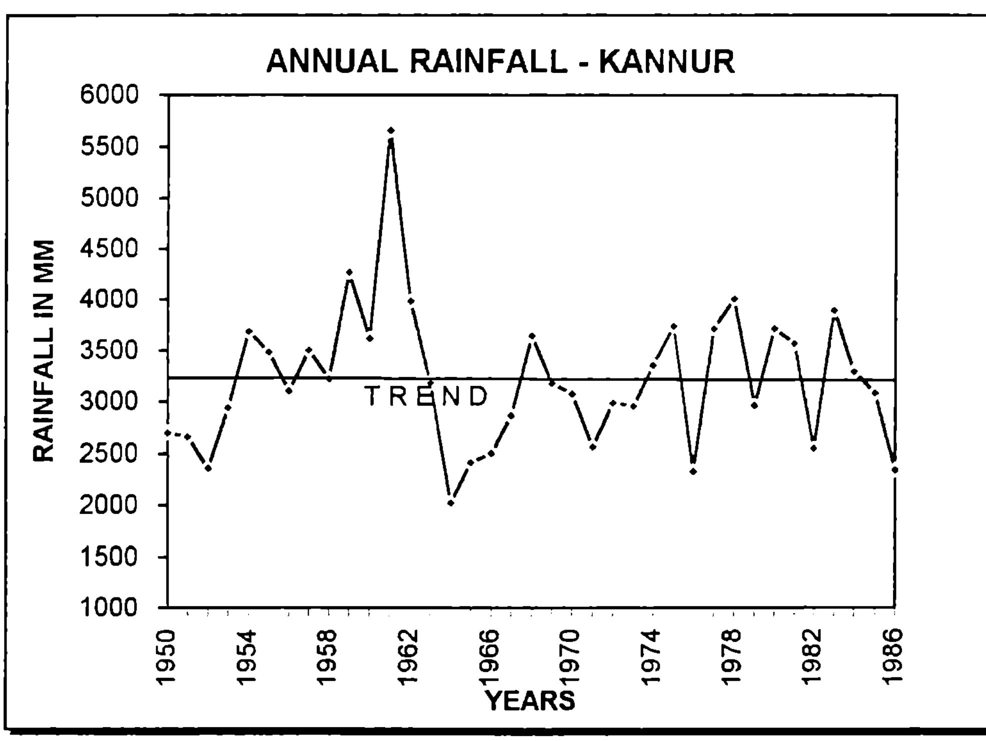


Fig. 4.3.2a. ANNUAL RAINFALL - KANNUR

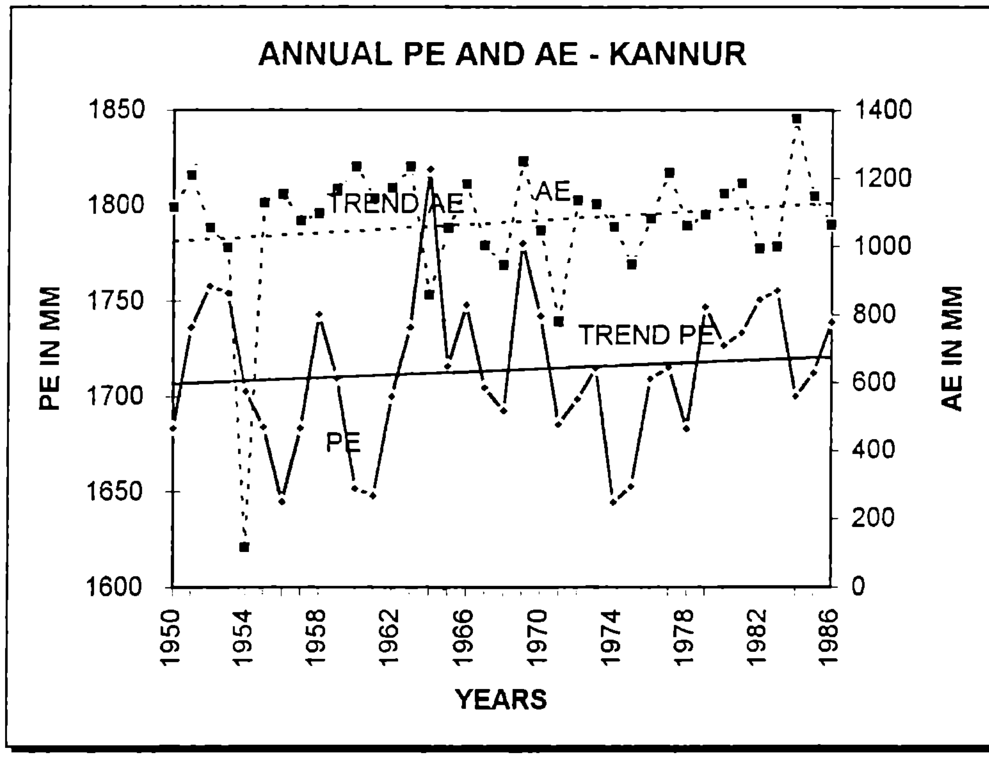


Fig. 4.3.2b. ANNUAL PE & AE - KANNUR

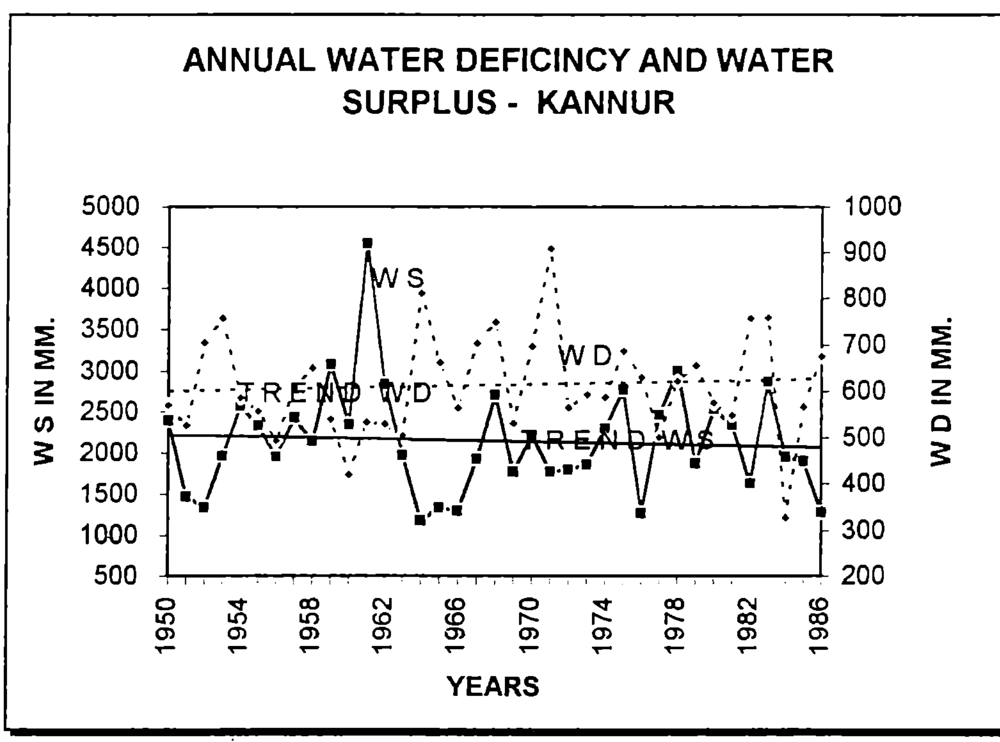


Fig. 4.3.2c. ANNUAL WD & WS - KANNUR

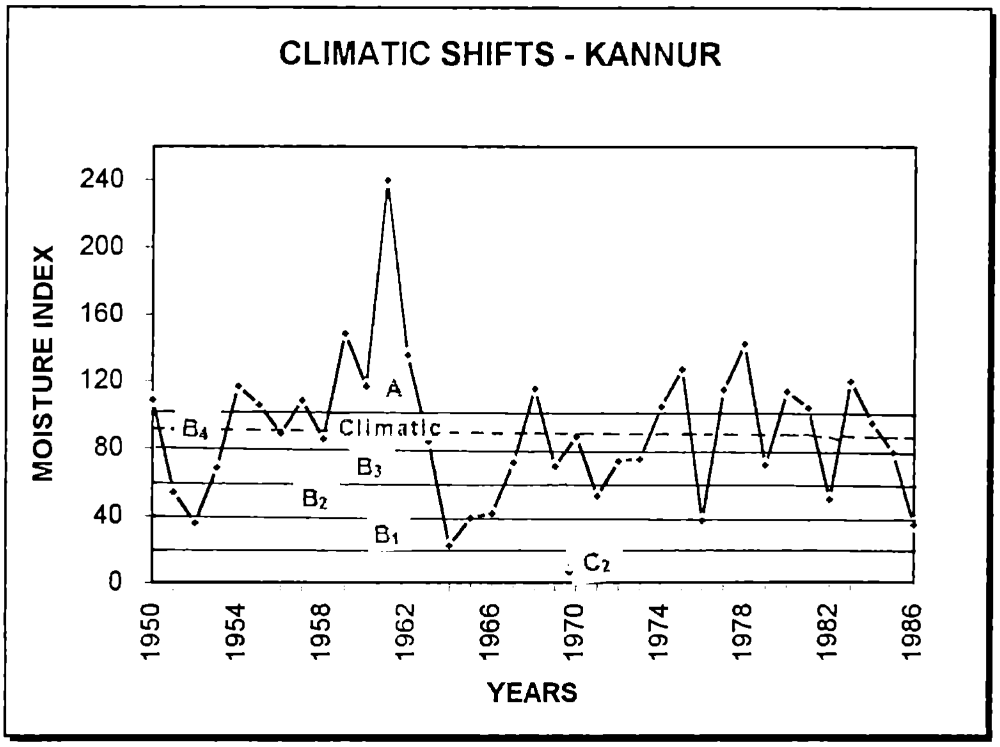


Fig. 4.3.2d. CLIMATIC SHIFTS - KANNUR

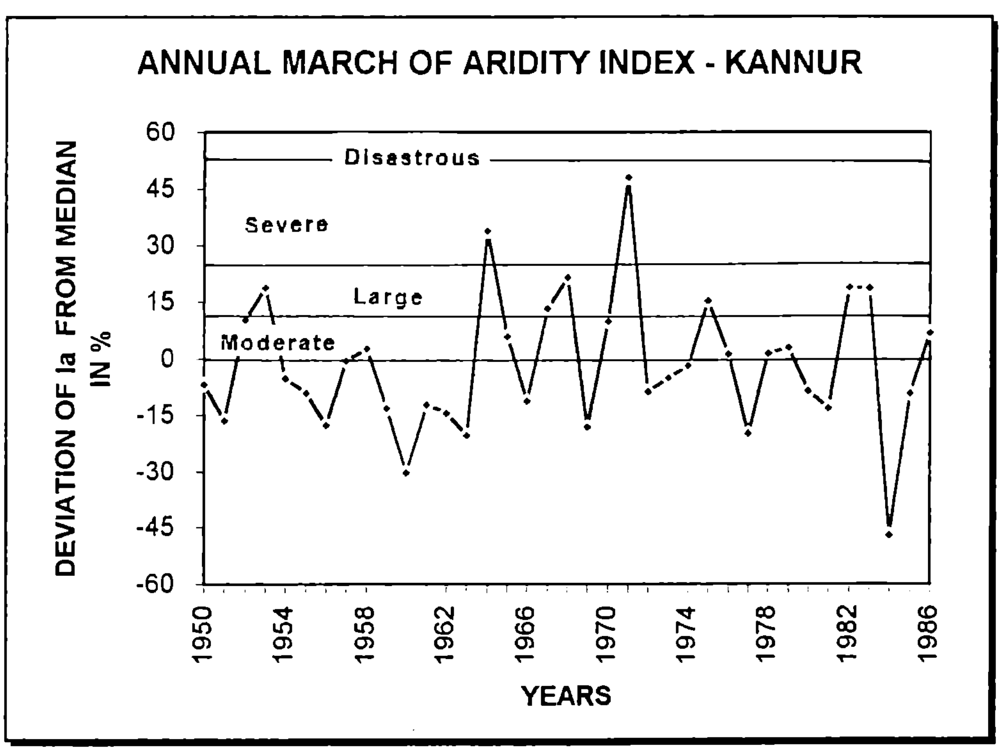


Fig. 4.3.2e. ANNUAL MARCH OF ARIDITY INDEX - KANNUR

4.3.3. IRIKKUR

Irikkur is located at $11^{0}58'$ N and $75^{0}35'$ E. It experiences a perhumid type of climate and has a mean annual rainfall of 3418 mm.

The annual rainfall pattern indicates a declining trend (Fig.4.3.3a). The highest annual rainfall of the station was 6919 mm. recorded in 1968. The lowest was recorded in 1974 when the annual rainfall was only 1087 mm.

The gradual increasing trend of PE and corresponding decrease in AE is vivid from Fig.4.3.2.b.

Irikkur too displays a diminishing trend in WS and an upward trend in WD. (Fig.4.3.3c)

The majority of the climatic shifts were within the humid type. But in 1974, when the rainfall was lowest, the climate shifted to semi-arid (D) type. (Fig.4.3.3d).

Including the year 1974, there were five disastrous droughts in Irikkur. However the total number of droughts were comparatively less. (Fig.4.3.3e).

4.3.4. PERINTHALMANNA

Perinthalmanna is located at $10^{0}58'$ N and $76^{0}14'$ E and receives a mean annual rainfall of 2787 mm. It shows a moderate increasing trend in rainfall.(Fig. 4.3.4a).

Like many other stations in the State, Perinthalmanna also shows an increasing trend in PE and a decreasing trend in AE. (Fig.4.3.4b). However, no trend was observed in the WS and WD (Fig.4.3.4c). The highest water surplus (3962 mm.) was

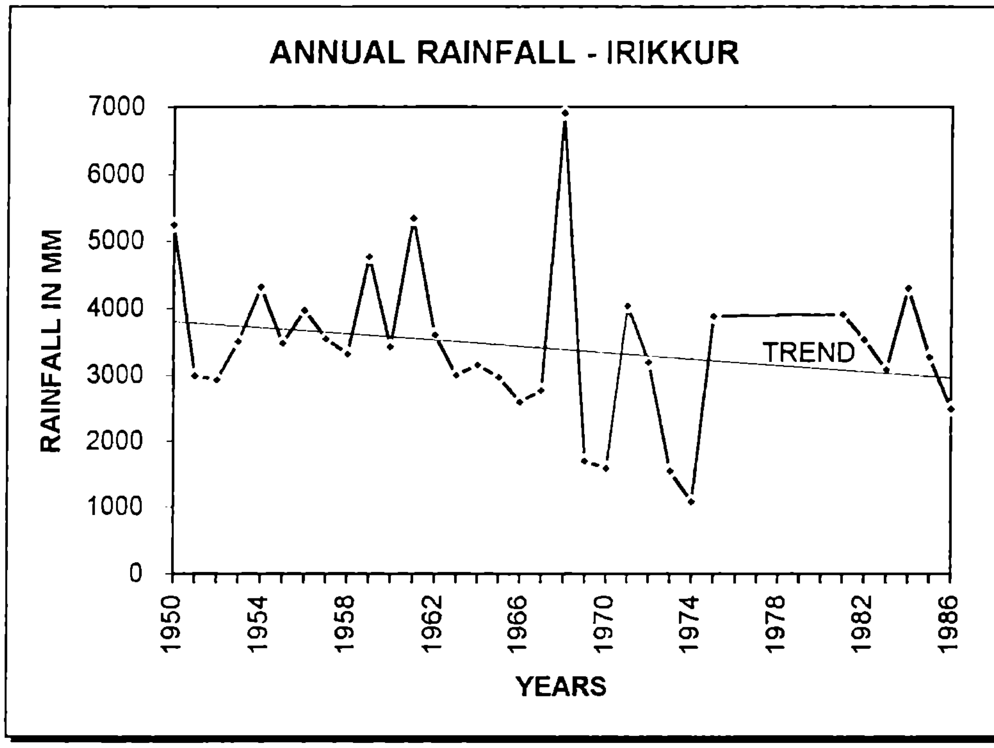


Fig. 4.3.3a. ANNUAL RAINFALL - IRIKKUR

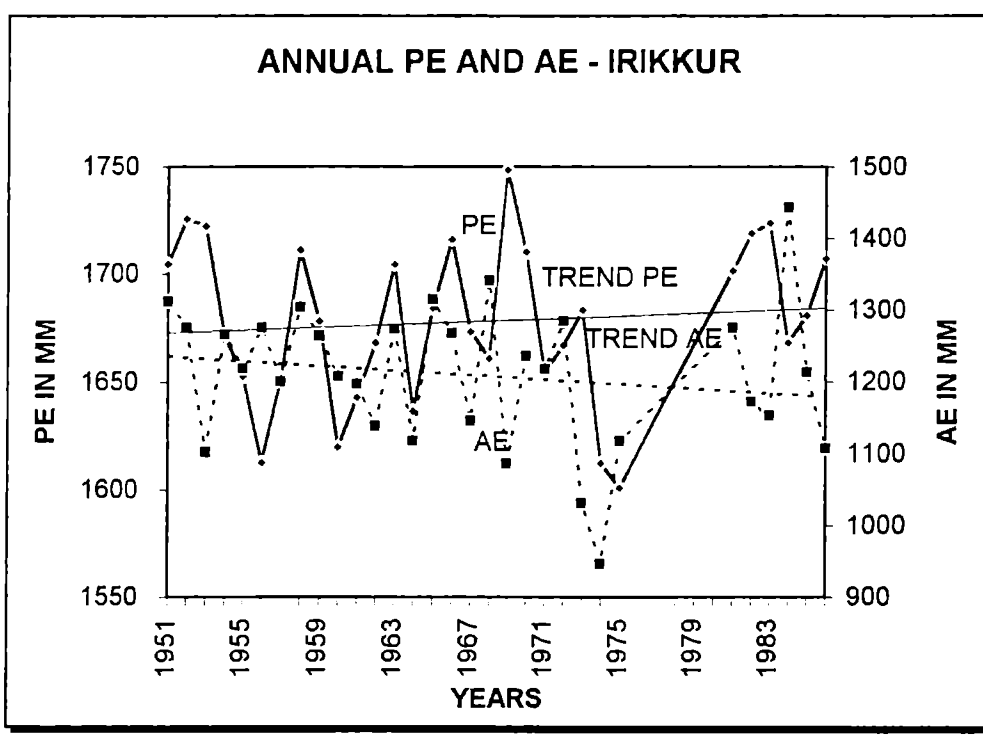


Fig. 4.3.3b. ANNUAL PE & AE - IRIKKUR

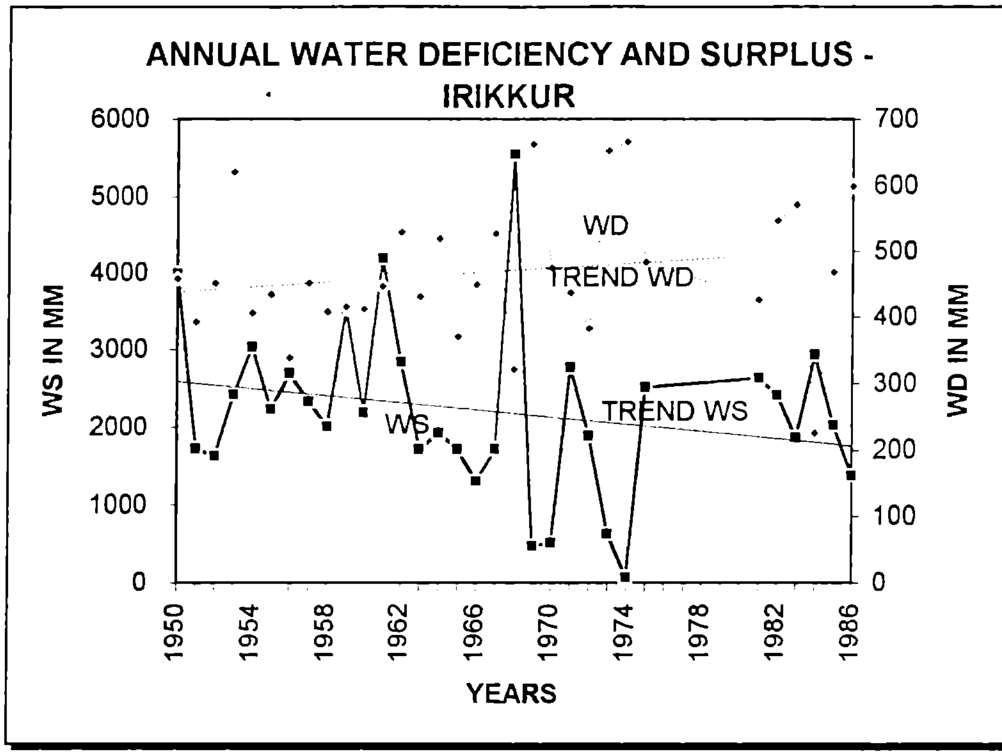


Fig. 4.3.3c. ANNUAL WD & WS - IRIKKUR

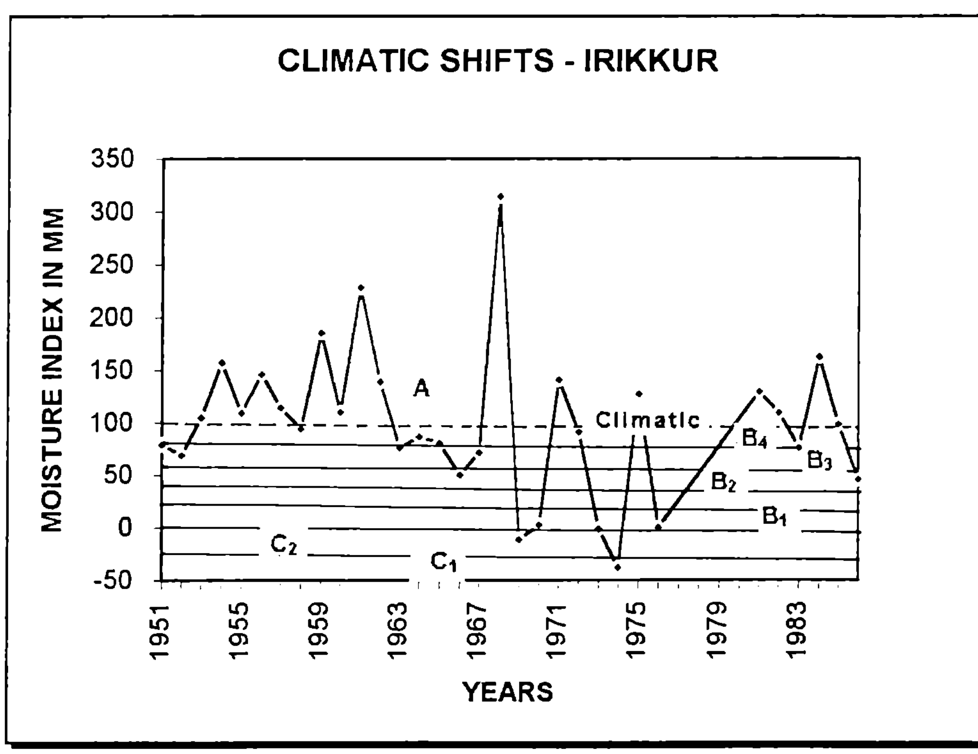


Fig. 4.3.3d. CLIMATIC SHIFTS - IRIKKUR

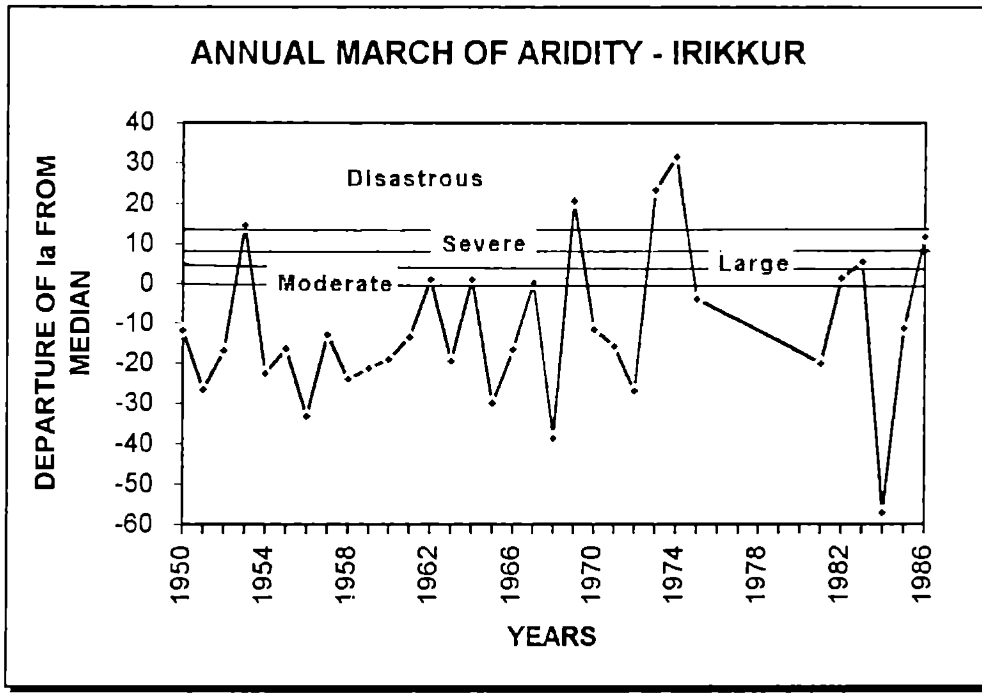


Fig. 4.3.3e. ANNUAL MARCH OF ARIDITY INDEX - IRIKKUR

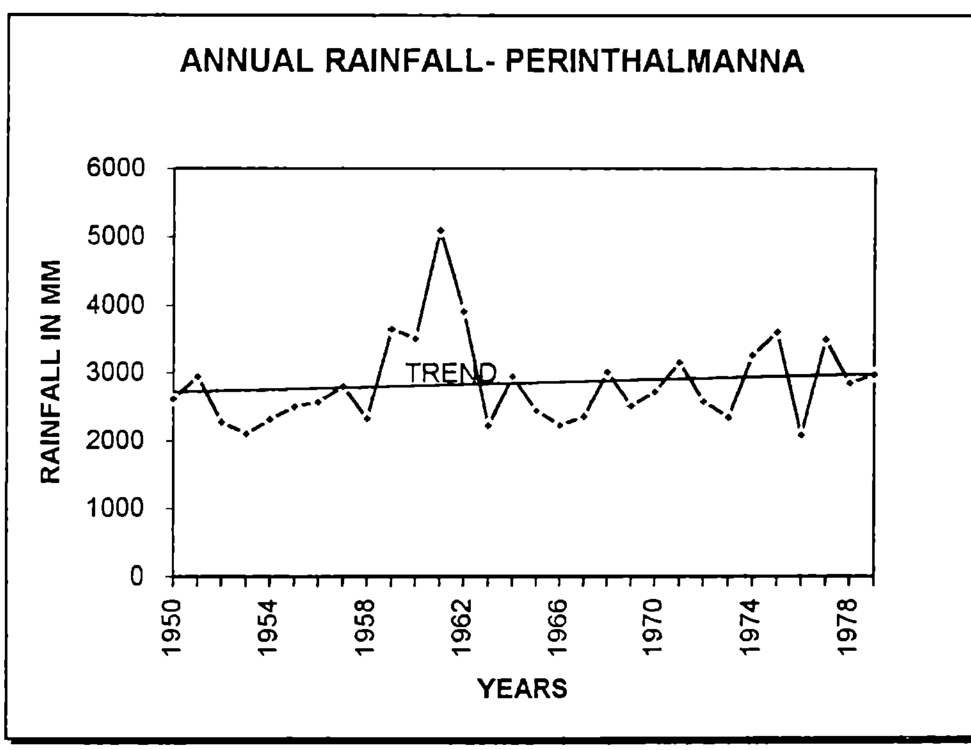


Fig. 4.3.4a. ANNUAL RAINFALL - PERINTHALMANNA

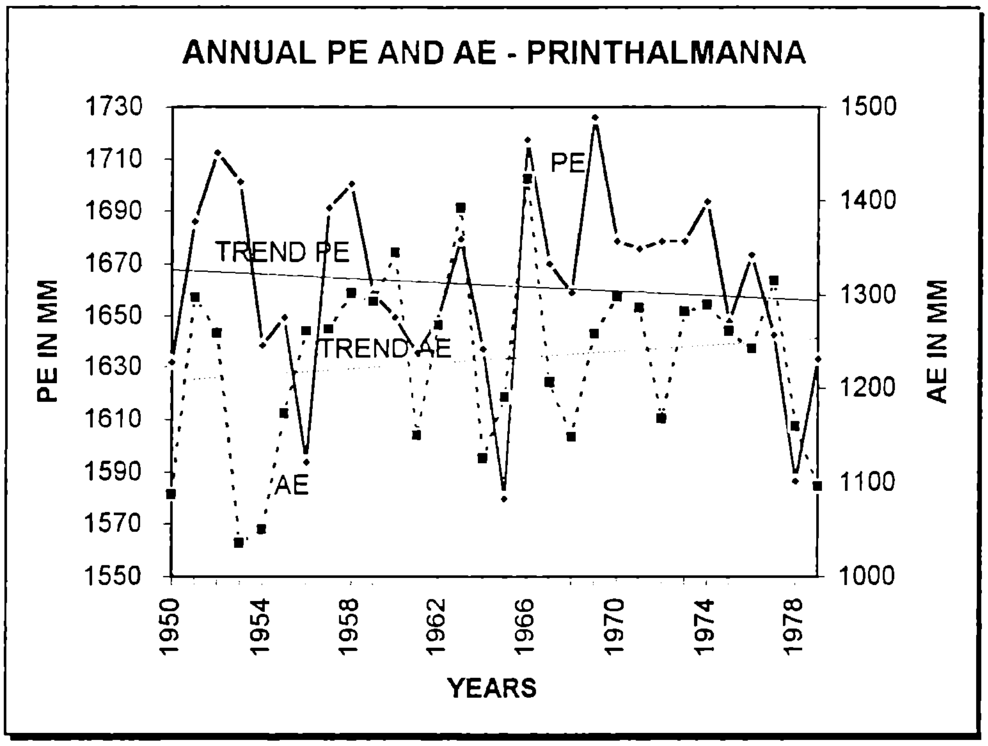


Fig. 4.3.4b. ANNUAL PE & AE - PERINTHALMANNA

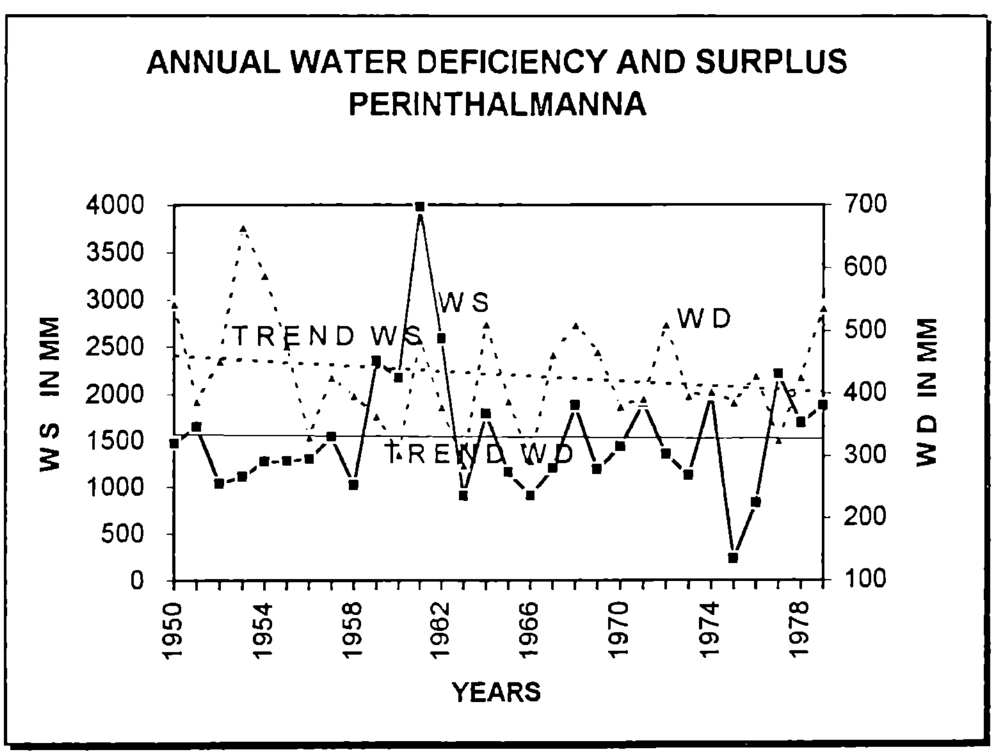


Fig. 4.3.4c. ANNUAL WD & WS - PERINTHALMANNA

recorded in the year 1961, and the highest water deficit (666 mm.) was experienced in the year1953.

Perinthalmanna experiences humid B_4 climate.A majority of the climatic shifts were within the humid type.(Fig.4.3.4d). Six years recorded shift towards moist sub-humid type.

This station had comparatively less number of droughts.(Fig.4.3.4e). There were two consecutive years of disastrous droughts in 1953 and 1954. There were also four severe droughts during this period

B. CENTRAL ZONE

4.3.5. MANNARAKKAD

Located at $10^0 59'$ N and $76^0 28'$ E, Mannarakkad receives 2710 mm. annual rainfall. During the period 1950-1986, 18 years recorded below normal rainfall. (Fig.4.3.5a). A marked declining trend in the annual rainfall can be noticed. The highest annual rainfall of 4416 mm .was recorded in 1961. The lowest was in the year 1983, when the annual rainfall was only 1520 mm.

The annual PE of Mannarakkad does not show any trend, while the AE shows a declining trend. (Fig.4.3.5b).

Following the rainfall pattern, the WS and WD displays a decreasing and increasing trend respectively. (Fig.4.3.5c).

The humid B_2 type of climate of Mannarakkad indicates varying shifts during the period 1950-1986. Seven years recorded shift towards C_2 type and five years towards perhumid type category. (Fig. 4.3.5d).

Two consecutive years of disastrous droughts occurred in 1983 and 1984. (Fig 4.3.5e). Another notable aspect is that , it had six consecutive years of droughts of higher magnitudes from 1981 to 1986.

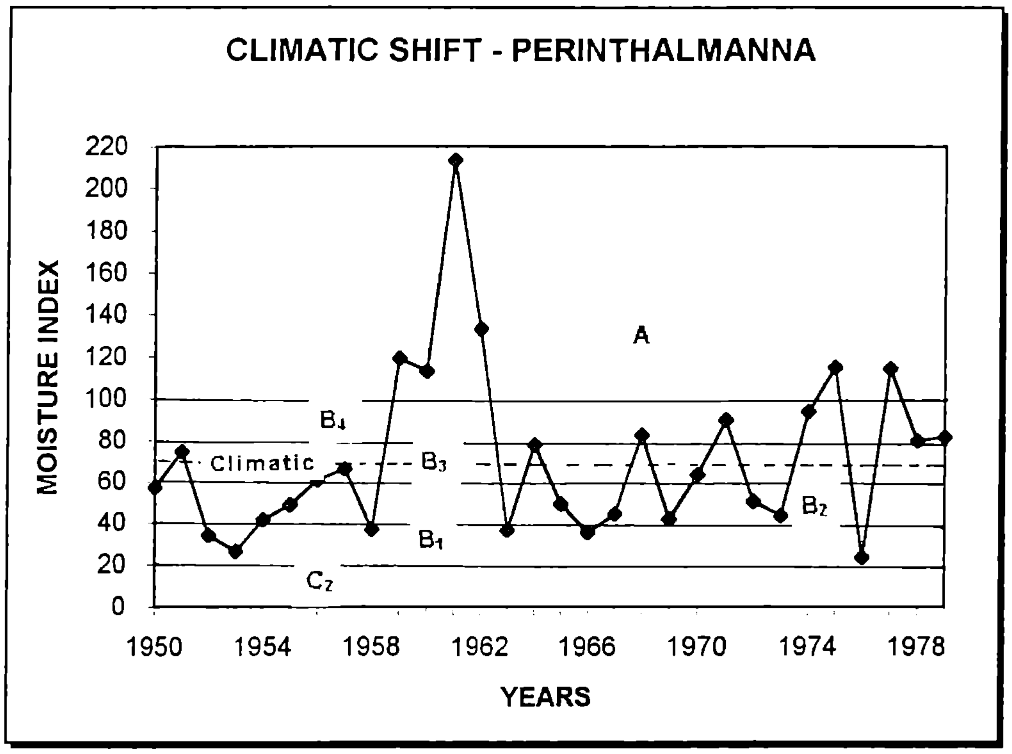


Fig. 4.3.4d. CLIMATIC SHIFTS - PERINTHALMANNA

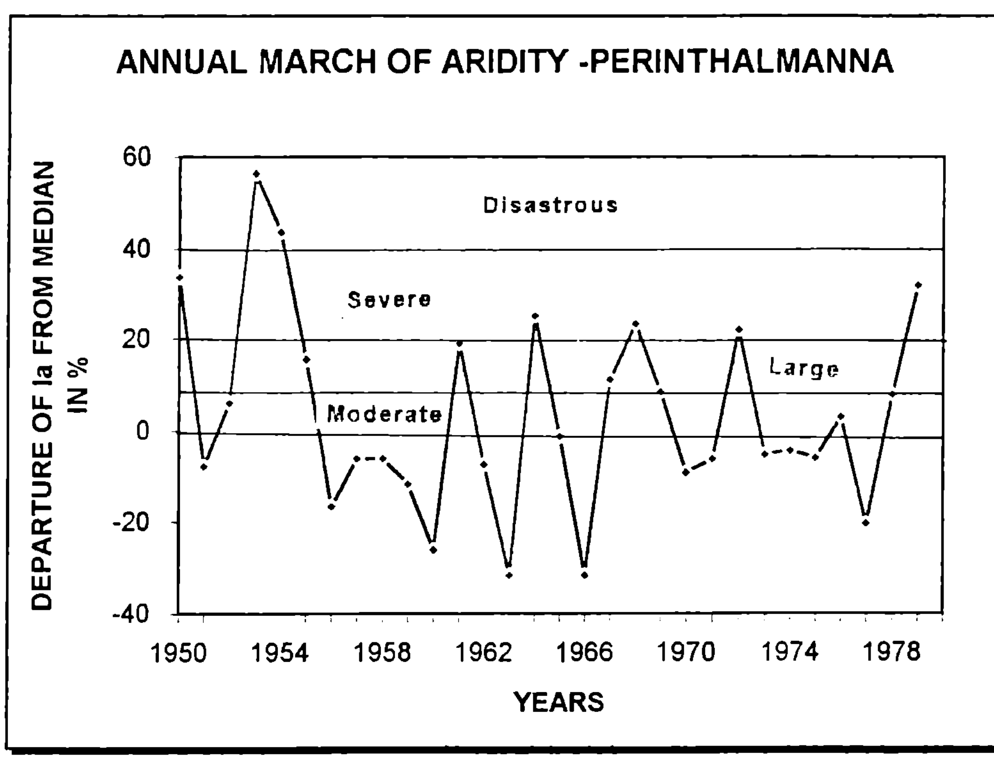


Fig. 4.3.4e. ANNUAL MARCH OF ARIDITY INDEX

PERINTHALMANNA

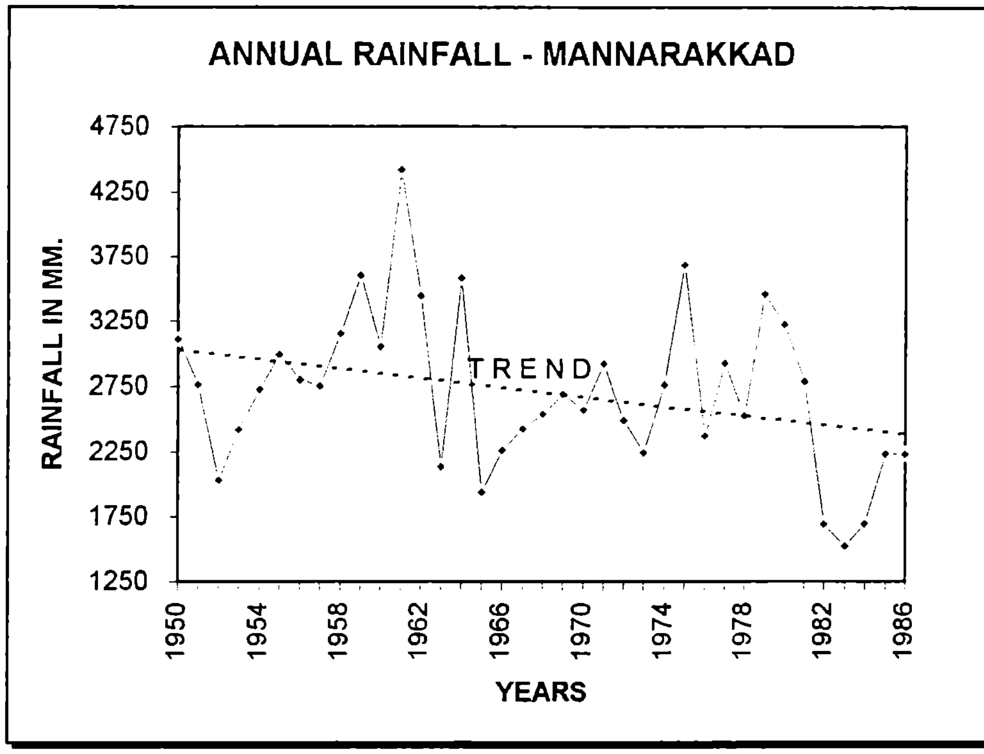


Fig. 4.3.5a. ANNUAL RAINFALL - MANNARAKKAD

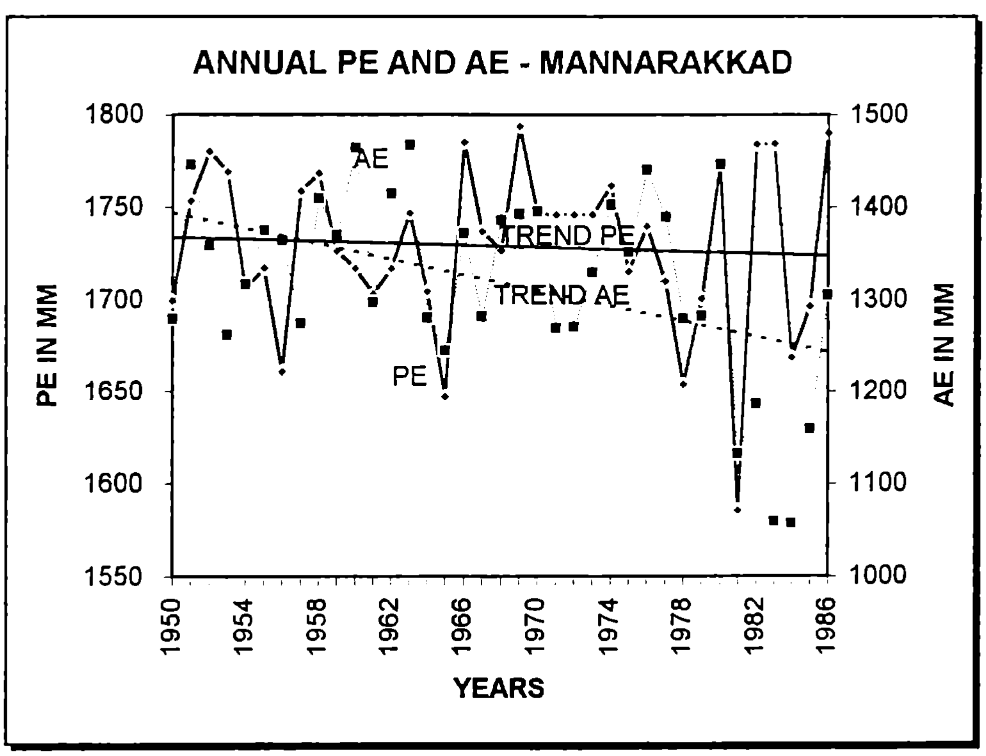


Fig. 4.3.5b. ANNUAL PE & AE - MANNARAKKAD

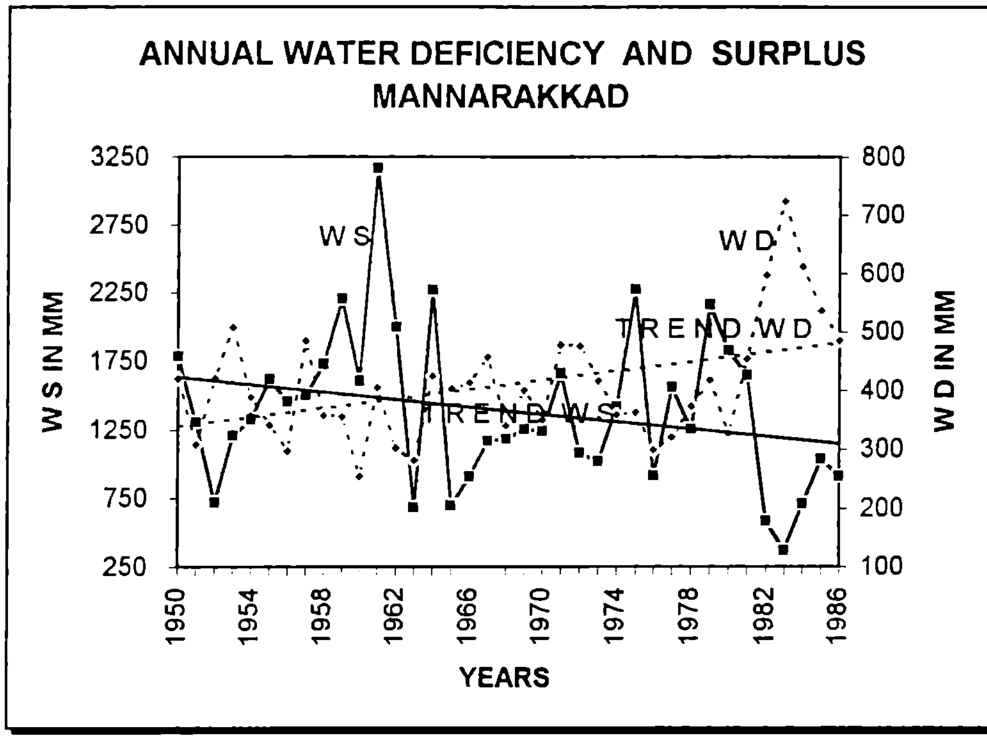


Fig. 4.3.5c. ANNUAL WD & WS - MANNARAKKAD

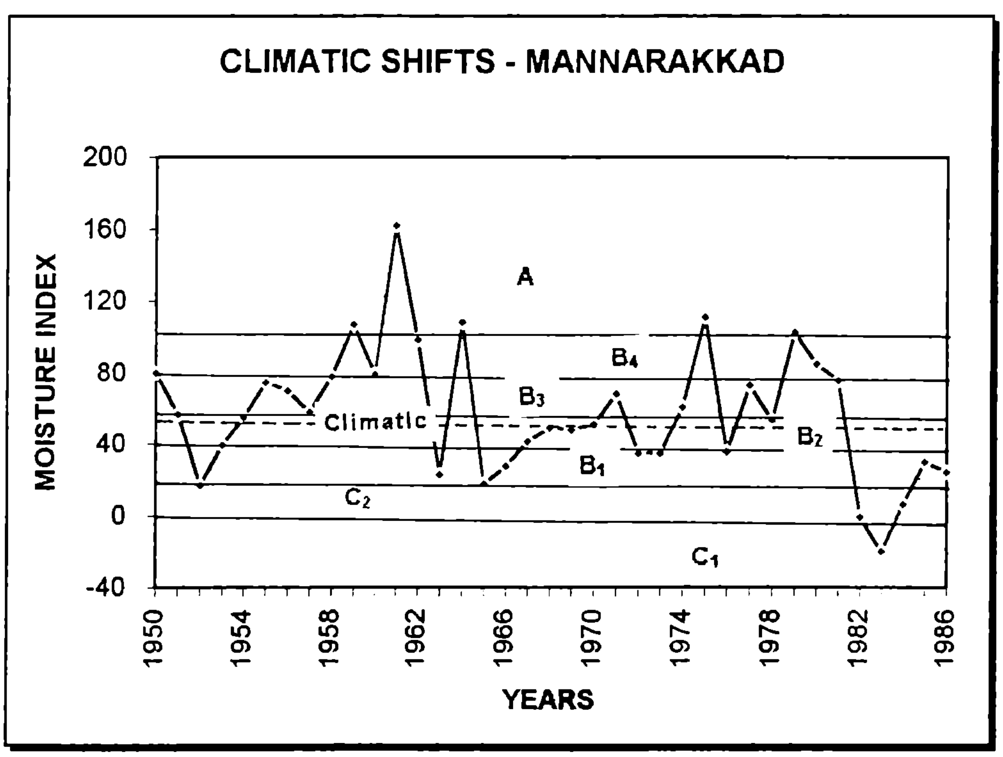


Fig. 4.3.5d. CLIMATIC SHIFTS - MANNARAKKAD

4.3.6. KODUNGALLUR

Kodungallur is located at $10^0 13'$ N and $76^0 12'$ E. It gets 2904 mm.of annual rainfall. With wide fluctuations in annual rainfall, which varies from 1889 mm . to 4518 mm., it displays a slight decreasing trend.(Fig. 4.3.6a).

A distinct increasing trend in PE and a decreasing trend in AE is evident from Fig.4.3.6b.

Following the pattern of rainfall, the WS shows a decreasing trend, while the WD is on the increase.(Fig. 4.3.6c).

Kodungallur has a B_3 type of climate. Five years recorded shifts towards perhumid type. Most of the shifts were within the humid type. (Fig. 4.3.6d).

The annual march of aridity index shows (Fig.4.3.6e) that there was only one disastrous drought in Kodungallur, in the year 1968. But 17 years experienced moderate droughts and there were large droughts in 1979, 1980 and 1983.

4.3.7. MALAYATTOOR

Located at $10^0 12'$ N and $76^0 31'$ E, Malayattoor receives 3156 mm. of annual rainfall. Here again about 50% of the years under study recorded below normal rainfall.(Fig. 4.3.7a). The annual rainfall pattern indicates a decreasing trend. The lowest recorded rainfall in Malayattoor was 1916 mm. (1974), and the highest was 4085 mm. (1982).

The annual PE pattern shows no trend, while the AE shows a moderate declining trend. (Fig.4.3.7b).

Like many other stations, marked decreasing trend in WS and increasing trend in WD is observed in Malayattoor also.(Fig. 4.3.7c).

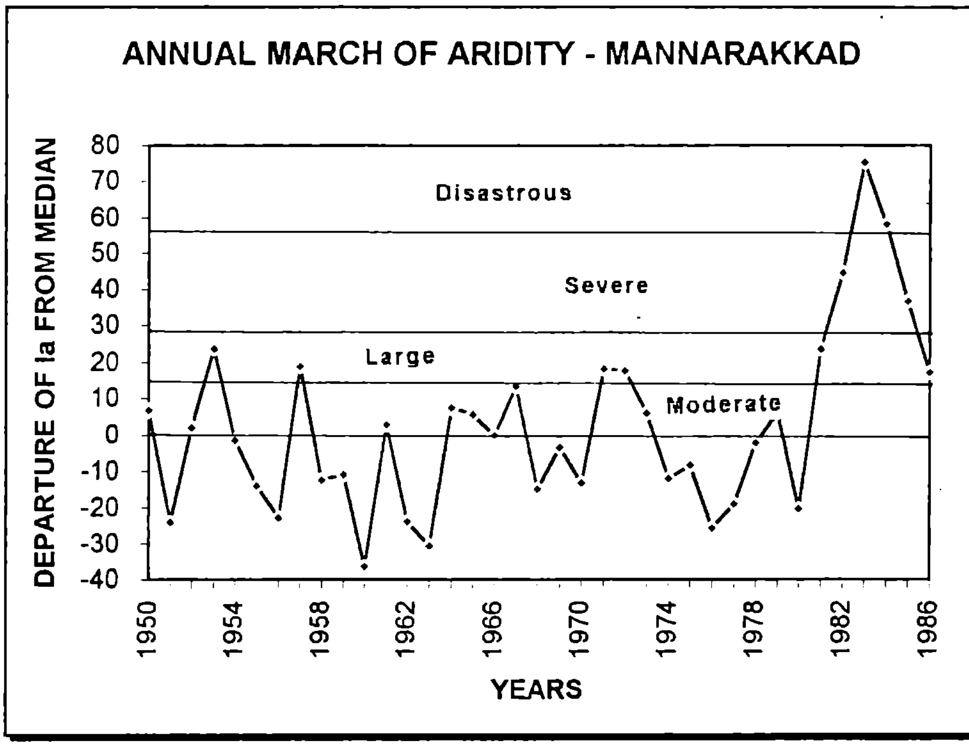


Fig. 4.3.5e. ANNUAL MARCH OF ARIDITY INDEX MANNARAKKAD

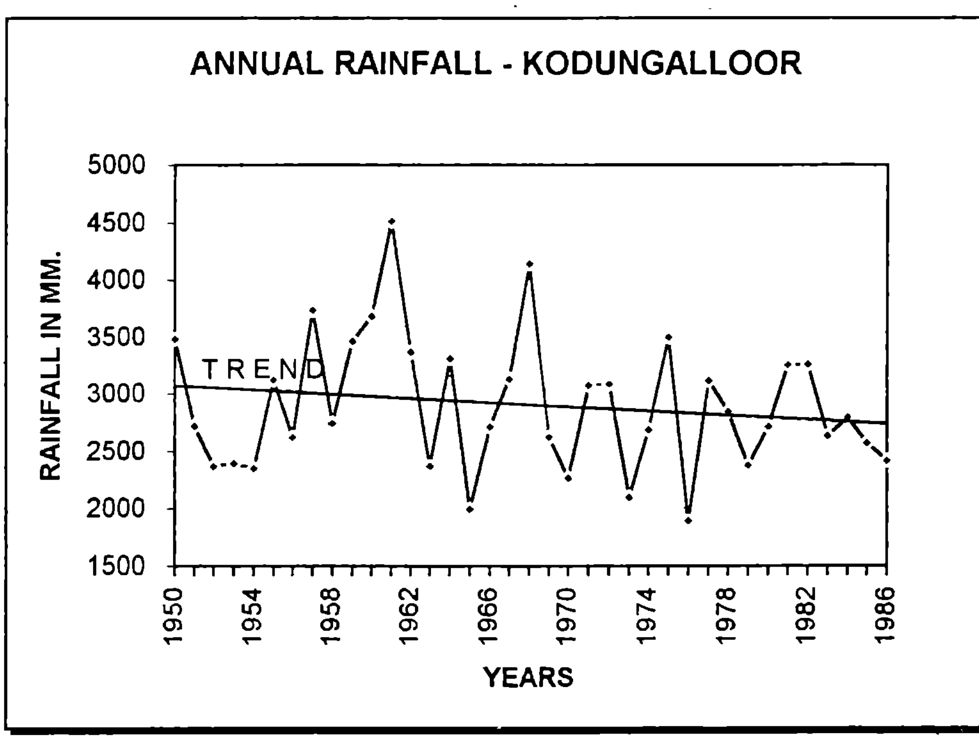


Fig. 4.3.6a. ANNUAL RAINFALL - KODUNGALLUR

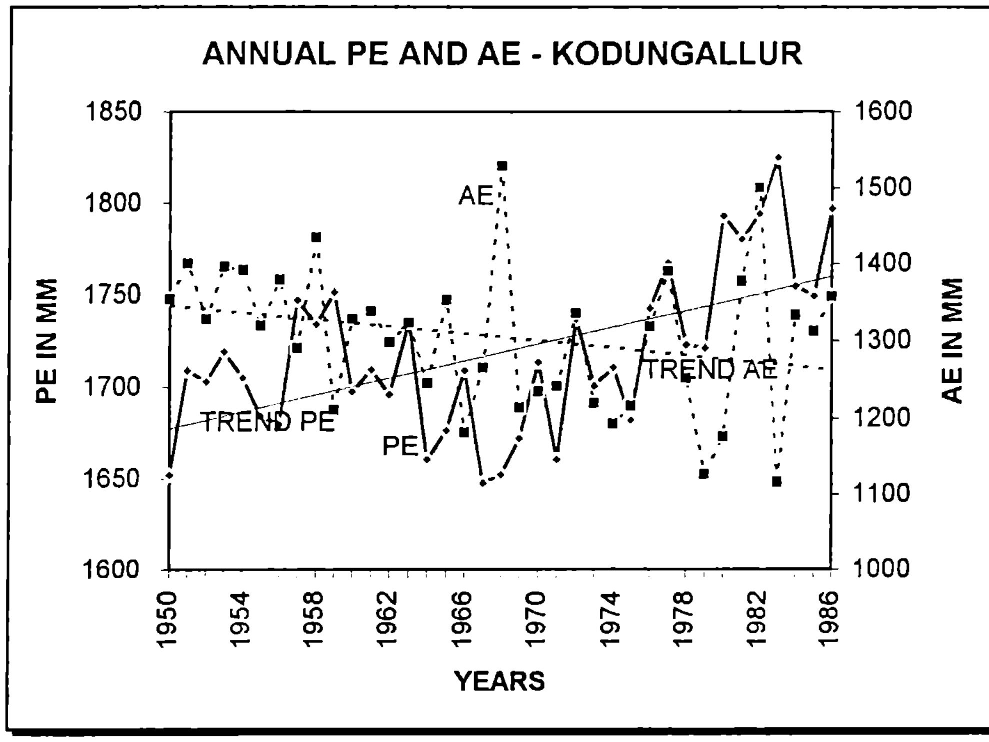


Fig. 4.3.6b. ANNUAL PE & AE - KODUNGALLUR

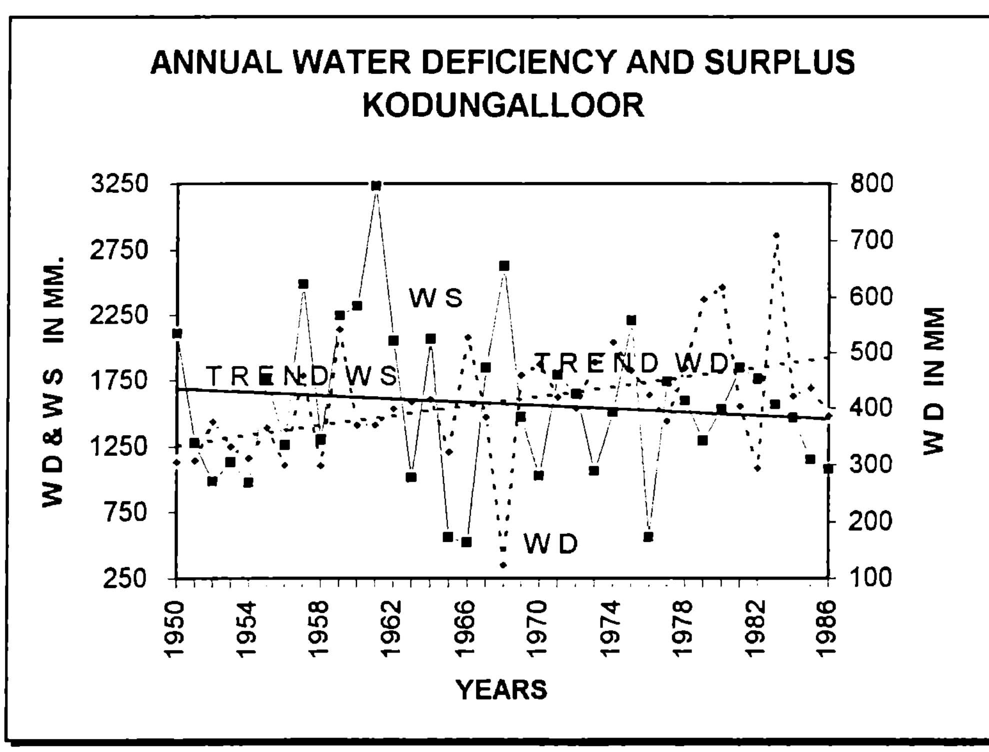


Fig. 4.3.6c. ANNUAL WD & WS - KODUNGALLUR

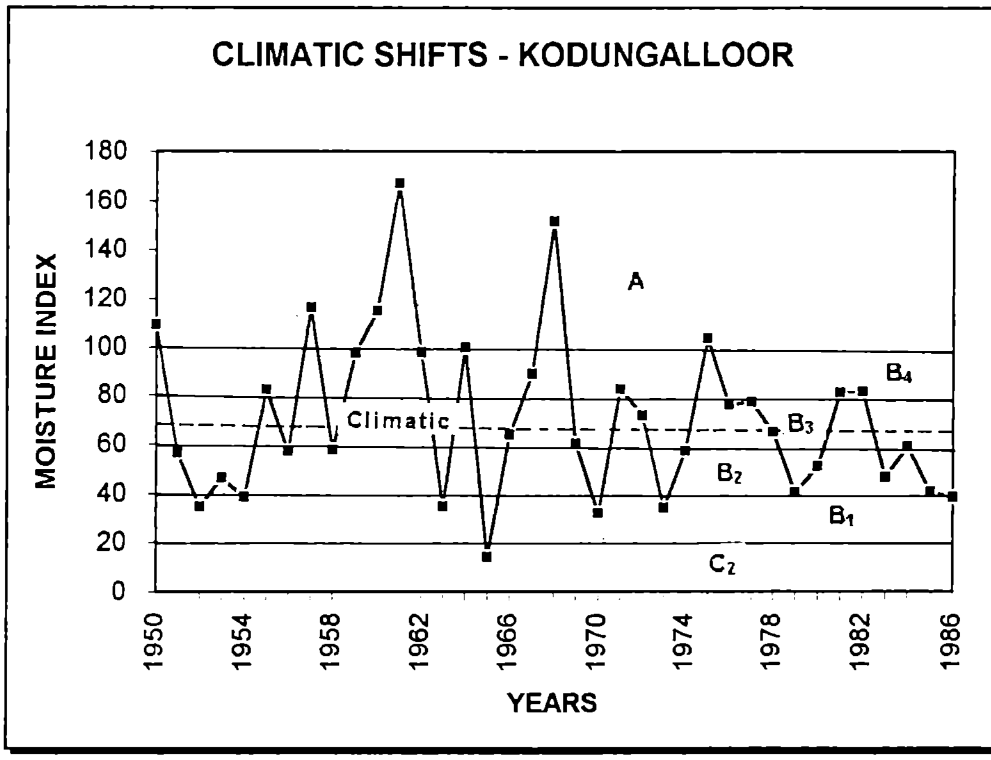


Fig. 4.3.6d. CLIMATIC SHIFTS - KODUNGALLUR

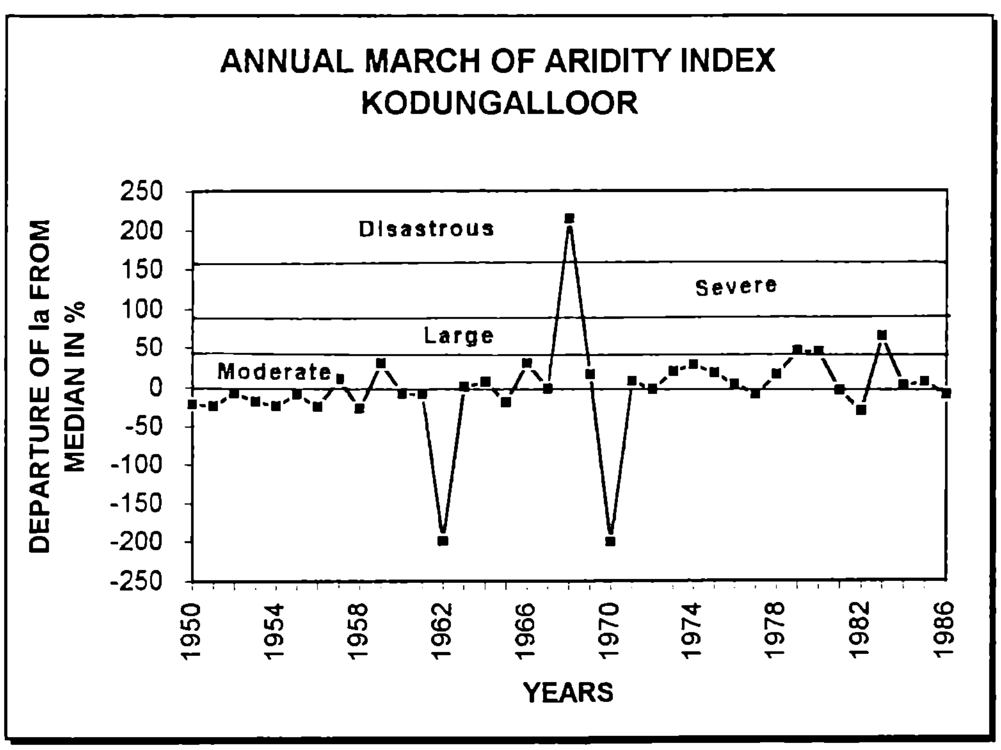


Fig. 4.3.6e. ANNUAL MARCH OF ARIDITY INDEX

KODUNGALLUR

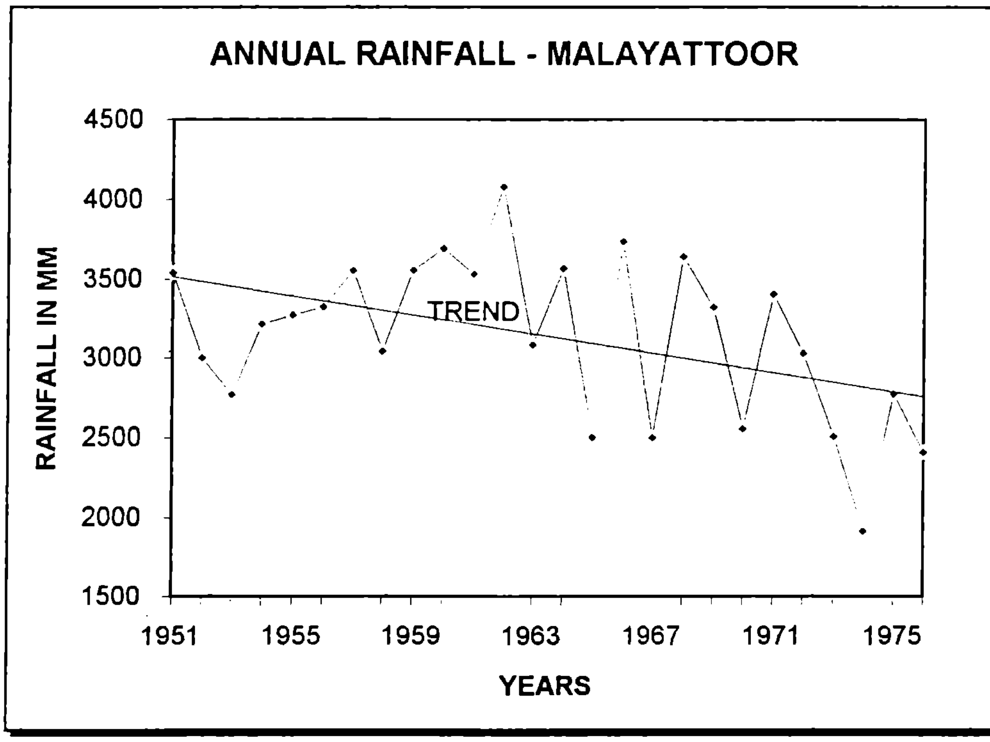


Fig. 4.3.7a. ANNUAL RAINFALL - MALAYATTOOR

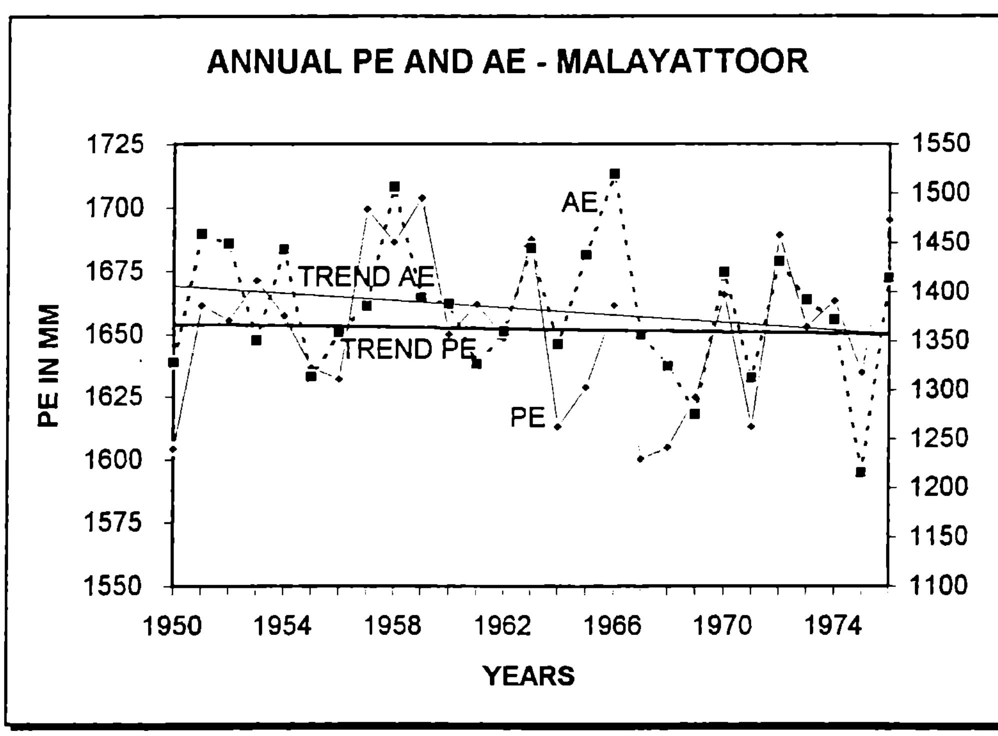


Fig. 4.3.7b. ANNUAL PE & AE - MALAYATTOOR

Malayattoor has a humid (B_4) type of climate. The climatic shift of this station is mainly towards perhumid side. (Fig.4.3.7d). The only major shift towards drier side was in the year 1974, when the moisture index dropped down to 19.8, indicating a shift towards C_2 type.

There were no disastrous droughts in Malayattoor.(Fig.4.3.7e). Eight years had moderate droughts, six years had large droughts and two years severe droughts.

C. SOUTHERN ZONE

4.3.8. NERIAMANGALAM.

Located at $10^0 03'$ N and $76^0 47'$ E Neriamangalam receives the highest annual rainfall in Kerala - 4637 mm. The highest annual rainfall received at Neriamangalam was 7787 mm.in 1950 and the lowest was 2359 mm.in 1961. Here too a declining trend can se seen in the rainfall pattern.(Fig.4.3.8a).

The annual PE and AE indicates a slight declining trend (Fig 4.3.8b).

Like many other stations, Neriamangalam also shows a decline in annual WS and increase in WD. (Fig.4.3.8c).

Consequent on receiving heavy rainfall, Nerimangalam experiences a perhumid type of climate. The only climatic shift recorded was in the year 1961, when the station experienced B_3 type climate. (Fig.4.3.8d).

Although Neriamangalam records highest rainfall, the wide annual fluctuations caused droughts of various magnitude. There were six moderate, five large, three severe and one disastrous droughts. (Fig.4.3.8e).

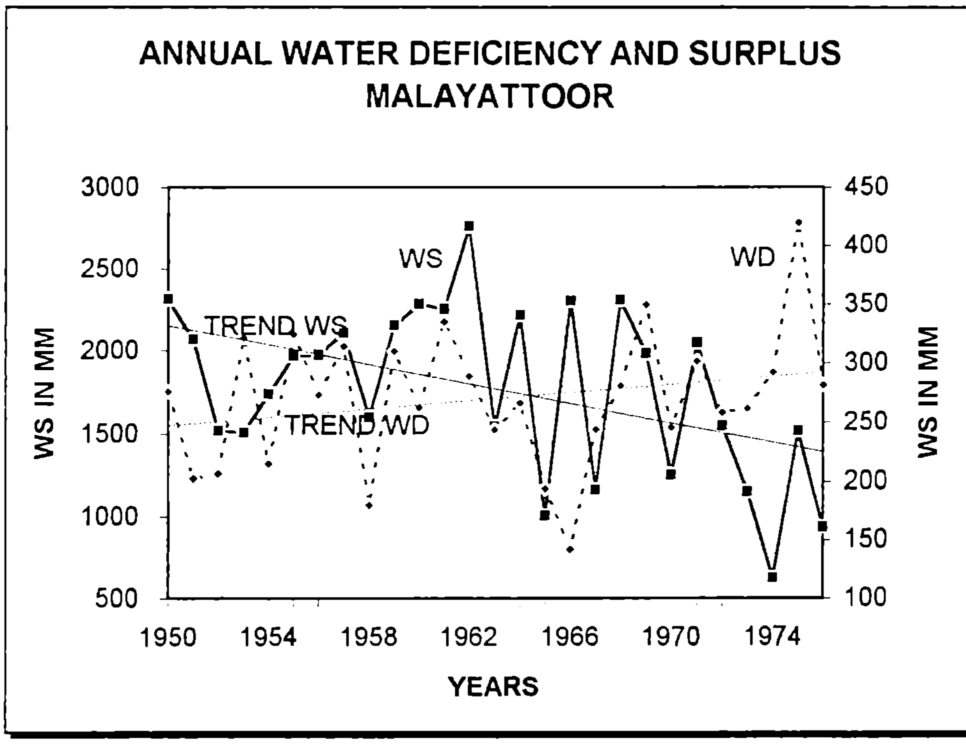


Fig. 4.3.7c. ANNUAL WD & WS - MALAYATTOOR

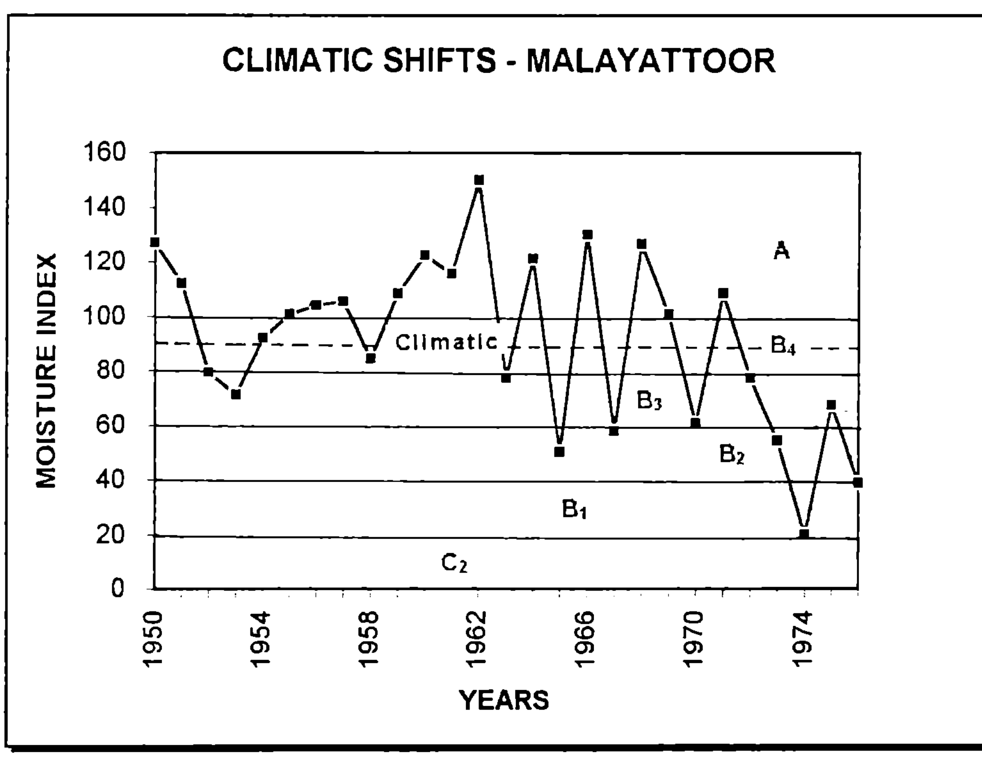


Fig. 4.3.7d. CLIMATIC SHIFTS - MALAYATTOOR

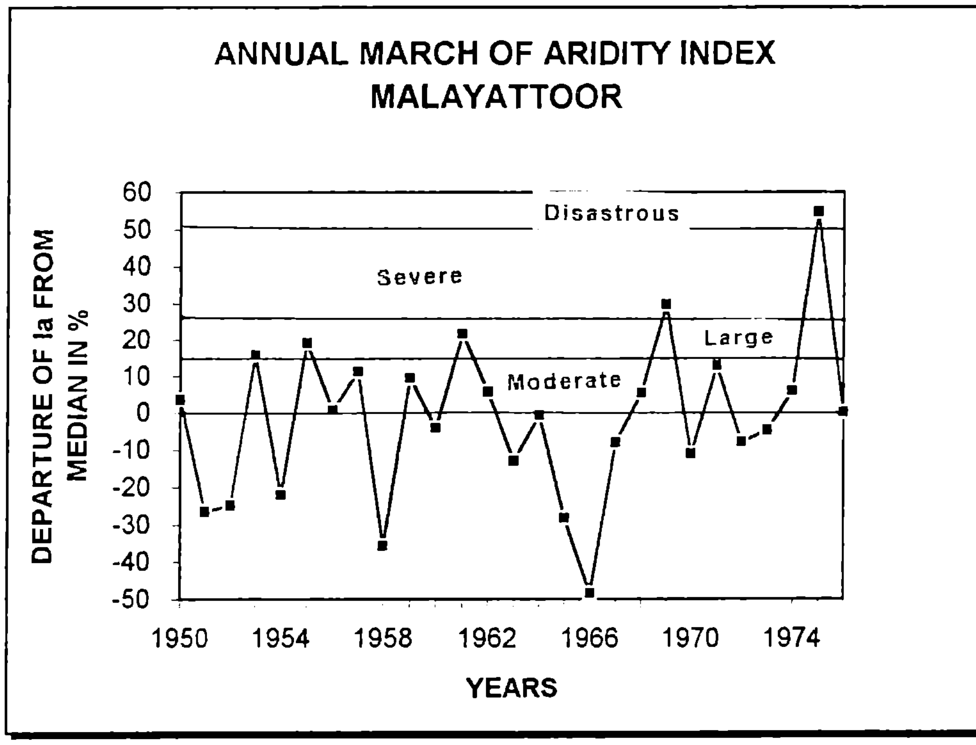


Fig. 4.3.7e. ANNUAL MARCH OF ARIDITY INDEX MALAYATTOOR

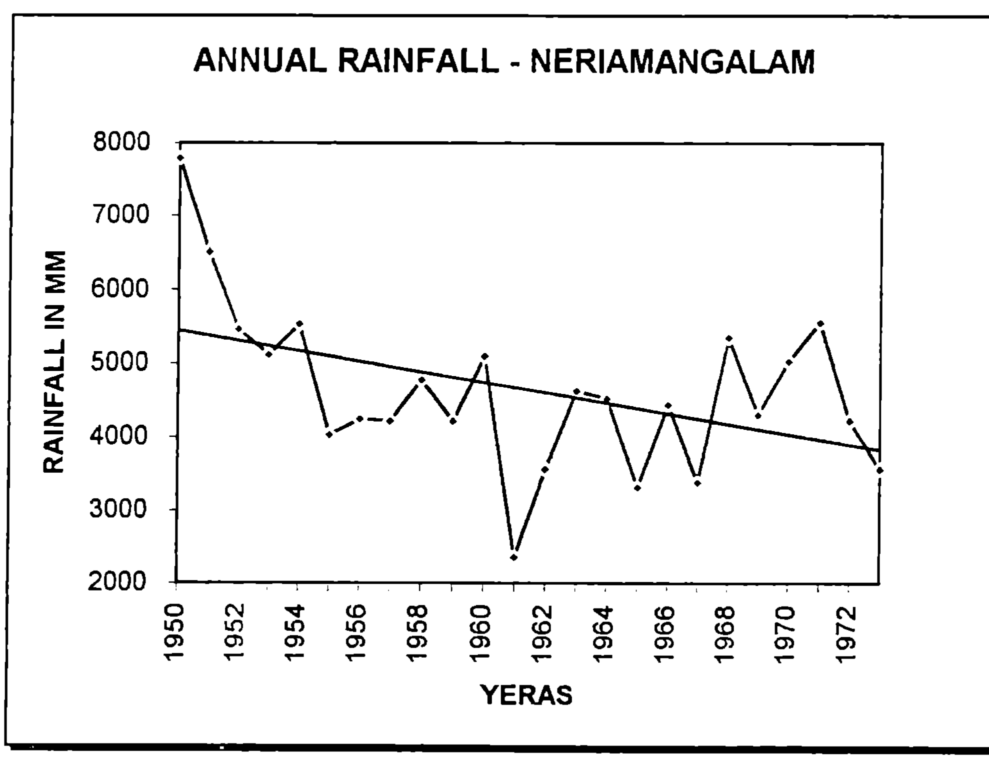


Fig. 4.3.8a. ANNUAL RAINFALL - NERIAMANGALAM

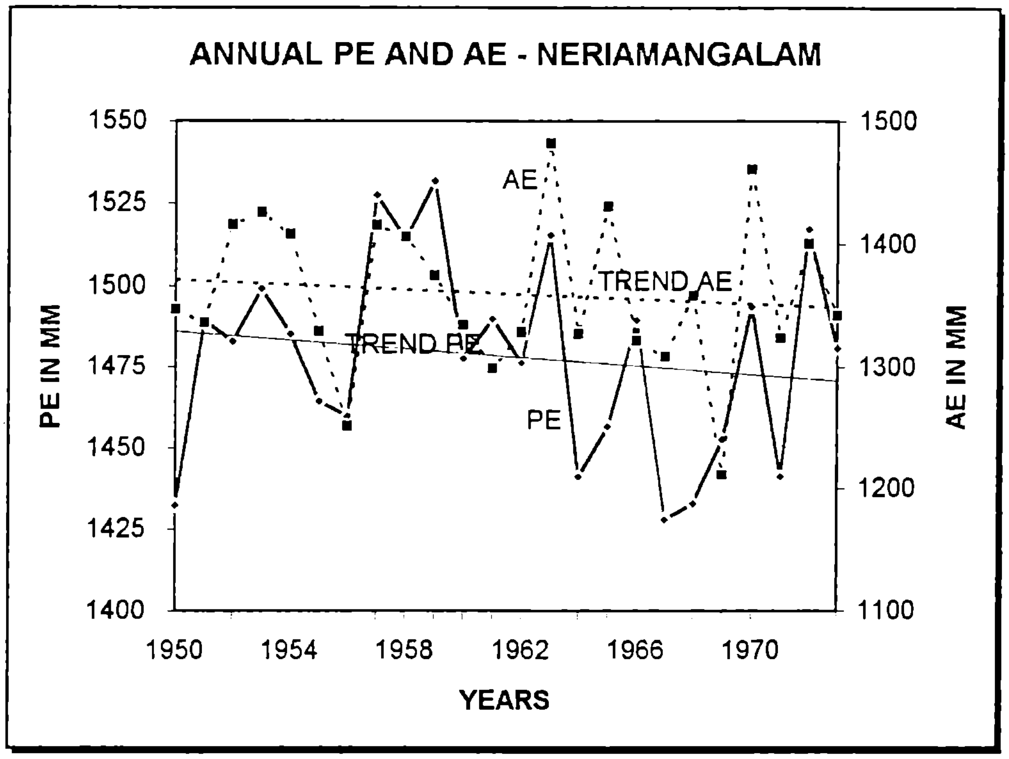


Fig. 4.3.8b. ANNUAL PE & AE - NERIAMANGALAM

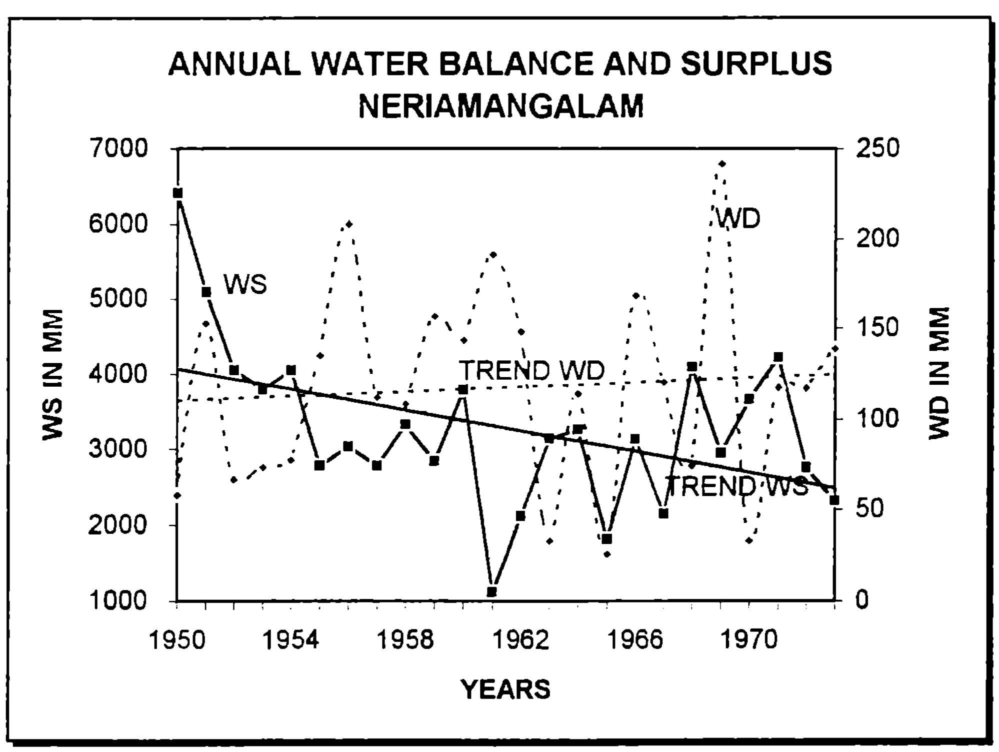


Fig. 4.3.8c. ANNUAL WD & WS - NERIAMANGALAM

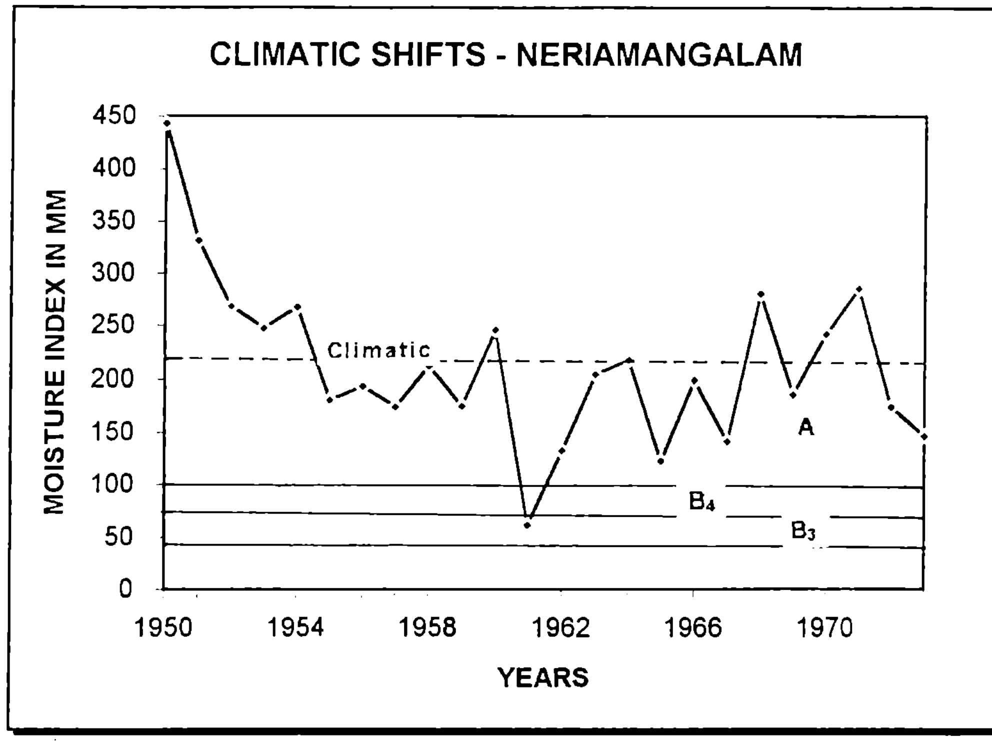


Fig. 4.3.8d. CLIMATIC SHIFTS - NERIAMANGALAM

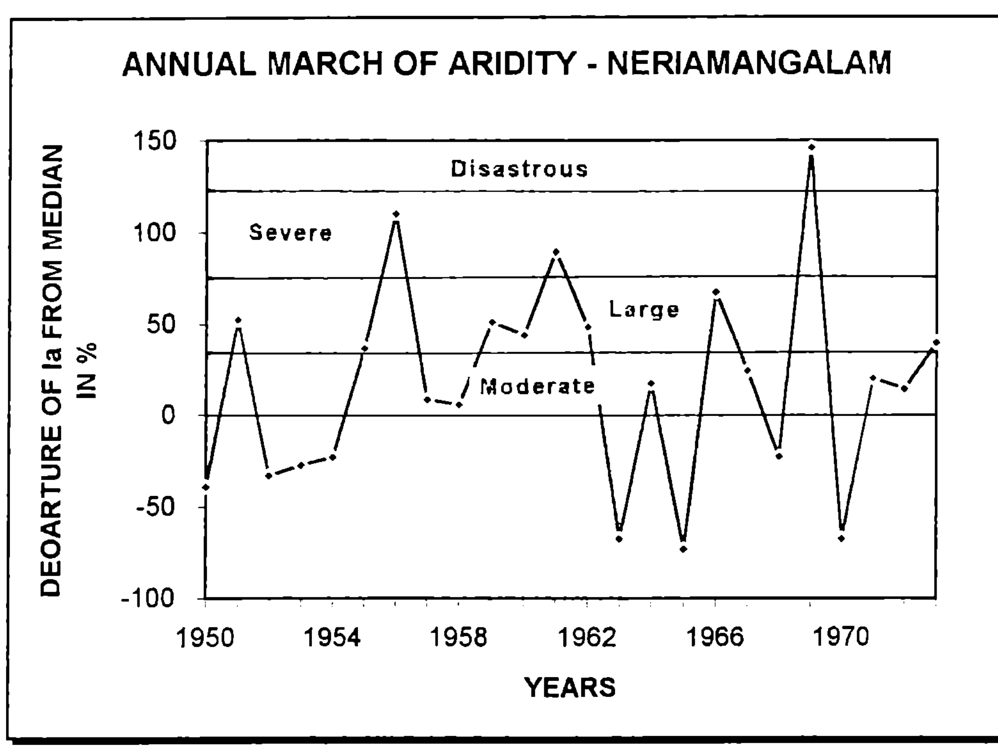


Fig. 4.3.8e. ANNUAL MARCH OF ARIDITY INDEX

NERIAMANGALAM

4.3.9. KOTTAYAM

Located at $9^0 35'$N and $76^0 32'$E, Kottayam is a midland station. It receives 2995 mm. of mean annual rainfall. With wide inter-annual variations, Kottayam also displays a declining trend in annual rainfall.(Fig.4.3.9a). Maximum annual rainfall of Kottayam was 4076 mm recorded in 1976 and the lowest was in the year 1965 (2016 mm).

The PE at this station shows an increasing trend. (Fig.4.3.9b), but no trend was observed in the AE. The highest annual PE was 1817 mm recorded in the years 1983 and 1986. The AE was lowest during 1971 and 1983.

Same pattern of trend is observed in the case of WS and WD. Annual WS shows a declining trend while the WD displays an increasing trend. (Fig.4.3.9c).

Kottayam experiences a humid type of climate. Fig.4.3.10d shows the inter-annual climatic shifts of Kottayam. Most of the shifts had occurred within the humid sub categories. During the period 1950-1986, 11 years show a shift towards per humid (A) type.

There were comparatively less number of droughts in Kottayam. (Fig.4.3.9e). In all there were 2 disastrous droughts (1978 and 1983) and three severe droughts (1953, 1973 and 1982.). Apart from this there were 5 large and 8 moderate droughts during this period.

4.3.10. ATTINGAL

Located at 8^0 42' N and 76^0 49' E, Attingal experiences a moist sub-humid type of climate. It receives a mean annual rainfall of 1771 mm. During the period 1950-1986, the year 1960

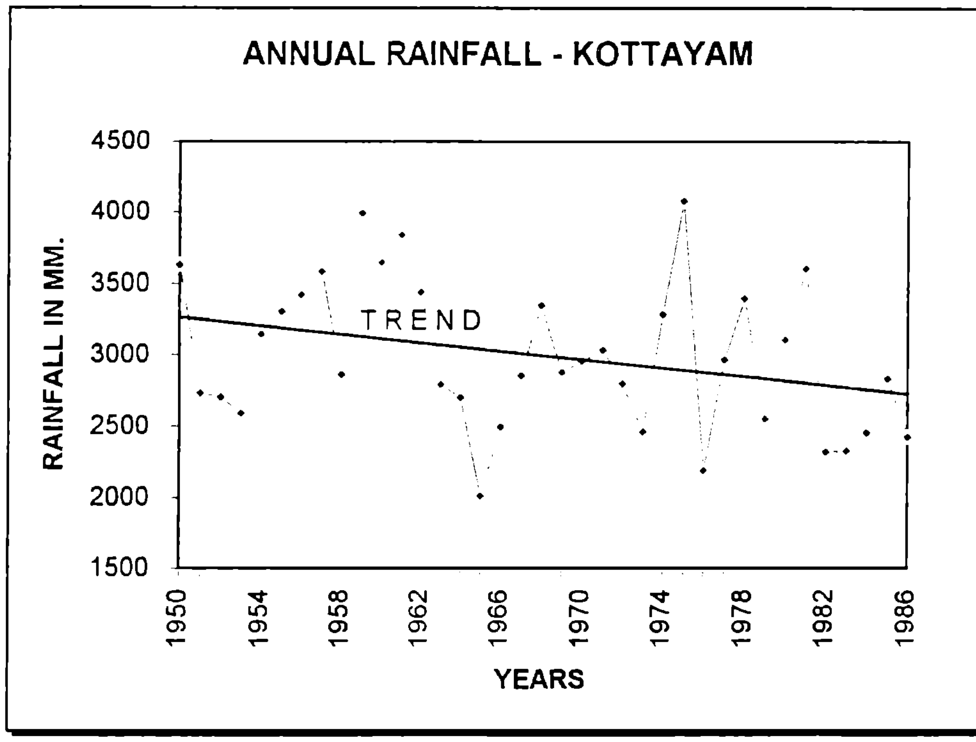


Fig. 4.3.9a. ANNUAL RAINFALL - KOTTAYAM

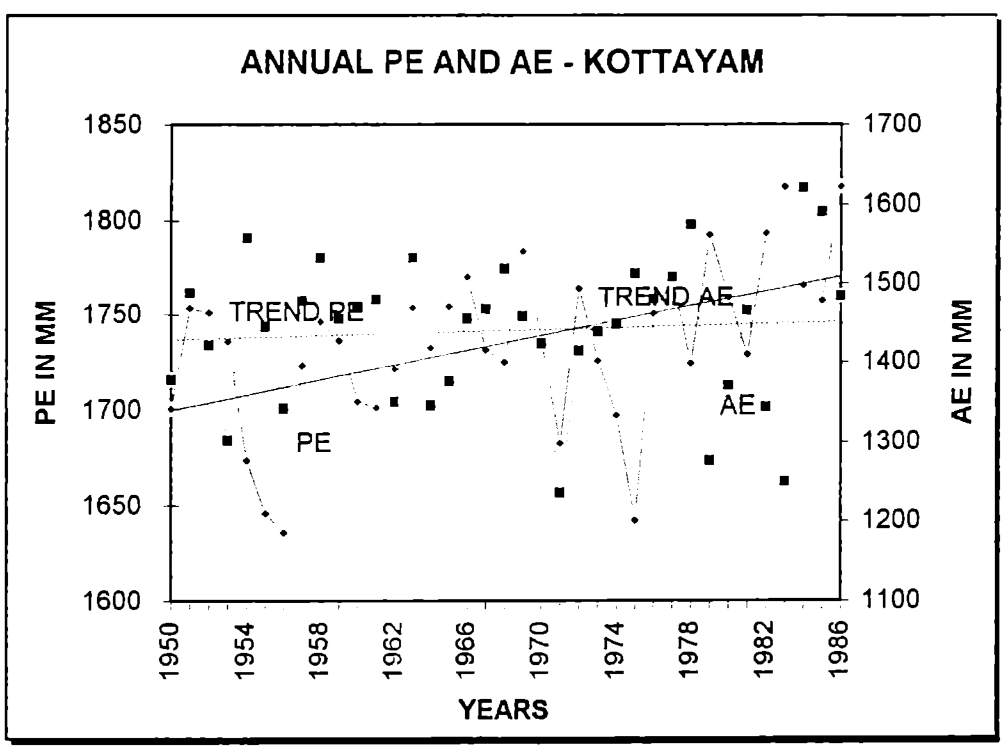


Fig. 4.3.9b. ANNUAL PE & AE - KOTTAYAM

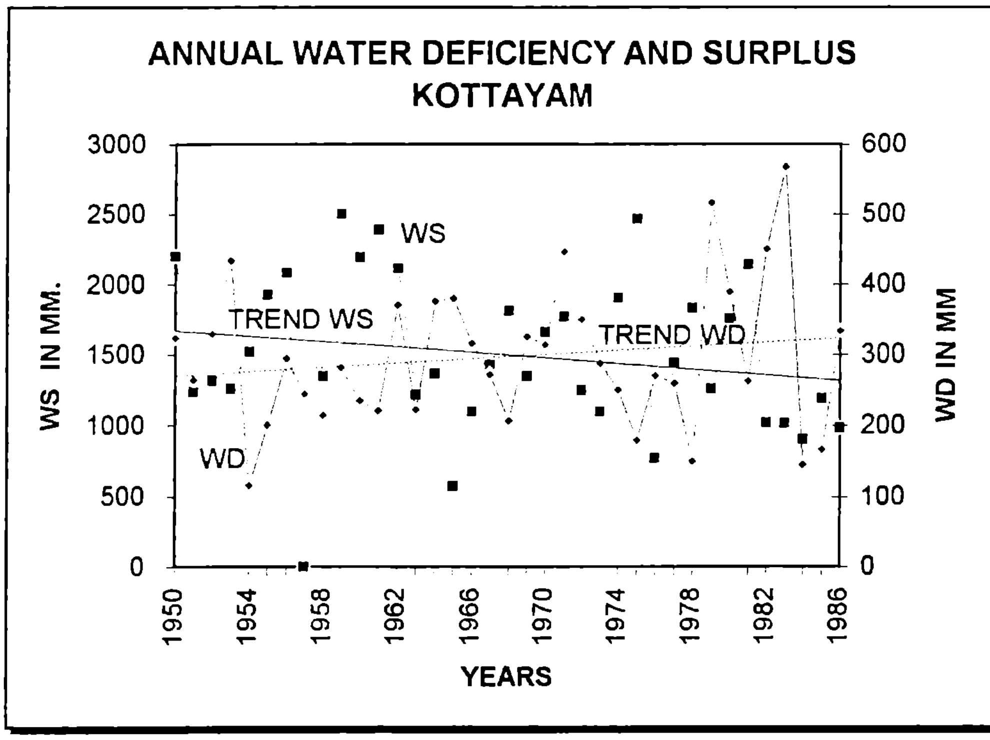


Fig. 4.3.9c. ANNUAL WD & WS - KOTTAYAM

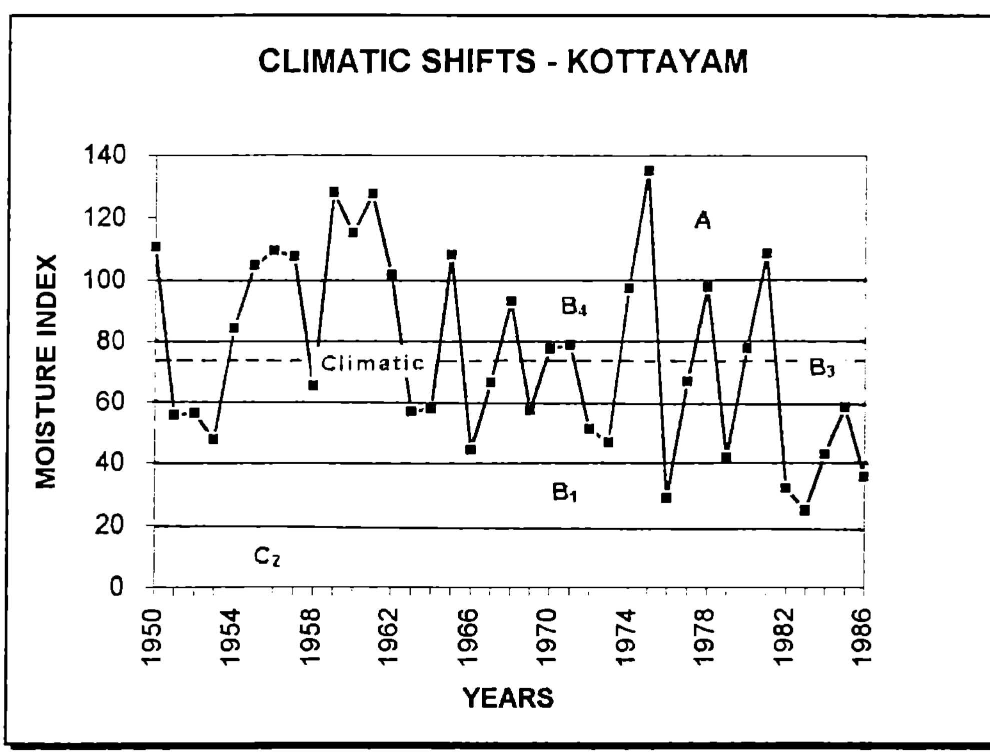


Fig. 4.3.9d. CLIMATIC SHIFTS - KOTTAYAM

was the wettest year, when it recorded 2880 mm. annual rainfall. The driest year was 1983 when the annual rainfall dropped down to a paltry 310 mm. The marked declining trend of annual rainfall in Attingal is clearly displayed in Fig.4.3.10a. Nearly 50% of the years had below normal rainfall.

A conspicuous increase in annual PE and corresponding decrease in annual AE is vividly portrayed in Fig.4.3.10b. The year 1983 had the highest water need (PE) - 1841 mm. Subsequently the lowest AE (312 mm.) was also in the same year.

Following the pattern of rainfall, the annual water surplus of Attingal also shows a declining trend. (Fig.4.3.10c). Maximum water surplus was recorded in the year 1960, when the annual WS was 1487 mm. During the period of observation, two more years had more than 1000 mm. Water surplus- in 1973 and 1985. In contrast to this the annual water deficit shows an increasing trend. It was above 1000 MM. during 1981,1982 and 1983. The highest WD was 1529 mm. recorded in the year 1983, which was the driest year of the station.

With the fluctuations in annual rainfall, the climate of a region is also expected to oscillate. It is obvious from Fig.4.3.10d that the general shift in climate of Attingal is towards the drier side. During the period 1950-1986, two years experienced shift towards arid (E) type and four years towards semi-arid (D) type. All these major shifts had occurred during the last decade.

The major climatic shifts towards drier side is also evident from Fig.4.3.10e, which indicates the type of droughts that occurred in Attingal. There were three years of disastrous droughts and two years of severe droughts during the period

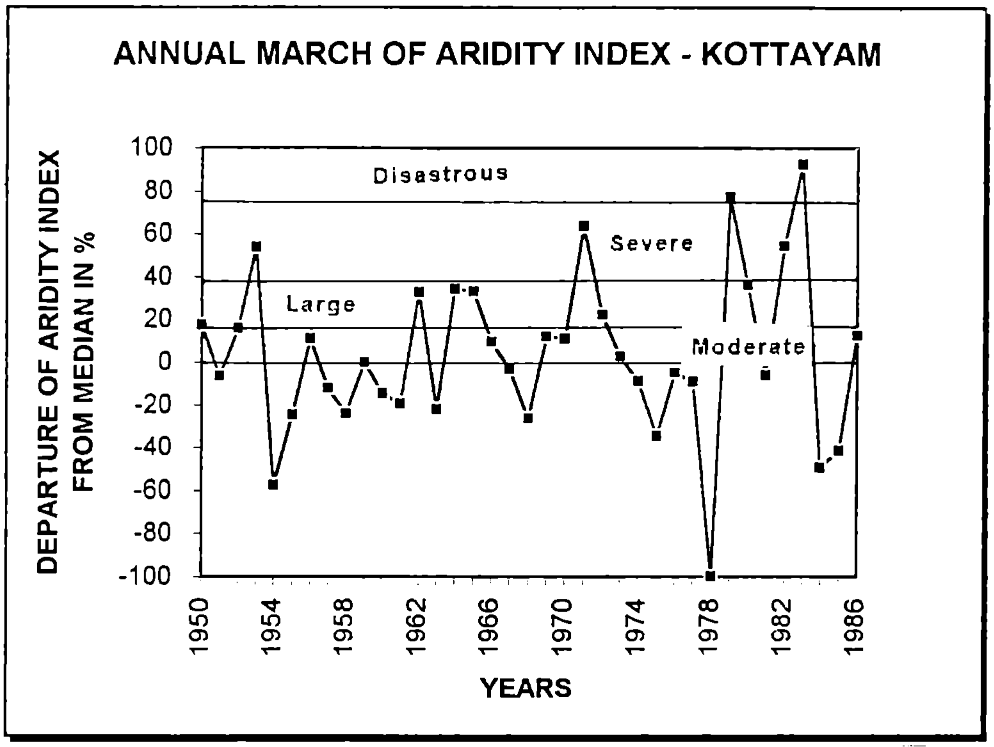


Fig. 4.3.9e. ANNUAL MARCH OF ARIDITY INDEX KOTTAYAM

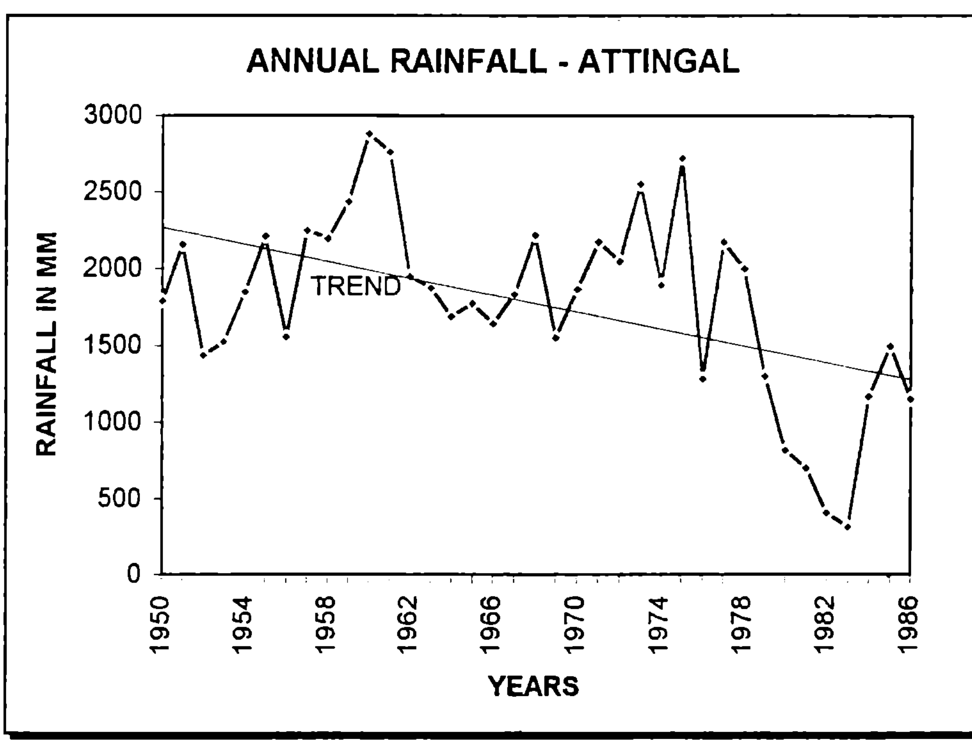


Fig. 4.3.10a. ANNUAL RAINFALL - ATTINGAL

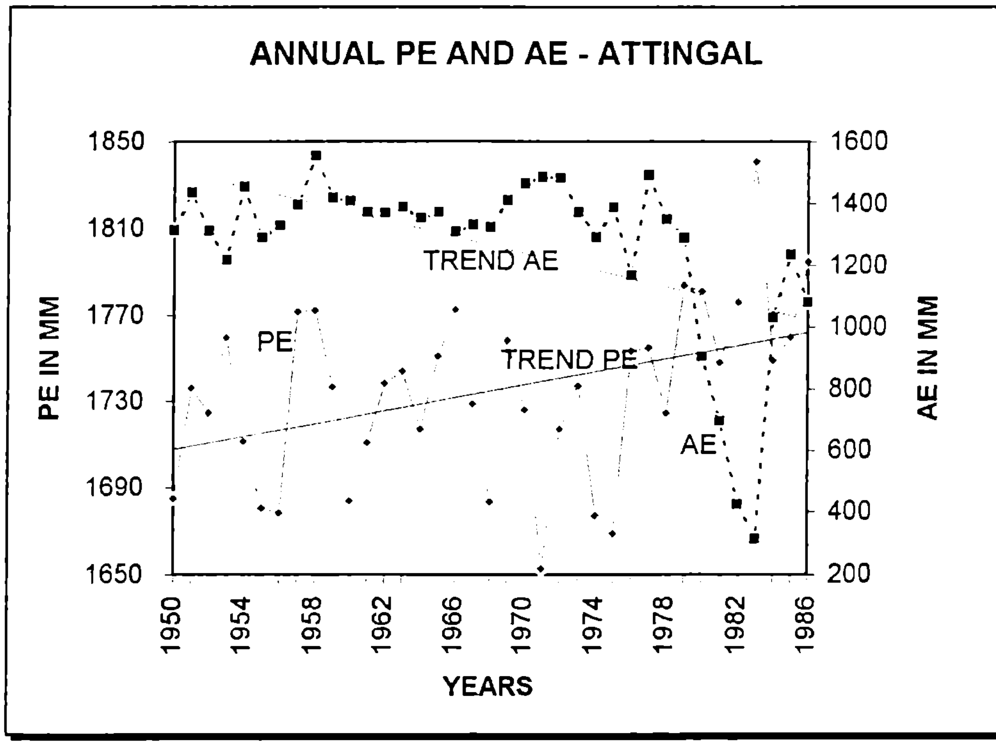


Fig. 4.3.10b. ANNUAL PE & AE - ATTINGAL

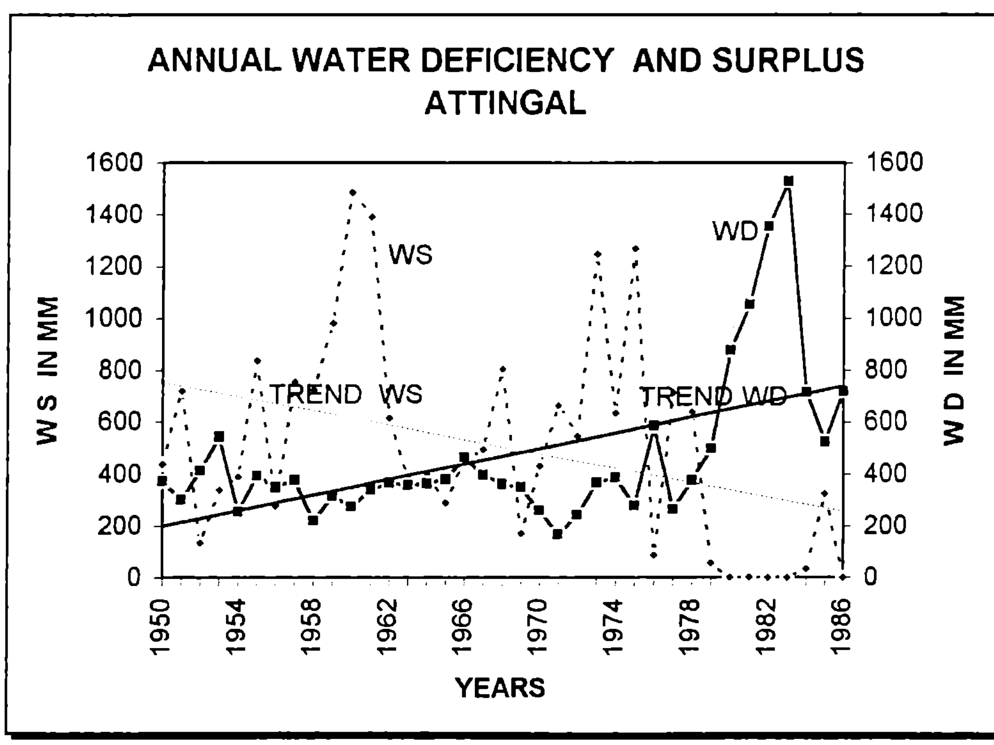


Fig. 4.3.10c. ANNUAL WD & WS - ATTINGAL

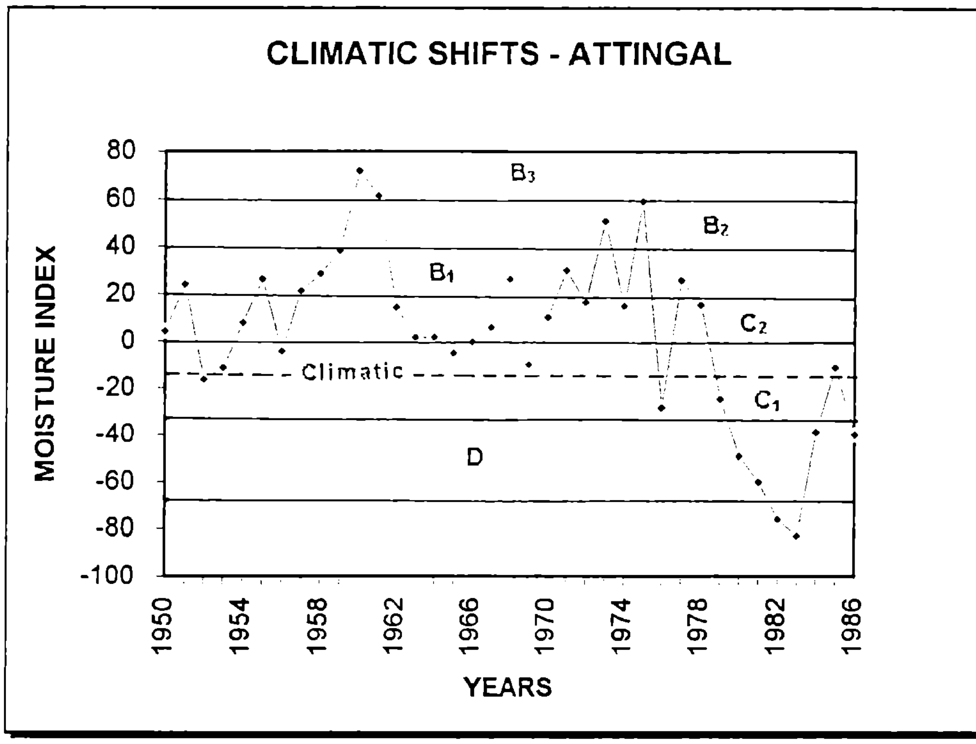


Fig. 4.3.10d. CLIMATIC SHIFTS - ATTINGAL

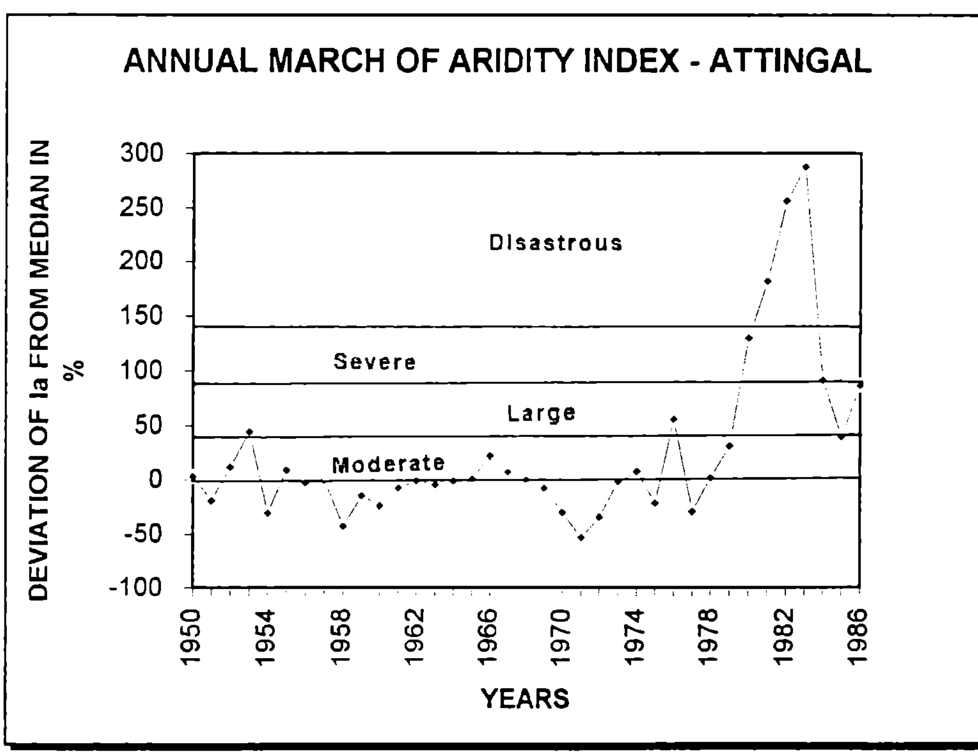


Fig. 4.3.10e. ANNUAL MARCH OF ARIDITY INDEX ATTINGAL

1980-1986. It is also evident that about 50% of the years had drought conditions of different magnitudes.

4.3.11. THIRUVANANTHAPURAM

Thiruvananthapuram is located at 8^0 29' N and 76^0 57' E. It receives 1821 mm.of mean annual rainfall. Though there were wide fluctuations in the annual rainfall during the period 1950-1980, no trend is observed.(Fig.4.3.11a). However, during this period, 18 years recorded below normal rainfall. The highest rainfall received in Thiruvananthapuram was 2419 mm. the year 1961, and the lowest was 1127 mm. in 1976.

The annual water need (PE) shows an increasing trend, while the AE shows no trend. (Fig.4.3.11b). The highest PE recorded in Thiruvananthapuram was 1753 mm.- 1979.

The years 1961 and 1976 showed maximum annual water surplus and deficit respectively. (Fig.4.3.11c). During the years 1956,1969 and 1976, the annual water surplus was zero.

Thiruvananthapuram experiences moist sub-humid type of climate (C_2). With the fluctuations in annual rainfall the climate shifted between humid (B_3) to semi-arid (D) type.(Fig.4.3.1d). During the period 1950-1980, 9 years experienced shifts towards dry sub-humid type (C_1), 13 years experienced shift towards moist sub-humid and 7 years shifted to wetter humid side (B). (Fig.4.3.11d).

The analysis of droughts experienced in Thiruvananthapuram reveals that there were 17 drought years of different magnitudes during the period of 31 years of investigation. The highest water deficit year 1976 experienced disastrous drought (Fig4.3.11e).

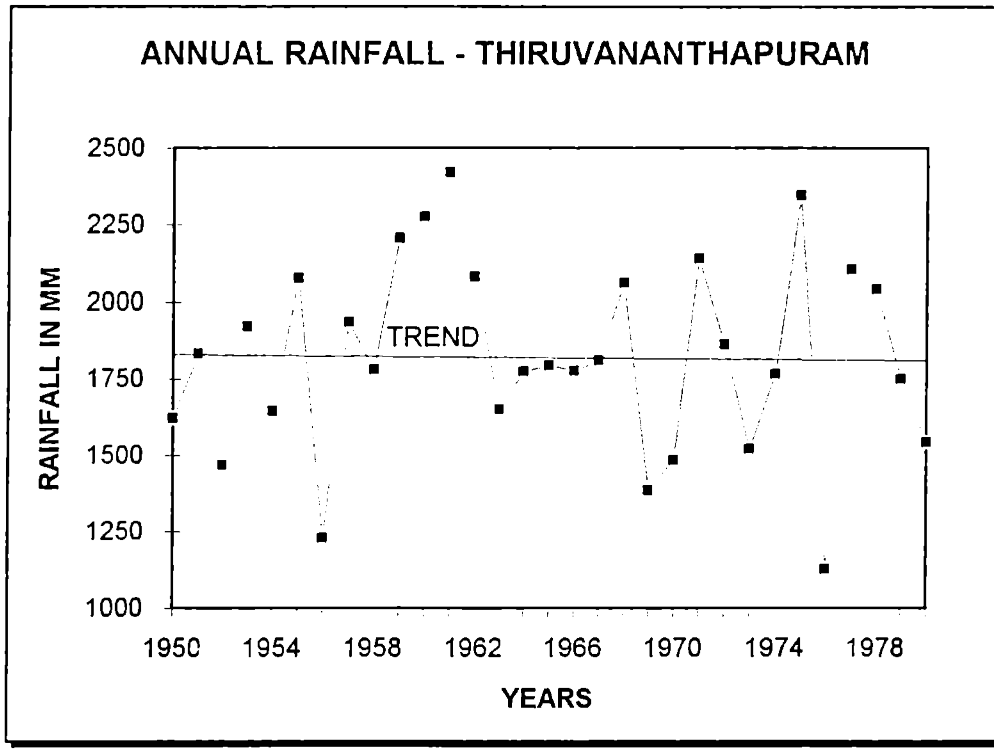


Fig. 4.3.11a. ANNUAL RAINFALL - THIRUVANANTHAPURAM

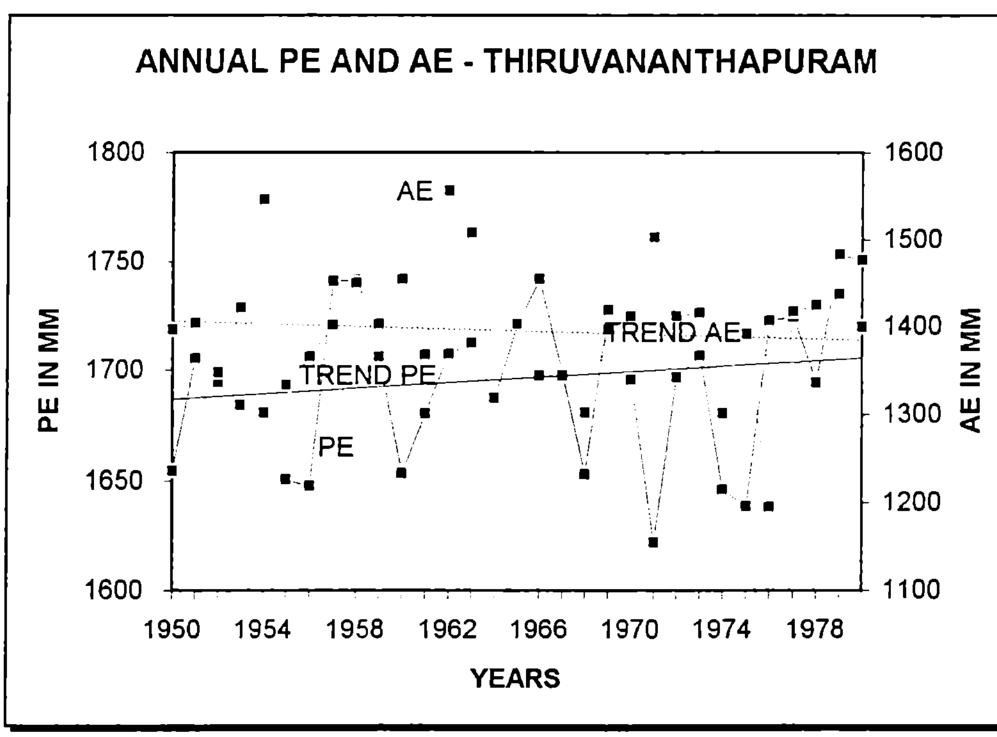


Fig. 4.3.11b. ANNUAL PE & AE - THIRUVANANTHAPURAM

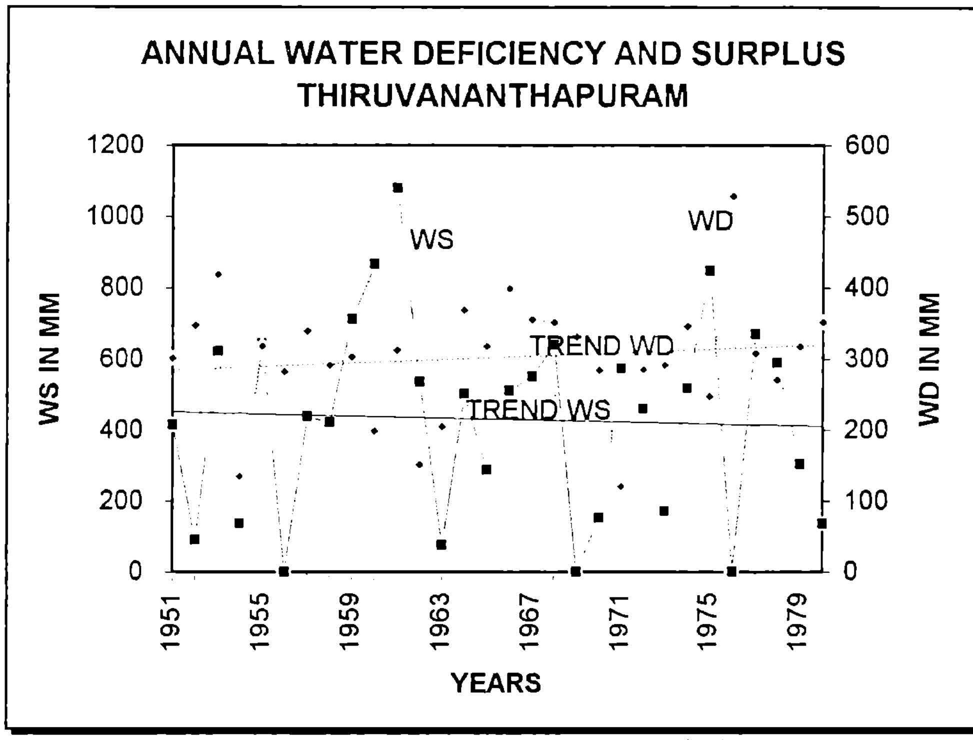


Fig. 4.3.11c. ANNUAL WD & WS - THIRUVANANTHAPURAM

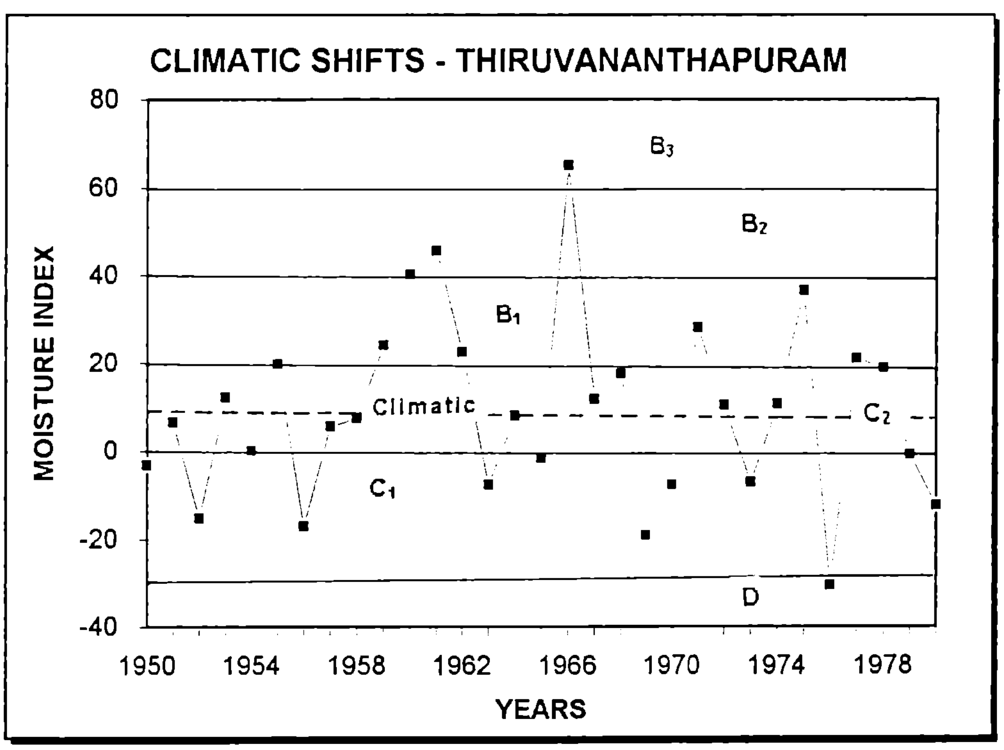


Fig. 4.3.11d. CLIMATIC SHIFTS - THIRUVANANTHAPURAM

D. HIGH ALTITUDE ZONE

4.3.12. MANANTHAVADY

Mananthavady is a highland station and is located at $11^0 48'$ N and 76^0 01' E. The mean annual rainfall is 2582 mm. Having more than 50% of years below normal rainfall, a declining trend in the annual rainfall pattern can be noticed. (Fig.4.3.12a).

Like most of the stations, Mananthavady also has a n increasing trend in PE and decreasing trend in AE. (Fig.4.3.12b).

Marked increase in WD and decrease in WS is the main feature of its water balance. (Fig 4.3.12c).

It comparatively had fewer major climatic shifts. Majority of the shifts were towards upper humid side. (Fig.4.3.12d).

Although the total number of droughts was less, it experienced two disastrous and four severe droughts .There were also five moderate and seven large droughts during the period 1950-1986.(Fig.4.3.12e).

4.3.13. VYTHIRI

This highland station located at $9^0 34'$ N and $76^0 59'$ E. receives 4143 mm of mean annual rainfall which is the second highest in Kerala, after Neriamangalam. The highest annual rainfall of 8259 mm.was recorded in 1961. Like many stations of Kerala, Vythiri also shows a declining trend. (Fig.4.3.13a).

The annual PE and AE values atVythiri indicate no trend. (Fig.4.3.13b).

Following the rainfall pattern the WS shows a declining trend , while the WD displays an increasing trend (Fig.4.3.13c). The abnormal year 1961 recorded highest WS.

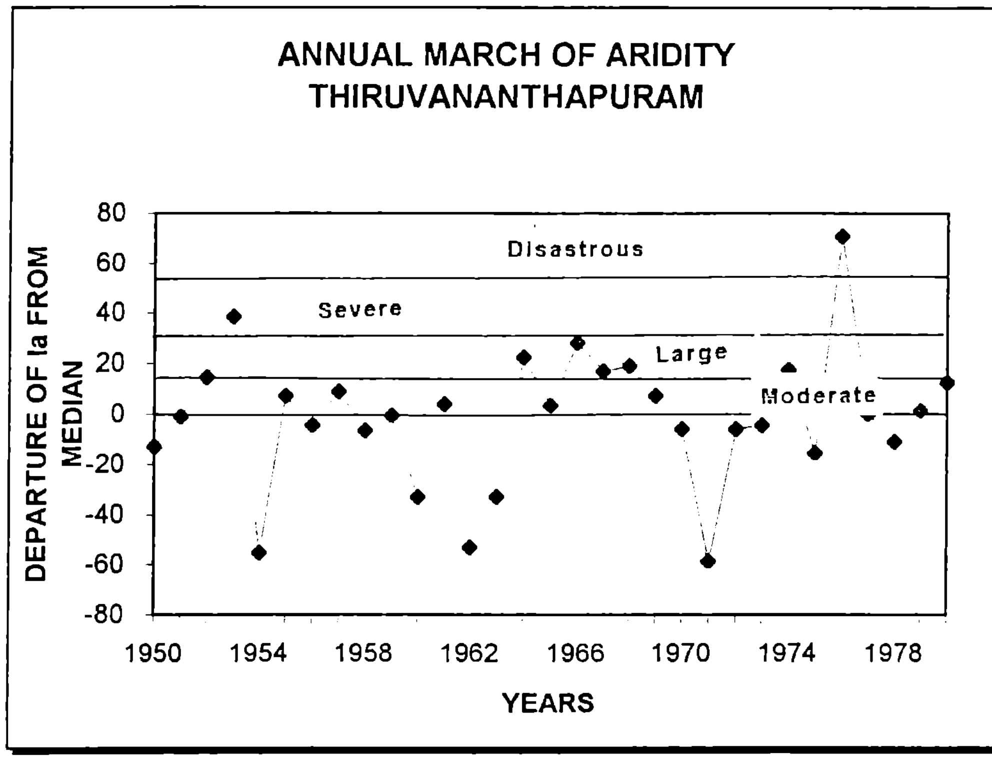


Fig. 4.3.11e. ANNUAL MARCH OF ARIDITY INDEX THIRUVANANTHAPURAM

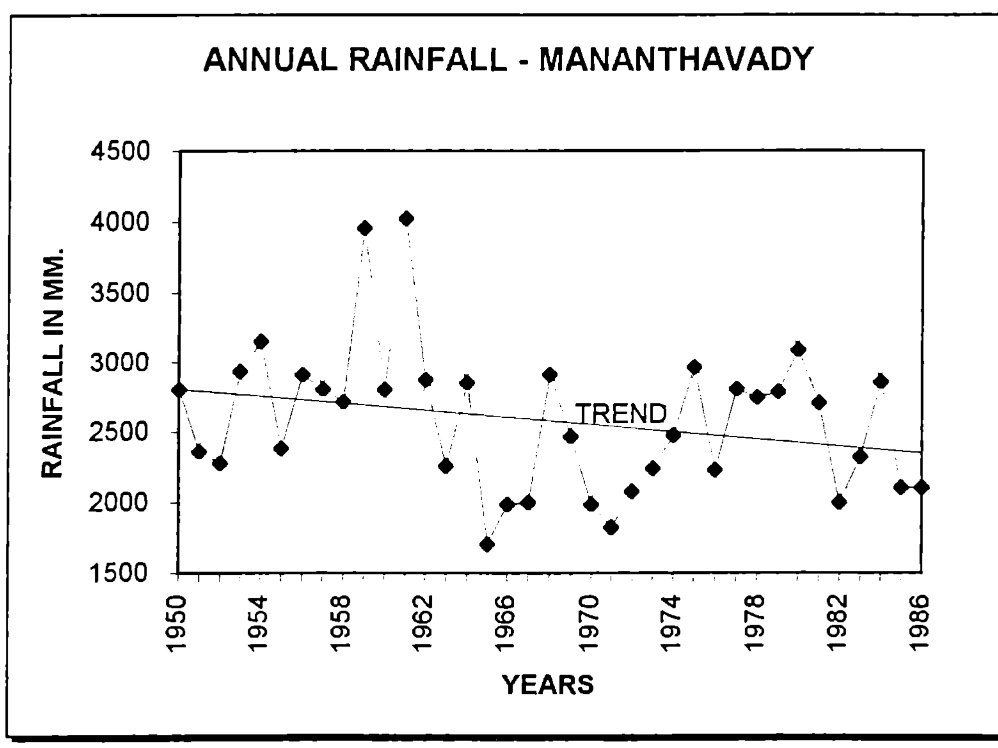


Fig. 4.3.12a. ANNUAL RAINFALL - MANANTHAVADY

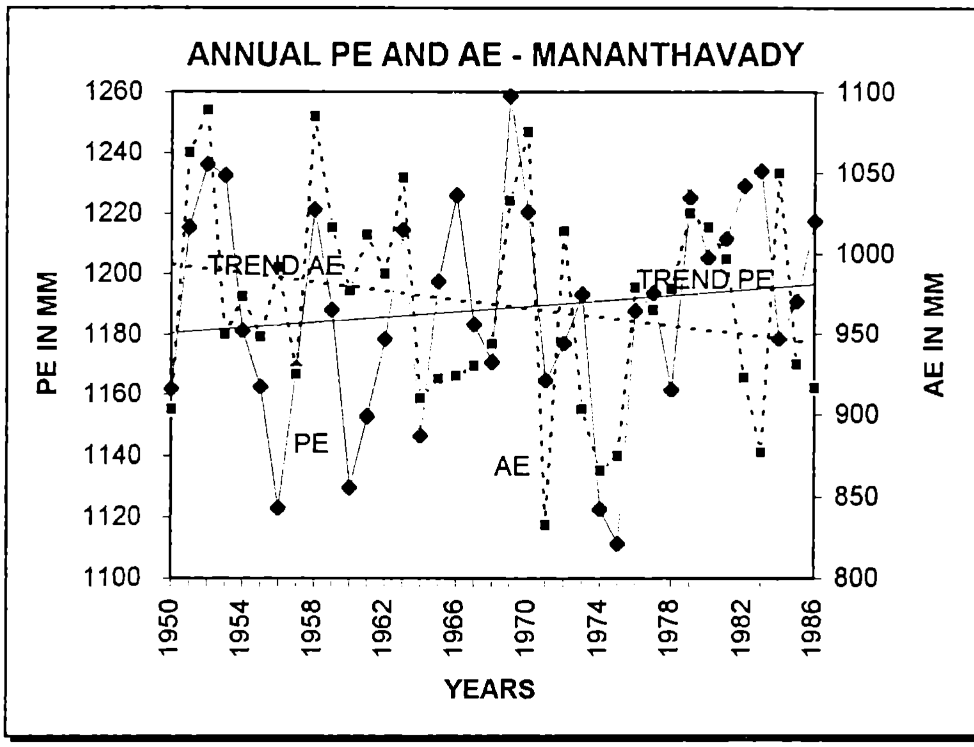


Fig. 4.3.12b. ANNUAL PE & AE - MANANTHAVADY

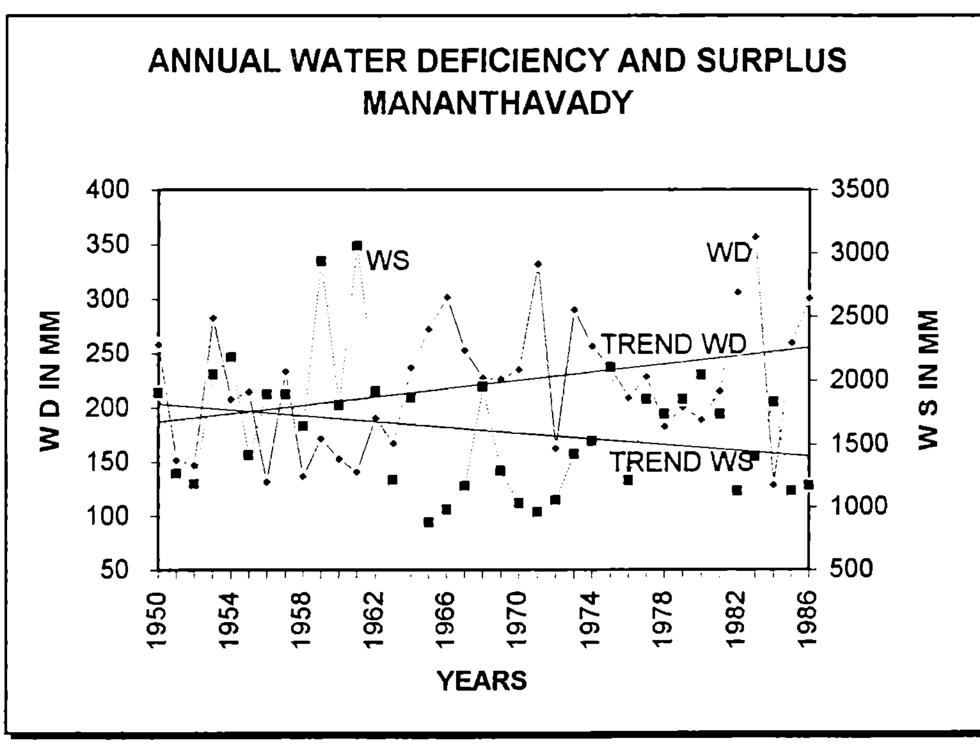


Fig. 4.3.12c. ANNUAL WD & WS - MANANTHAVADY

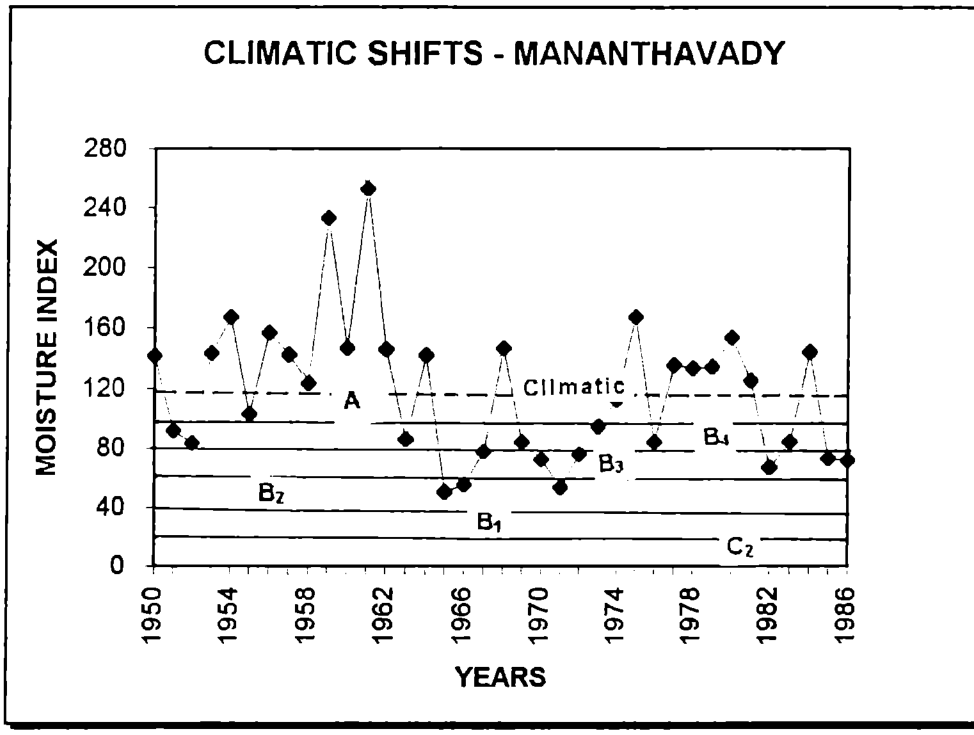


Fig. 4.3.12d. CLIMATIC SHIFTS - MANANTHAVADY

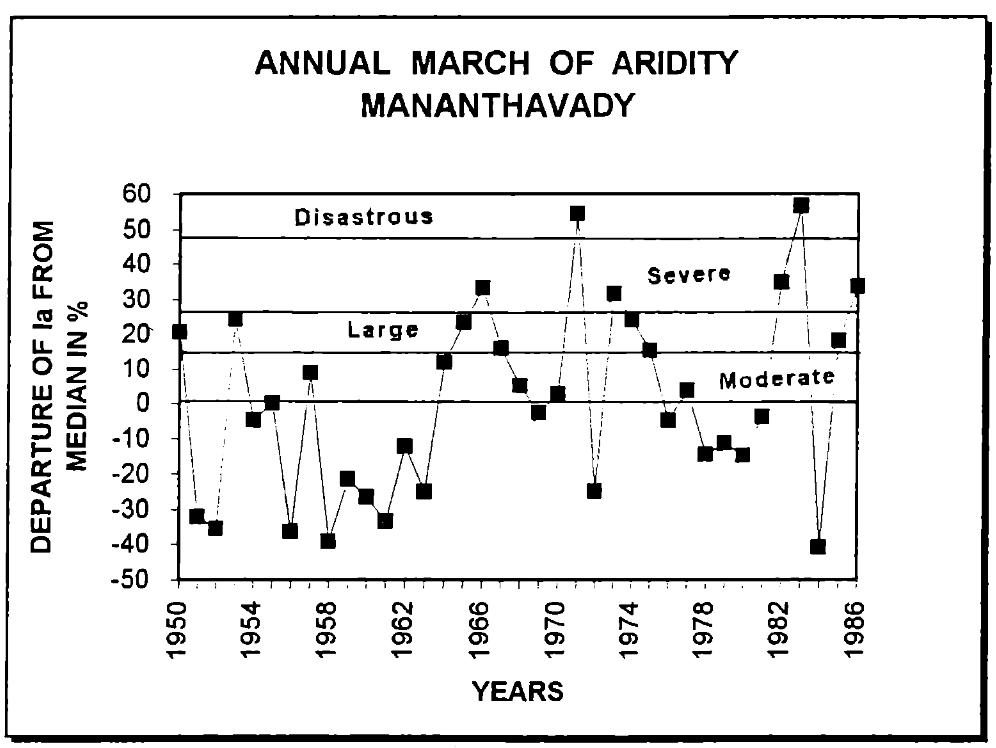


Fig. 4.3.12e. ANNUAL MARCH OF ARIDITY INDEX

MANANTHAVADY

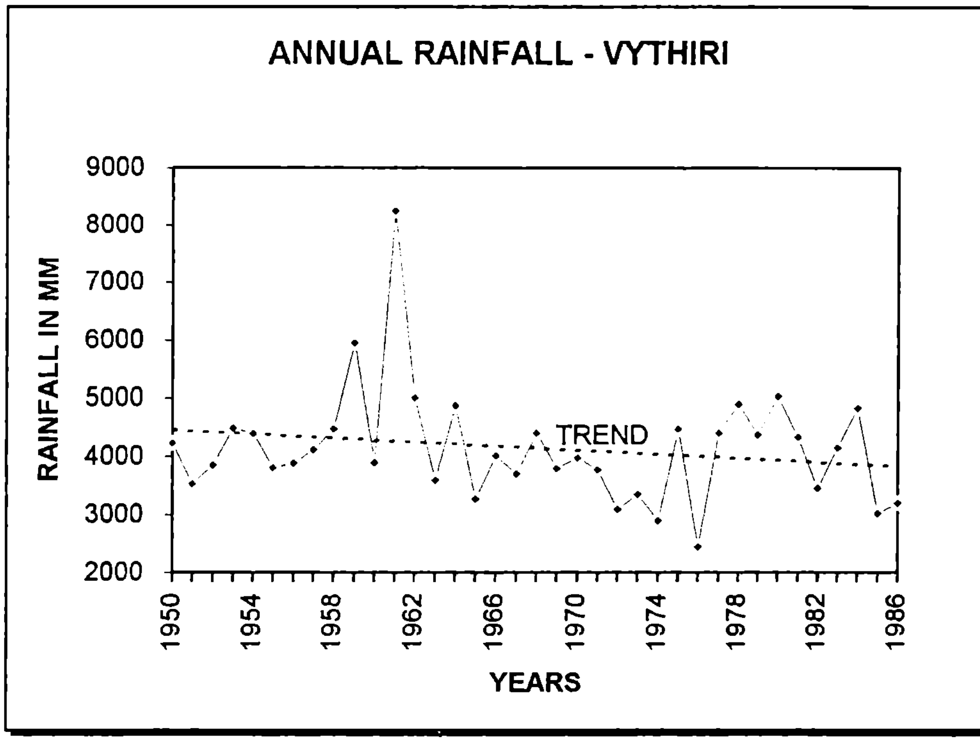


Fig. 4.3.13a. ANNUAL RAINFALL - VYTHIRI

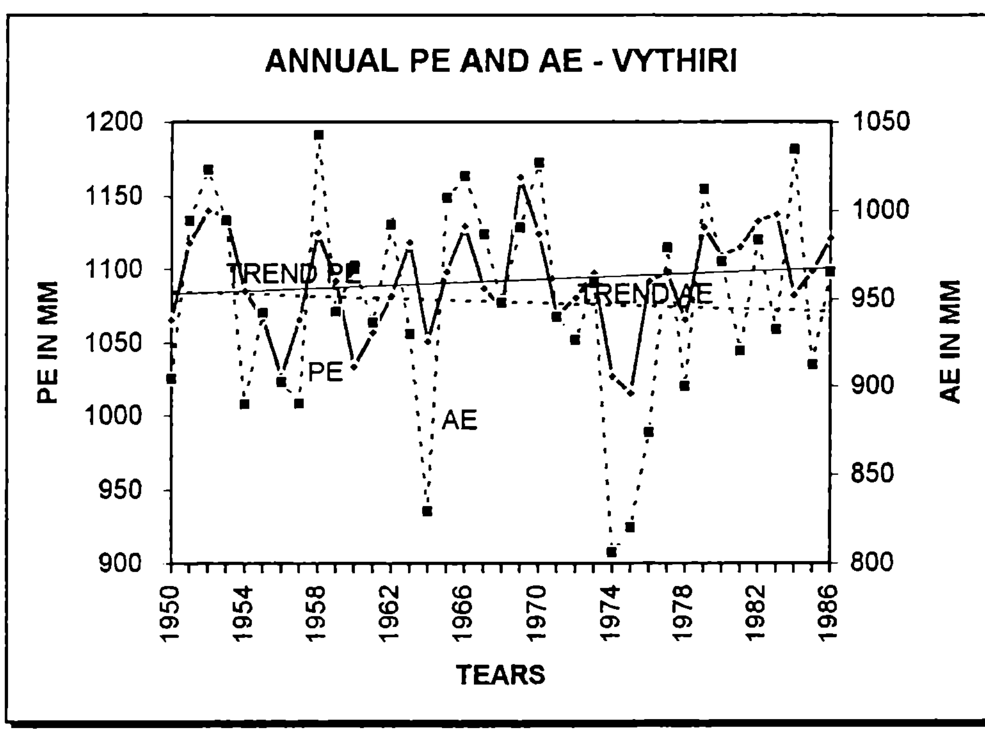


Fig. 4.3.13b. ANNUAL PE & AE - VYTHIRI

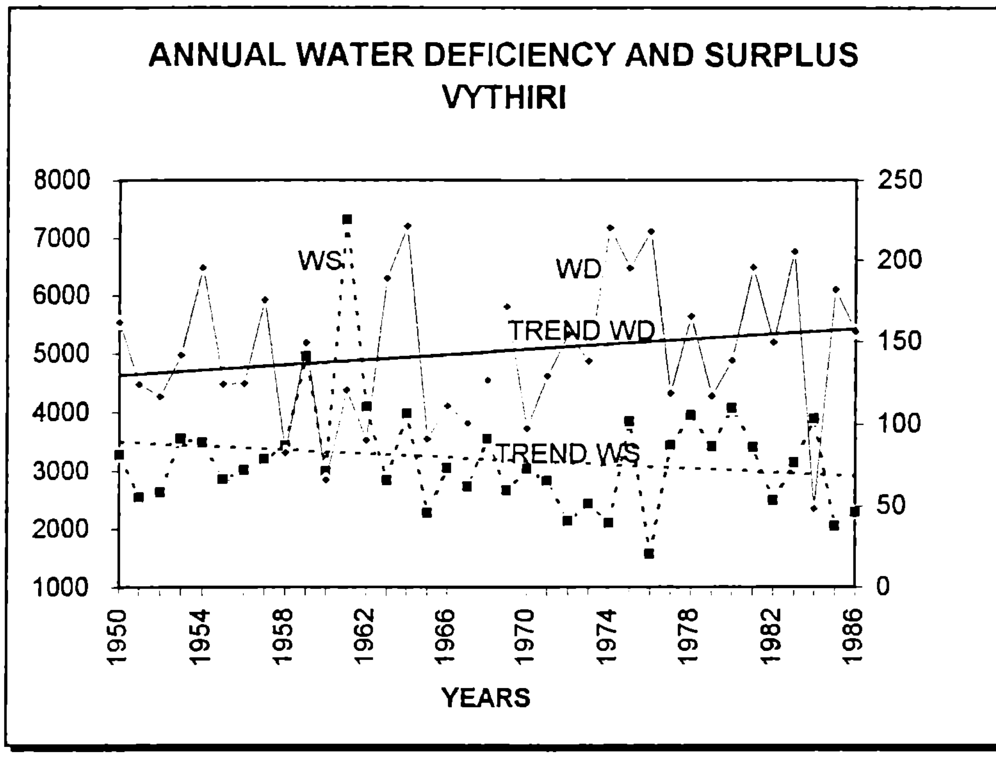


Fig. 4.3.13c. ANNUAL WD & WS - VYTHIRI

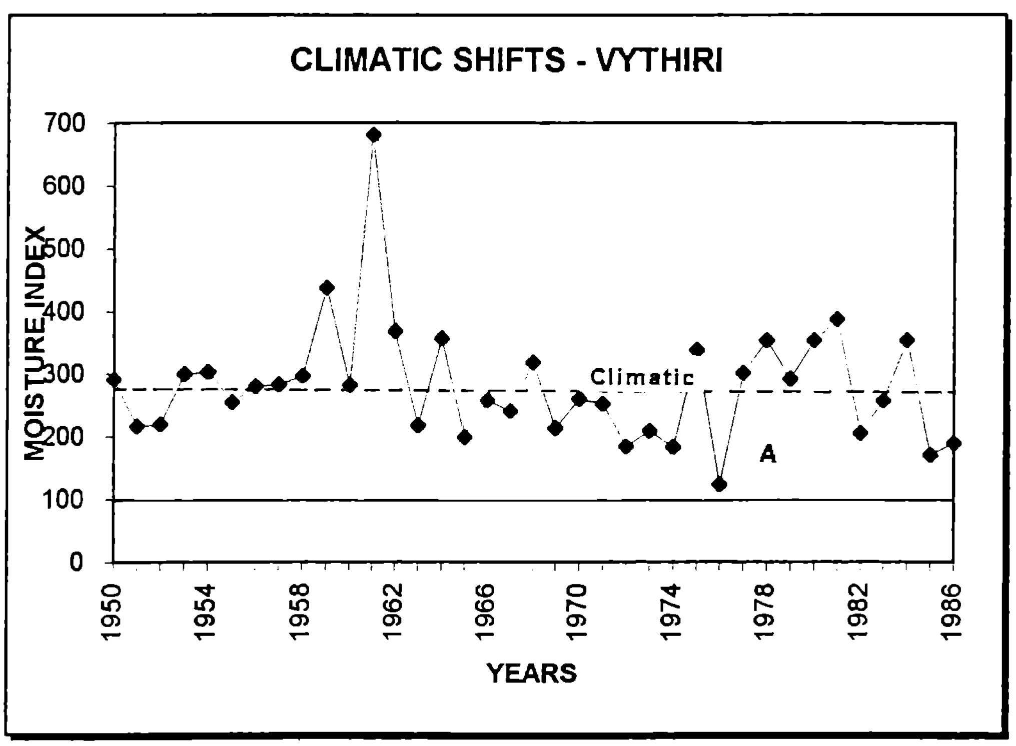


Fig. 4.3.13d. CLIMATIC SHIFTS - VYTHIRI

The moisture index value at Vythiri was always above 100, indicating the absence of any climatic shifts from its perhumid type.(Fig.4.3.13.d).

In contrast to this, the fluctuations in rainfall caused drought conditions in Vythiri also. (Fig.4.3.13e). There were even two disastrous and six severe droughts. Moderate and large droughts were comparatively less.

4.3.14. MARAYOOR

Marayoor is located in the rain shadow region of Kerala at $10^0 16'$ N and $77^0 09'$ E. It receives 1332 mm. of annual rainfall. In contrast to other stations in Kerala, Marayoor shows an increasing trend in annual rainfall pattern. (Fig. 4.3.14a). The highest rainfall of Marayoor was recorded in the year 1970, when the annual value was 2668 mm.

Like Devikulam, Marayoor also shows an increasing trend in PE and AE. (Fig. 4.3.14b).

Marayoor is the only station in Kerala which shows increase in WS and Decrease in WD. (Fig. 4.3.14c).

Marayoor experiences a humid (B_1) type of climate. This fluctuated between semi-arid and perhumid type during the period 1950-1980. (Fig. 4.3.14d). Majority of the shifts were within the humid type. Climate shifted to semi-arid type in 1962 and 1963, and to perhumid type in 1970.

Moderate drought conditions prevailed over Marayoor in 11 years, apart from 2 severe and 1 disastrous droughts. (Fig. 4.3.14e).

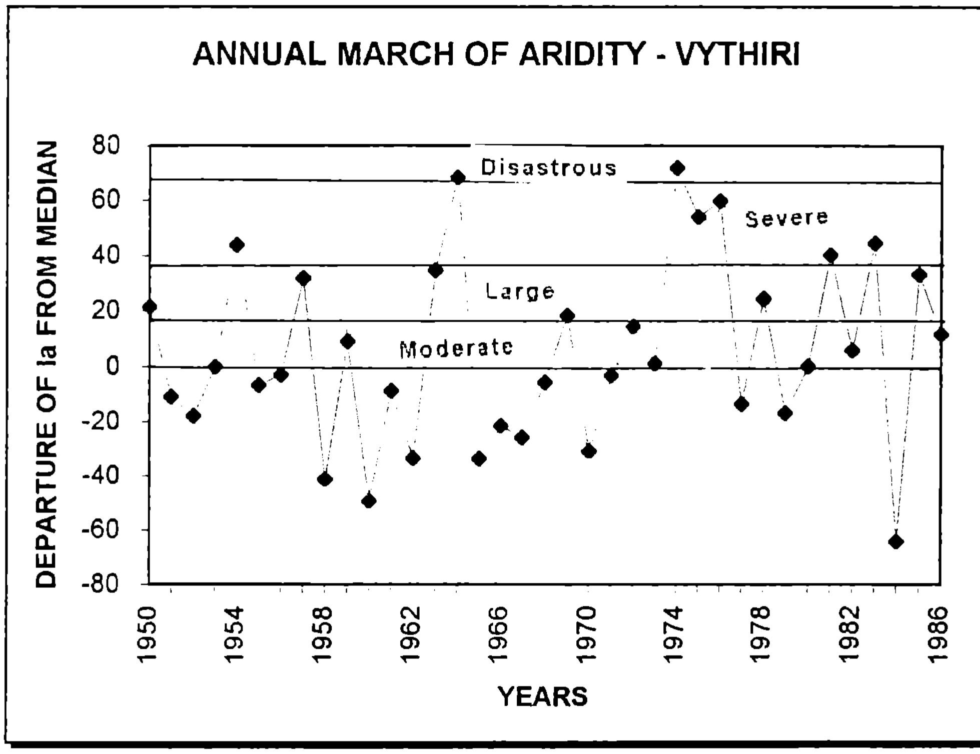


Fig. 4.3.13e. ANNUAL MARCH OF ARIDITY INDEX - VYTHIRI

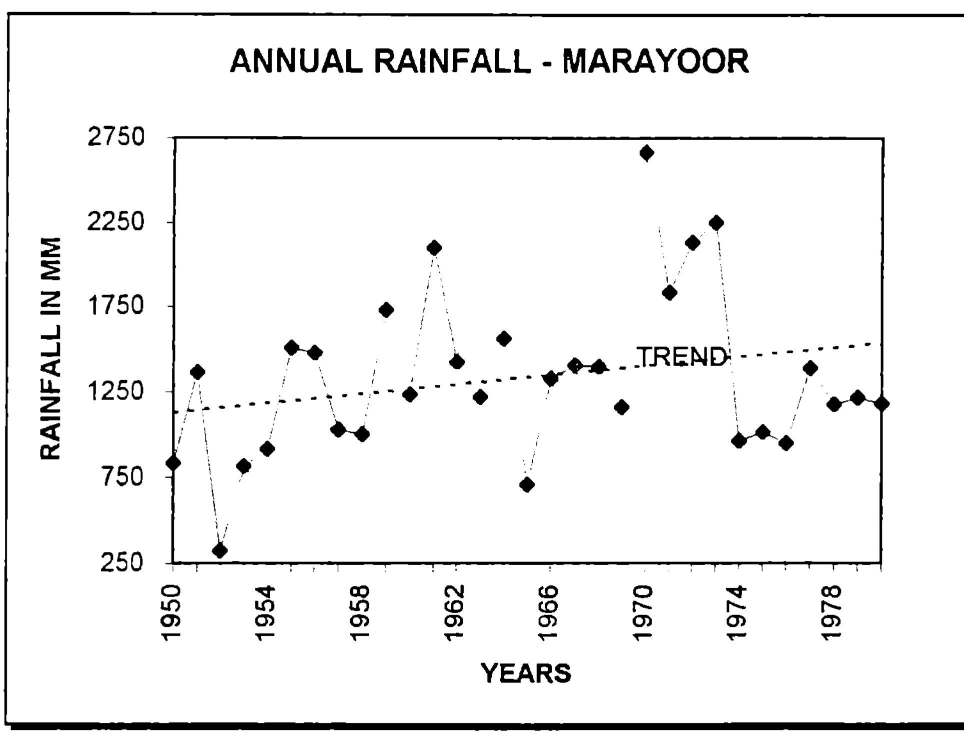


Fig. 4.3.14a. ANNUAL RAINFALL - MARAYOOR

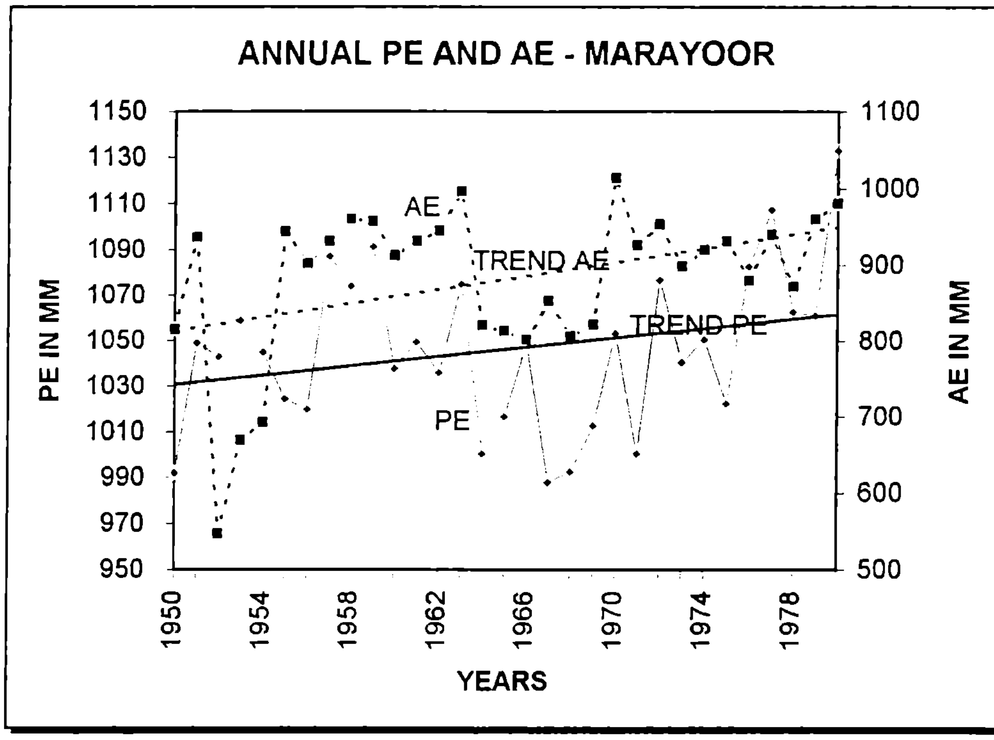


Fig. 4.3.14b. ANNUAL PE & AE - MARAYOOR

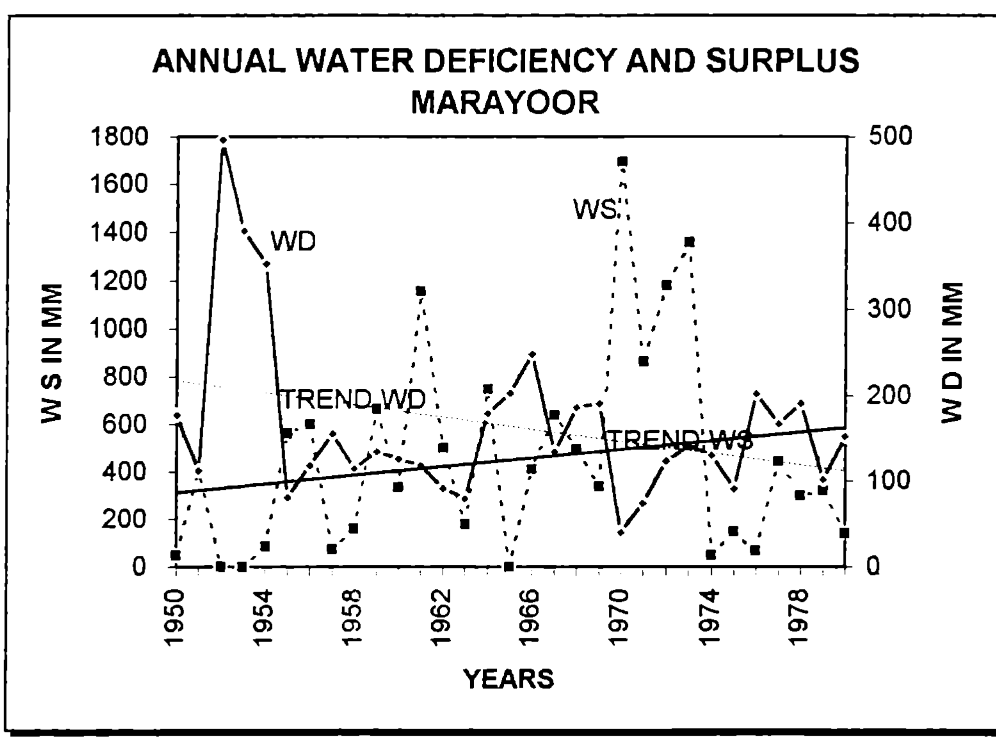


Fig. 4.3.14c. ANNUAL WD & WS - MARAYOOR

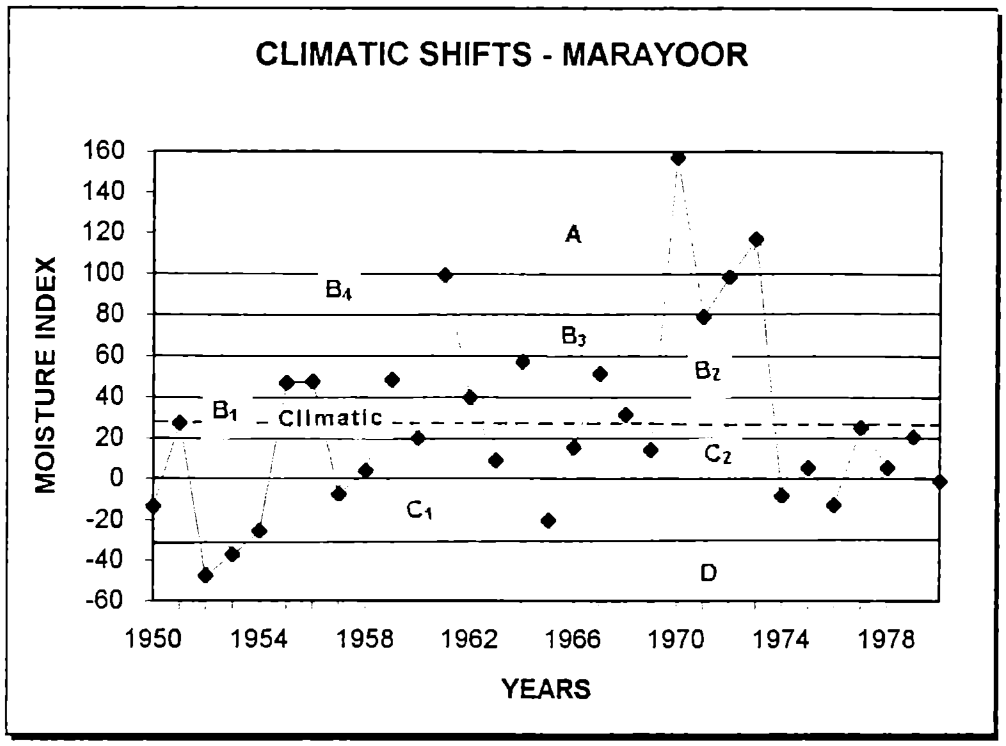


Fig. 4.3.14d. CLIMATIC SHIFTS - MARAYOOR

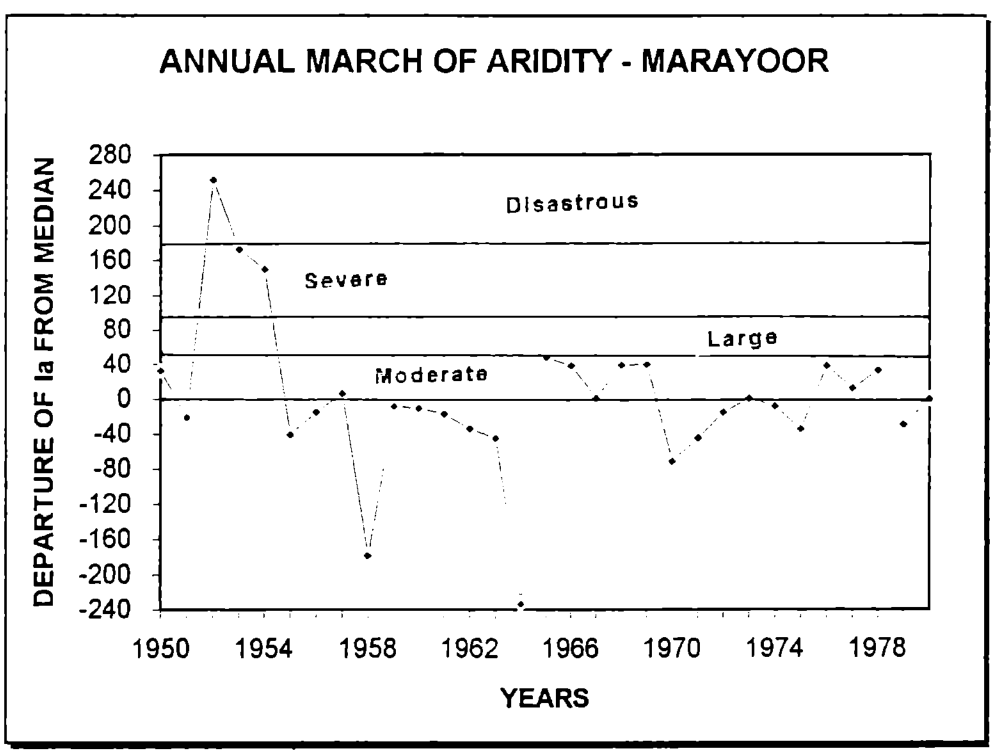


Fig. 4.3.14e. ANNUAL MARCH OF ARIDITY INDEX

MARAYOOR

4.3.15. DEVIKULAM

Devikulam also is a highland station and is located at 10^0 04' N and 77^0 06' E. It receives an annual rainfall of 2526 mm. Although 15 years during the period 1950-1980 had below normal rainfall in Devikulam, the annual pattern does not shoe any trend.(Fig.4.3.15a).

The Actual Evapotranspiration and the Potential Evapotranspiration show a slight increasing trend. (Fig.4.2.15b).

Though, the mean annual water deficit is comparatively less in Devikulam, it shows an increasing rend. (Fig.4.3.15.c). Devikulam also experiences comparatively high water surplus.

Devikulam experiences a perhumid type of climate. Absence of any major shift in climate is a conspicuous feature of Devikulam. Only one year, 1967, shifted to B_3 type.(Fig. 4.3.15d).

Fig. 4.2.15e shows the annual march of aridity index in Devikulam. It is obvious that even though there were no major climatic shifts, the inter-annual variations of rainfall caused drought conditions, even of disastrous magnitude. The year 1968 experienced a severe drought and 1969 had a disastrous drought There were also 8 moderate droughts, of which 6 were consecutive years from 1972, and 5 large droughts in Devikulam during the period 1950-1980.

4.3.16. KARIKODE

Karikode is located at 9^0 50' N and $76^0$40' E. The mean annual rainfall of Karikode is 3086 mm. Marked declining trend in the annual rainfall is evident from the Fig.4.3.16a. 15 years

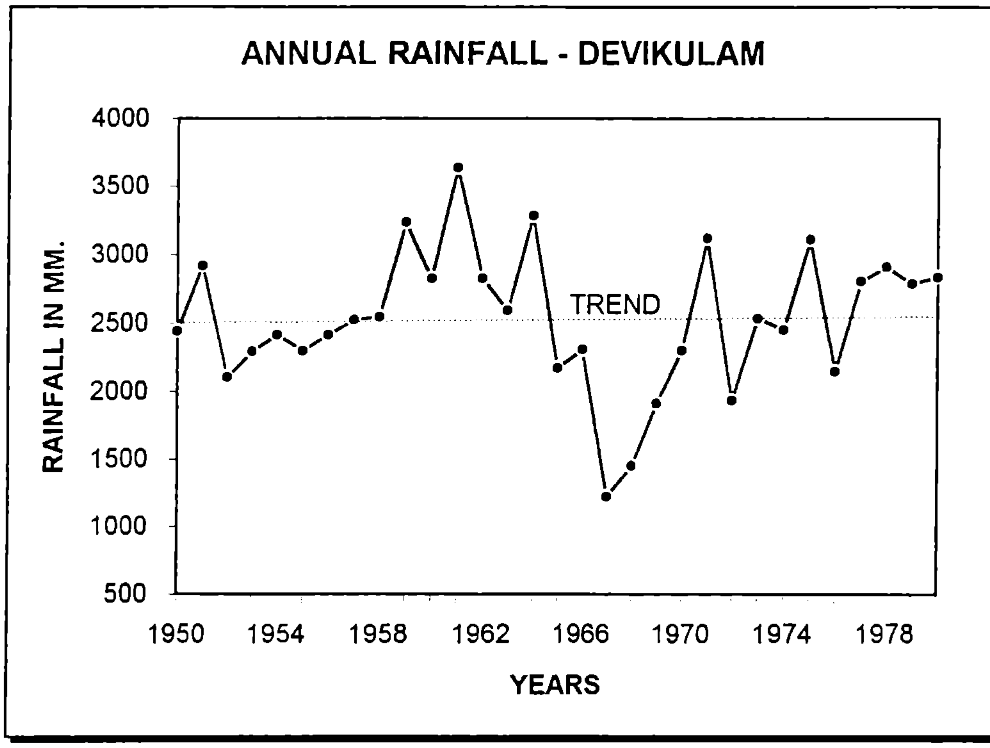


Fig. 4.3.15a. ANNUAL RAINFALL - DEVIKULAM

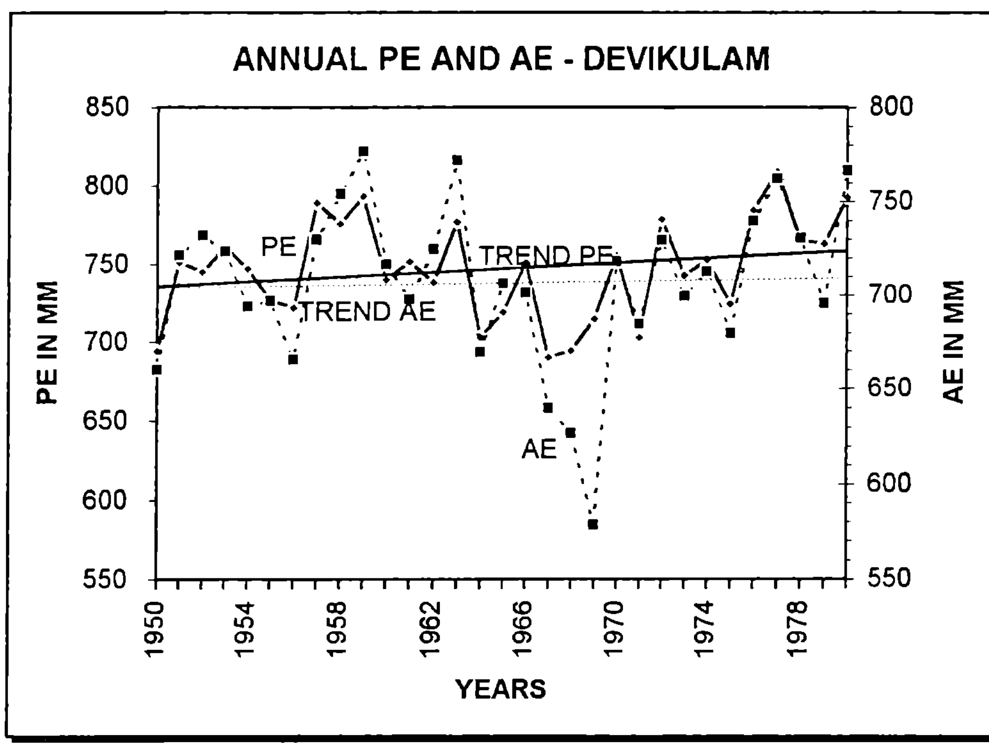


Fig. 4.3.15b. ANNUAL PE & AE - DEVIKULAM

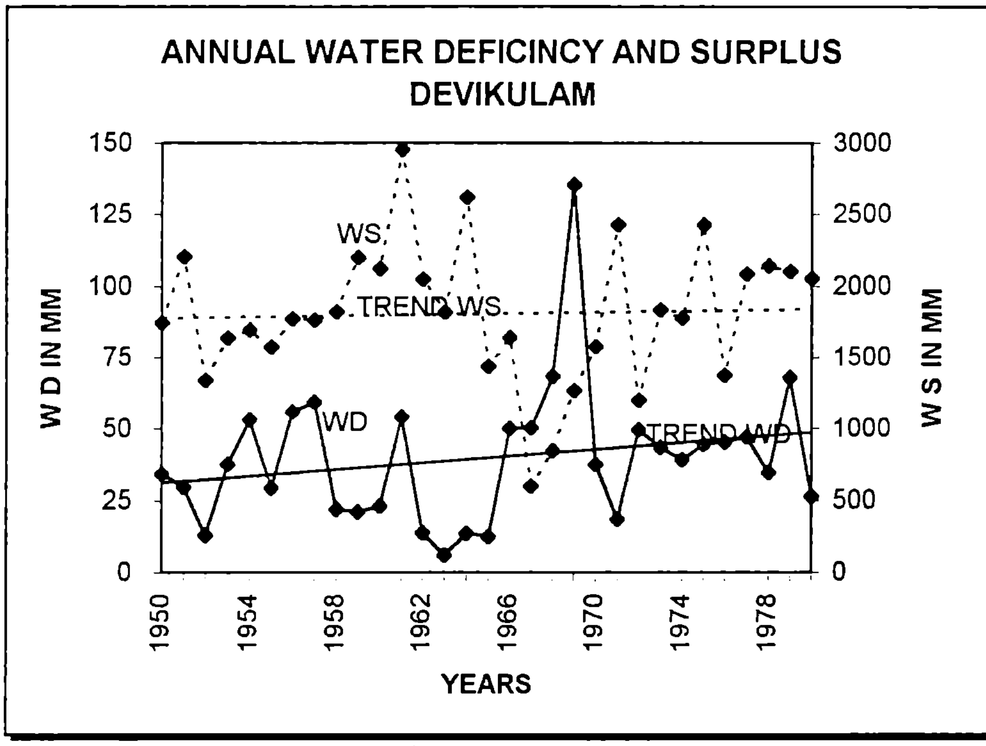


Fig. 4.3.15c. ANNUAL WD & WS - DEVIKULAM

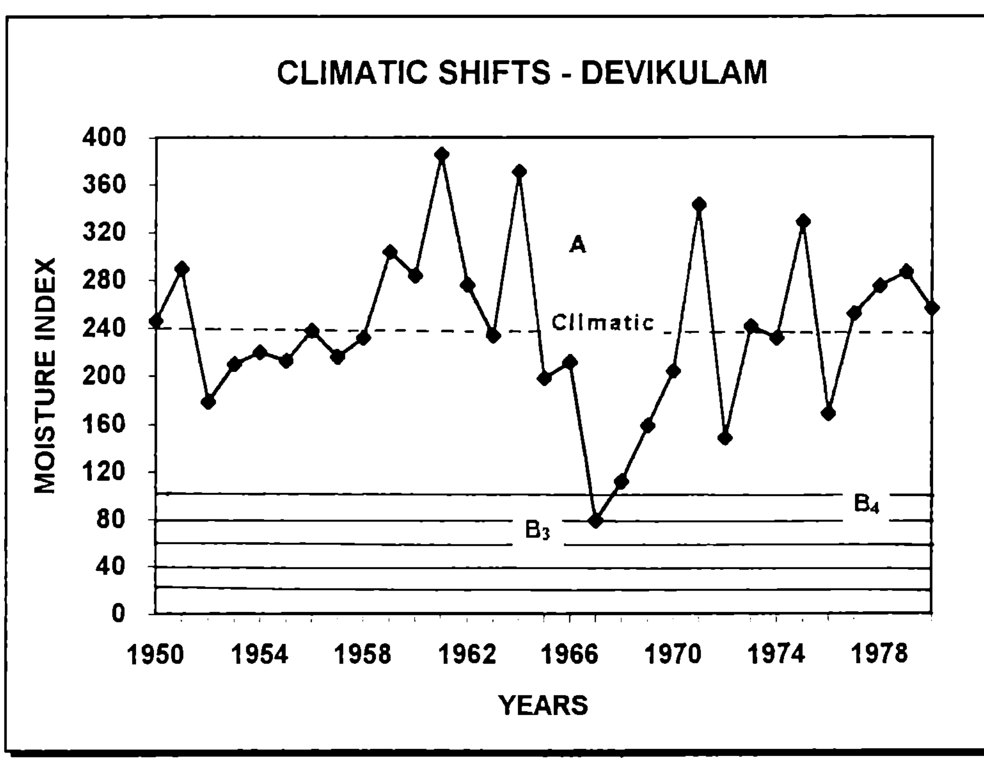


Fig. 4.3.15d. CLIMATIC SHIFTS - DEVIKULAM

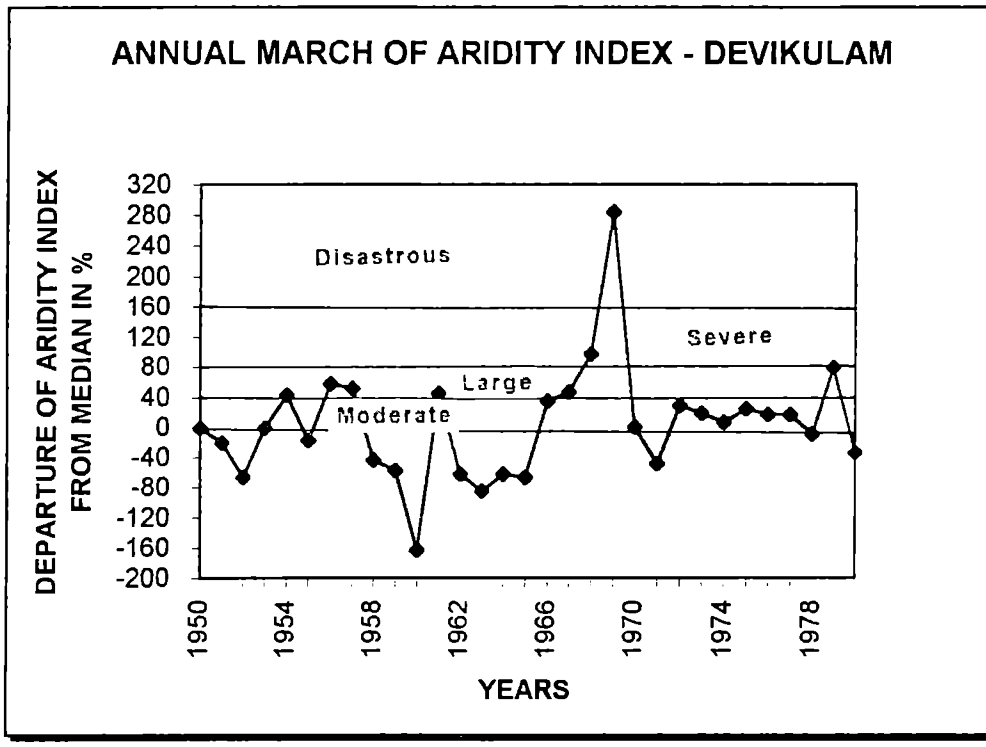


Fig. 4.3.15e. ANNUAL MARCH OF ARIDITY INDEX DEVIKULAM

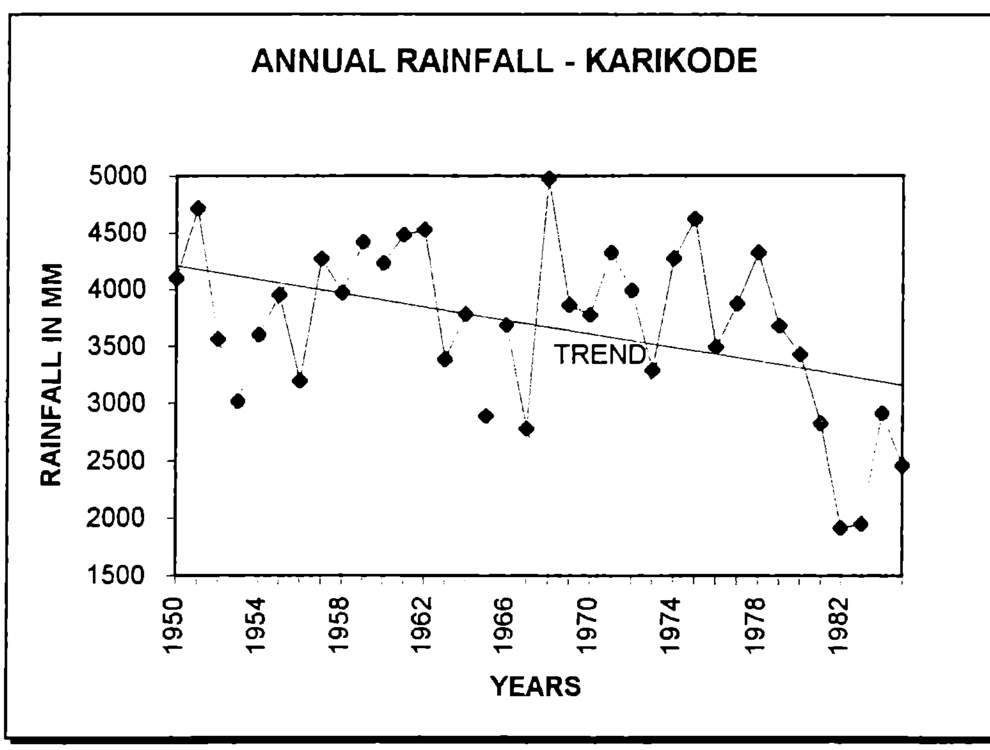


Fig. 4.3.16a. ANNUAL RAINFALL - KARIKODE

during the period 1950-1985 received below normal rainfall, the lowest being 1919 mm. in 1982.

One peculiarity of Karikode is that there were no wide fluctuations in the annual PE, even though it shows an increasing trend. Contrary to other stations, where the AE shows a decreasing trend, Karikode displays an increasing trend. (Fig.4.3.16b).

With the increasing PE and declining rainfall, the annual water surplus is bound to decrease. This is clearly visible in Karikode also.(Fig.4.3.16c). The water surplus varied between 536 mm to 3432 mm. Although there are wide fluctuations in the water deficit, it shows no trend.

Karikode experiences a perhumid type of climate. In most of the years the shifts were within the perhumid type.(Fig.4.3.16d). A progressive shift towards drier side is noticed from 1978 onwards.

Like Vandanmedu, Karikode also had a few droughts. (Fig.4.3.16e). There were only two severe and two disastrous droughts in Karikode during the period 1950-1985.

4.3.17. VANDANMEDU

This highland station is located at 9^0 43'N and 77^0 08'E. It receives 2018 mm. mean annual rainfall. Even though there were wide fluctuations in the annual rainfall, no trend is noticed in its pattern. (Fig.4.3.17a). Annual rainfall was lowest (1253mm.) in the year 1967, and the highest (2873 mm.) was recorded in the year 1961. Vandanmedu received below normal rainfall during 13 years in the period 1950-1980.

Vandanmedu also shows an increasing trend in PE, while

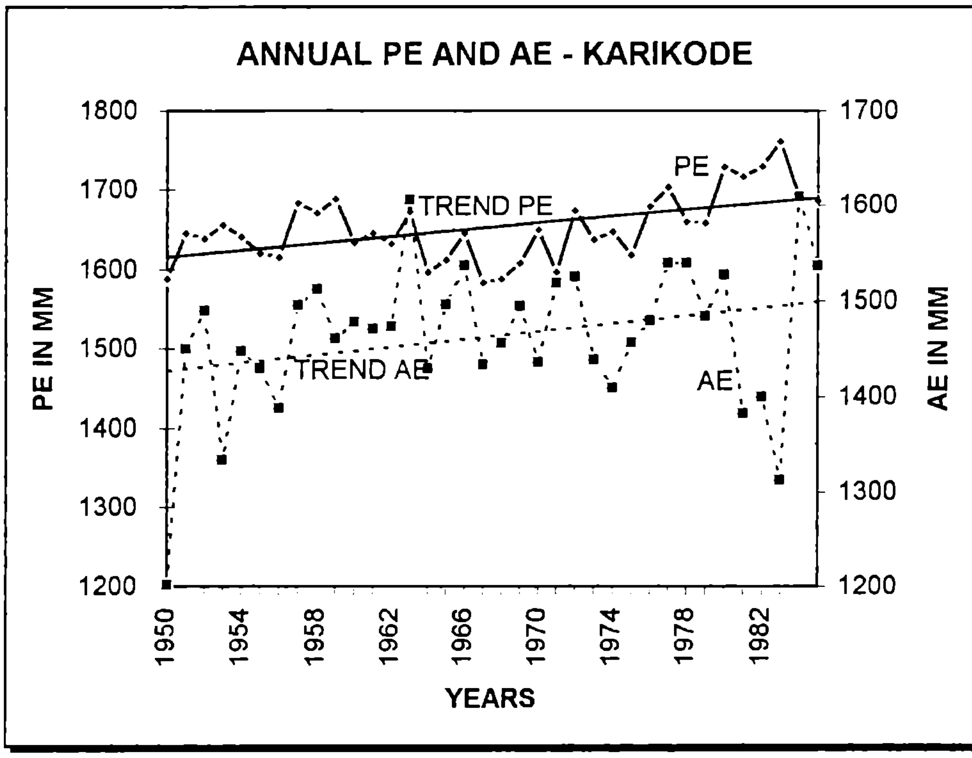


Fig. 4.3.16b. ANNUAL PE & AE - KARIKODE

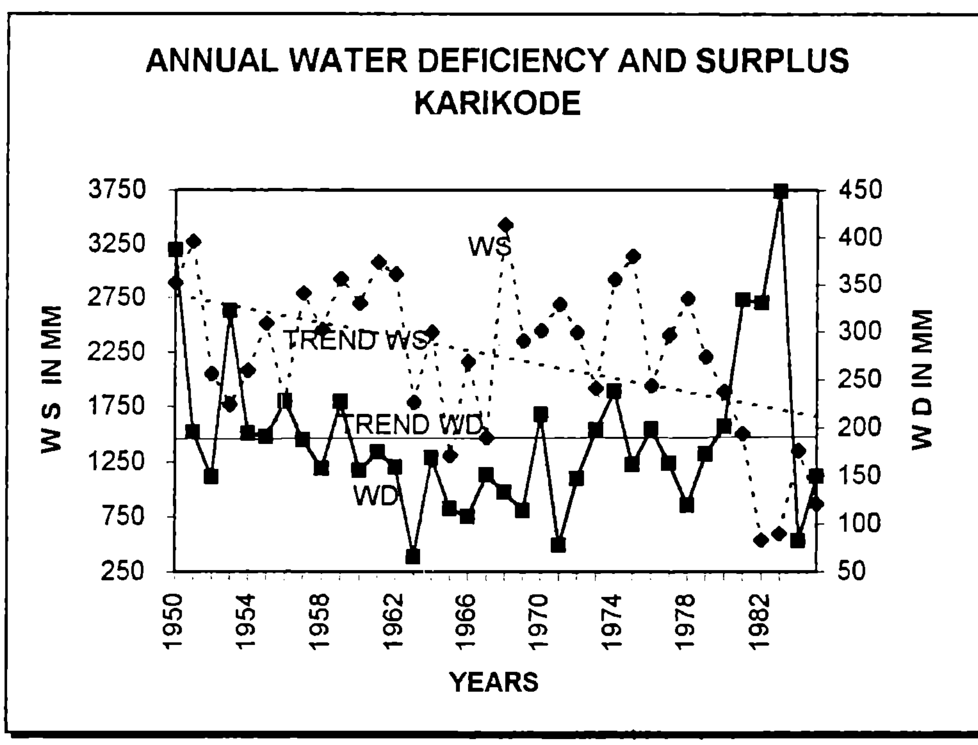


Fig. 4.3.16c. ANNUAL WD & WS - KARIKODE

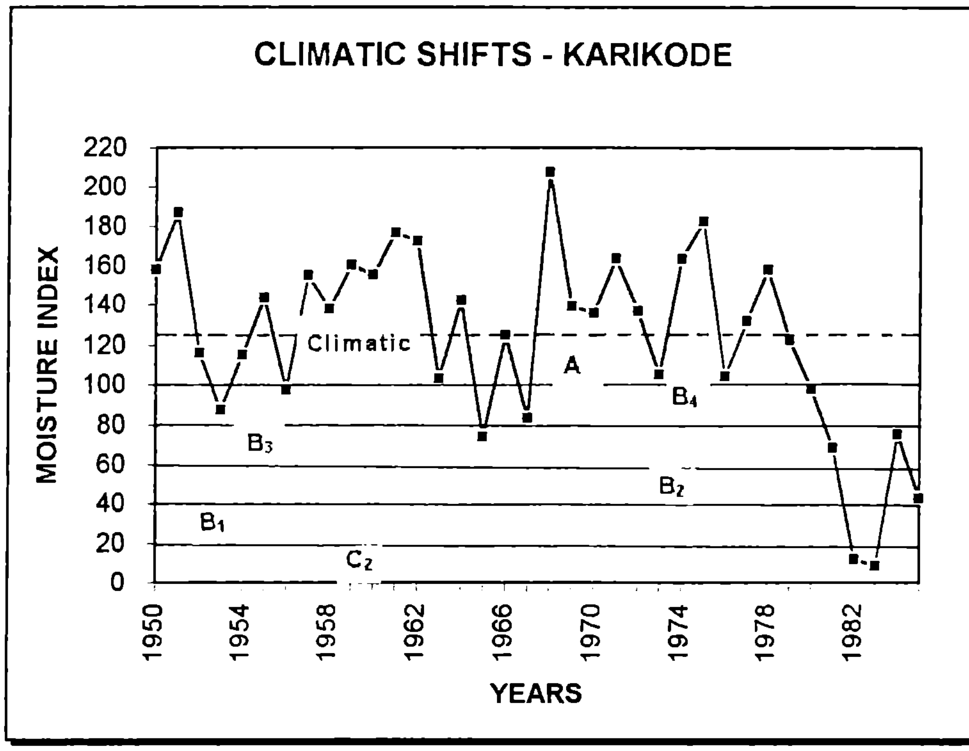


Fig. 4.3.16d. CLIMATIC SHIFTS - KARIKODE

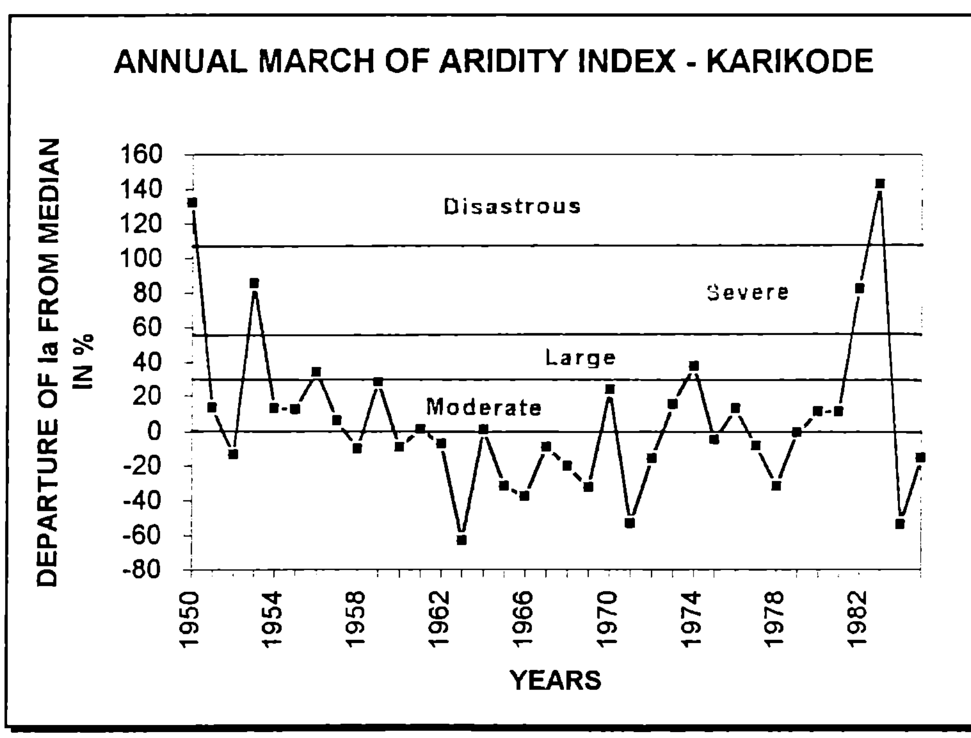


Fig. 4.3.16e. ANNUAL MARCH OF ARIDITY INDEX

KARIKODE

the AE displays no trend. (Fig.4.3.17b). The year 1980 had the highest water need (1133 mm).

The annual water deficiency of Vandanmedu is increasing (Fig.4.3.17c), while the WS shows no trend.

A humid type of climate prevails in Vandanmedu. It is obvious from Fig.4.3.17d that most of the climatic shifts experienced by Vandanmedu is within the sub categories of B type. 14 years experienced shift towards per humid type.

There were no disastrous droughts in Vandanmedu. The total number of droughts was also comparatively low here, only 7 moderate, 2 large, and 6 severe droughts. (Fig.4.3.17e).

4.3.18. PEERMED.

Located at $9^{0}34'$ N and $76^{0}59'$ E, Peermed has a perhumid type of climate. It receives a high mean annual rainfall of 4094 mm..(Fig.4.3.18a). Very high rainfall (8426 mm.), was recorded in the year 1968.

The annual PE of Peermed displays an increasing trend, while the AE shows no trend.(Fig.4.3.18b). Conspicuous increasing trend of WS and decreasing trend of WD is obvious from Fig.4.2.18c. Consequent on receiving highest amount of annual rainfall, the year 1968 had the highest water surplus.

The noticeable feature at Peermed is the absence of any climatic shifts. The moisture index value fluctuated between 142 and 779, indicating that all the years had per humid type of climate.(Fig.4.3.18d). Since the mean moisture index value is 301, these fluctuations are enough to create drought conditions even of disastrous magnitude. (Fig.4.3.18e). There were 13 disastrous droughts in Peermed during the period 1950-1986.

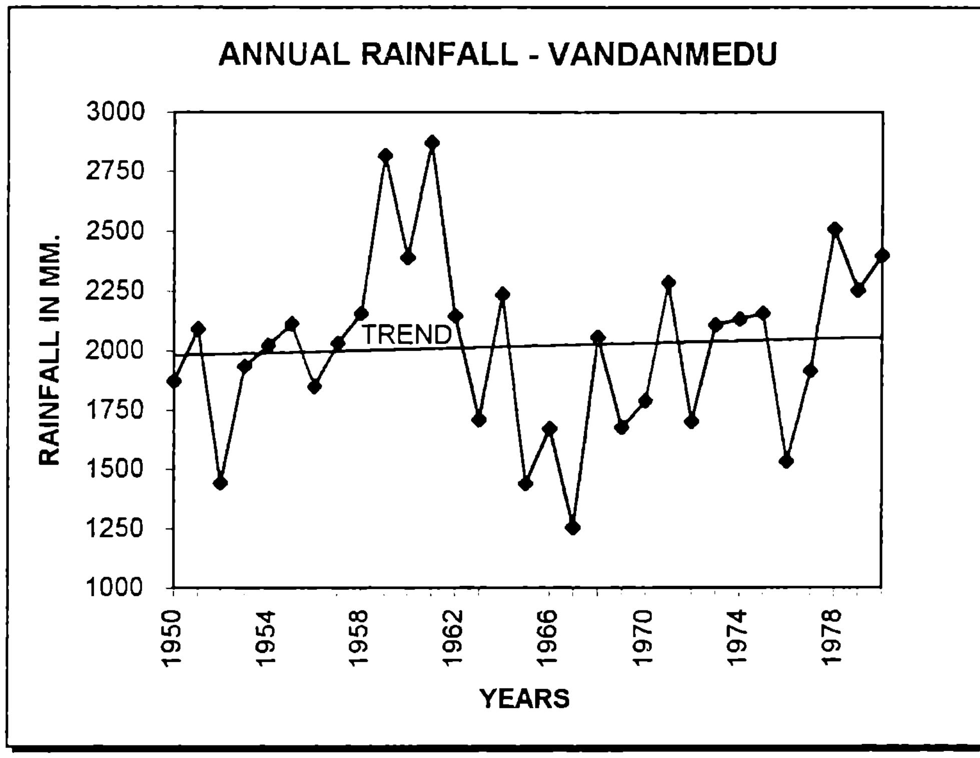


Fig. 4.3.17a. ANNUAL RAINFALL - VANDANMEDU

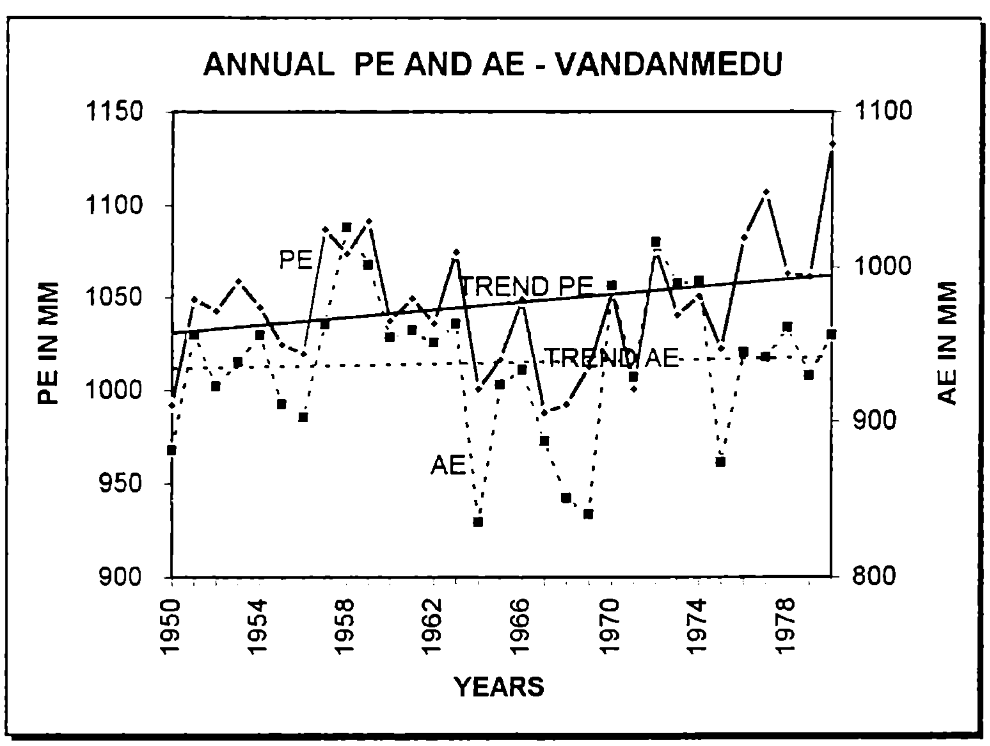


Fig. 4.3.17b. ANNUAL PE & AE - VANDANMEDU

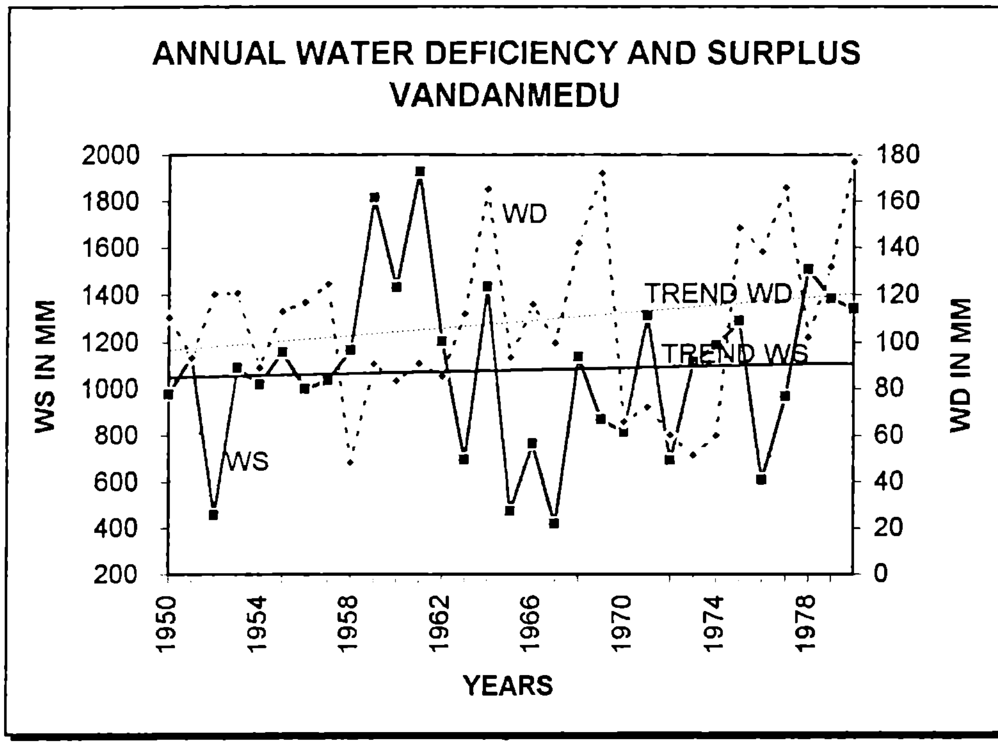


Fig. 4.3.17c. ANNUAL WD & WS - VANDANMEDU

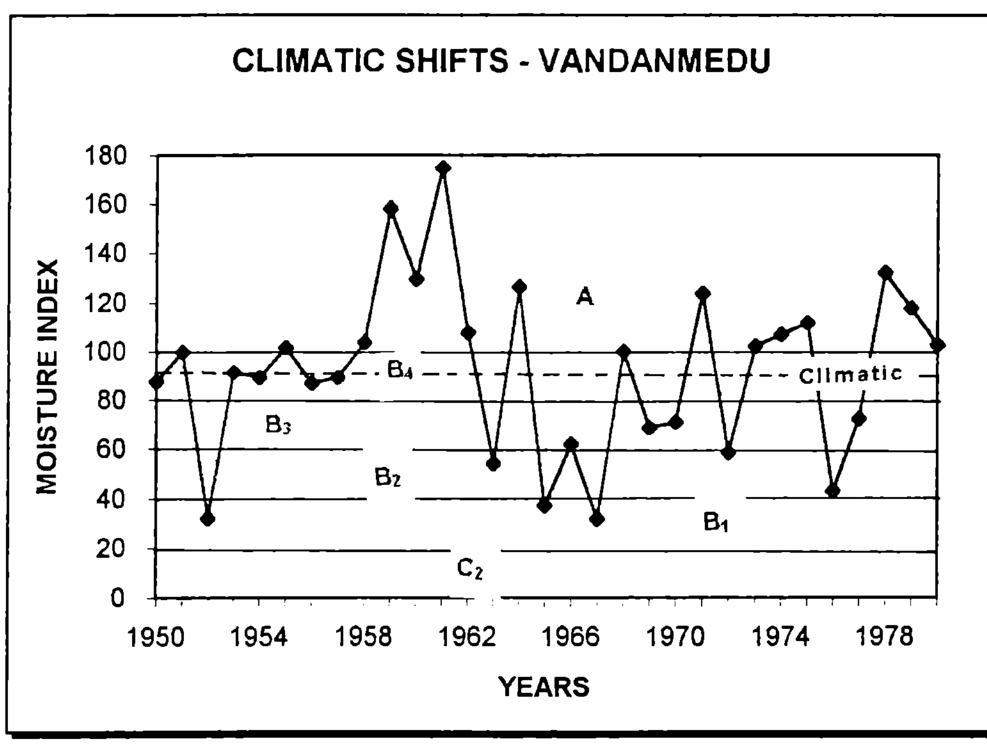


Fig. 4.3.17d. CLIMATIC SHIFTS - VANDANMEDU

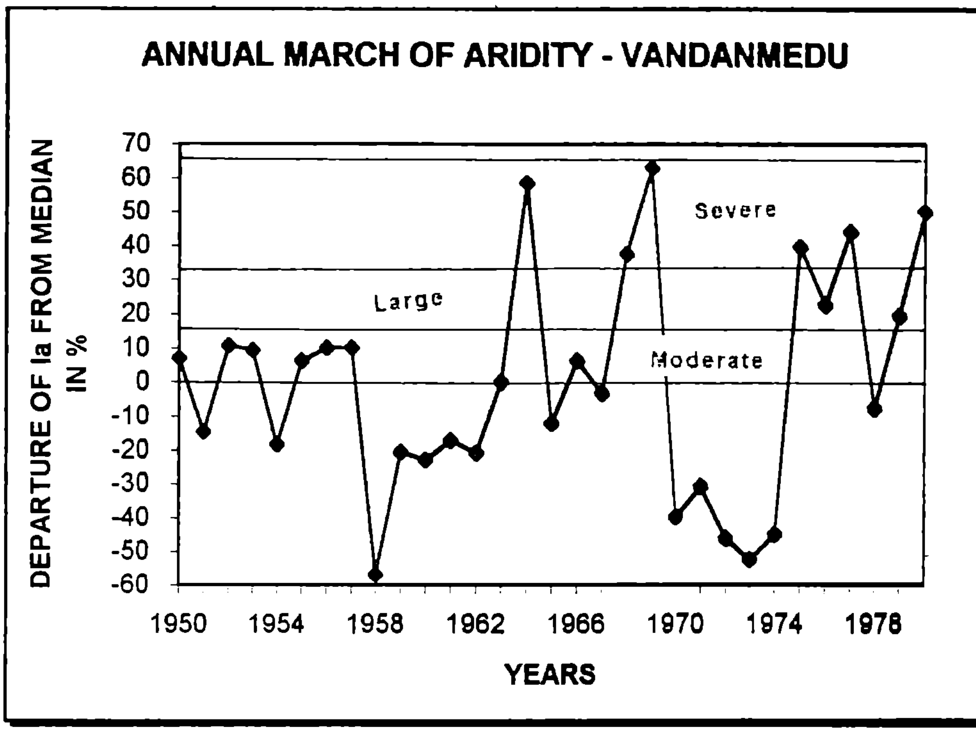


Fig. 4.3.17e. ANNUAL MARCH OF ARIDITY INDEX VANDANMEDU

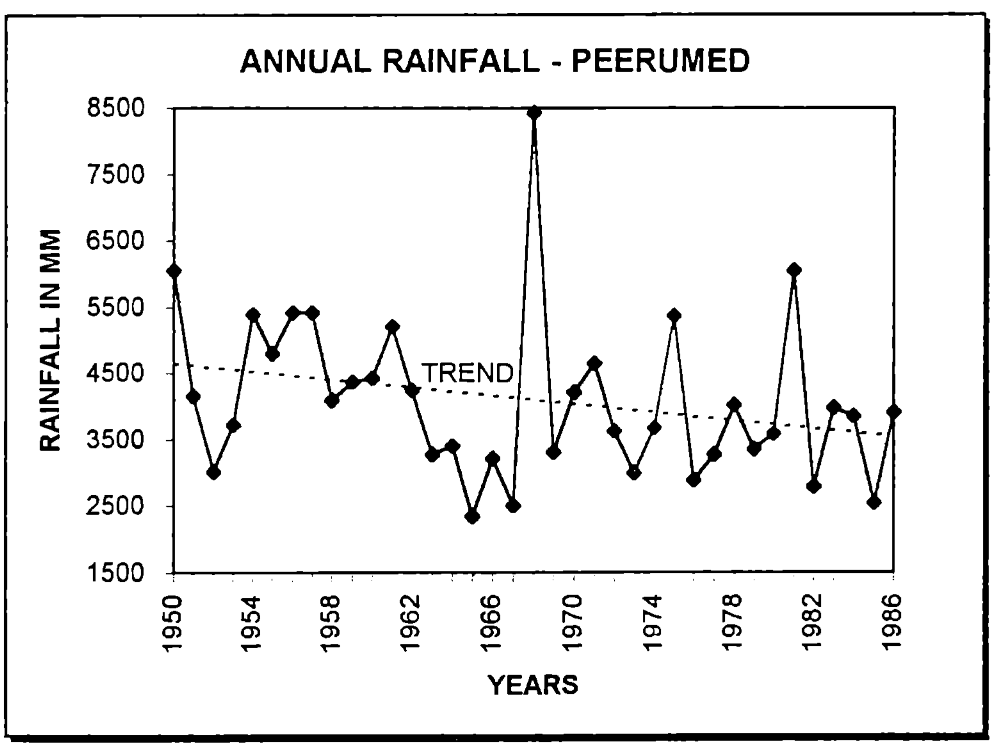


Fig. 4.3.18a. ANNUAL RAINFALL - PEERMED

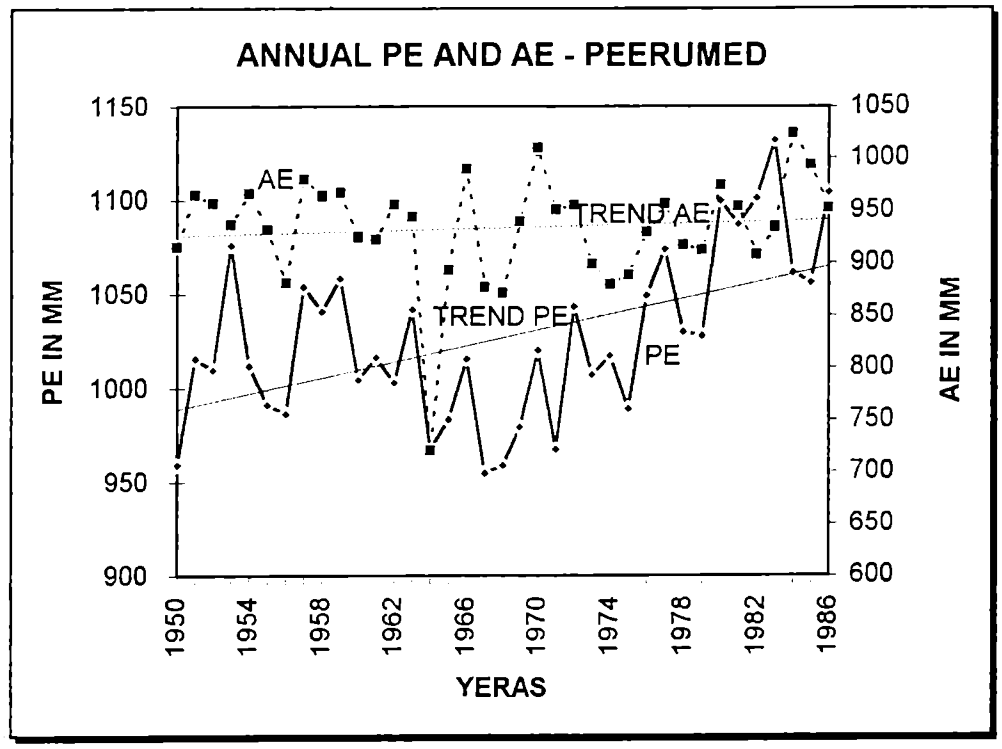


Fig. 4.3.18b. ANNUAL PE & AE - PEERMED

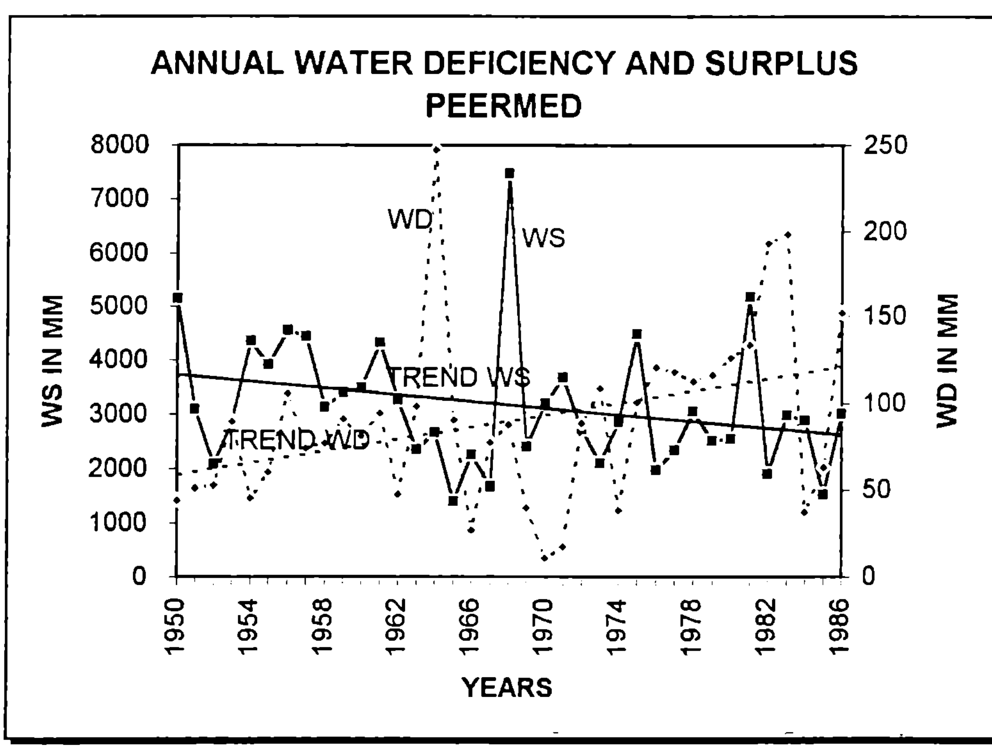


Fig. 4.3.18c. ANNUAL WD & WS - PEERMED

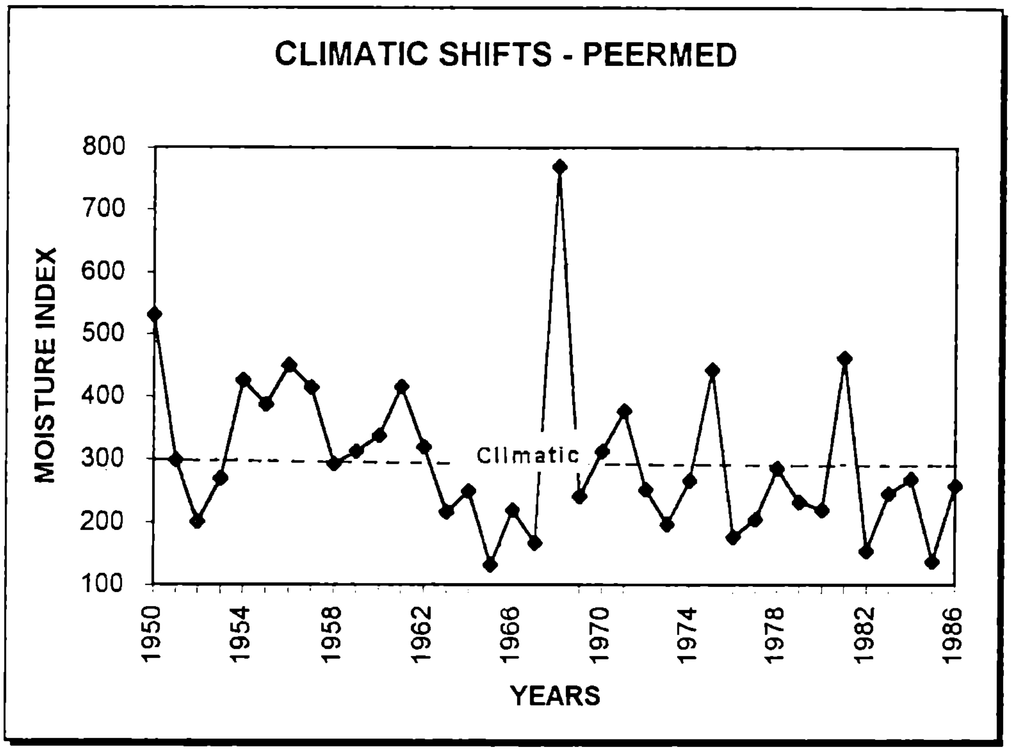


Fig. 4.3.18d. CLIMATIC SHIFTS - PEERMED

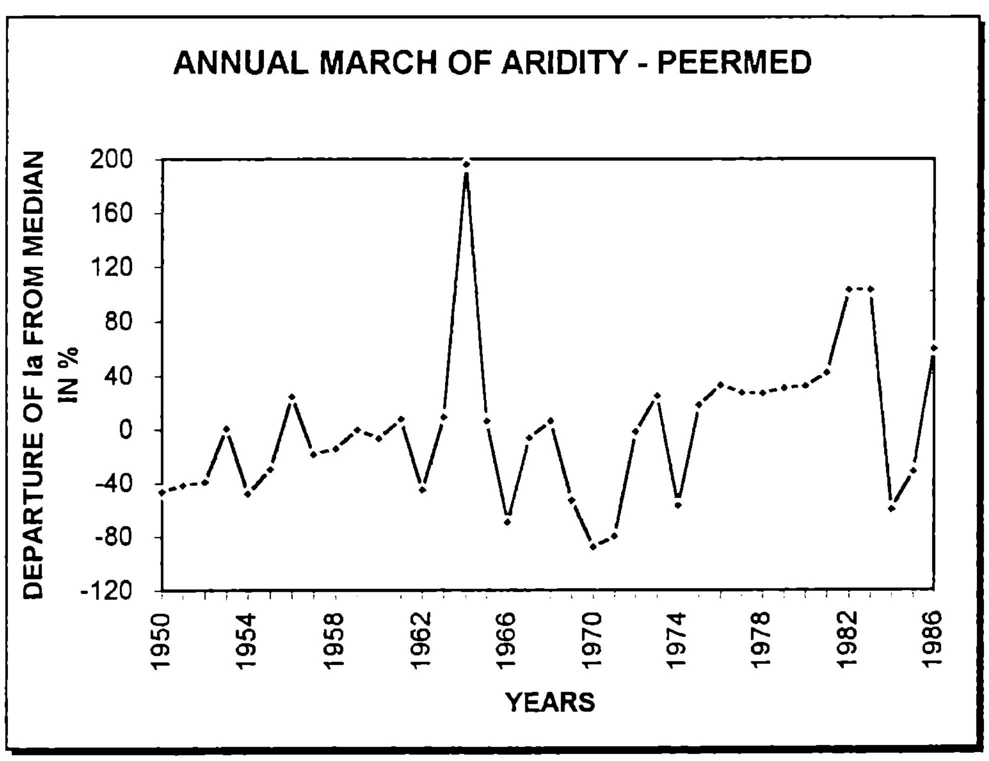


Fig. 4.3.18e. ANNUAL MARCH OF ARIDITY INDEX PEERMED

E. PROBLEM ZONE

4.3.19. CHERTHALA

Cherthala is located at 9^0 42'N and 76^0 20'E. This coastal station receives an annual rainfall of 2779 mm. The annual rainfall pattern shows a declining trend. (Fig.4.3.19a). The highest annual rainfall of this station was 3911 mm. recorded in 1962, and the lowest was 1668 mm. 1983.

A marked increase in annual PE and decrease in AE are the prominent features of the water balance of Cherthala. The highest PE and lowest AE were recorded in 1983. (Fig.4.3.19b)

In consequence to the rainfall pattern, the annual water surplus also shows a declining trend. The year1962 had the highest water surplus (2367mm.). The annual water deficiency displays an increasing trend. (Fig.4.3.19c). Cherthala experienced highest water deficiency in the year 1983, when the itwas 768 mm.

Cherthala experiences humid (B_3) type of climate. A majority of the shifts experienced by Cherthala was within the humid categories. During two years (1983 and 1986) the climate shifted towards dry sub-humid (C_1) type. Moist sub-humid (C_2) type was experienced in 1976, 1982, 1984 and 1985. During 1950, 1957, 1959, 1960, 1961, 1962, 1968 and 1975, the moisture index was above 100, indicating the climatic shift towards Perhumid (A) type. (Fig.4.3.19d).

There were no disastrous droughts in Cherthala, but it experienced one severe, two large and seventeen moderate droughts during the period 1950-1986. (Fig.4.3.19e.)

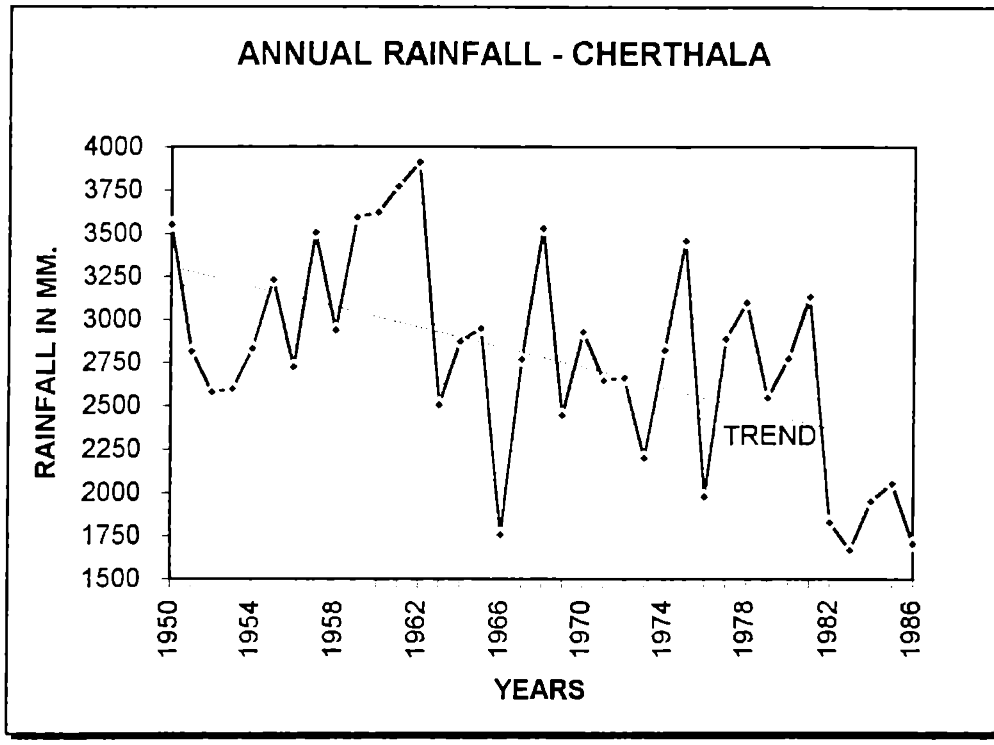


Fig. 4.3.19a. ANNUAL RAINFALL - CHERTHALA

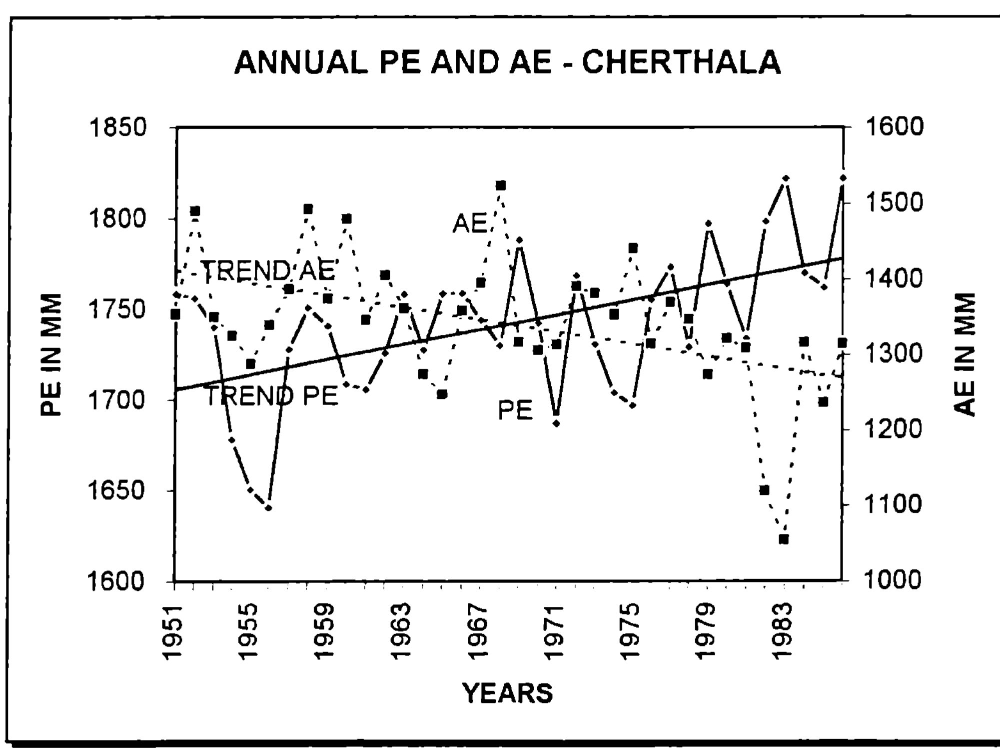


Fig. 4.3.19b. ANNUAL PE & AE - CHERTHALA

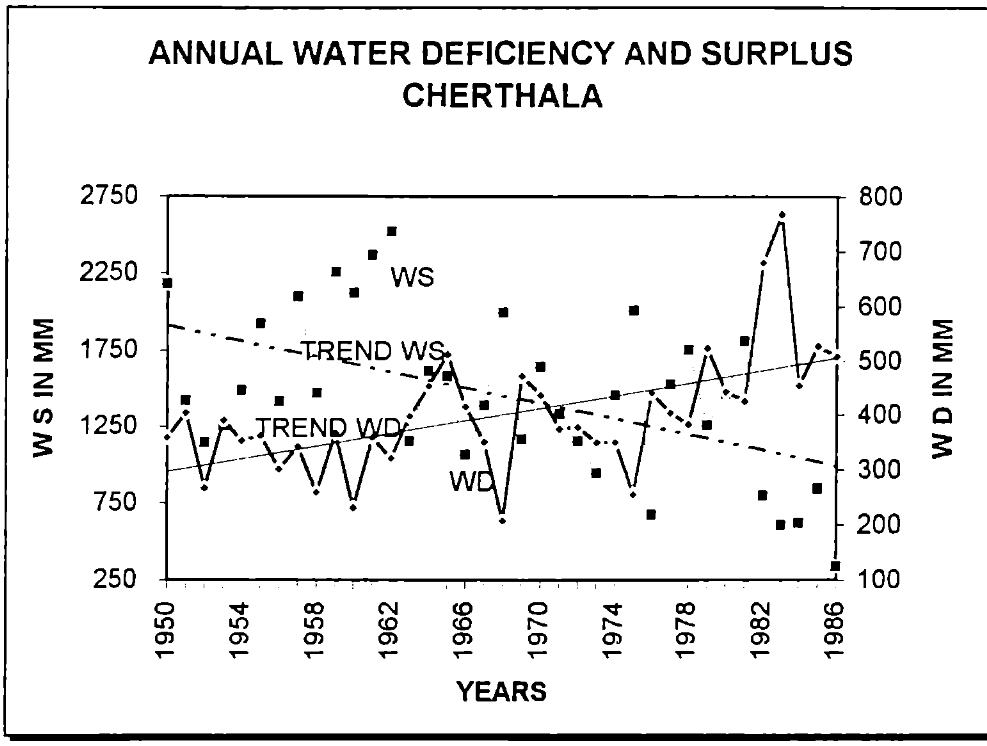


Fig. 4.3.19c. ANNUAL WD & WS - CHERTHALA

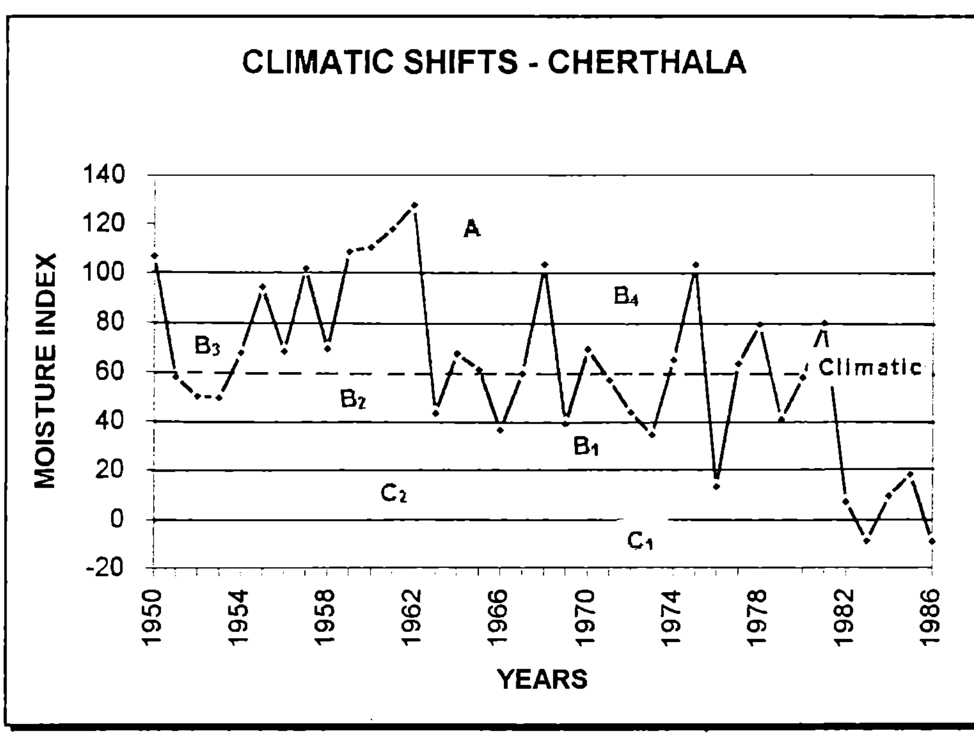


Fig. 4.3.19d. CLIMATIC SHIFTS - CHERTHALA

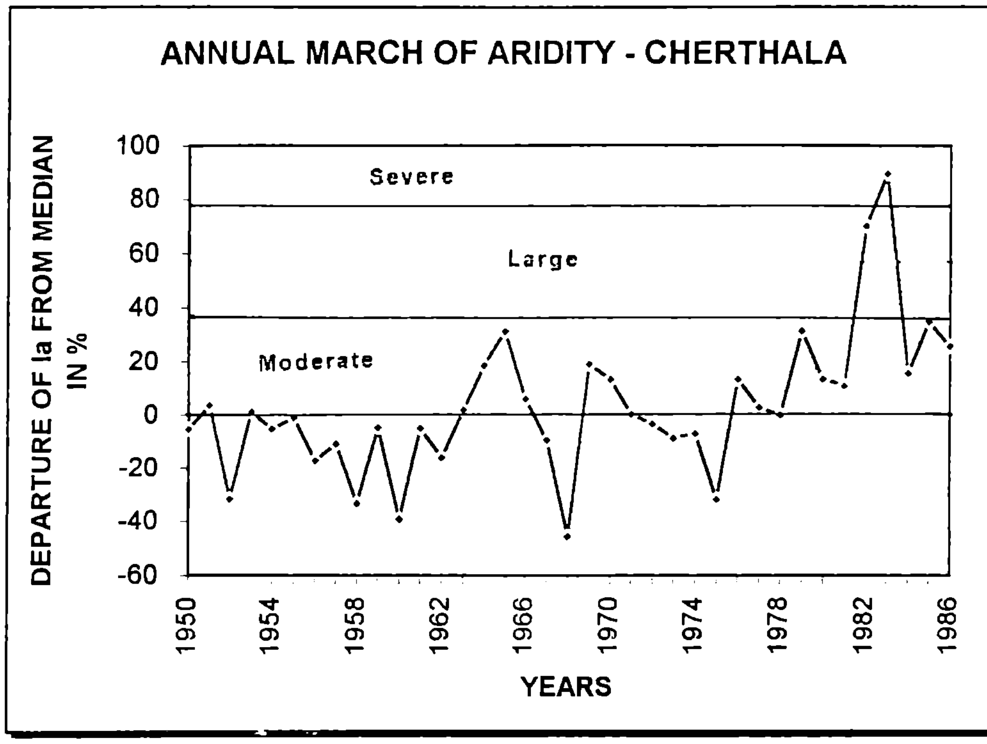


Fig. 4.3.19e. ANNUAL MARCH OF ARIDITY INDEX CHERTHALA

The above analysis reveals the following facts.

1. Annual rainfall of Kerala is declining. This is proved from the fact that almost all the stations showed a declining trend in annual rainfall. In this study the simple technique of fitting regression trend line was adopted to observe the linear trend. The declining rainfall ternd of the State has also been proved by James (1991), using the power spectrum analysis.

2. Rainfall distribution is more critical than the annual amount. This is evident by the fact that most of the perhumid stations, which do not show any major climatic shifts, had drought conditions, even of disastrous magnitude.

CHAPTER 5

LAND USE PATTERN AND ITS SPATIO - TEMPORAL VARIATIONS

Land is a basic natural resource and plays a conspicuous role in the socio-economic development of a nation. The land use pattern of a region reflects its environmental and socio-economic conditions. Changes in environmental conditions such as the changes in climate, physical characteristics of the land, economic and institutional changes ,etc., necessitates the need for shift in the present land use pattern of most of the regions. In order to achieve this goal, an understanding of the evolution of the present land use pattern of the region and its trends is a pre-requisite. This would help take proper remedial measures to have a sustainable development.

5.1 PRESENT LAND USE PATTERN OF KERALA.

With limited land resources available, Kerala has attained stability in its land use pattern over the years. The State as a whole has 27.85% of the total geographical area under forests. Land put to non-agricultural uses account for 9.11%, Permanent pastures, grazing lands and miscellaneous tree crops occupy 0.96%. Fallow lands account for 4.37% and the Net sown area of the State is 57.71%.

The land use pattern of individual districts vary significantly from the State averages.

5.1.1.AREA UNDER FORESTS.

Idukki and Pathanamthitta districts have more than 40% of the total geographical area under forests. 30% to 40% of geographical area is under forests in Kollam, Thrissur, Palakkad, and Wayanad districts. Thiruvananthapuram and Malappuram districts have 20% to 30%, Kozhikode and Kannur districts have 10% to 20% and Kottayam, Ernakulam and Kasargod districts have less than 10% of forest lands. Alappuzha is the only district in the State which virtually does not have any forest area.(Fig.5.1).

5.1.2.LAND PUT TO NON-AGRICULTURAL USES.

Area under this category range from 3.93% in Wayanad district to 17.67% in Alappuzha district. Four districts viz. Pathanamthitta, Idukki, Malappuram and Wayanad have less area under this category than the State average value of 9.11%. Ernakulam district has 15.25% of total geographical area under this category. The higher percentage of land put to non-agricultural uses in Alappuzha and Eranakulam districts is due to the fact that these two districts have more built-up area and also more area under water bodies. Alappuzha is the most densely populated district and Ernakulam is the most urbanised.

5.1.3.PASTURES,GRAZING LANDS AND MISCELLANEOUS TREE CROPS.

Area under this category of land use in most of the districts is less than the State average value of 0.96%. Idukki (2.37%), Kannur (1.94%), Palkkad (1.63%), Kasargod (1.59%) and Wayanad (1.16%) are other districts which have more area under this category.

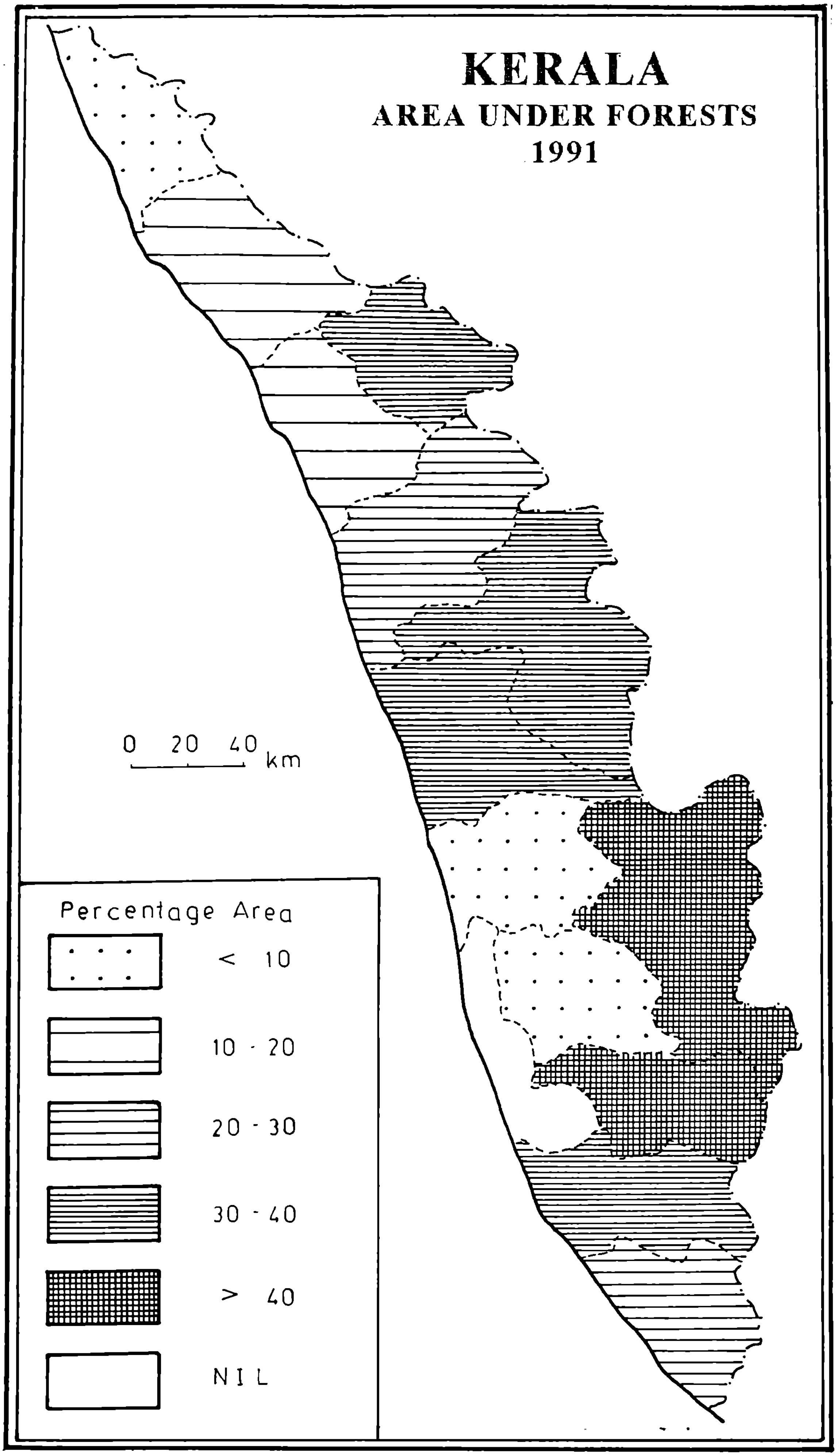


Fig. 5.1. KERALA - FORESTS

5.1.4. FALLOW LANDS.

Relatively high proportion of fallow lands are found in Kasargod (11%), Palakkad (8.27%), Malappuram (6.39%) and Idukki (5.12%) districts. Thiruvananthapuram, Kollam and Pathanamthitta districts have less than 1% of total geographical area under this land use class. In other districts it varies from 1.92% to 4.58%.

5.1.5.NET SOWN AREA.

Seven districts viz., Thiruvananthapuram, Alappuzha, Kottayam, Ernakulam, Kozhikode, Kannur and Kasargod, have more area under cultivation than the State average of 57.71%. Among these, Kottayam district has the highest percentage Net Sown Area (82.79%). Area under this category is comparatively low in the hilly districts of Pathanamthitta and ldukki. In all other districts it ranges from 49.6% to 57 2%.

5.2 LAND USE CHANGES - STATE LEVEL

5.2.1. CHANGES IN AREA UNDER FORESTS :

Forests occupied 27.37% of the total geographical area of the State during 1961. The statistics show that there has not been much changes in the forest lands of the State, except for a marginal increase of 0.5% during 1981(Table 5.1).

5.2.2 CHANGES IN LAND PUT TO NON-AGRICULTURAL USES.

The area under this category of land use shows marginal fluctuations during the past three decades. It was 9.07 % during 1961, decreased to 8.94% during 1971 and increased to 9.26%

during 1981. It shows a marginal decline again in 1991, when this category of land use had a share of 9.11% of the total geographical area of the State. The decrease in area under this class of land use is mainly due to the decrease in area under barren and uncultivable land and the increase is because of the increase in built-up areas and other non-agricultural uses.

5.2.3 CHANGES IN PASTURES, GRAZING LANDS AND MISCELLANEOUS TREE CROPS.

This category of land use steadily declined from 1961, when it occupied 6.38% of total geographical area. It declined to 3.88 in 1971, 1.62 % in 1981, and 0.96% in 1991. This steady decline can be attributed to the fact that more and more of these marginal lands were brought under cultivation during these periods.

5.2.4 CHANGES IN FALLOW LANDS.

Fallow lands occupied 6.51% of total geographical area of the State during 1961. It declined to 3.17% during 1971 and registered an increase of 2.06% during 1981, when it accounted for 5.25% of total geographical area. It again declined to 4.23% during 1991.

AREAS IN PERCENTAGES

LAND USE CATEGORY	1961	1971	1981	1991
FORESTS	27.57	27.35	27.85	27.85
LAND PUT TO NON-AGRICULTURAL USES	9.07	8.94	9.26	9.11
PASTURES	6.38	3.88	1.62	0.96
FALLOW LANDS	6.51	3.17	5.23	3.37
NET AREA SOWN	50.67	56.66	56.06	57.71

Table.5.1. KERALA - LAND USE CHANGES (%).

5.2.5 CHANGES IN NET SOWN AREA.

The State's net sown area increased from 50.67% in 1961 to 56.66 % in 1971, registering a decadal increase of 5.99 %. There was a marginal decrease of net sown area during 1981, when it accounted for 56.04 % of total geographical area. During 1991 the net sown area rose to 57.71 %, registering a decadal increase of 1.67 %.

5.3. DISTRICT LEVEL LAND USE CHANGES.

Land use changes within the various districts are different from the State average figures. Since the formation of the State in 1957, many districts were re-organised and new districts were formed. In this analysis only those districts which were originally existed during the formation of the State have been selected. Changes have been calculated taking the actual percentage occupancy of each land use category with respect to total geographical area.

5.3.1.THIRUVANANTHAPURAM DISTRICT.

Thiruvananthapuram is the only district in the State which has not undergone any administrative re-organisation. The has a total geographical area of 218600 hectares. Table 5.2 shows the land use pattern of the district during the four periods under study. The increase in Land Put to Non-Agricultural uses and corresponding decrease in area under Pastures, Fallow lands and Net sown area is quite significant.

During the decade 1961-1971 the area under Forests registered a decline of 0.5%. Land Put to Non-Agricultural uses increased by 1.7%, Pastures, Grazing lands and Miscellaneous tree crops showed a decline of 0.6%. Fallow lands also showed a decline during this period.(Fig.5.2a).

AREAS IN PERCENTAGES

LAND USE CATEGORY	1961	1971	1981	1991
FORESTS	20.29	20.29	22.81	22.81
LAND PUT TO NON-ARICULTURAL USES	6.13	7.80	8.93	9.84
PASTURES	0.72	0.53	0.10	0.07
FALLOW LANDS	3.49	0.77	2.46	0.94
NET AREA SOWN	69.00	70.60	65.60	66.33

Table 5.2 .THIRUVANANTHAPURAM DISTRICT-LAND USE (%)

During the decade 1971-1981 Forests, Land Put to Non-Agricultural Uses and Fallow lands increased, while the Pastures and Net Sown Area decreased. The decline of Pastures and Net Sown Area during this period is because of more and more land of this category was converted for residential purposes. (Fig.5.2b)

The decade 1981-1991 was more stable when compared to the previous two decades with respect to land use changes. There was no change in the area under Forests and Pastures. Land Put to Non-Agricultural Uses increased by 1% and Net Sown Area by 0.7%, while the Fallow lands registered 1.5% decrease. (Fig.5.2c)

5.3.2 KOLLAM DISTRICT.

Kollam district has total geographical area of 251838 hectares. The increase in Net Sown Area and Land Put to Non-Agricultural Uses over the three decades and the decrease in

Fig.5.2a

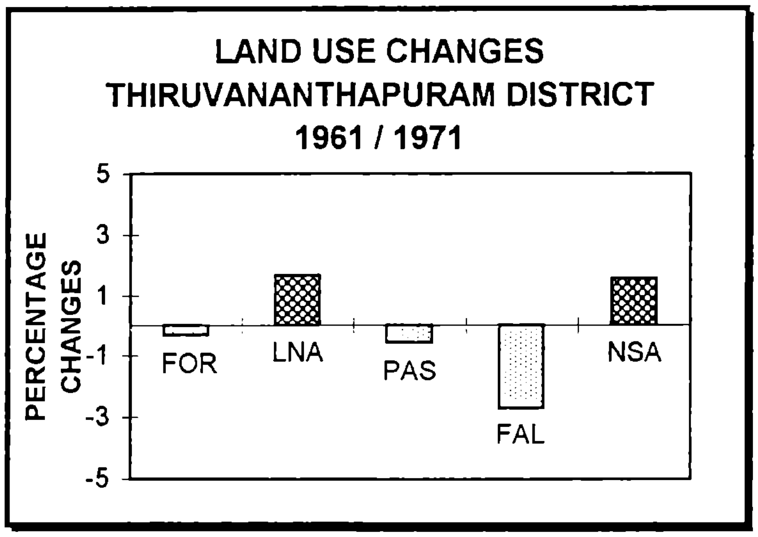
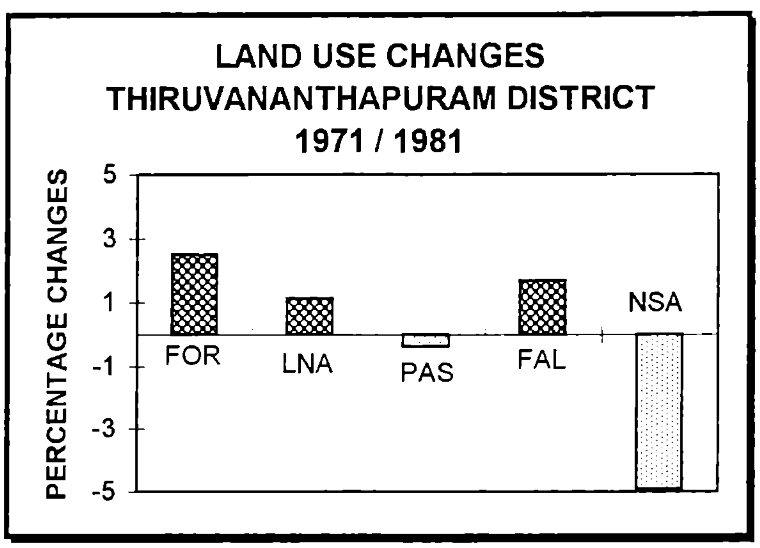


Fig.5.2b



LNA - LAND PUT TO NON-AGRICULTURAL USES
PAS - PASTURES
FAL - FALLOW LANDS
NSA - NET SOWN AREA

Fig.5.2c

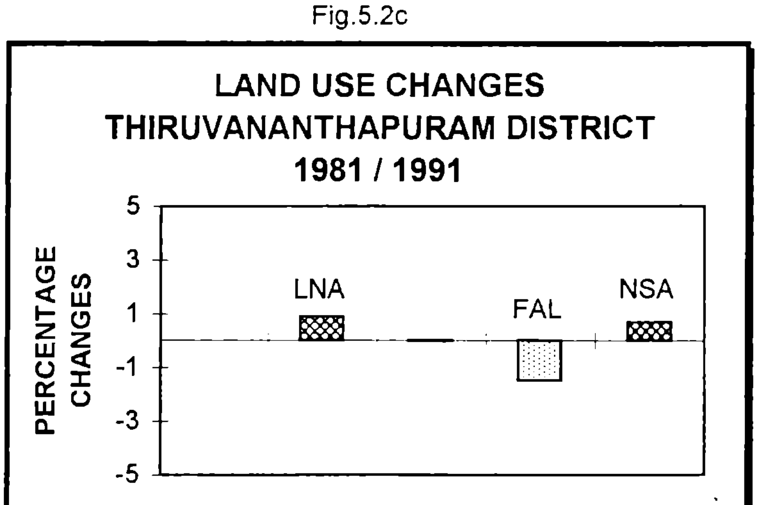


Fig. 5.2. LAND USE CHANGES - THIRUVANANTHAPURAM DISTRICT

Fig.5.3a

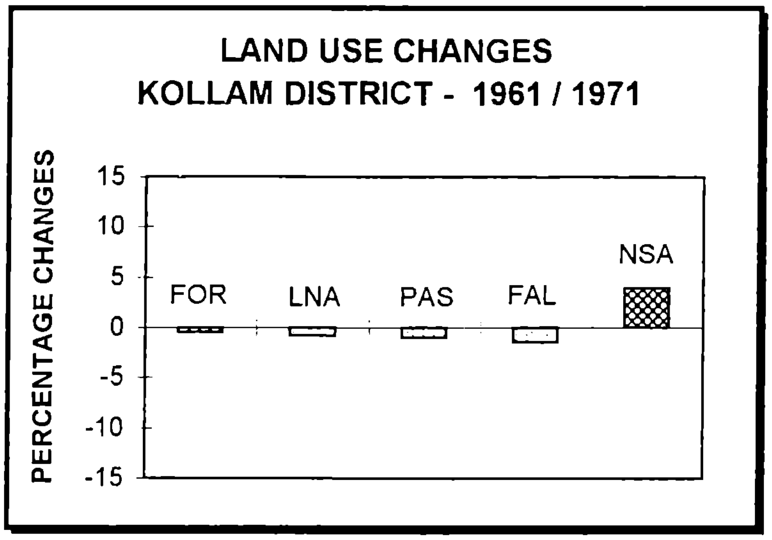
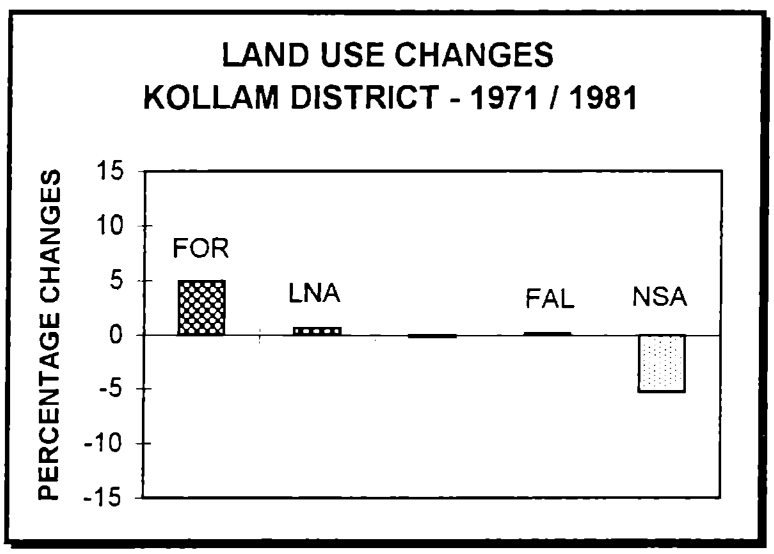


Fig.5.3b



FOR - FORESTS
LNA - LAND PUT TO NON-AGRICULTURAL USES
PAS - PASTURES
FAL - FALLOW LANDS
NSA - NET SOWN AREA

Fig.5.3c

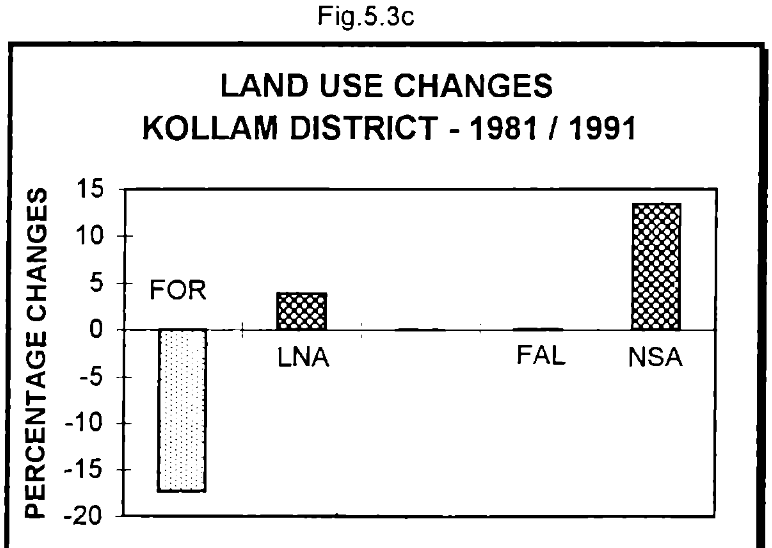


Fig. 5.3. LAND USE CHANGES - KOLLAM DISTRICT

area under Forests are the major aspects of land use changes of Kollam district. (Table 5.3).

During 1961-1971 all the land use categories except the Net Sown Area registered marginal decrease. Net Sown Area, in the mean time, increased by 4%.(Fig.5.3a).

In the decade 1971-1981, excepting the Net Sown Area, all the land use categories registered increases. Area under Forests increased by 4.7%, while the Net Sown Area decreased by 5.45%.(Fig. 5.3b).

Major decrease of 17.4% in the area under Forests was recorded in the decade 1981-1991. Land Put to Non-Agricultural uses increased by 3.9% and the Net Sown Area by 13.5%. It is, hence, obvious that the decrease in forests is due to the conversion of these lands to non-agricultural purposes and for the extension of cultivation. (Fig.5.3c).

AREAS IN PERCENTAGES

LAND USE CATEGORY	1961	1971	1981	1991
FORESTS	45.44	44.91	49.77	32.34
LAND PUT TO NON-AGRICULTURAL USES	5.89	5.06	5.65	9.56
PASTURES	1.47	0.40	0.13	0.09
FALLOW LANDS	2.22	0.72	0.90	0.99
NET SOWN AREA	44.98	48.91	43.52	47.00

Table 5.3. KOLLAM DISTRICT - LAND USE (%)

5.3.3.ALAPPUZHA DISTRICT.

One of the noticeable features of the land use pattern of Alappuzha district is the absence of forests. Being a coastal district, Alappuzha had a small area under low land forests until 1981- about 0.28%. Alappuzha is the most densely populated district in the State. It has a total geographical area of 136058 hectares. Because of the pressure of population, the forest lands available were cleared for cultivation and residential purposes. Another major feature of the land use pattern of the district is the increase in Land Put to Non-agricultural Uses and decrease in Net Sown Area.

The Land Put to Non-Agricultural Uses increased from 6.92% in 1961 to 17.67% in 1991, while the Net Sown Area decreased from 84.88% in 1961 to 77.63% in 1991. (Table.5.4).

Most of these changes were recorded during 1971-1981. (Fig.5.4a, 5.4b, 5.4c). As in other districts land use changes were minimal during 1981-1991.

AREAS IN PERCENTAGES

LAND USE CATEGORY	1961	1971	1981	1991
FORESTS	0.27	0.27	0.27	0.00
LAND PUT TO NON-AGRICULTURAL USES	6.92	7.11	17.20	17.67
PASTURES	3.33	3.69	0.10	0.12
FALLOW LANDS	4.60	1.26	2.91	4.38
NET AREA SOWN	84.88	87.67	79.48	77.63

Table.5.4. ALAPPUZHA DISTRICT - LAND USE (%)

5.3.4.KOTTAYAM DISTRICT.

Kottayam district has a total geographical area of 219550 hectares, and it has the distinction of being the district with highest Net Sown Area. A marked decrease in area under Forests and increase in area under Land Put to Non- Agricultural Uses and Net Sown Area are the prominent features of the land use changes of Kottayam district. (Table 5.5)

Fig.5.4a

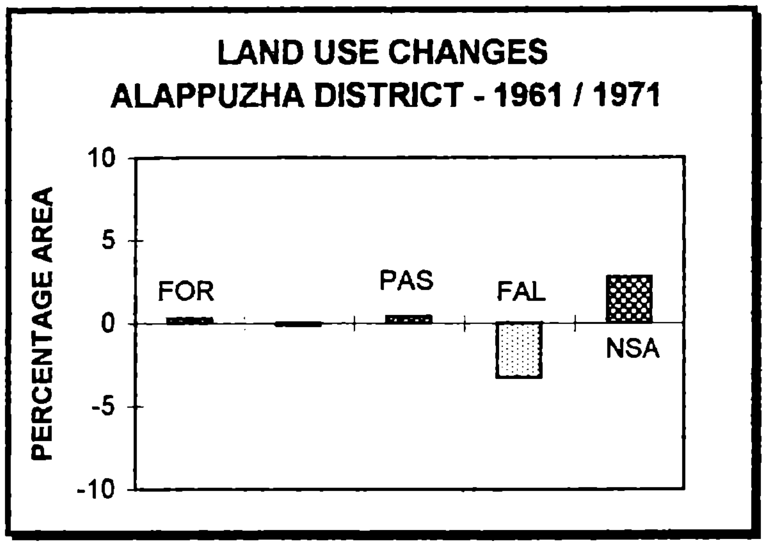
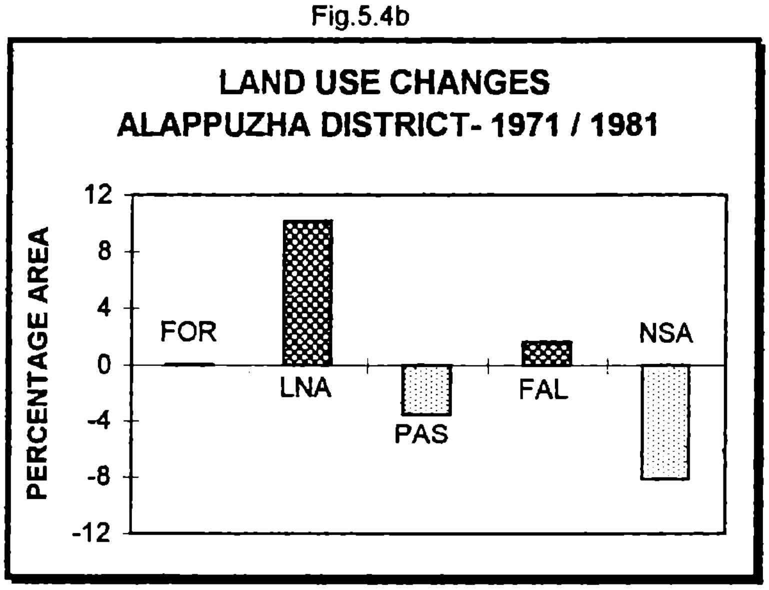


Fig.5.4b



FOR - FORESTS
LNA - LAND PUT TO NON-AGRICULTURAL USES
PAS - PASTURES
FAL - FALLOW LANDS
NSA - NET SOWN AREA

Fig.5.4c

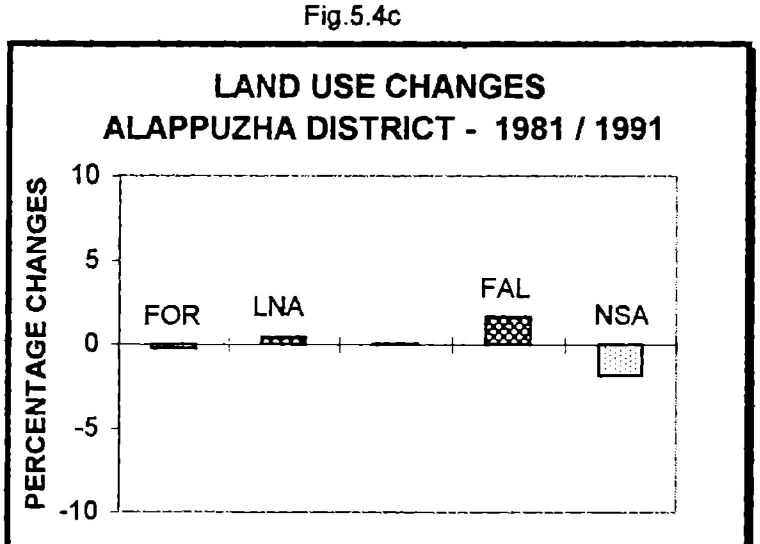


Fig. 5.4. LAND USE CHANGES - ALAPPUZHA DISTRICT

The district recorded a decrease in all land use categories except the Net Sown Area during 1961-1971. The decrease in area under forests was 4.9%, while other categories recorded marginal decline. The Net Sown Area increased by 10.75% during this period. Fig.5.5a).

Major changes in the land use pattern of the district occurred during the period 1971-1981. (Fig.5.5b). Forests reduced by 31.2%, while the Net Sown Area increased by 27.1% during this period. Land Put to Non-Agricultural Uses registered an increase of 5.3%.

The only major change recorded during 1981-1991 was the increase in Land Put to Non-Agricultural Uses, which went up by 10.9% during this period. (Fig.5.5c).

AREAS IN PERCENTAGES

LAND USE CATEGORY	1961	1971	1981	1991
FORESTS	39.72	34.87	3.71	3.71
LAND PUT TO NON-AGRICULTURAL USES	6.23	4.41	9.66	10.60
PASTURES	3.52	1.45	0.19	0.10
FALLOW LANDS	5.01	3.07	3.16	2.80
NET SOWN AREA	45.52	56.20	83.29	82.79

Table.5.5. KOTTAYAM DISTRICT - LAND USE (%).

5.3.5.ERNAKULAM DISTRICT.

The district has a total geographical area of 235319 hectares. Marked decline in area under Forests and corresponding increase of Land put to Non-Agricultural Uses and Net Sown Area are the main features of the land use changes of Eranakulam district. (Table.5.6)

Fig.5.5a

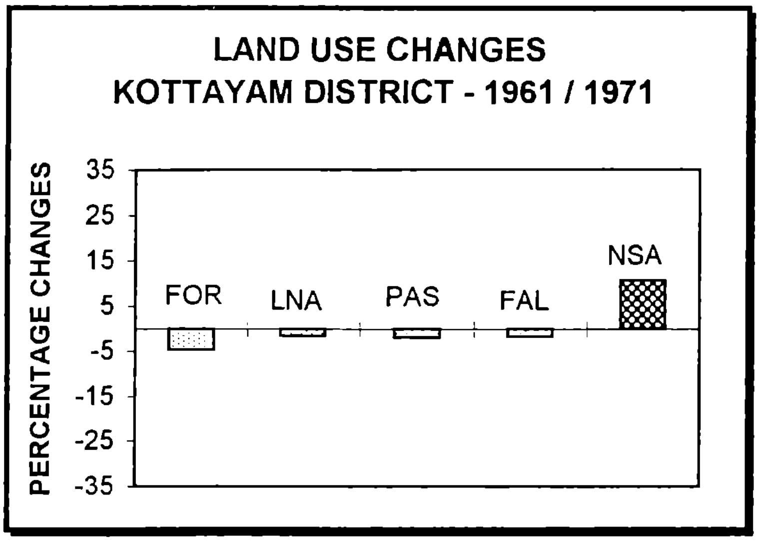
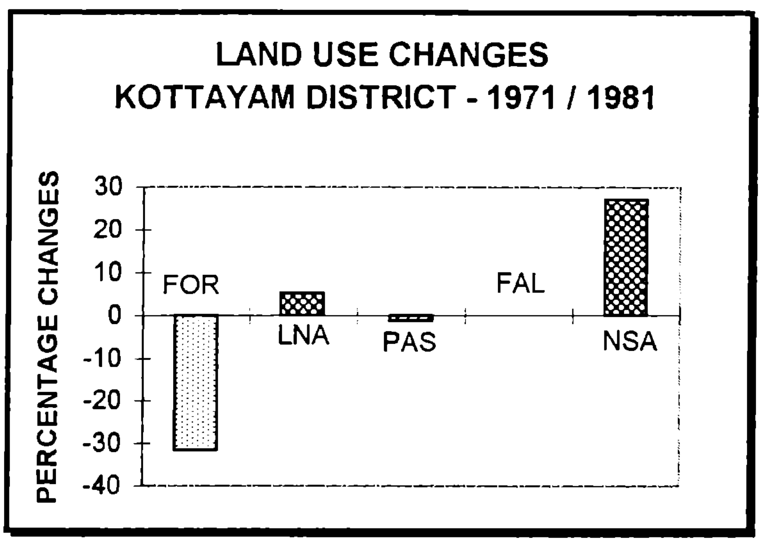


Fig.5.5b



FOR - FORESTS
LNA - LAND PUT TO NON-AGRICULTURAL USES
PAS - PASTURES
FAL - FALLOW LANDS
NSA - NET SOWN AREA

Fig.5.5c

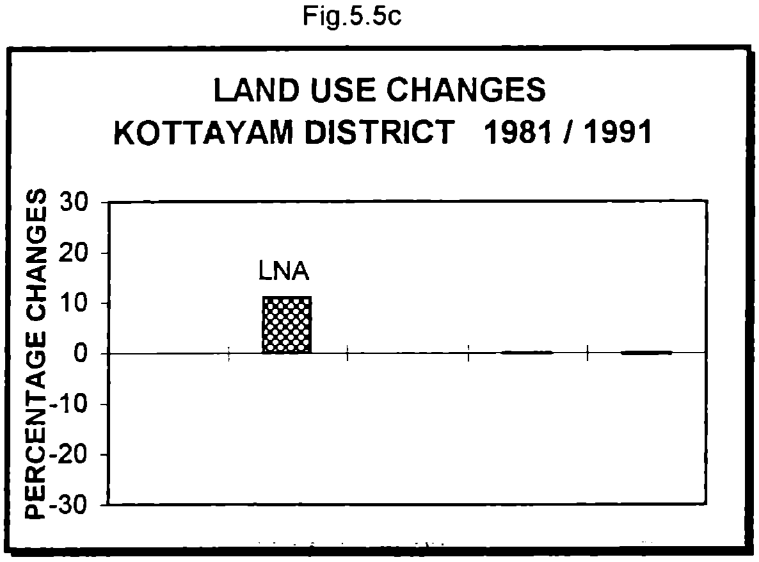


Fig. 5.5. LAND USE CHANGES - KOTTAYAM DISTRICT

Area under Forests declined by 4.22% during the period 1961-1971. Pastures and Fallow lands also recorded decline in area by 3.6% and 2.2% respectively. Land put to Non-Agricultural Uses and Net Sown Area registered increases during this decade. Net Sown Area increased by 9.3%. (Fig. 5.6a).

There was marked decline in area under Forests during the second decade. Forests declined by 9.74%. Land put to Non-Agricultural Uses and Net Sown Area increased by 5.5% and 2.5% respectively. (Fig.5.6b).

AREAS IN PERCENTAGES

LAND USE CATEGORY	1961	1971	1981	1991
FORESTS	17.41	13.19	3.45	3.45
LAND PUT TO NON-AGRICULTURAL USES	9.03	9.78	15.28	15.25
PASTURES	4.40	0.79	0.85	0.36
FALLOW LANDS	0.17	2.97	4.86	3.58
NET AREA SOWN	63.99	73.27	75.76	77.36

Table.5.6. ERNAKULAM DISTRICT - LAND USE (%)

During the third decade, the land use almost stabilised. There was a 1.3% decline in the area under Fallow lands and 1.6% increase in the Net Sown Area. (Fig.5.6c).

5.3.6.THRISSUR DISTRICT.

Like many other districts, Thrissur district also shows decline in area under Forests and increase in Net Sown Area. (Table 5.7).

Relatively equal shares of area under Forests and Net Sown Area were the characteristic feature of the land use pattern of Thrissur district until 1981. A minor decrease in Forests and

Fig.5.6a

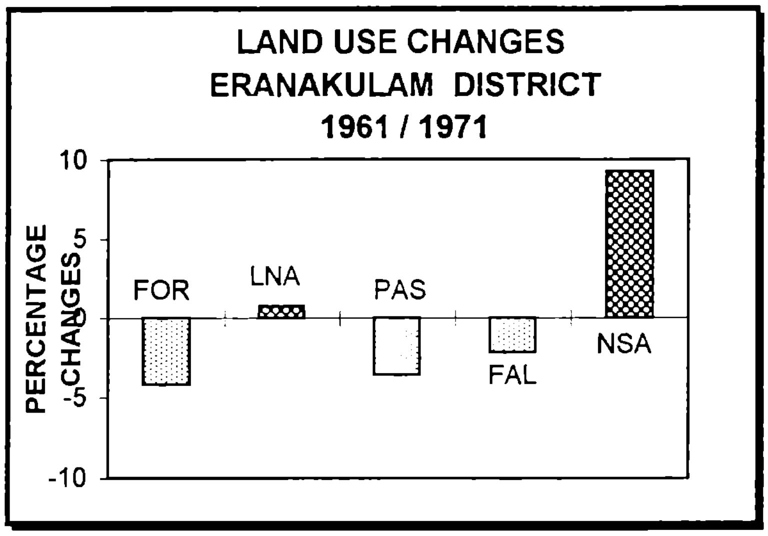
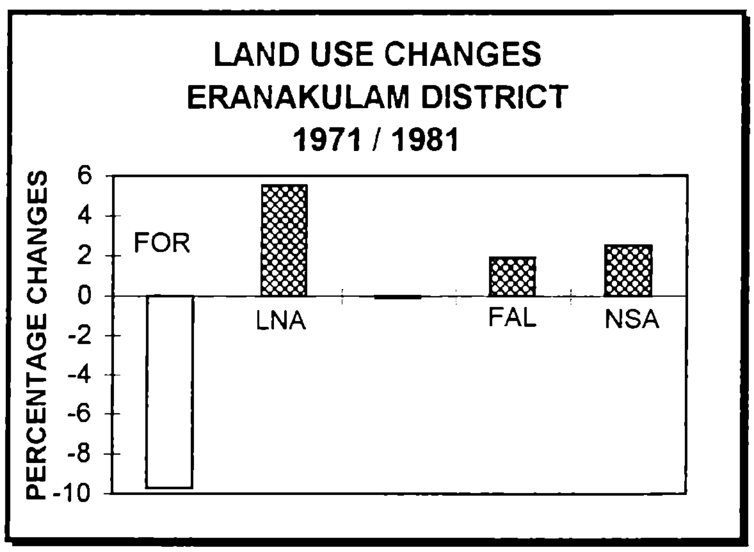


Fig.5.6b



LNA - LAND PUT TO NON-AGRICULTURAL USES
PAS - PASTURES
FAL - FALLOW LANDS
NSA - NET SOWN AREA

Fig.5.6c

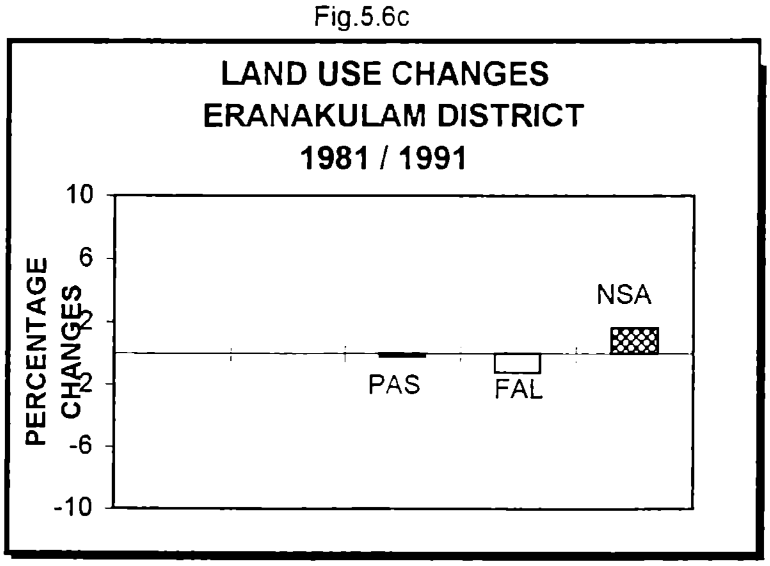


Fig. 5.6. LAND USE CHANGES - ERNAKULAM DISTRICT

Fallow lands, and corresponding increase in other categories were noticed during the decade 1961-1971. (Fig.5.7a).

During the decade 1971-1981 Forests declined by 9.6% and Pastures by 1.3%. Net Sown Area, Land Put to Non-Agricultural Uses and Fallow lands increased by 5.9%, 1.9% and 3.1% respectively during the same period.(Fig.5.7b).

Reflecting the stabilised nature of the land use pattern, the decade 1981-1991 registered only minor changes.

AREAS IN PERCENTAGES

LAND USE CATEGORY	1961	1971	1981	1991
FORESTS	45.17	44.25	34.61	34.61
LAND PUT TO NON-AGRICULTURAL USES	6.02	6.28	8.18	9.45
PASTURES	0.86	1.77	0.50	0.34
FALLOW LANDS	4.11	1.30	4.38	4.02
NET SOWN AREA	43.84	46.40	52.33	51.60

Table.5.7. THRISSUR DISTRICT - LAND USE (%)

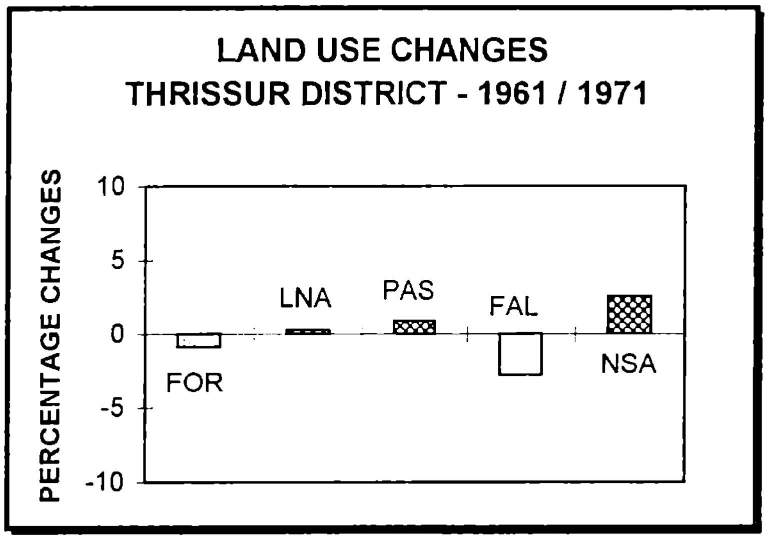
5.3.7.PALAKKAD DISTRICT

One peculiar feature of Palakkad district is the increase in area under Forests. (Table 5.8).

The first decade saw decrease in area under all categories except the Net Sown Area, which increased by 17.9%. (Fig.5.8a).

The second decade registered major changes in all land use categories. Forests increased by 15.7% and Fallow lands by 5.8%. Land Put to Non-Agricultural Uses decreased by 3.1%, while the increase in Net Sown Area was by 3.73%. (Fig.5.8b)

Fig.5.7a



FOR - FORESTS
LNA - LAND PUT TO NON-AGRICULTURAL USES
PAS - PASTURES
FAL - FALLOW LANDS
NSA - NET SOWN AREA

Fig.5.7b

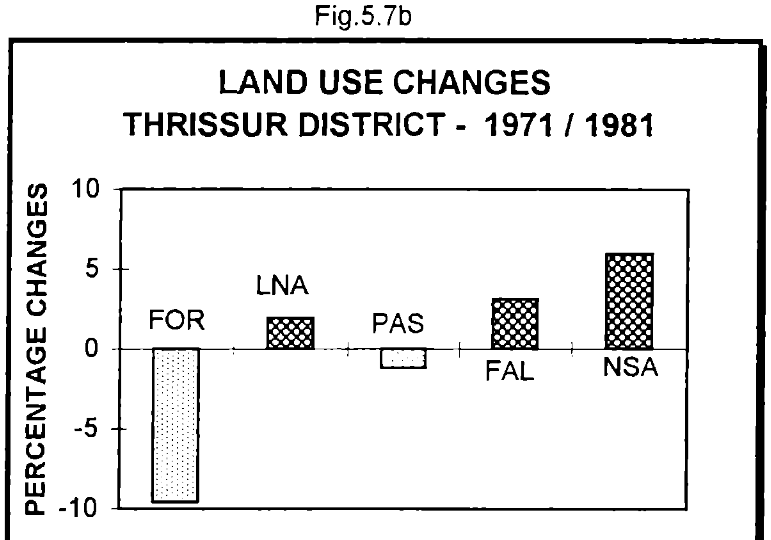
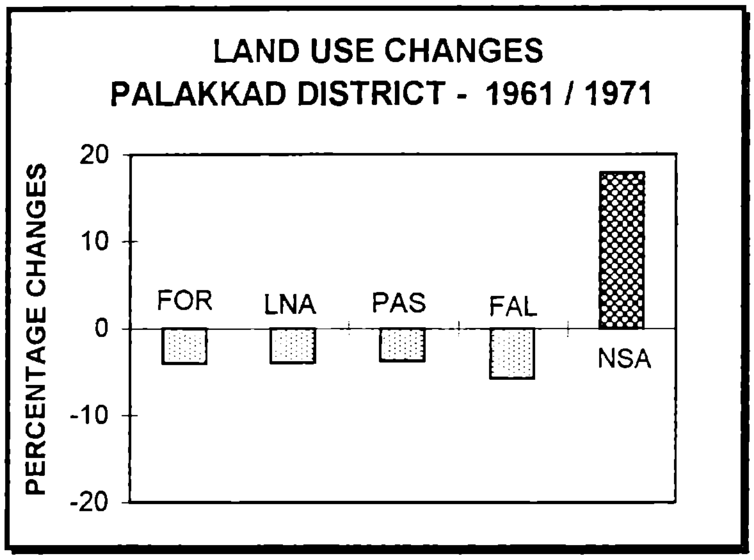


Fig. 5.7. LAND USE CHANGES - THRISSUR DISTRICT

Fig.5.8a



FOR - FORESTS
LNA - LAND PUT TO NON-AGRICULTURAL USES
PAS - PASTURES
FAL - FALLOW LANDS
NSA - NET SOWN AREA

Fig.5.8b

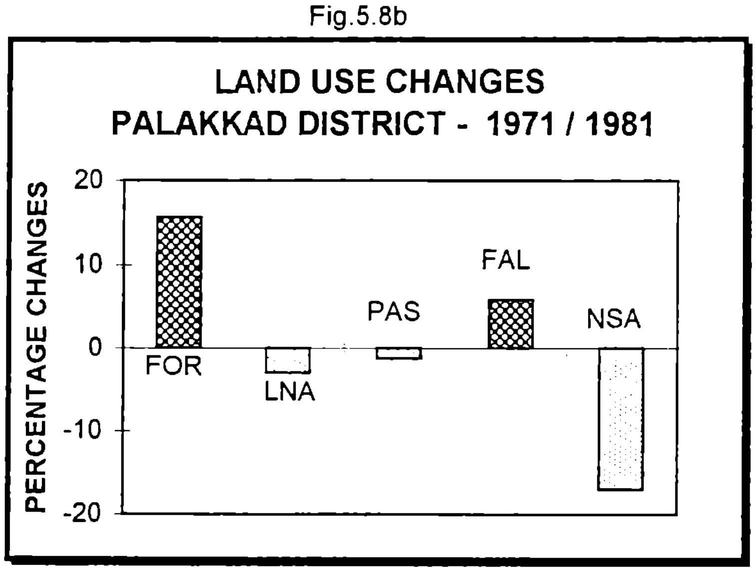


Fig. 5.8. LAND USE CHANGES - PALAKKAD DISTRICT

AREAS IN PERCENTAGES

LAND USE CATEGORY	1961	1971	1981	1991
FORESTS	19.53	15.37	31.04	31.04
LAND PUT TO NON-AGRICULTURAL USES	17.56	13.45	10.40	9.54
PASTURES	7.21	3.33	2.04	1.63
FALLOW LANDS	8.00	2.18	8.01	8.22
NET AREA SOWN	48.51	49.60	52.33	51.66

Table.5.8. PALAKKAD DISTRICT - LAND USE (%)

As in other districts, the third decade saw little changes in Palakkad District also.

5.3.8.KOZHIKODE DISTRICT.

Kozhikode district also showed the same trend as the other districts in the land use changes.(Table.5.9).

From Fig.5.9a, it is obvious that the increase in area under Forests and Non-Agricultural Uses were compensated by corresponding decrease in Pastures, Fallow land and Net Sown Area during 1961-1971.

AREA IN PERCENTAGE

LAND USE CATEGORY	1961	1971	1981	1991
FORESTS	29.33	35.04	20.73	17.74
LAND PUT TO NON-AGRICULTURAL USES	6.80	15.44	7.46	9.70
PASTURES	6.84	1.80	2.89	0.92
FALLOW LANDS	8.00	4.15	2.91	1.92
NET AREA SOWN	49.03	43.60	66.01	69.72

Table.5.9. KOZHIKODE DISTRICT - LAND USE (%).

The decade 1971-1981 saw 14.3% decrease in Forests, 8% decrease in Land Put to Non-Agricultural Uses and 1.2% decline in Fallow lands. The increase in Net Sown Area was phenomenal during this period - 22.4%. (Fig.5.9b).

During 1981-1991 all the land use categories, except the Land Put to Non-Agricultural Uses, registered decline. Land Put to Non-Agricultural Uses increased by 2.2%. (Fig.5.9c).

5.3.9.KANNUR DISTRICT.

The typical characteristic of the land use pattern of Kannur district was relatively high proportion of area under Pastures and Fallow lands. (Table.5.10)

Net Sown Area increased by 9.1% during the first decade in Kannur district. Land Put to Non-Agricultural Uses increased marginally by 1.3% during this period. (Fig.5.10a).

In the decade 1971-1981 there was considerable decrease (13.3%) in Pastures, and corresponding increase of 11.1% was noticed in the Net Sown Area. (Fig.5.10b). Net Sown Area increased by 9.1% during the first decade in Kannur district. Land Put to Non-Agricultural Uses increased marginally by 1.3% during this period.

AREAS IN PERCENTAGES

LAND USE CATEGORY	1961	1971	1981	1991
FORESTS	11.56	11.43	12.58	16.42
LAND PUT TO NON-AGRICULTURAL USES	13.03	14.28	13.35	10.13
PASTURES	19.32	16.44	3.17	1.94
FALLOW LANDS	12.41	5.15	7.32	3.61
NET AREA SOWN	43.58	52.70	63.78	67.90

Table.5.10. KANNUR DISTRICT - LAND USE (%).

Fig.5.9a

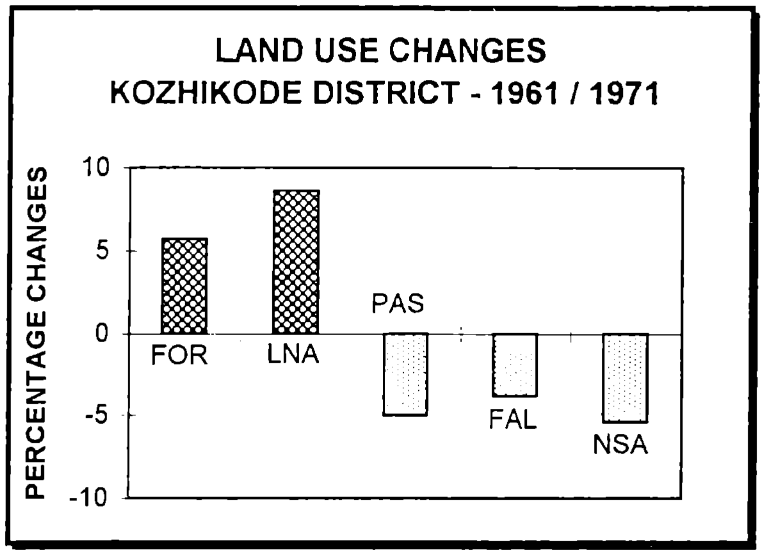
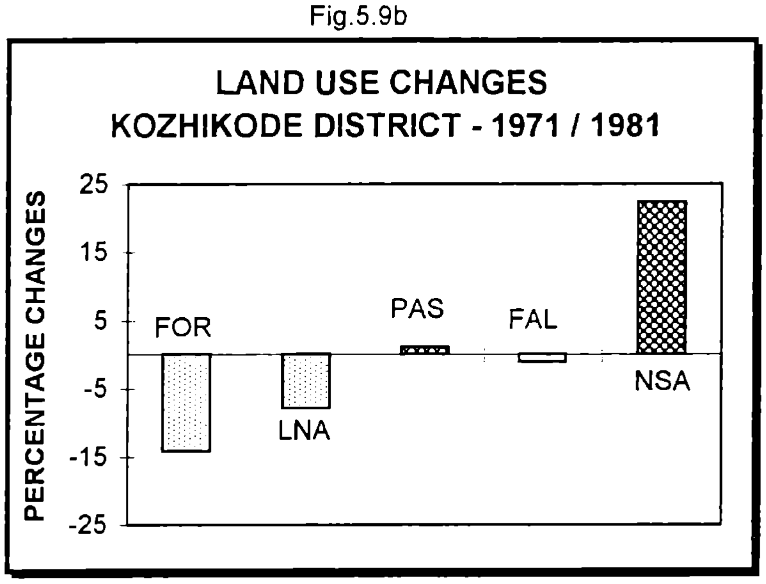


Fig.5.9b



FOR - FORESTS
LNA - LAND PUT TO NON-AGRICULTURAL USES
PAS - PASTURES
FAL - FALLOW LANDS
NSA - NET SOWN AREA

Fig.5.9c

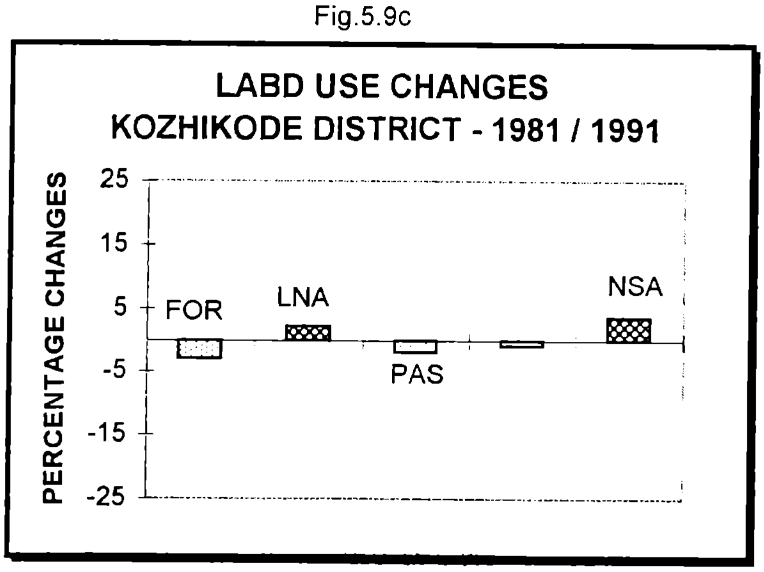


Fig. 5.9. LAND USE CHANGES - KOZHIKODE DISTRICT

In the decade 1971-1981 there was considerable decrease (13.3%) in Pastures, and corresponding increase of 11.1% was noticed in the Net Sown Area.

The area under Forests and Net Sown Area increased, while the other land use categories declined, during the decade 1981-1991.(Fig.5.10c).

5.4. OVERALL LAND USE CHANGE

The overall land use change calculated using Weaver's(1954) methodology indicate that the State had an overall gross land use change of 10.54% during the period 1961-1991. Of this 5.99% of changes occurred during the first decade (1961-1971), and can be considered as the most dynamic period with respect to land use changes. In the second decade (1971-1981), the gross overall change was 2.88%, followed by 1.67 % during the third decade (1981-1991). This clearly shows that the land use pattern of the State had almost stabilised during these periods.

The district-wise figures show a varied picture. Those districts which have undergone administrative re-organisations show higher percentage changes during the decade when the re-organisation was effected. (Table 5.11).

Thiruvananthapuram is the only district in the State which has not undergone any administrative re-organisation. Hence it recorded least overall change- 10.19%. About half of this change (5.13%) has occurred during the second decade. This was followed by Thrissur and Alappuzha districts which recorded 15.91% and 17.25% of gross overall change. Here again two thirds of the changes have occurred in the second decade.

Fig.5.10a

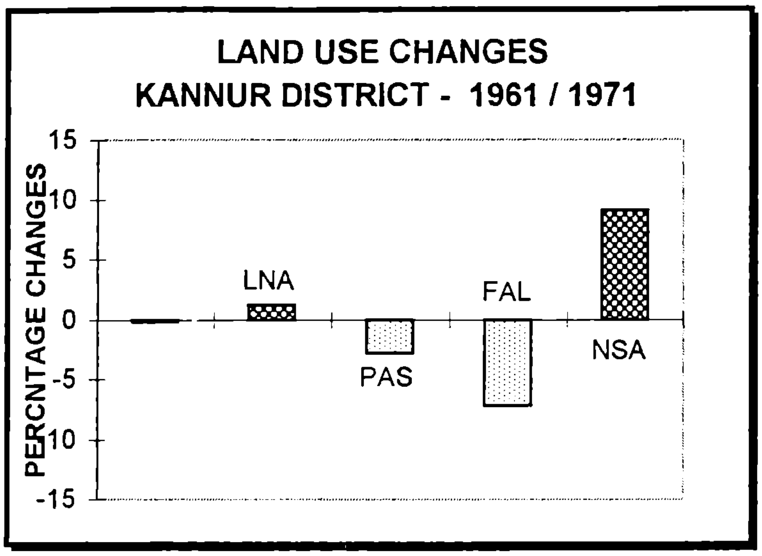
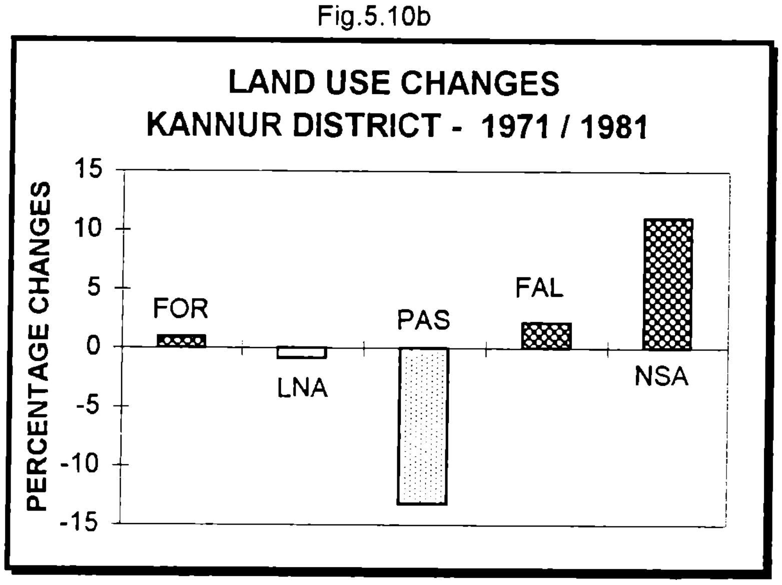


Fig.5.10b



FOR - FORESTS
LNA - LAND PUT TO NON-AGRICULTURAL USES
PAS - PASTURES
FAL - FALLOW LANDS
NSA - NET SOWN AREA

Fig.5.10c

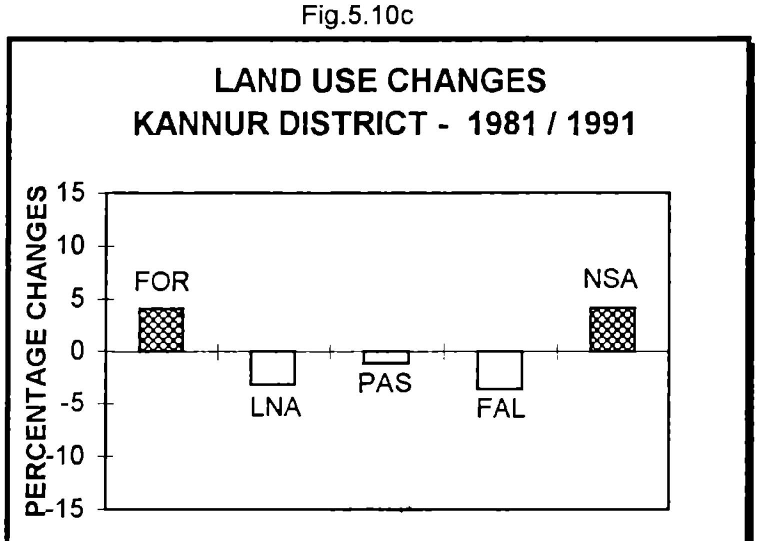


Fig. 5.10. LAND USE CHANGES - KANNUR DISTRICT

PERCENTAGE CHANGES

DISTRICTS	I DECADE 1961-1971	I I DECADE 1971-1981	I I I DECADE 1981-1991	TOTAL
Thiruvananthapuram	3.25	5.34	1.60	10.19
Kollam	3.93	5.68	17.45	27.06
Alappuzha	3.34	11.78	2.13	17.25
Kottayam	10.68	32.42	0.94	44.04
Eranakulam	10.03	9.88	1.80	21.51
Thrissur	3.73	10.91	1.27	15.91
Palakkad	17.92	21.50	1.30	40.72
Kozhikode	14.32	23.50	5.95	43.00
Kannur	10.37	14.20	8.60	33.17
STATE	**5.99**	**2.88**	**1.67**	**10.59**

Table.5.11. KERALA - OVERALL LAND USE CHANGES (%).

A very high percentage of gross overall change was recorded in Kottayam (44.04%), Kozhikode (43.8%) and Palakkad (40.72%) districts. The other districts Kollam (27.06%), Ernakulam (21.51%) and Kannur (33.17%) have moderate gross overall change.

Significantly, all the districts excepting Kollam and Ernakulam experienced maximum gross overall change during the second decade (1971-1981). Kollam experienced two thirds of the gross overall change during the third decade (1981-1991). Eranakulam district experienced more than half of the changes during the first decade (1961-1971).

CHAPTER 6

AGRICULTURAL LAND USE AND ITS SPATIO-TEMPORAL VARIATIONS IN RELATION TO CLIMATIC FLUCTUATIONS

Kerala, like many other states of the country, has an agrarian economy. Agriculture and allied sectors contribute about 37% of the State's total income and employ about 50% of the work force. Nearly 58% of the total geographical area of the State is under cultivation.

Agricultural landuse is the way in which the land is utilised for the cultivation of crops and other agricultural activities and is reflected in the cropping pattern of the region. Cropping pattern is the allocation of the total cropped area among the various crops grown by farmers. This depends on many factors such as soil types, topography, climate, cultural practices and government policies of the particular region. Changes in agricultural landuse of a region occur due to the changes in these factors. The changes in soil types and topography usually occur over a very long period of time. Hence, the other factors have more influence on the agricultural landuse changes. Among these, the climate is the most dynamic element and plays a dominant role the short-term changes of landuse.

Of the various climatic elements the two dominant controls of agriculture are temperature and rainfall. For the successful agriculture both these parameters are of utmost importance. When sufficient thermal and moisture inputs (solar radiation and precipitation) are avilable agricultural prodution would be at potential levels. In areas where one of these elements is in short supply, that element would be the critical factor in determining agricultural yields. In higher altitudes and latitudes, therefore, temperature becomes the limiting factor. Whereas in Tropical regions more than sufficient heat input is available, prcipitation avilability becomes the limiting factor. In the present study, therefore, rainfall fluctuations are related to agricultural area, production and yields, in an attempt to study their inter-relationships.

The first Section of this Chapter presents a detailed description about the cropping pattern of the State and its spatio-temporal variations. The second Section describes the influence of short-term fluctuations of rainfall on the agricultural landuse of the State.

6.1. AGRICULTURAL LANDUSE OF KERALA.

The favourable climate and topographic conditions of the State allow a wide variety of crops to be cultivated. Agriculture in Kerala is unique with respect to its homestead farming, which is practised in all parts of the State. A homestead consists of the area surrounding the house. A major feature of this system of farming is the cultivation of all varieties of crops which include coconut, arecanut, fruits and vegetables, and some livestock. "More than 80 percent of the produce generated in the homestead is consumed in the house itself and the remaining 20 percent provide subsidiary income to the house owner".(NARP,1989).

The crops cultivated in the State include cereals such as paddy, jowar and ragi, pulses, sugar crops, spices and condiments such as pepper, ginger, chilli, clove, cardamom, turmeric and arecanut. Also cultivated are fruits and vegetables like banana, pineapple, jack, mango and cashew. The major non-food crops include coconut, coffee, tea, rubber and cocoa.

It is evident from Table 6.1 that the State has experienced a shift in cropping pattern in favour of non-food crops during the three decades since 1961. Food crops accounted for 66.2%of the total cropped area of the State in 1961,which declined to 49.5% in 1990, a decrease of 17.1%. At the same time the area under non-food crops registered a corresponding increase (17.1%).

YEAR	FOOD CROPS	CHANGE	NON-FOOD CROPS	CHANGE	TOTAL CROPPED AREA	CHANGE
1961	1565 (66.2)		784 (33.8)		2349	
		+28.7		-4.41		+94.39
1991	1496 (49.5)		1529 (50.5)		3020	

AREA IN '000 HECTARES. FIGURES IN PARENTHESIS SHOW PERCENTAGE AREA

Table 6.1.SHIFT IN CROPPING PATTERN IN KERALA

When considering the absolute area it is obvious that there is a phenomenal 94.4% increase in the area under non-food crops and only a marginal decrease of 4.41% under food crops. The increase of total cropped area during this period was 28.6%. This shows that Kerala is one among the few States where farmers respond quickly to price incentives as new crops can be planted to take advantage of the changing prices.

6.1.1. CROP COMBINATIONS

"The geographical investigation of agriculture which purports to select various crops or agricultural elements to be studied collectively in an area, may be termed as combination analysis or combinational analysis". (Singh and Dhillon, 1994). The crop combination of a region reflects its agro-ecological conditions. Many studies have been done in Kerala using different techniques of combination analysis. Weaver's methodology was used by the Centre for Earth Science Studies in its 'Resource Atlas of Kerala'.(1984). It gives various combinations in different districts which range from five to ten crops. Saravanan(1994) used both Weaver's and Doi's methods to evaluate the crop combination of the State.

In this study, the technique developed by Coppock(1964) has been used for the analysis of crop combination. The detailed methodology and the advantage of this technique over others is described in Chapter 2. The derived combination vary from two crops in Alappuzha, Thrissur and Kozhikode districts to five crops in Idukki district. (Fig.6.1). Coconut forms the first ranking crop in nine districts, while rice is the first ranking crop only in Palakkad district. Idukki has pepper as the first ranking crop, followed by rubber, cardamom, tea and coffee. This indicates that the district has predominantly plantation crops. Another noticeable combination is in the Palakkad district where groundnut forms one of the major crops, which occupies the fourth position.

In the northern districts of Kannur and Kasargod, cashew forms a predominant crop occupying the second position. Malappuram district also has cashew, as the fourth ranking crop.

A significant proportion of coffee is grown in Wayanad district where it is the first ranking crop. Tapioca appears in the combination only in the southern districts of Pathanamthitta, Kollam and Thiruvananthapuram.

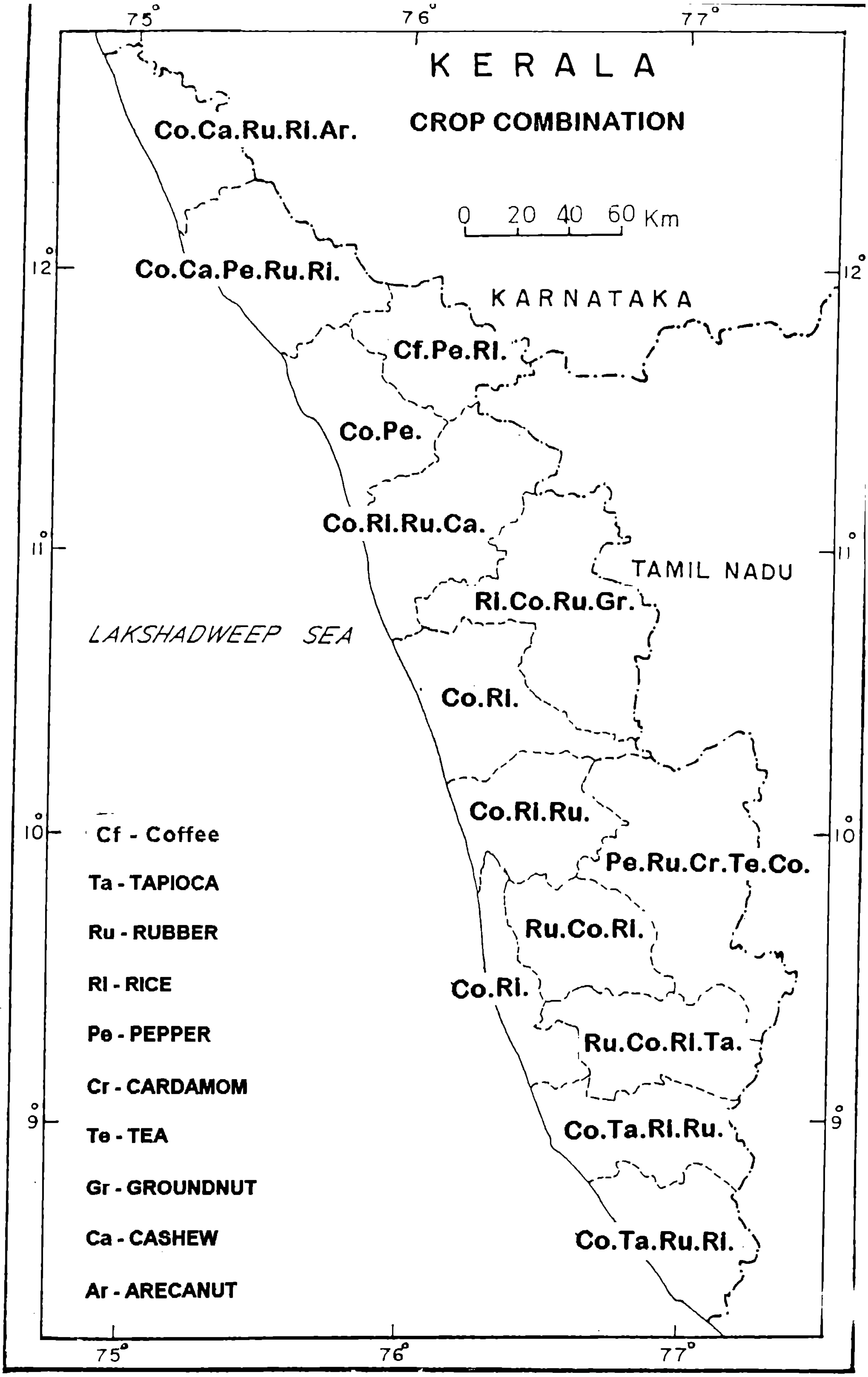


Fig. 6.1. KERALA - CROP COMBINATION

6.1.2. REGIONAL CONCENTRATION AND SPATIO-TEMPORAL VARIATIONS OF MAJOR CROPS

Four major crops have been selected in this study.viz., paddy, tapioca, coconut and rubber. Even though a variety of crops are cultivated in different parts of the State, these four major crops together occupy more than 75% of the total cropped area in most of the districts.

6.1.2a. PADDY *(Oryza sativa).*

Paddy is cultivated in Kerala under a wide variety of agro-ecological conditions such as in water logged areas, high altitude areas and coastal saline tracts. Paddy requires a mean temperature of 16^0 C to 20^0 C during the flowering stage and 18^0 C to 32^0 C during the ripening stage. In Kerala, paddy is cultivated mainly during the following three seasons.

1.Virippu - Autumn (first) crop.
April / May to September / October
2.Mundakan - Winter (second) crop.
September / October to December / January
3.Punja - Summer (third) crop.
December / January to March / April.

The Kerala Agricultural University has developed varieties of location and season specific, both ordinary and high yielding, paddy for different parts of the State.

The highest concentration of paddy is found in Alappuzha and Thrissur districts. In Alappuzha paddy occupies 34.9% of the total cropped area and in Thrissur it account for 34.5%. This is followed by Ernakulam and Palakkad districts where paddy occupies 25.6% and 27.3% respectively (Fig.6.2).

Inspite of the fact that rice is the staple food of people of Kerala, paddy shows drastic reduction in area in the State. From 752690 hectares in 1961 it reduced to 541327 hectares in 1991, a decrease of 28%. Individual districts also follow the same trend. Table 6.2 shows the changes of area, production and yield of paddy in Kerala.

Excepting Ernakulam district, which registered a 4.6% increase in area, all other districts had a phenomenal decrease in area under paddy. The highest decrease was in Kozhikode district (78.4%), and the lowest was in Alappuzha (1.8%).

Corresponding to the decrease in area, paddy production also decreased in many districts. Here again Kozhikode district registered about 80% decrease in production. Alappuzha, Kottayam, Ernakulam and Thrissur districts marked an increase in paddy production during the period 1961-1991.

Inspite of reduction in area and production, paddy yields show increase in all the districts, except Kollam and Kozhikode. In these two districts the yield declined by 40.1% and 44.5% respectively. The increase in yield is result of the use of high yielding varieties of paddy and better management practices.

At this juncture it is necessary to caution that with the increasing population, increase in yield alone is not sufficient to meet the ever increasing demand. "The current level of production in the State meets only 42 per cent of the domestic requirements. It is estimated that by the turn of the century, the population of the State would grow to 33 million and would need 3.90 million tonnes of rice, which is three times the current

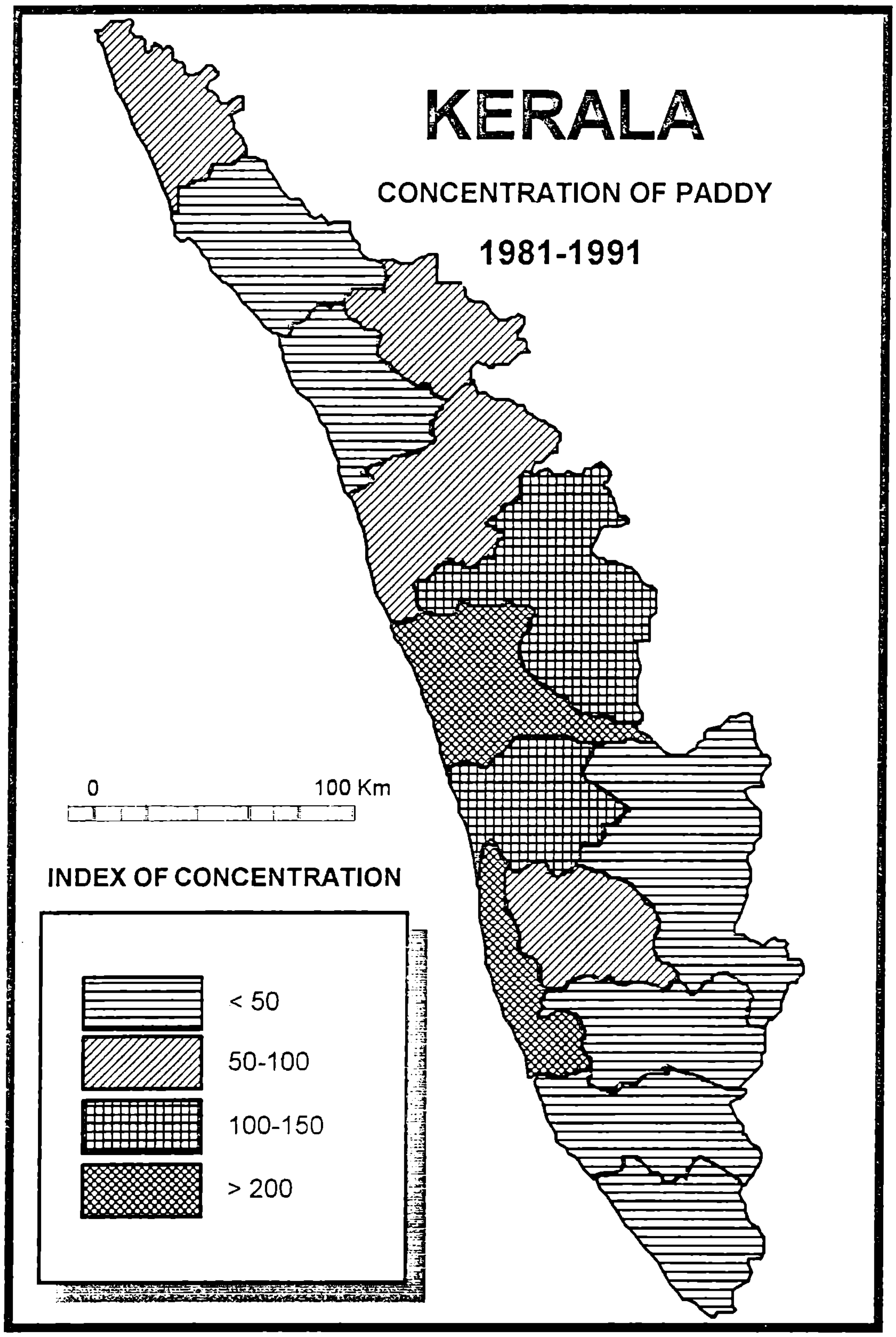


Fig. 6.2. KERALA - CONCENTRATION OF PADDY

DISTRICTS	AREA			PRODUCTION			YIELD		
	1961-71	1981-91	CHANGE	1961-71	1981-91	CHANGE	1961-71	1981-91	CHANGE
Thiruvananthapuram	38661	26435	-31.6	55145	42023	-23.8	1427	1606	12.5
Kollam	49364	38426	-22.2	14839	64256	-54.7	2805	1679	-40.1
Alappuzha	81840	80367	-1.8	116521	136380	17.8	1424	1927	35.3
Kottayam	42215	32176	-23.8	59016	66745	13.1	1391	1734	24.7
Idukki	12797	7484	-41.5	20999	14874	-29.2	1331	2011	51.08
	(1971-81)								
Ernakulam	84553	88473	4.6	106640	124168	16.4	1262	1405	11.3
Thrissur	107423	96161	-10.5	135668	142865	5.31	1261	1499	18.5
Palakkad	197679	162145	-17.9	331922	328074	-1.2	1677	2029	23.9
Malppuram	89290	67709	-24.2	124471	93475	-24.9	1392	1392	0
	(1971-81)								
Kozhikode	103132	22312	-78.4	121883	24668	-79.8	1985	1102	-44.5
Kannur	94007	42417	-55.2	113612	57955	-48.9	1207	1418	17.5
STATE	752690	541327	-28.1	1003930	1060350	5.6	1334	1959	46.9

Table.5.2

CHANGES IN AREA, PRODUCTION AND YIELD OF PADDY IN KERALA

AREA IN HECTARES : PRODUCTION IN TONNES : YIELD IN Kg. / Hect.
CHANGES IN PERCENTAGE

internal production".(NARP,1989). Hence efforts should be made to increase the production substantially.

6.1.2b.TAPIOCA *(Manihot esculenta).*

Tapioca is known as the poor man's staple food. It is also an essential raw material for a number of industries. The area under tapioca in the State declined from 236670 hectares in 1961 to 140881 hectares in 1991, a decrease of 40.1%. Production of tapioca increased from 1644600 tonnes in 1961-1971 to 2657865 tonnes in 1981-1991, an increase of 61.5%. Table 6.3 shows area, production and yield of tapioca in different districts of the State.

Tapioca is mainly concentrated in the southern districts. High concentrations are found in Thiruvananthapuram and Kollam districts, where it accounts for 24.2% and 17.1% of total cropped area respectively. A secondary concentration is found in Pathanamthitta and Kottayam districts. (Fig.6.3).

The three districts which registered increases in area under tapioca are, Kannur, Palakkad and Idukki, where the increase was 73.5%, 41%, and 11.6% respectively. In all other districts, the area under tapioca declined. Kozhikode district had a substantial decline of 76.2% during this period.

Tapioca production declined in Kollam, Alappuzha, Malppuram, and Kozhikode districts too. An appreciable increase of 189.8% in Kannur and 102..8% in Palakkad districts in seen during this period. All the districts show increase in the yield.

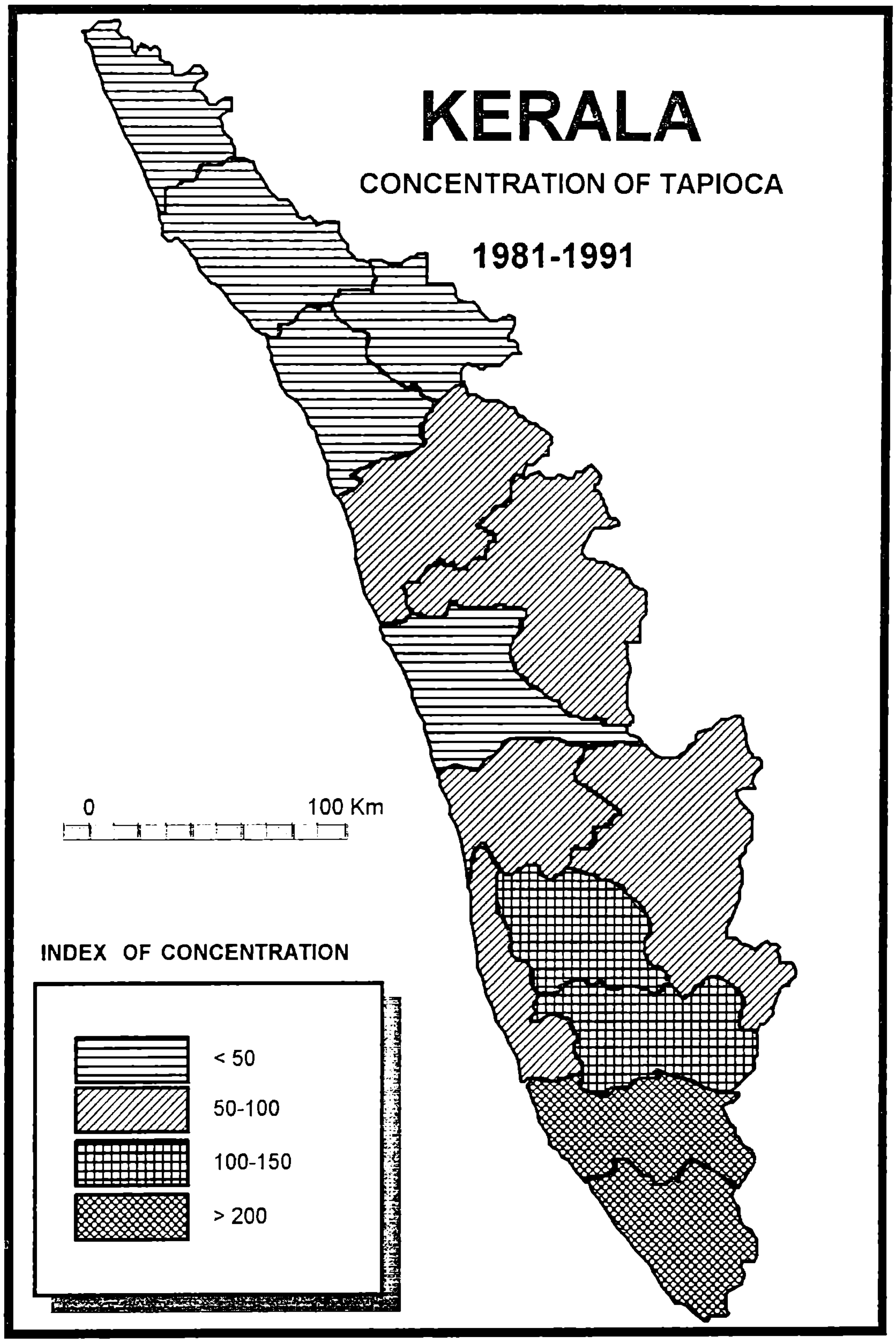


Fig. 6.3. KERALA - CONCENTRATION OF TAPIOCA

DISTRICTS	AREA			PRODUCTION			YIELD		
	1961-71	1981-91	CHANGE	1961-71	1981-91	CHANGE	1961-71	1981-91	CHANGE
Thiruvananthapuram	57809	49889	-13.7	668028	808150	20.9	11486	16259	41.5
Kollam	69335	42884	-38.1	845515	686868	-18.7	11534	16154	40.1
Alappuzha	25416	19667	-22.6	295321	286372	-3	11926	15348	28.7
Kottayam	37056	30413	-17.9	571872	559137	-1.3	14385	18484	28.5
Idukki	7412	8270	11.6	153201	173236	13.1	21199	21396	0.9
	(1971-81)								
Ernakulam	15476	13115	-15.3	163907	205711	23.7	10578	16050	51.7
Thrissur	6658	5337	-19.8	94124	140854	102.8	9823	15987	62.1
Palakkad	8507	11996	41	94124	190854	102.8	9823	15987	62.7
Malappuram	24186	15622	-35.4	337369	226540	-32.9	14078	14770	4.9
	(1971-81)								
Kozhikode	17185	4087	-76.2	186375	51079	-72.6	10715	12413	15.8
Kannur	7353	12759	73.5	73934	214241	189.8	10135	17310	70.8
STATE	236670	141881	-40.1	164460	2657865	61.6	6949	18733	169.6

Table.6.3

CHANGES IN AREA, PRODUCTION AND YIELD OF TAPIOCA IN KERALA

AREA IN HECTARES : PRODUCTION IN TONNES : YIELD IN Kg. / Hect.

CHANGES IN PERCENTAGE

6.1.2c.COCONUT. *(Cocos nucifera)*

Coconut is extensively grown through out the State. It is grown mainly in homesteads and small farms. There are about 2.5 million coconut holdings in Kerala, with about 170 million palms and with an average palm density of 229 palms per hectare. Coconut requires a mean annual temperature of 27^0C. Prolonged spells of extensive variation in temperature is harmful to the plant. It requires 1300-2300 mm. of annual rainfall. In Kerala it is grown in a wide variety of soil types such as laterite, sandy loam, alluvium and reclaimed marshy lands. In 1961, the State had 504820 hectares of coconut land, which increased to 863061 hectares in 1991, a phenomenal 70.9% increase. Table 6.4 shows the district wise details of changes of area, production and yield of coconut.

Coconut displays a widespread distribution rather than a localised concentration like other crops.(Fig.6.4). Highest concentration is found in Kozhikode district, where it has 24.8% of total cropped area under this crop. A major noticeable feature of coconut is the concentration in the coastal districts.

A reduction in area is noticed in Alappuzha, Kottayam, Idukki and Kozhikode districts. Thrissur registered 61.5% increase in area. The mean production of coconut declined in most of the districts. Here again only Thrissur district shows a noticeable increase in production (57.2%). Another conspicuous feature is the decline of yield in all the districts.

6.1.2d. RUBBER (*Hevea brasiliensis*)

Rubber is grown in Kerala under a wide variety of topographical conditions, from sea level to 500 m.of altitude. It needs about 2000 mm.of annual rainfall, well distributed through

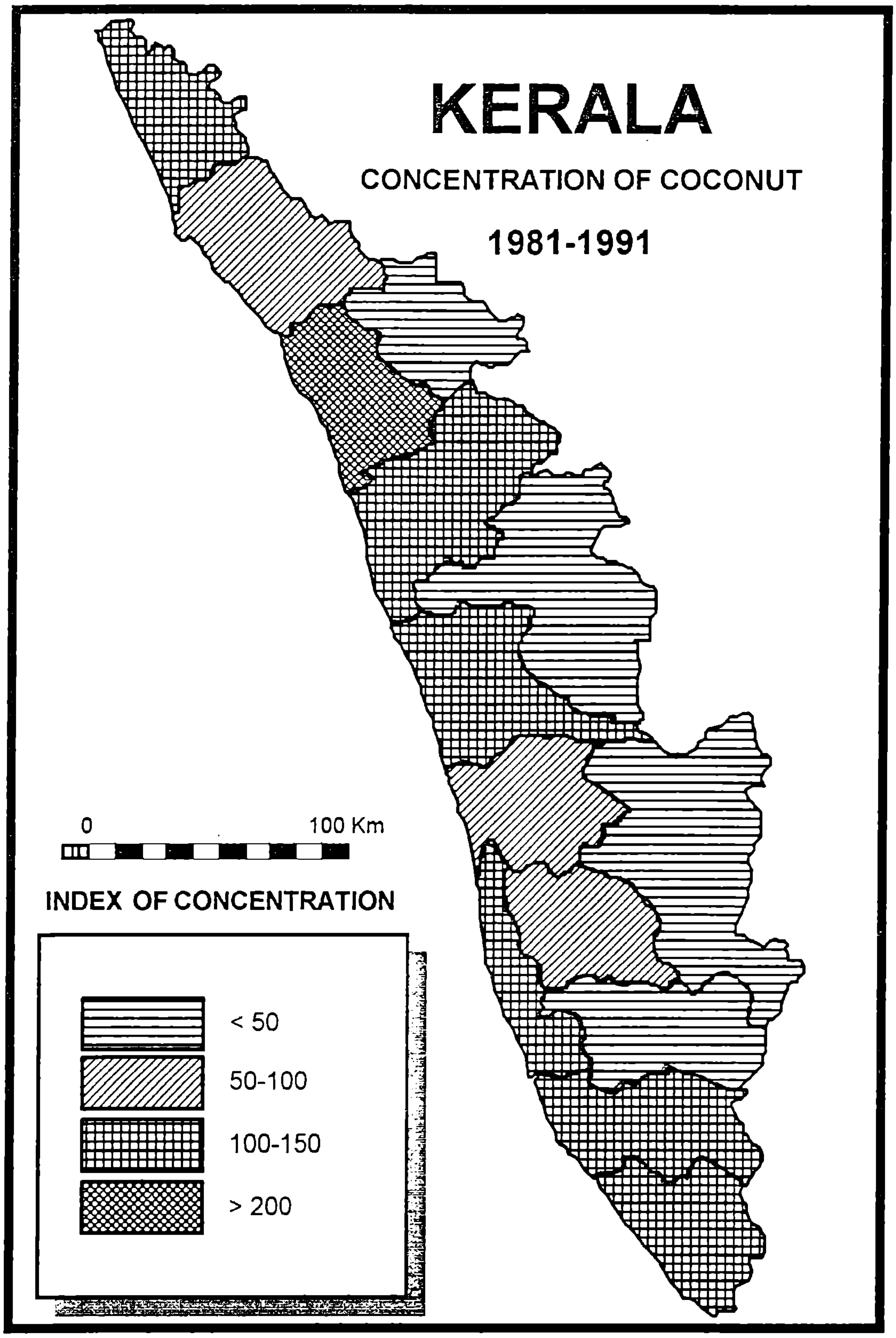


Fig. 6.4. KERALA - CONCENTRATION OF COCONUT

DISTRICTS	AREA			PRODUCTION			YIELD		
	1961-71	1981-91	CHANGE	1961-71	1981-91	CHANGE	1961-71	1981-91	CHANGE
Thiruvananthapura	61609	77314	25.5	388	3920	1	6277	5042	-19.7
Kollam	75225	76948	23	443	299	-32.5	5910	3876	-34.4
Alappuzha	75805	67782	-10.6	498	399	-19.9	6563	5828	-11.2
Kottayam	67968	59832	-12	362	281	-22.4	5395	4629	-14.2
Idukki	18720	17749	-5.2	74	62	-16.2	3786	3363	-11.2
	(1971-81)								
Ernakulam	52467	57413	9.6	315	325	3.2	6032	5677	-5.9
Thrissur	39871	64295	61.3	250	383	57.2	6277	6035	-3.8
Palakkad	24329	26487	8.9	115	85	-26.1	4925	3229	-34.9
Malappuram	66591	67314	1.1	311	282	-9.3	4689	4156	-11.4
	(1971-81)								
Kozhikode	117679	106764	-9.3	743	580	-21.9	6331	5434	-14.2
Kannur	71349	75268	5.5	330	288	-12.7	4824	3854	-20.1
STATE	587723	719733	22.5	3444	3438	-0.07	5888	4760	-19.2

Table.6.4

CHANGES IN AREA PRODUCTION AND YIELD OF COCONUT IN KERALA

AREA IN HECTARES : PRODUCTION IN MILLION NUTS : YIELD IN NUMBERS / Hect.

CHANGES IN PERCENTEGE

out the year. Rubber plants require a mean temperature of 21^0C to 35^0C.

Rubber registered a marked increase in area in the State. From 133080 hectare in 1961, it increased to 425768 hectare in 1991- an outstanding increase of 220%. Production of rubber also show an incredible increase- it went up from 24890 tonnes in 1961 to 263109 tonnes in 1991. Various districts within the State also show the pattern of growth. (Table.6.5.).

Kottayam district has the highest concentration of rubber (Fig.6.5), where it accounts for 34.4% of total cropped area. A secondary concentration is found in Kollam, Pathanamthitta and Idukki districts.

A substantial increase in area is noticed in Thiruvananthapuram and Palakkad districts, while in Kozhikode district it declined by 14.4%. The increase in production of rubber was exceptional in Thiruvananthapuram and Kannur districts. These two districts registered an incredible increase of 515.9% and 474.4% respectively. Corresponding to this the yield also increased considerably in all the districts, except in Idukki where it suffered a marginal decline.

6.1.3. SPATIO-TEMPORAL VARIATIONS OF CROP PRODUCTIVITY

The varying topographic, edaphic and climatic conditions of the State result in the spatial variation of crop productivity. Temporal variations of agricultural productivity occur because of changes in any of the above mentioned factors and also because of changes in socio-economic conditions of the region, technological advancements and changes in government policies.

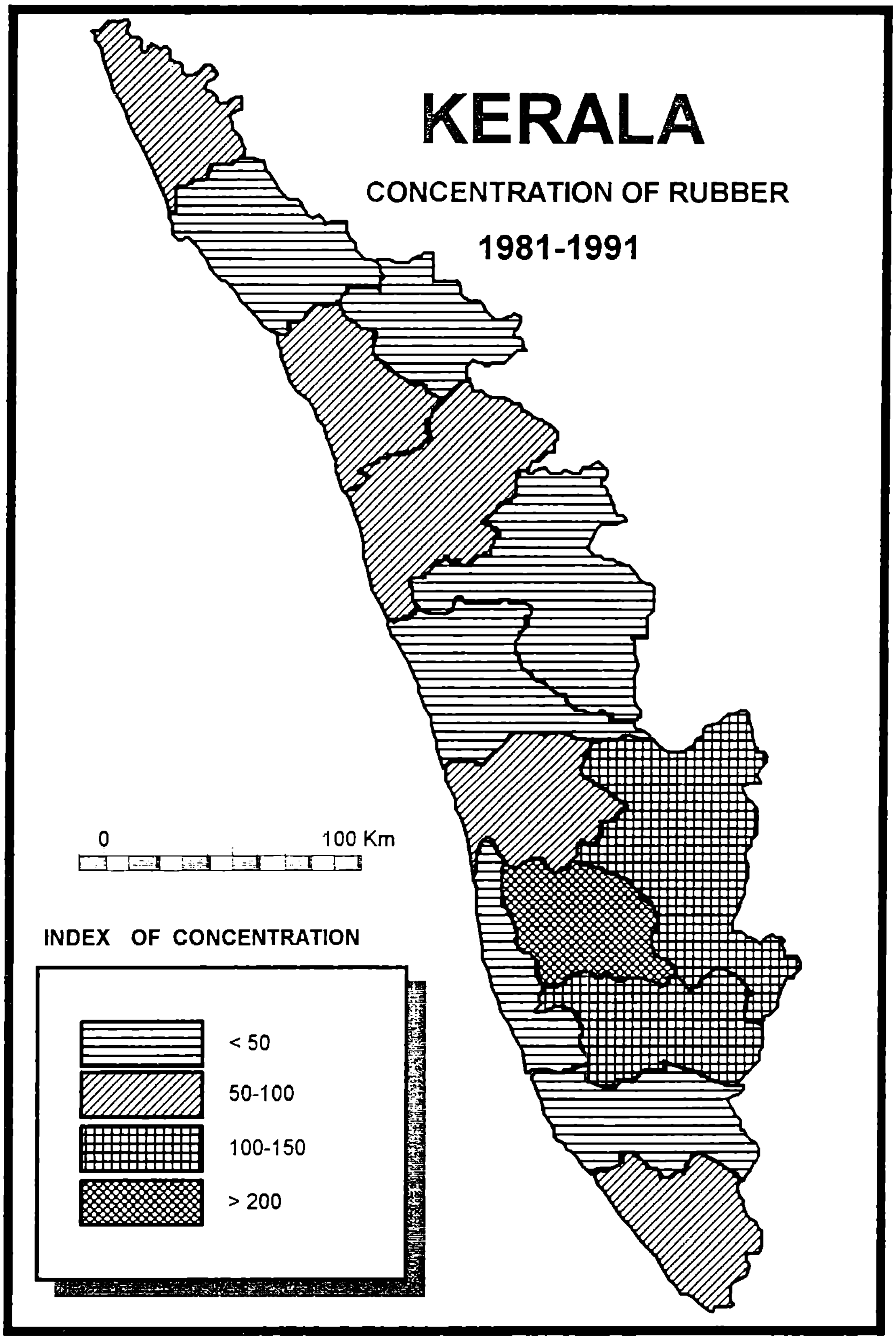


Fig. 6.5. KERALA - CONCENTRATION OF RUBBER

DISTRICTS		AREA			PRODUCTION			YIELD	
	1961-71	1981-91	CHANGE	1961-71	1981-91	CHANGE	1961-71	1981-91	CHANGE
Thiruvananthapura	5030	13918	176.7	1372	8450	515.9	255	609	138.8
Kollam	25721	35022	36.2	9203	21355	132	350	611	74.6
Alappuzha	2756	3533	30.1	552	1529	177	185	513	177.3
Kottayam	46662	60955	30.6	14688	31758	116.2	312	502	60.9
Idukki	15674	21484	37.1	9835	12570	27.8	627	598	-4.6
	(1971-81)								
Ernakulam	21154	22733	7.5	5064	14686	190	229	688	200.4
Thrissur	7442	9519	27.9	3656	6938	89.8	486	744	53.1
Palakkad	6923	14890	115.2	1852	7482	30.4	253	492	94.5
Malappuram	16349	18331	12.1	8746	11677	33.5	531	636	19.8
	(1971-81)								
Kozhikode	195626	167385	14.4	7019	9999	42.5	349	583	67
Kannur	12864	20853	62.1	2017	11586	474.4	150	508	238.7
STATE	133080	425768	219.9	24980	263109	953.3	188	618	228.7

Table.6.5

CHANGES IN AREA, PRODUCTION AND YIELD OF RUBBER IN KERALA

AREA IN HECTARES : PRODUCTION IN TONNES : YIELD IN Kg. / Hect.

CHANGES IN PERCENTAGE

The technique propounded by Singh and Dhillon(1994) is used in this study to evaluate the spatio-temporal variations of the selected crops. Since this technique takes into account both the yield index and concentration index, it gives a better picture of the levels of productivity.

6.1.3a. PADDY.

The State's average crop yield and concentration indices ranking coefficient of paddy was 5.8 in 1961-1971. Alappuzha and Kozhikode districts had high productivity levels (Fig.6.6). A low level of productivity prevailed in Idukki and Kannur districts.

A considerable change in the levels of productivity of paddy can be noticed during 1981-1991 period (Fig.6.7). It changed from medium level to high level in Kottayam, Ernakulam and Thrissur districts, while in Kozhikode it dropped down to low level from the high position it had in 1961-1971. This decline in Kozhikode is mainly due to the drastic reduction of paddy area and corresponding decline in production during the period.

6.1.3b. TAPIOCA.

In consequence to the concentration of tapioca in the southern districts, they had a high level of productivity In 1961-1971. (Fig.6.8).The productivity of Idukki increased resulting in the shift from low level to high.(Fig.6.9.). Another conspicuous feature is a drop in productivity levels of Malappuram and Kozhikode districts.

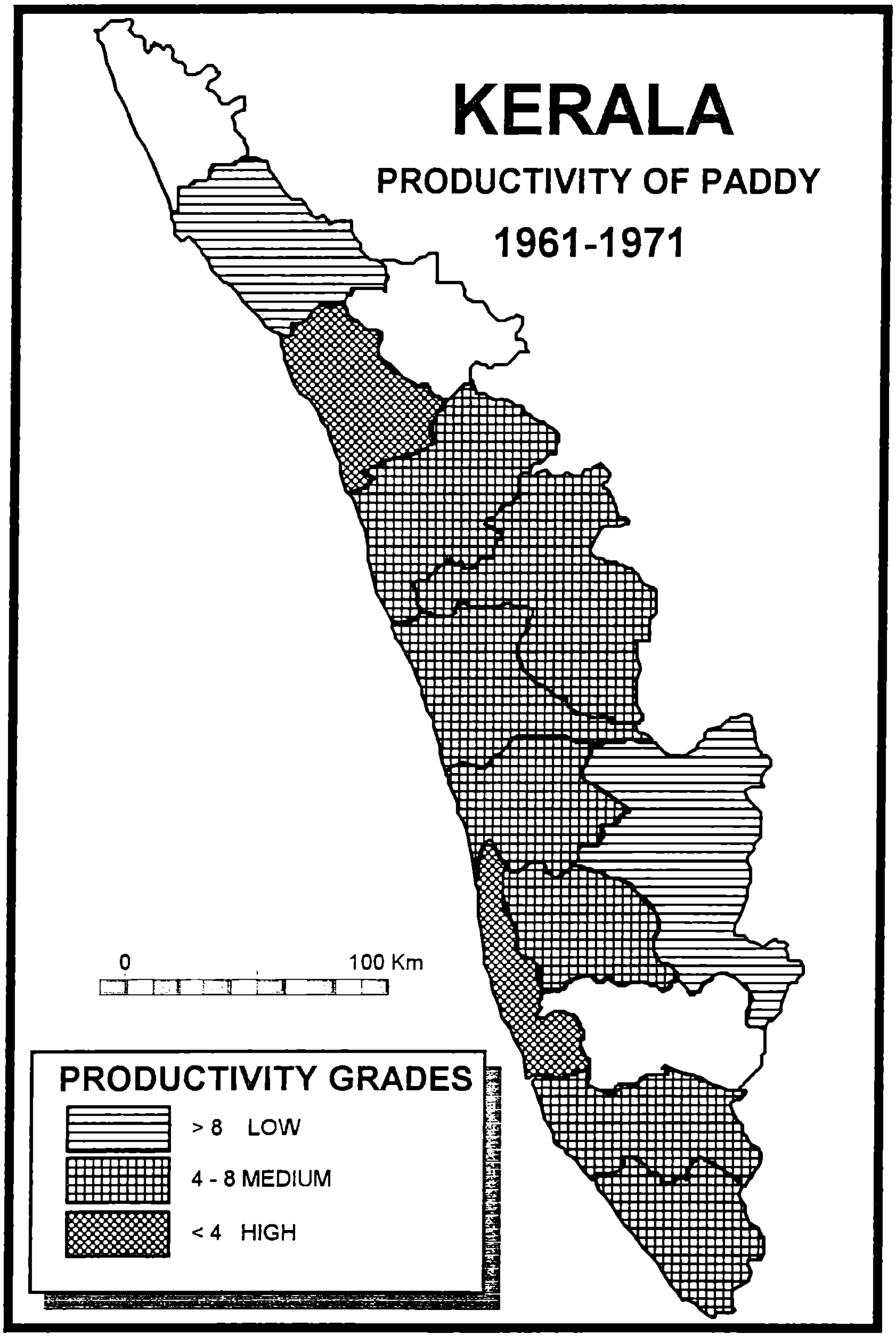


Fig. 6.6. KERALA - PRODUCTIVITY OF PADDY : 1961-1971

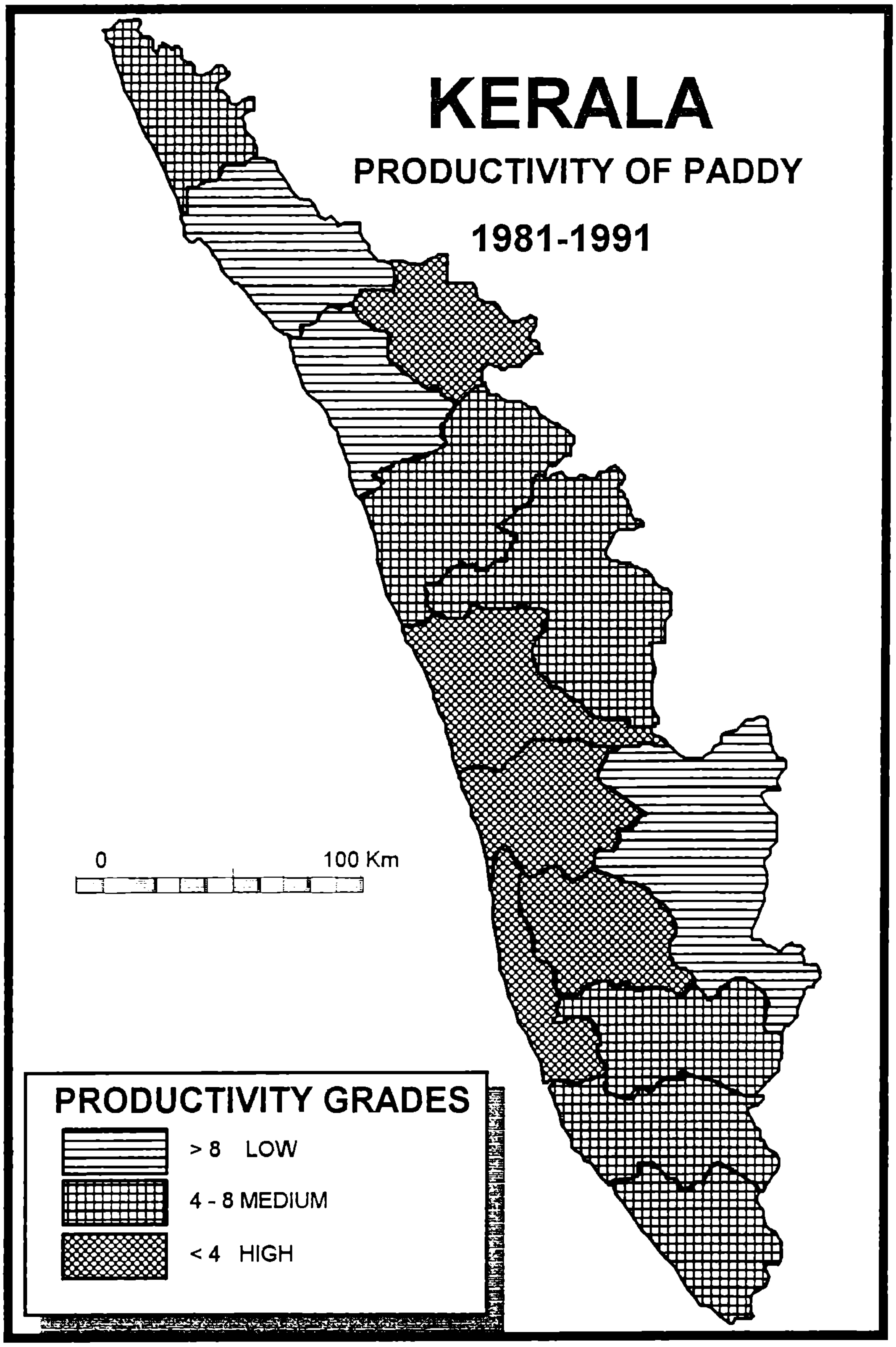


Fig. 6.7. KERALA - PRODUCTIVITY OF PADDY : 1981-1991

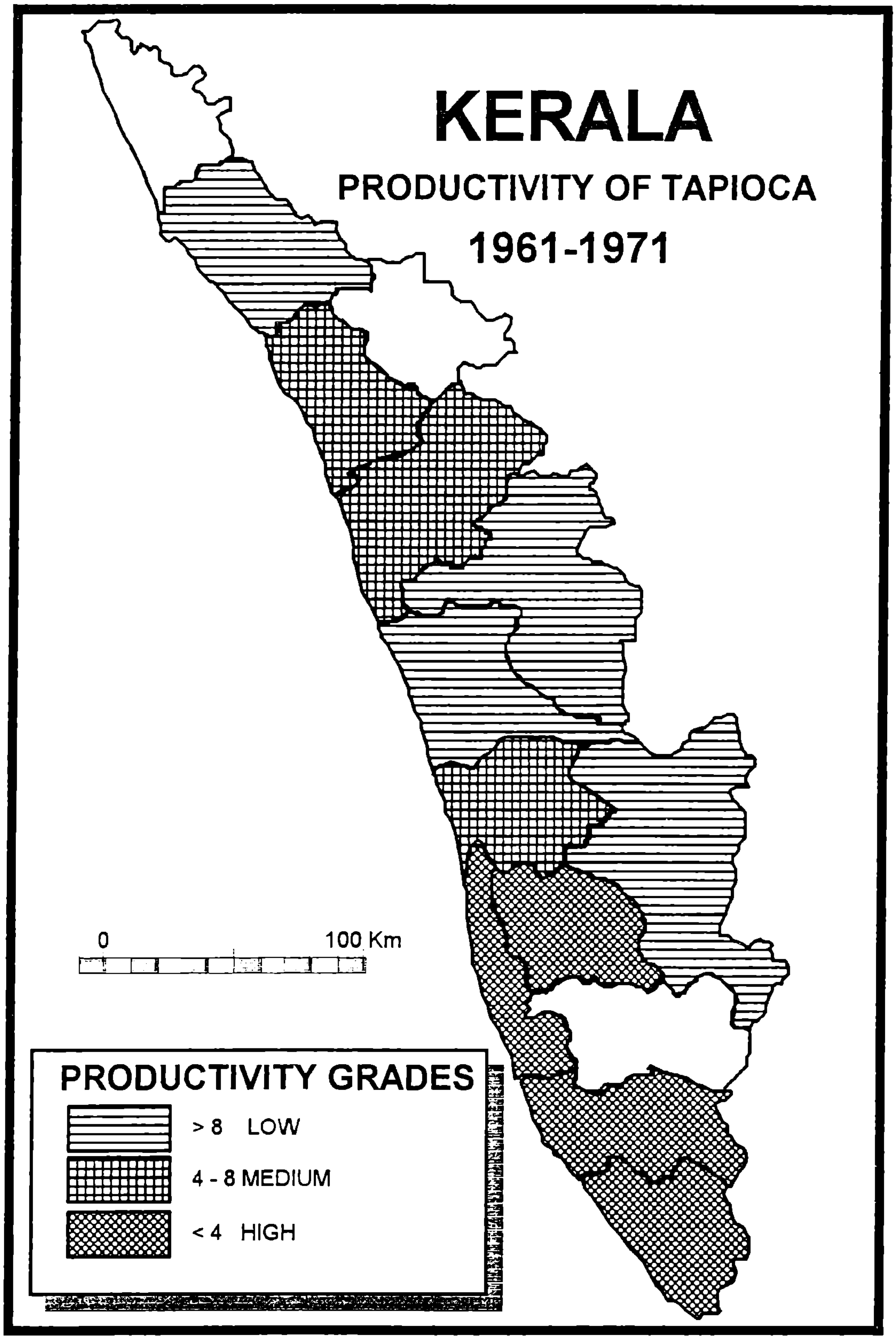


Fig. 6.8. KERALA - PRODUCTIVITY OF TAPIOCA : 1961-1971

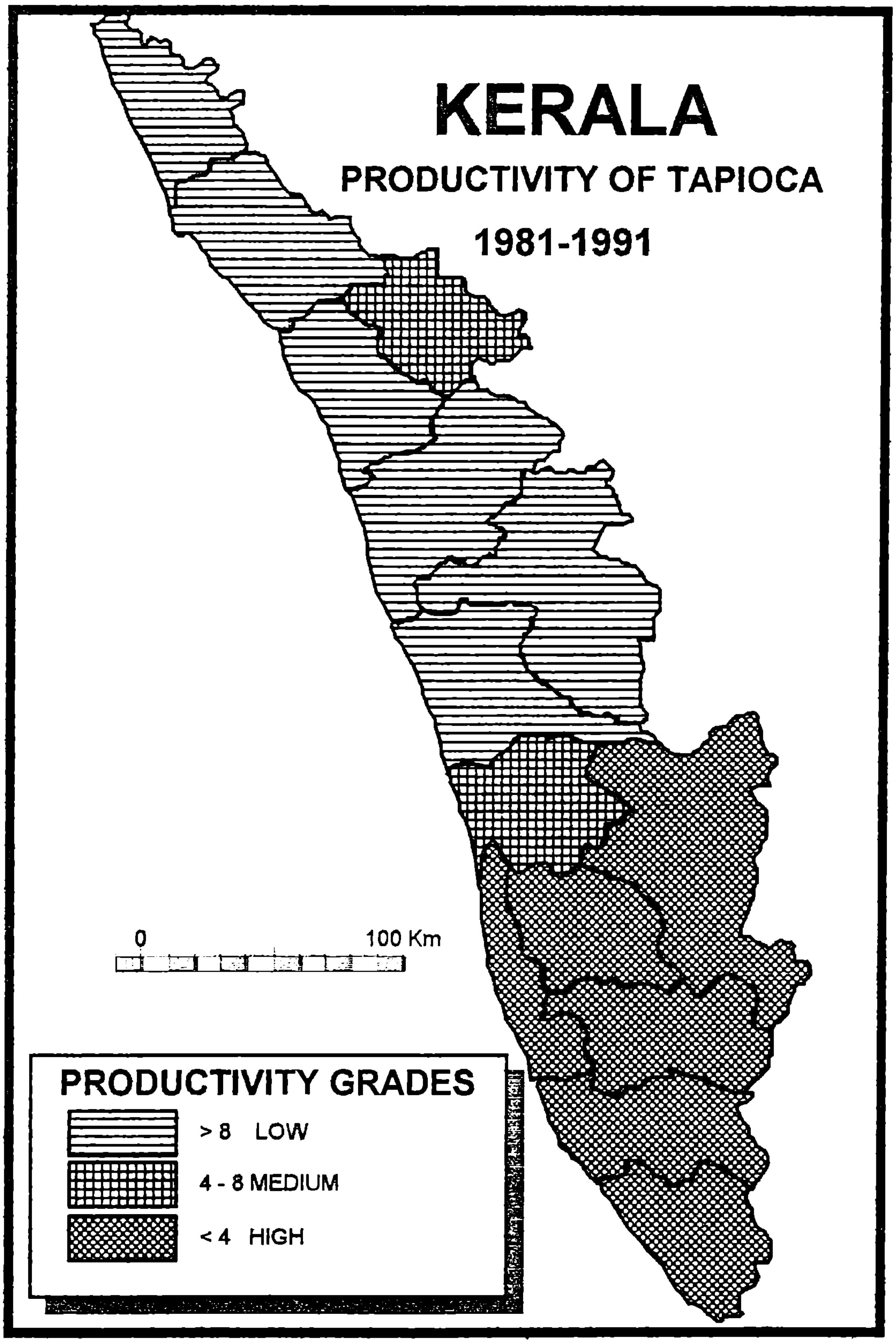


Fig. 6.9. KERALA - PRODUCTIVITY OF TAPIOCA : 1981-1991

6.1.3c. COCONUT.

Thiruvananthapuram, Alappuzha and Kozhikode districts had high level productivity during the period 1961-1971.(Fig.6.10). These districts remained in the high productivity gategory in 1981-1991 period also. Major changes noticed are the decline in Kottayam and increase in Thrissur.(Fig.6.11).

6.1.3d RUBBER.

The productivity of rubber follows the regional concentration of the crop. Kottayam district had the highest level of productivity during 1961-1971. (Fig.6.12), which continued in 1981-1991 also. (Fig.6.13). Palakkad district registered an increase in productivity, while Thiruvananthapuram, Kollam and Malappuram districts had a decline.

6.1.4. SPATIAL VARIATION OF AGRICULTURAL EFFICIENCY.

Agricultural efficiency of a region depends on the inputs such as the number and types of crops cultivated, their areal extent, climatic and edaphic conditions agricultural practices, and the output in the form of yield per hectare of various crops. The average yield of the crops reflect all these parameters, and hence is taken as the best index of agricultural efficiency. In some cases the areal extent of the crops often influence the yield. Hence an index which takes into account both the per hectare yield and the areal extent of crops, is a most useful tool for assessing the agricultural efficiency.

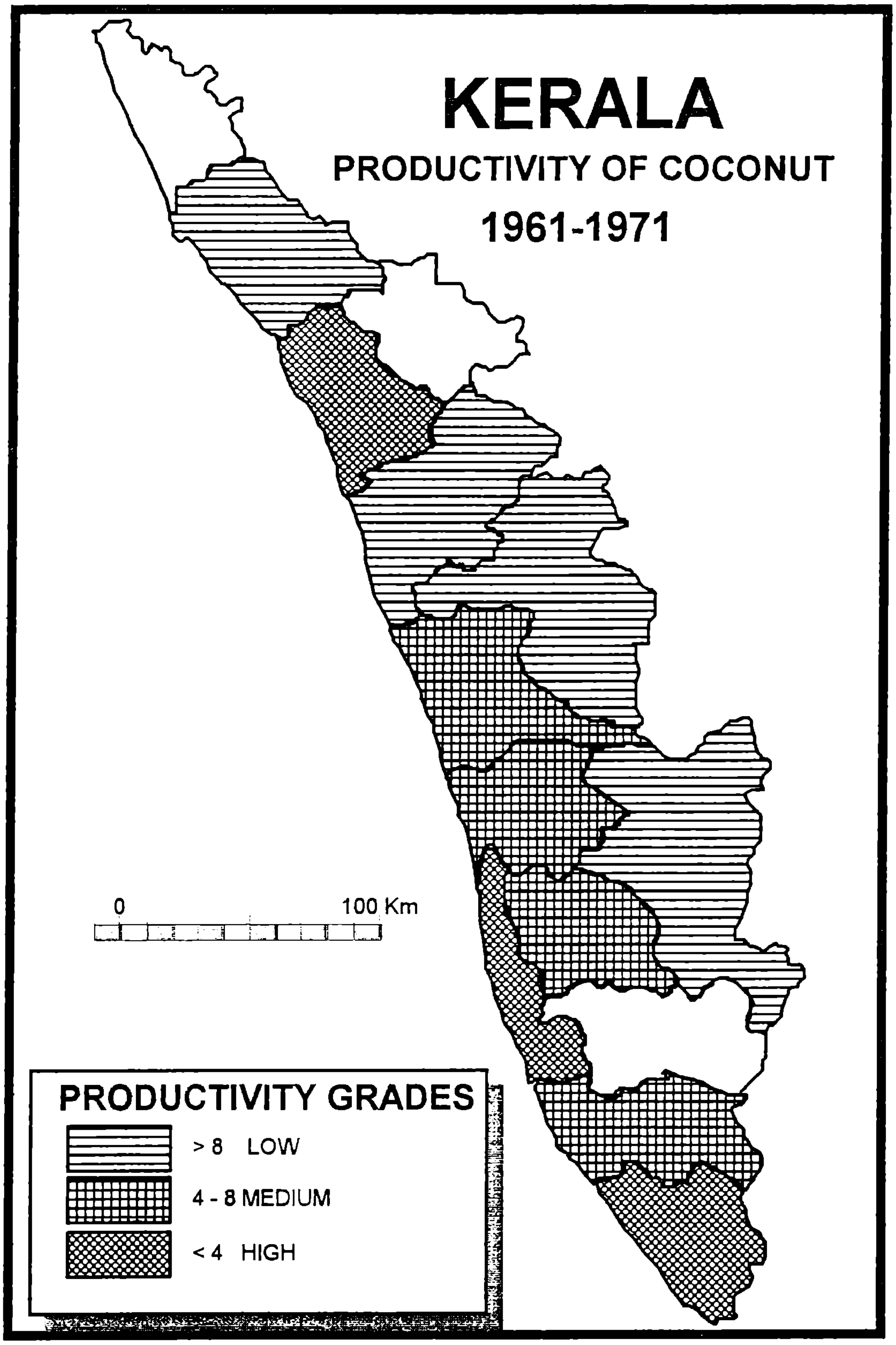


Fig. 6.10. KERALA - PRODUCTIVITY OF COCONUT : 1961-1971

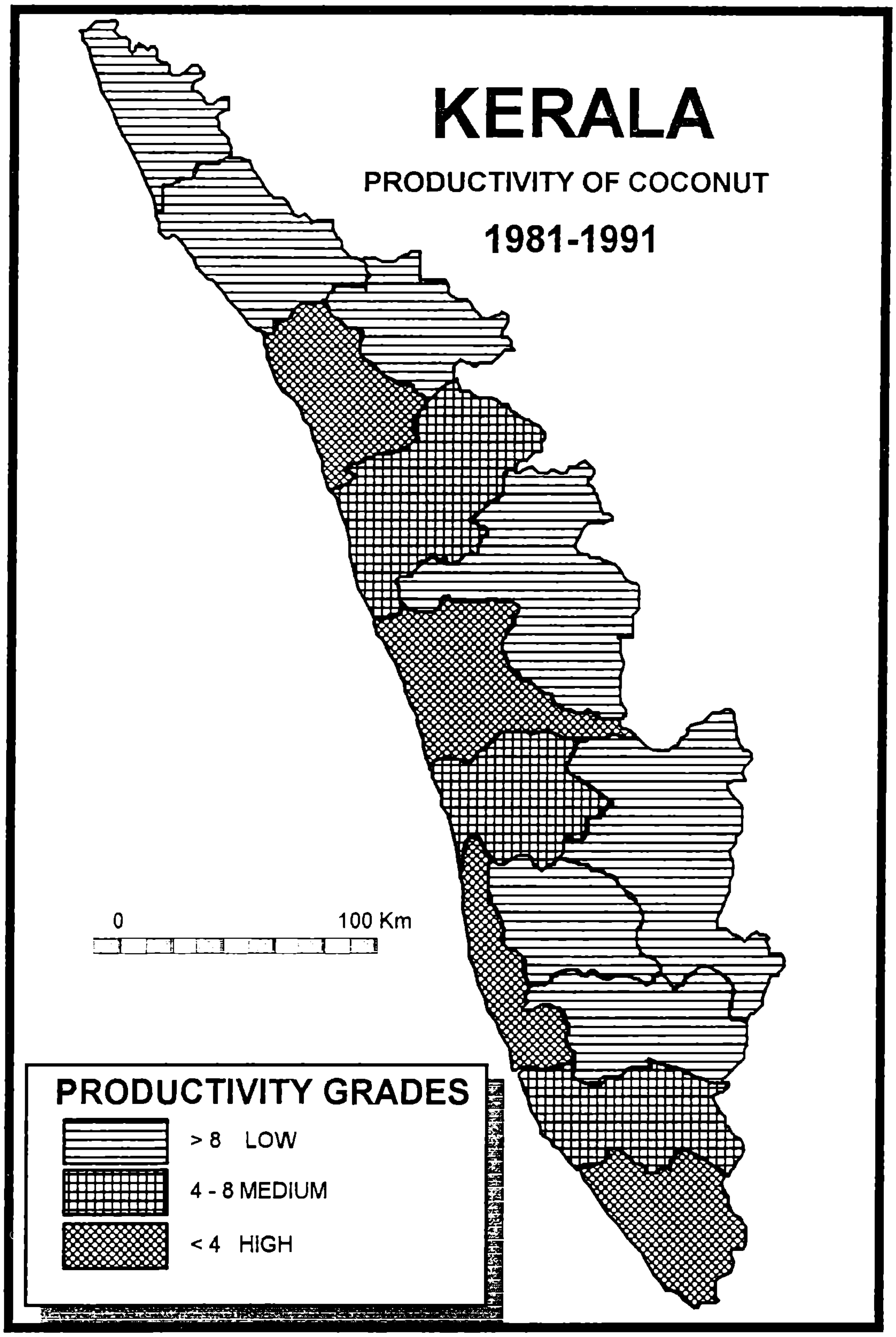


Fig. 6.11. KERALA - PRODUCTIVITY OF COCONUT : 1981-1991

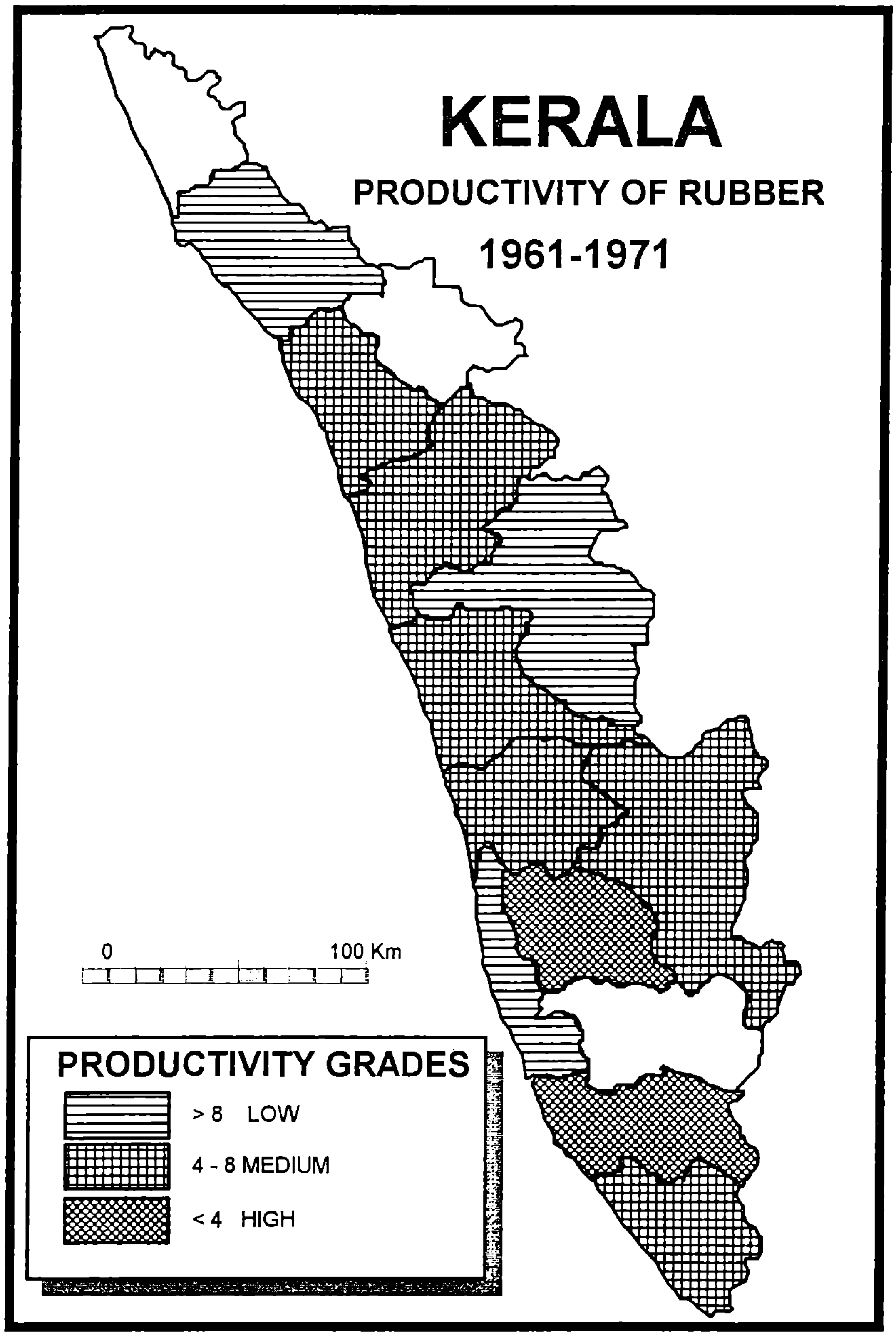


Fig. 6.12. KERALA - PRODUCTIVITY OF RUBBER : 1961-1971

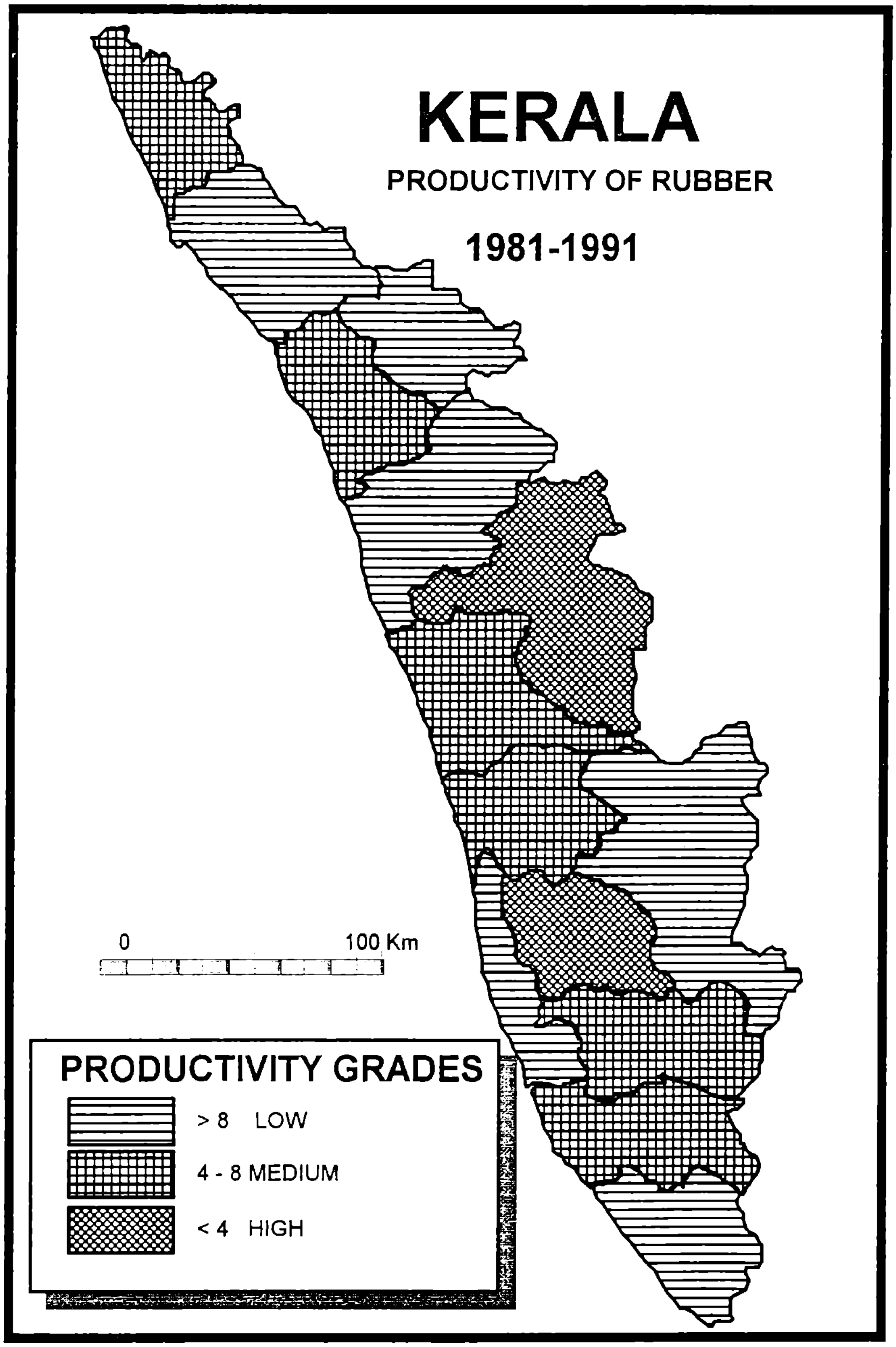


Fig. 6.13. KERALA - PRODUCTIVITY OF RUBBER : 1981-1991

In this study the Weighted Composite Index of regional inequality in Agricultural efficiency proposed by Singh et.al.(1994), is followed.

The Weighted Composite level of Agricultural Efficiency (V_W) values range from 83 in Palakkad to 584 in Idukki. Table 6.6 gives the district wise V_W values.

In order to identify the spatial characteristics of agricultural efficiency the V_W values are plotted on a map.(Fig.6.14). It is possible to identify five regions of different levels of efficiency. Out of the 14 districts in the State, 5 districts have very high and high efficiency levels. Six districts have low to very low levels and the remaining three districts have medium level. This clearly indicates that those districts where the number of crops are more, with almost equal share of crop lands, the efficiency is high. This invariably is found in the hilly districts of the State, where the efficiency level is remarkably very high.

DISTRICTS	V_W(%)
1. THIRUVANANTHAPURAM	130
2. KOLLAM	132
3. PATHANAMTHITTA	210
4. APPUZHA	92
5. KOTTAYAM	122
6. IDUKKI	584
7. ERNAKULAM	109
8. THRISSUR	87
9. PALAKKAD	83
10. MALAPPURAM	87
11. KOZHIKODE	97
12. WAYANAD	265
13. KANNUR	175
14. KASARGOD	164

Table.6.6. WEIGHTED COMPOSITE LEVEL OF AGRICULTURAL EFFICIENCY IN KERALA 1981-1991

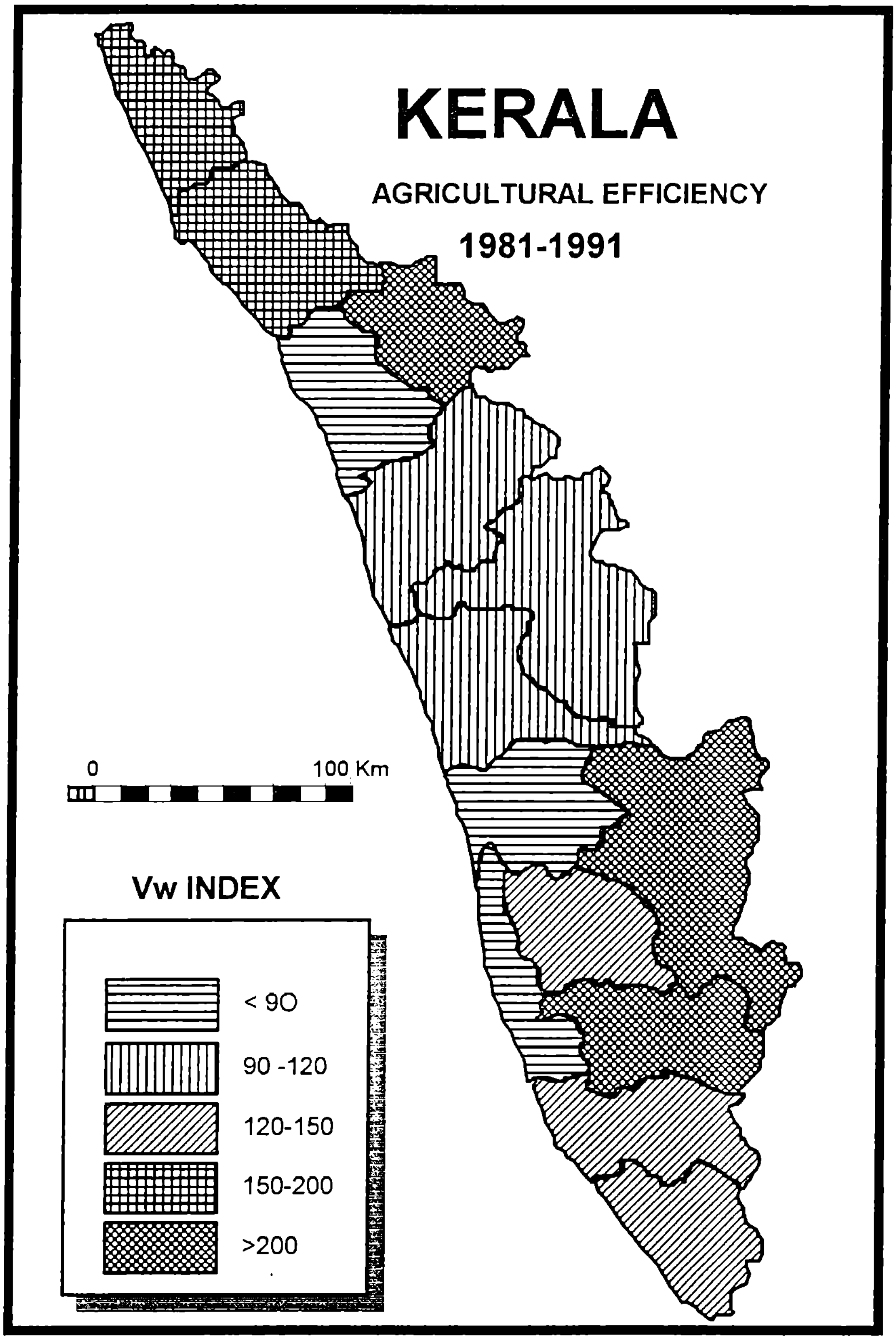


Fig. 6.14. KERALA - AGRICULTURAL EFFICIENCY

The efficiency level could be increased through intensive cultivation by way of multiple cropping, areal extension of crops to places where they can be suitably cultivated and through proper scientific agricultural practices.

6.2. INFLUENCE OF SHORT-TERM RAINFALL FLUCTUATIONS ON THE AGRICULTURAL LAND USE.

The relationship between climate and agriculture is a well studied subject. It is a known fact that each crop or plant species requires a specific set of climatic conditions for its growth and production. Since there are spatial and temporal variations in the climate of the Earth, the agricultural systems also vary accordingly. Even in regions which experience uniform climatic conditions, the seasonal variation of climatic elements often will have adverse effects on the agriculture of that region. In the temperate regions of the Earth, the diurnal and seasonal ranges of temperature are the limiting factor in agriculture. In the tropical regions, on the other hand, the seasonal range of temperature is less important for crops and hence the amount and distribution of rainfall plays a dominant role in controlling the agriculture. It should be mentioned here, that these are general conditions and may vary according to the local circumstances even within one climatic region.

Indian agriculture still depends heavily on the monsoons. The link between the vagaries of monsoons and its effect on the agriculture is a well known fact. The rainfall deficits often lead to drought conditions and excess of rainfall may result in flooding - both these can cause crop failure and consequent stress on the economy.

In this section the influence of inter-annual variations of rainfall on the agricultural landuse and crop production of Kerala is studied. Since the seasonal and annual variations of temperature in Kerala is minimum, only annual rainfall variations are considered in this analysis.

Like in many other States of the country, Kerala's agriculture also depends heavily on the monsoon rainfall. Even though the mean annual rainfall of Kerala is much higher than the national average, the inter-annual variations often affect the agricultural production. One way of combating this is by providing adequate irrigation facilities and proper water management practices.

Of the total 3021116 hectares of total cropped area in the State, only 387411 hectares are irrigated which accounts for 12.8%. This clearly indicates the degree of dependence of the State's agriculture on rainfall. The regional variations in the gross area irrigated reflect the influence of rainfall on agriculture in the individual districts.(Table.6.7.).

Only two districts, Ernakulam and Thrissur, have more than 25% of total cropped area under irrigation. Six districts have only less than 5%. This emphasises that the cultivation in these districts are practically rainfed.

AREA IN HECTARES

DISTRICTS	GROSS IRRIGATED AREA	TOTAL CROPPED AREA
1. THIRUVANANTHAPURAM	7896	202255
2. KOLLAM	4964	218267
3. PATHANAMTHITTA	8243	127563
4. ALAPPUZHA	31208	165993
5. KOTTAYAM	9978	235741
6. IDUKKI	3620	204999
7. ERNAKULAM	63756	246720
8. THRISSUR	79672	211646
9. PALAKKAD	82239	343372
10. MALAPPURAM	34769	268971
11. KOZHOKODE	5664	213179
12. WAYANAD	5536	176095
13. KANNUR	18392	265558
14. KASARGOD	33942	140757
STATE	**387411**	**3021116**

Table.6.7. GROSS AREA UNDER IRRIGATION AND TOTAL CROPPED AREA IN KERALA : 1991-1992

6.2.1.VARIATION OF CROP AREA, PRODUCTION AND YIELD DUE TO INTER-ANNUAL FLUCTUATION OF RAINFALL.

The technological advancements and socio-economic changes often result in the increase in crop production and yield. But the annual variations of area, production, and yield of a particular crop may be attributed to the fluctuation of rainfall and its distribution.

In this study simple linear regression analysis is done for the set of data on area, production and yield of selected crops with annual rainfall of selected stations. These stations are assumed to be the representative of the respective districts in which they are located. The coefficient of determination (R^2) values obtained through regression analysis gives the degree of dependence of these parameters on rainfall

6.2.1a. ATTINGAL.

Attingal, located in Thiruvananthapuram district, receives nearly 80% of its annual rainfall during the SW monsoon season. Since Thiruvananthapuram district has got only 3.9% of total cropped area under irrigation, the agriculture in the district is predominantly dependent on rainfall.

Coefficient of variability of area, production and yield of paddy, tapioca and coconut are comparatively less. On the other hand, rubber has very high variability of 53%,71.3% and 37% respectively in its area, production and yield. (Table.6.8.).

41.5% of variation in area and 54.6% of variation in production of paddy is determined by the variation in annual rainfall. This explains the high dependability of paddy crop on rainfall, in the absence proper irrigation facilities in the district. The R^2 value for area and production of rubber is also quite high. 34.5% of variations in area and 29.8% of variations in production of rubber, is determined by variations in the annual rainfall. The dependability on rainfall for the area and production of tapioca and coconut are comparatively less. But tapioca and coconut yield shows high R^2 values.

IN PERCENTAGE

	COEFFICIENT OF VARIABILITY			COEFFICIENT OF DETERMINATION		
CROP	AREA	PRODUCTION	YIELD	AREA	PRODUCTION	YIELD
Paddy	18.9	15.3	9.3	41.5	54.6	0
Tapioca	20.5	26.5	20.1	12.3	4.8	37.9
Coconut	12.2	15.8	14.2	10.1	6.0	28.6
Rubber	53.0	71.3	37.0	34.5	28.8	15.2

Table.6.8. COEFFICIENT OF VARIABILITY AND COEFFICIENT OF DETERMINATION IN AREA, PRODUCTION AND YIELD OF MAJOR CROPS : ATTINGAL

6.2.1b. CHERTHALA.

Comparatively low coefficient of variabilities in area, production and yield of paddy and coconut, and high variability of tapioca and rubber are the marked features in Cherthala. (Table.6.9).

Relatively high R^2 values can be noticed in the area under coconut and production and yield of rubber. This indicates the changes in these elements are highly influenced by the annual rainfall of the station.

In Alappuzha district, paddy is mainly cultivated in the Kuttanad region, which is a low lying land. The Kayal lands are usually utilised for this purpose, after draining out the excess impounded water. During the punja season, if sufficient water is not available, other seasonal crops are cultivated. Hence the rainfall dependency of paddy in this region is considerably less, which is reflected in the low R^2 values.

IN PERCENTAGE

	COEFFICIENT OF VARIATION			COEFFICIENT OF DETFRMINATION		
CROP	AREA	PRODUCTION	YIELD	AREA	PRODUCTION	YIELD
Paddy	13.1	13.3	15.3	10.7	0.5	10.4
Tapioca	34.3	36.2	27.5	18.0	0.1	18.9
Coconut	16.6	26.0	22.6	39.0	15.0	1.6
Rubber	20.7	58.0	60.7	17.8	30.0	24.9

Table.6.9. COEFFICIENT OF VARIABILITY AND COEFFICIENT OF DETERMINATION IN AREA, PRODUCTION AND YIELD OF MAJOR CROPS : CHERTHALA

6.2.1c. KOTTAYAM.

Kottayam district has only 4.23% of total cropped area under irrigation. A high variability in area, production and yield of tapioca and rubber is observed in Kottayam (Table.6.10.).

IN PERCENTAGE

	COEFFICIENT OF VARIABILITY			COEFFICIENT OF DETERMINATION		
CROP	AREA	PRODUCTION	YIELD	AREA	PRODUCTION	YIELD
Paddy	17.7	17.2	19.4	3.7	2.9	13.0
Tapioca	33.6	35.9	24.9	5.0	9.8	26.0
Coconut	16.5	27.8	18.7	0.1	3.1	11.2
Rubber	31.6	52.6	31.0	8.8	10.0	3.0

Table.6.10.COEFFICIENT OF VARIABILITY AND COEFFICIENT OF DETERMINATION IN AREA, PRODUCTION AND YIELD OF MAJOR CROPS : KOTTAYAM.

It is evident from Table 6.10 that only a few changes in area, production and yield can be attributed to the fluctuations in rainfall in Kottayam district. For example, even though there is

52.6% variability in the production and 31% in yield of rubber, only 10 % of fluctuations of production and 3% fluctuations in yield are influenced by the changes in annual rainfall.

Similarly, only 3.7% of changes in area, 2.9% of production and 13 % of yield of paddy are determined by the fluctuations of rainfall, while the coefficient variability of area, production and are 17.7%, 17.2% and 19.4% respectively. Hence it can be stated that the majority of inter-annual fluctuations of agriculture in Kottayam are due to other factors.

6.2.1d. MALAYATTOOR

Ernakulam district, where the station Malayattoor is located, has 25.84% of total cropped area under irrigation. Of this about 74% is used for irrigating paddy. This indicates that the dependability of paddy on rainfall in the district is comparatively less. (Table 6.11.).

IN PERCENTAGES

	COEFFICIENT OF VARIABILTY			COEFFICIENT OF DETERMINATION		
CROPS	**AREA**	**PRODUCTION**	**YIELD**	**AREA**	**PRODUCTION**	**YIELD**
Paddy	11.3	13.9	11.1	13.2	16.9	7.0
Tapioca	25.5	28.0	28.9	0.2	30.5	30.1
Coconut	12.6	14.4	8.4	1.8	3.2	46.1
Rubber	43.3	60.6	37.2	3.2	34.2	41.2

Table.6.11.COEFFICIENT OF VARIABILITY AND COEFFICIENT OF DETERMINATION OF AREA, PRODUCTION AND YIELD OF MAJOR CROPS : MALAYATTOOR

Rubber had a high variability in area, production and yield in Ernakulam district, followed by tapioca. From the R^2 values it becomes clear that only 13.2% of changes in area, 16.9% in of other crops on rainfall can be explained as due the fairly good irrigation facilities available in the district.

IN PERCENTAGES

COEFFICIENT OF VARIABILITY				COEFFICIENT OF DETERMINATION		
CROPS	AREA	PRODUCTION	YIELD	AREA	PRODUCTION	YIELD
Paddy	12.2	9.3	11.2	7.1	0.4	6.5
Tapioca	29.2	32.6	27.7	2.0	2.0	12.0
Coconut	24.2	23.3	8.7	11.0	9.6	31.0
Rubber	13.1	34.1	36.2	21.2	14.6	19.6

Table.6.12.COEFFICIENT OF VARIABILITY AND COEFFICIENT OF DETERMINATION IN AREA, PRODUCTION AND YIELD OF MAJOR CROPS : KODUNGALLOOR

6.2.1f. MANNARAKKAD.

Palakkad district, where this station is located, is popularly known as the 'Granary of Kerala', because it produces about 32.5 % of the total paddy output in Kerala. It has 27.2% of the total paddy area of the State. The district has also got a fairly good irrigation facility. 23.9% of total cropped area is irrigated. Among this a major share (82.1%) is used for irrigating paddy.

The district has low variability in area, production and yield of paddy. Other crops have a relatively high variability.(Table.6.13).The coefficient of determination shows that the influence of inter-annual variations of rainfall on the area, production and yield of many crops in the district is comparatively low.

production and 7% in yield of paddy are determined by the fluctuations in rainfall. As mentioned earlier, this is due to the reason that more paddy areas are irrigated in the district, than any other crop.

While the rainfall variations have little effect on area under tapioca, its production and yield are determined by rainfall to a large extent. The same pattern can be seen in the case of rubber and coconut. 46.1% of variations of coconut yield, 34.2% variations of production and 41.2% changes of yield of rubber, are influenced by the fluctuations of annual rainfall.

6.2.1e. KODUNGALLOOR.

Kodungalloor is located in the Thrissur district. The district has the highest area under irrigation- 37.64% of the total cropped area. Of the total 69065 hectares of paddy in the district, 44825 hectares have irrigation, which account for 64.4% of the total paddy area. Similarly 29015 hectares, out of the total 84789 hectares, of coconut area, have irrigation. This account for 34.2%.

The district has a low coefficient of variability in area, production and yield of paddy, while it is moderate in the case of other crops (Table 6.12). The coefficient of determination values show that the dependability of area, production and yield of many crops is comparatively of minimal significance. The inter-annual fluctuations of rainfall in the district have a fair amount of influence on the area and yield of rubber and on the yield of coconut. 31% of variations in the yield of coconut and 21.2% of area of rubber and 19.6% of rubber yield are determined by the fluctuations of rainfall. The low dependability

IN PERCENTAGES

	COEFFICIENT OF VARIABILITY			COEFFICIENT OF DETERMINATION		
CROPS	AREA	PRODUCTION	YIELD	AREA	PRODUCTION	YIELD
Paddy	10.1	9.3	10.5	7.5	0.6	5.3
Tapioca	45.0	52.4	33.5	9.4	11.2	18.0
Coconut	25.0	27.9	31.7	15.2	2.1	10.5
Rubber	44.0	66.1	39.8	15.3	22.3	18.5

Table.6.13. COEFFICIENT OF VARIABILITY AND COEFFICIENT OF DETERMINATION IN AREA, PRODUCTION AND YIELD OF MAJOR CROPS : MANNARAKKAD

6.2.1g. KANNUR.

Kannur district has 18932 hectares of gross irrigated area, which is 7.3% of the total cropped area of the district. Relatively high coefficient variability is found in all the crops, especially in the case of tapioca and rubber.(Table.6.14).

IN PERCENTAGES

	COEFFICIENT OF VARIABILITY			COEFFICIENT OF DETERMINATION		
CROPS	AREA	PRODUCTION	YIELD	AREA	PRODUCTION	YIELD
Paddy	38.1	35.2	10.8	6.0	21.0	0.4
Tapioca	52.8	61.8	31.0	14.0	0	19.0
Coconut	16.1	15.0	25.5	12.0	6.1	0.8
Rubber	26.6	64.3	55.9	0	0	0.3

Table.6.14. COEFFICIENT OF VARIABILITY AND COEFFICIENT OF DETERMINATION OF AREA, PRODUCTION AND YIELD OF MAJOR CROPS : KANNUR

It is obvious from Table.6.14. that the high variability of area, production and yield of many crops in Kannur is not because of the fluctuations in rainfall, except in the case of production of paddy and, area and yield of tapioca. 21 % of variations in paddy production, 14% variations of area and 19% changes of yield of tapioca are caused by the inter-annual variations of rainfall in the district.

From the above analysis, the following conclusions can be arrived at.

1. With the fluctuations in rainfall the agricultural landuse also changes. This is evident from the coefficient of determination obtained for area under different crops in various districts.

2. The production and yield of many crops are determined primarily by the amount of annual rainfall.

3. The degree of dependency of crops on rainfall varies from place to place and based on the availability of irrigation facilities.

4. The variability of area, production and yield of many crops in the State are not only because of the fluctuations in rainfall, but also because of other determinants of agricultural system of particular locality.

CHAPTER 7

SUMMARY AND CONCLUSION

Climatic variability is the result of the variation in the rotation of the earth, changes in the axis of its inclination, unequal distribution of land and water and unevenness of its surface. The most direct influence of climate is reflected in crop cultivation. Since each crop requires certain specific climatic requirements, any variations in this would adversely affect the growth and output. Crop failure due to variations in climate could be disastrous in a country where agriculture is the backbone of its economy. This necessitates the need for an understanding of climatic variations at the regional level, especially of short-term variations. This would help take proper remedial measures so that the impact is minimised. A brief review of major studies carried out in the field of land use, impact of climatic variations on crop production, application of water balance approach and agricultural regionalisation are given in the first Section of the Second Chapter. The second Section of this Chapter gives the details of materials and methods adopted in this study.

The third chapter consists of a discussion of the important physical features of Kerala State. The location, extent, administrative divisions, physiography, drainage, geology, soils and vegetation types are discussed.

The wide variations in the topography from the coastal regions to the Western ghats, have resulted in the evolution of a broad climatic spectrum over the State. The salient features of agroclimatology of the region have been described in the Fourth Chapter. The spatial and temporal distribution of temperature, rainfall, rainfall variability, relative humidity and winds have been presented in the second section of this Chapter.

Due to the influence of the South-West monsoon the maximum temperature is recorded in the pre-monsoon months. At the coastal stations the maximum temperature is often around 33^0C during April while the minimum temperature is around 22^0C during January. The interior stations have a higher maximum temperature (about 37^0C), and minimum temperature is usually less than that at the coastal stations.

The lowest mean monthly temperature at all stations in the State occur in July or August and the highest during the pre-monsoon months.

The State receives abundant rainfall mainly from the South-West monsoon. The mean annual rainfall of the state is about 300 cm. Most part of the State has two peaks of rainfall - one during the South-West monsoon period and the other during the North-East monsoon period. 66 % of the total annual rainfall the State is contributed by the South-West monsoon. The monsoon rainfall is more than 80% of the annual rainfall in the extreme northern part of the State and gradually decreases to about 45% in the extreme south. The North-East monsoon season lasts from October to November and contribute about 18% of the annual rainfall of the State. The southern districts of the State get about 30% of the annual rainfall during this period, while it accounts for ,only 9 % of the annual rainfall in the northern districts. The rainfall variability of the State as a whole is low - it ranges from 15% in the northern districts to 30 % in the southern districts.

Being located on the coast, the relative humidity of the State is usually high. The average relative humidity of the coastal regions of the State is about 77%. A maximum of around 88% occurs during monsoon months, while the minimum is about 66 %, experienced during January.

The agroclimatic zonation of the State has been presented in the Second Section of the Fourth Chapter. Under the National Agricultural Research Project, the State was divided into the following five agroclimatic zones.

a. Northern Zone: Comprises of Kasargod, Kannur, Kozhikode and Malappuram districts .This zone has a 293 km of coastline. The highland comprises of about 300 sq.kms. and midland about 400 sq.kms.

b. Central Zone: This zone includes all the areas of the State excluding the high ranges, Coastal zone and Kole lands of Ernakulam, Thrissur and Palakkad districts.

c. South Zone: Consists of Kottayam, Alappuzha, Pathanamthitta, Kollam and Thiruvananthapuram districts.

d. High Altitude Zone : This encompasses the high ranges with an elevation above 750m of Wayanad, Palakkad, Idukki, Kollam and Thiruvananthapuram districts. It has a total geographical area of 11140 sq.km.

e. Problem Area Zone : This include the lowland areas, Onattukara, Kuttanad and Kole lands, Pokkali and low rainfall areas of Malappuram, Thrissur, rnakulam, Kottayam and Alappuzha.

In the third section of this Chapter detailed analysis of rainfall, potential evapotranspiration (PE), actual evapotranspiration (AE), water surpluses (WS), water deficits (WD), climatic shifts and incidence of droughts have been projected for nineteen selected stations over the State. Of this seven stations are in the Highland Zone, four each in the Northern and Southern Zone , three in the Central Zone and one in the Problem Zone.

In the Northern Zone only Irikkur displayed a noticeable decreasing trend in the annual rainfall, while the other three stations -Perinthalmanna, Kannur and Kasargod - did not show any trend. PE and WD showed increasing trend in all the stations of this Zone, while WS exhibited declining trend in all stations. AE also revealed decreasing trend in all stations except Kannur, where it showed increasing trend. In this zone majority of the climatic shifts were towards drier side. Significantly, Irikkur had the largest number of disastrous droughts (5) among all the stations studied in Kerala. Perinthalmanna had two, disastrous droughts, Kannur had one, while Kasargod did not experience any disastrous droughts.

All the stations in the Central Zone showed declining trend in rainfall, actual evapotranspiration and water surplus. PE displayed increasing trend only in Kodungalloor, while in Malayattoor and Mannarakkad there were no conspicuous trend in PE. In this zone also the majority of the climatic shifts experienced by these stations were towards the drier side. Mannarakkad had two disastrous droughts, Kodungalloor had one, while Malayattoor did not experience any disastrous droughts during the period of study.

Three stations - Attingal, Kottayam and Neriamangalam - among the 4 southern zone stations exhibited marked declining trend, while the other station Thiruvananthapuram did not show any trend. The station Neriamangalam receives highest mean annual rainfall in Kerala - 4637mm.

Thiruvananthapuram, Attingal and Kottayam showed increasing trend in PE, while Neriamangalam displayed a decreasing trend. Excepting Thiruvananthapuram, all the stations presented a declining trend in AE. The water surplus (WS) of Thiruvananthapuram, Attingal and Neriamangalam displayed decreasing trend, while the water deficit (WD) of these stations showed increasing trend.

In general, the Southern Zone stations experienced climatic shifts equally towards moist and drier sides. Of the four stations, Attingal had highest disastrous droughts (3), while the other three stations had one each during the period of study. While Neriamangalam had three severe droughts, the stations had one severe drought.

Of the seven stations in the Highland Zone five are in Idukki district and two in Wayanad district. Among these Marayoor showed an increasing trend in rainfall, while the other stations showed marked declining trend. All the stations exhibited increase in PE. Increase in WS was seen at three stations - Devikulam, Marayoor and Vandanmedu. Of these, Devikulam and Vandanmedu showed increasing in WD also. Peermedu and Marayoor showed prominent climatic shifts towards drier side. Vythiri, Mananthavady and Karikode had two disastrous droughts, while the other stations had one each, excepting Vandanmedu, which did not have any disastrous droughts. On the other hand, Vandanmedu had six severe droughts during this period.

To summarise, almost all the stations in all agroclimatic zones showed a declining trend in rainfall, AE and WS. Most of the stations exhibit an increasing trend in AE and WD.

These results are in conformity with the findings of James (1991).He had further shown that many of the stations which do not show any significant decreasing trend in annual rainfall or even some stations which have shown increasing tendencies , have exhibited very significant decreasing trend in annual AE. Stations in the northern half of the State which do not exhibit any significant decrease in annual rainfall or increase in PE, show a prominent decreasing trend in AE. This implies that the seasonal distribution of both rainfall and PE play a major role in these cases.

In all stations excepting the one in High Altitude Zone, which exhibit decreasing trend in rainfall have shown decreasing trend in WS too. Of the seven stations in this zone four stations show decreasing trend in WS while three display an increasing trend.

According to James (1991), the water surplus and hydrologically available water is getting reduced much faster than the actual rainfall itself. At many stations water surplus and deficit co-exist in different seasons of the year. Even though the State as a whole does experience heavy rainfall, mainly due to South-West monsoon, and large water surpluses are observed, they are showing decreasing trend. On the other hand water deficits are also present at most stations and have been showing increasing trend. In fact the average annual water surplus is about six times the water deficit, though there are many regions without any surplus. Water surplus occurs for only in a few months: about 89% of the surpluses occur in the monsoon season and during the cool weather season there is no surplus any where in the State. About the half of the annual water deficits are experienced during the winter and pre monsoon months.

The coexistence of water surplus and water deficit at different times of the year in different parts of the State is an important aspect of its hydrometeorology.

As is well known, the moisture regime of any region is influenced more by the temporal distribution of rainfall than by its cumulative total. An year or crop growing season may experience above normal rainfall but still be affected by droughts of severe or disastrous magnitude.

Studies of climatic shifts over the state show that the moisture regime of the different agroclimatic zones in the State undergo wide fluctuations both in the drier and wetter directions. Very often the shifts cause the climatic regime to move into more humid or less humid classes. As most stations in the State belong to the humid and perhumid categories, shift in the wetter directions are not ecologically significant. In such humid climates shifts into the drier categories because of deficient rainfall that is more critical in influencing the agricultural land use.

A general comparison of the number and categories of droughts years 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 the 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 magnitude reveals interesting facts. During many of the years when the climate shifted to the drier side stations experienced droughts of one or other categories. However, during some years many stations did not experience droughts eventhough shifts in climate to the drier side were observed. There have also been occasions when even severe or disastrous droughts have been observed when there have been increase in moisture index (I_m) values. At some stations droughts have occurred even when there were no perceptible climatic shifts.

These results highlight the greater ecological importance of appropriate rainfall distribution than of rainfall totals. It is possible for the crops to experience droughts during certain periods of their growth even if there is excessive rainfall during other periods. Moisture stress during critical phases of crop growth cannot be mitigated by excessive water availability during other phases.

The first Section of the Fifth Chapter presents the existing land use pattern of the State. It is observed from this study that with the available limited land resources Kerala has attained stability in its land use pattern over the years. The State as a whole has 27.85% of the total geographical area under forests. Land put to non-agricultural uses account for 9.11%, Permanent pastures, grazing lands and miscellaneous tree crops occupy 0.96%. Fallow lands account for 4.37% and the Net Sown Area of the State is 57.71%.

The land use pattern of individual districts vary significantly from the State averages. Idukki and Pathanamthitta districts have more than 40% of the total geographical area under forests. Land put to Non-Agricultural uses range from 3.93% in Wayanad district to 17.67% in Alappuzha. Pathanamthitta, Idukki, Malappuram and Wayanad districts have less area under this category than the State average value of 9.11%. The area under Pastures, Grazing lands and Miscellaneous tree crops in most of the districts are less than the State average of 0.96%. Idukki, Kannur, Palakkad, Kasargod and Wayanad are the districts which have more area under this category. Relatively high proportion of fallow lands are found in Kasargod, Palakkad, Malappuram and Idukki districts. Seven districts viz., Thiruvananthapuram, Alappuzha, Kottayam, Ernakulam, Kozhikode, Kannur and Kasargod, have more area under cultivation than the State average of 57.71%. Among these, Kottayam district has the highest percentage Net Sown Area (82.79%).

The second Section of this Chapter is devoted to the land use changes that have taken place at the State level during the period 1961 to 1991.

Forests occupied 22.37% of the total geographical area of the State during 1961 and marginally increased to 22.89% in 1991. The area under non-agricultural uses has not shown any significant change during the three decades. However, area under pastures, grazing lands and miscellaneous tree crops steadily declined from 6.38% in 1961 to 0.96% in 1991. This decline may be due to the fact that these marginal lands were brought under cultivation. Fallow lands declined from 6.51% to 3.23% during the three decades, while the net area sown increased from 50.67% to 57.71%.

The third Section of this Chapter focuses on the land use changes in the various districts of the State. The major land use changes that has taken place in Thiruvananthapuram district for the last three decades is that the area under non-agricultural uses has increased to 9.84%, while fallow lands have significantly declined.

Kollam district recorded major decrease of 13.1% in the area under forests. Correspondingly large increase of 12% was noticed in the net sown area. The land put to non-agricultural uses also showed significant increase.

One of the noticeable features of land use pattern of Alappuzha district is the absence of forests. While the land put to non-agricultural uses increased by 10.75%, the net sown area decreased by 7.25% in the district.

Kottayam district has the distinction of having the highest net sown area (82.79%). The land under forests decreased by as much as 36%, while the net sown area increased by 27%.

In Ernakulam district net sown area increased by about 13.37% and land put to non-agricultural uses by 6% during the three decades. Significant decrease was noticed in area under forests and pastures.

Like many other districts Thrissur district also show a decline in area under forests (-10.6) and increase in net sown area (+12.3%). The land put to non-agricultural uses also increased by about 3.4% during the last three decades.

One peculiar feature of Palakkad district is the substantial increase in the area under forests by about 11.5%. The land put to non-agricultural uses declined by 8% and pastures by about 5.6%.

Kozhikode district show a notable jump in the net sown area, by 20.7%, while experienced sharp fall in the area under forests (-11.6%). the area under pastures and fallows also decreased considerably in the district.

The net sown area of Kannur district increased by 24.3%, while the area under forests increased by 5%. This was compensated by decrease in pastures (-17.4%), fallow lands (-8.8%), and land put to non-agricultural uses (-3%).

The overall changes of land use is discussed in the section four of the Fifth Chapter. It is seen that the State had an overall gross land use change of 10.54% during the period 1961-1991. Of this 5.99% of changes occurred during the first decade (1961-1971), and can be considered as the most dynamic period with respect to land use changes. In the second decade (1971-1981), the gross overall change was 2.88%, followed by 1.67 % during the third decade (1981-1991). This clearly shows that the land use pattern of the State has almost stabilised during these periods.

The Sixth Chapter of this thesis is devoted to the discussion of the agricultural land use over the State and its spatio-temporal variations in relation to rainfall fluctuations. The first Section of this Chapter presents a detailed description about the cropping pattern of the State and its sptio-temporal variations. The second Section describes the influence of short term fluctuations of rainfall in the agricultural land use of the State.

The favourable climate and topographic conditions of the State allows a wide variety of crops to be cultivated. Agriculture in Kerala is unique with respect to its homestead farming, which is practised in all parts of the State.

The crops cultivated in the State include cereals such as paddy, jowar and ragi, pulses, sugar crops, spices and condiments such as pepper, ginger, chilli, clove, cardamom, turmeric and arecanut. Also cultivated are fruits and vegetables like banana, pineapple, jack, mango and cashew. The major non-food crops include coconut, coffee, tea, rubber and cocoa.

The State has experienced a shift in cropping pattern in favour of non-food crops. Food crops accounted for 66.2% of the total cropped area of the State in 1961, which declined to 49.5% in 1990, a decrease of 17.1%. At the same time the area under non-food crops registered a corresponding increase (17.1%).

When considering the absolute area it is obvious that there is a phenomenal 94.4% increase in the area under non-food crops and only a marginal decrease of 4.41% under food crops. The increase of total cropped area during this period was 28.6%.

The derived combination vary from two crops in Alappuzha, Thrissur and Kozhikode districts to five crops in ldukki district. Coconut forms the first ranking crop in nine districts, while rice is the first ranking crop only in Palakkad district. Idukki has pepper as the first ranking crop, followed by rubber, cardamom, tea and coffee. This indicates that the district has predominantly plantation crops. Another noticeable combination is in the Palakkad district where groundnut forms one of the major crops, which occupies the fourth position.

In the northern districts of Kannur and Kasargod, cashew forms a predominant crop occupying the second position. Malappuram district also has cashew, as the fourth ranking crop.

A significant proportion of coffee is grown in Wayanad district where it is the first ranking crop. Tapioca appears in.the combination only in the southern districts of Pathanamthitta, Kollam and Thiruvananthapuram.

Four major crops, paddy, tapioca, coconut and rubber have been selected to study their regional concentration and spatio-temporal variations. Of these, paddy is cultivated mainly during the following three seasons.

1.Virippu - Autumn (first) crop. April / May to September / October

2.Mundakan - Winter (second) crop. September / October to December / January

3.Punja - Summer (third) crop. December / January to March / April.

The highest concentration of paddy is found in Alappuzha and Thrissur districts. Inspite of the fact that rice is the staple food of the people of Kerala, the area under paddy reduced drastically in the State. From 752690 hectares in 1961 it decreased to 541327 hectares in 1991. Alappuzha and Kozhikode districts have high productivity levels.

The area under tapioca in the State declined from 236670 hectares in 1961 to 140881 hectares in 1991. Tapioca is mainly concentrated in the southern districts. High concentrations are found in Thiruvananthapuram and Kollam districts. In consequence to the high concentration of tapioca in the southern districts, they also have high productivity levels.

Coconut is extensively grown through out the State In 1961 the State had 504820 hectares of coconut land, which increased to 863061 hectares in 1991. The productivity levels of coconut are high in Thiruvananthapuram, Alappuzha and Kozhikode districts.

Rubber registered remarkable increase in area. It increased from 133080 hectares in 1961 to 425768 hectares in 1991- an outstanding increase of 220%. Kottayam district has highest concentration of rubber, where it accounts for 34.4% of total cropped area. Rubber productivity follows the general concentration pattern. Kottayam district has the highest productivity level.

Agricultural efficiency of a region depends on the inputs such as the number and types of crops cultivated, their areal extent, climatic and edaphic conditions agricultural practices, and the output in the form of yield per hectare of various crops. Hence an index which takes into account both the per hectare yield and the areal extent of crops, is a most useful tool for assessing the agricultural efficiency.

In this study the Weighted Composite Index of regional inequality in Agricultural efficiency proposed by Singh et.al.(1994), is followed.

The Weighted Composite level of Agricultural Efficiency (V_W) values range from 83 in Palakkad to 584 in Idukki.

Five regions of different levels of efficiency have been identified. Out of the 14 districts in the State, 5 districts have very high and high efficiency levels. Six districts have low to very low levels and the remaining three districts have medium level. This clearly indicates that those districts where the number of crops are more, with almost equal share of crop lands, the efficiency is high. This invariably is found in the hilly districts of the State, where the efficiency level is remarkably very high.

The second Section of this Chapter discusses the influence of rainfall fluctuations on the agricultural land use. Like in many other States of the country, Kerala's agriculture also depends heavily on the monsoon rainfall. Even though the mean annual rainfall of Kerala is much higher than the national average, the inter-annual variations often affect the agricultural production. One way of combating this is by providing adequate irrigation facilities and proper water management practices. Of the total 3021116 hectares of total cropped area in the State, only 387411 hectares are irrigated which accounts for 12.8%. This clearly indicates the degree of dependence of the State's agriculture on rainfall.

Only two districts, Ernakulam and Thrissur, have more than 25% of total cropped area under irrigation. Six districts have only less than 5%. This emphasises that the cultivation in these districts are practically rainfed.

Simple linear regression analysis has been done in this investigation to study the influence of annual rainfall fluctuation on the area production and yield of selected crops. Towards this end data from seven stations have been utilised in this study, assuming that these stations are representative of the districts in which they are located. The summary of the results of this analysis are as follows.

At Attingal in Thiruvananthapuram district, 41.5 % of annual variations in area and 55% of variations in the production of paddy is determined by the annual variations in rainfall. This clearly indicates the heavy dependence of the district on the annual rainfall for paddy cultivation. Similarly, 34.5% of variation of area and 29.8% of variation of production of rubber are determined by the variation of the district's annual rainfall. The dependability of the area and production of tapioca and coconut on rainfall are much lesser.

At Cherthala in Alappuzha district, influence of rainfall on the production of paddy and tapioca are very small. The production of coconut and rubber are influenced to a large extent. The coconut area is also highly influenced by the variation of rainfall.

At Kottayam less than 10% of the area and production of any of the four crops is affected by rainfall variation.ie. the majority of inter-annual fluctuations in the area production and yield of major crops in the district are due to factors other than rainfall.

At Malayattoor in Ernakulam district and Kodungalloor in Thrissur district, the dependability of crops on rainfall are comparatively less. This can be explained as due to the fairly good irrigation facilities available in these districts.

Palakkad district, for which Mannarakkad is the representative station, produces about one third of the total paddy output in Kerala. The district also has fairly good irrigation facilities and hence the dependability of crops on rainfall is less.

At Kannur 21% of the variations of paddy productions may be attributed to the fluctuations of annual rainfall, while 19% changes in the yield of tapioca and 14% variation in the area are caused by the inter-annual variation of rainfall.

It is observed from this study that the rainfall fluctuations do cause significant changes in agricultural land use. The total production and yield of major crops are determined to a large extent by the rainfall values. However where ever sufficient irrigation facilities are available, the degree of dependability of crops on rainfall is much lower.

It is clear from the above results that the State as a whole, experience heavy rainfall and large water surplus while water deficits are not altogether absent Further more, the rainfall over the State seems to be decreasing and the water surplus is getting reduced at a much faster rate than the rainfall, when, at the same time, water deficits are increasing. This means, from the agricultural point of view, the irrigation potential is getting reduced along with the availability of water. Water conservation is therefore not only important but also necessary, critical and urgent.

By a proper management of surface water, when available, the deficits in the other seasons can be reduced. A large quantity of utilizable surface water flows to the Arabian Sea unexploited and unharnessed This can be avoided to a large extent by the construction of dams and reservoirs at proper locations. However, since the State is densely populated and most of the land is exploited, construction of large dams could give rise to rehabilitation problems and environmental degradation. It is therefore advisable to plan comparatively smaller and ecologically viable projects at suitable locations. Heavy rainfall during the monsoon months leads to intensive soil erosion . Therefore soil conservation is an important aspect of land use planning. Terracing, contour bunding and afforestation are generally suggested techniques for soil conservation.

The broad agroclimatic zonation followed in this study suggests that in general the land has been exploited with a fairly high degree of efficiency. However, inorder to arrive at most suitable land use pattern for the State, it is essential that detailed maps of soil, physiography and geology of the State are superimposed on maps depicting the agroclimatic zones. This technique should be adopted and a comprehensive and optimum land use map be prepared with the help of Geographical Information System (GIS). It is also important that once the area are demarcated for specific agricultural land use, they are further studied in detail to evolve the optimum crop combination and cropping pattern, so that the highest levels of agricultural productivity in the area may be achieved. With such an approach, sustainable agriculture can be developed ensuing long term progress of the region.

The analysis of agroclimatological parameters, climatic shifts and droughts and their influence on the major crops revealed that climatic parameters influenced agriculture significantly. Further agroclimatological features are also important determinants in the choice of appropriate land use strategies and cropping pattern, though in this study it has not been possible to quantify their exact influence. Future work is necessary in this direction to determine the finite relationship between variation in climate and meteorological parameters and agricultural land use variability. Towards this end it may be essential to use appropriate crop-climate and crop-weather models along with the information generated by the GIS mentioned above. Such an effort would be a significant step forward in planning optimum land use over the State.

In conclusion, it may be said that the development of the State is inextricably linked to the availability of water through rainfall, with all its inherent inter-seasonal, intra-seasonal and spatial variabilities. Formulation of most suitable land use strategy is important through the co-ordination of various users of precious natural resources of land, water and atmosphere. It is hoped that the results of the present investigation would help in the judicious planning for the optimum use of available resources.

BIBLIOGRAPHY

Agrawal, Ranjana., Jain, R.C., and Jha, M.P., (1983) : Joint Effects of Weather Variables on Rice Yield, *Mousam*, Vol.34, No.2, pp.189-194.

Agricultural Statistics of Kerala - 1975, (1976) : Bureau of Economics and Statistics, Govt. of Kerala, p. 95

Agricultural Statistics of Kerala - 1986-87, (1988) : Dept. Of Economics and Statistics, Govt. of Kerala., p. 12.

Agricultural Statistics of Kerala - 1988-89, (1990) : Dept. Of Economics and Statistics, Govt. of Kerala, p. 12.

Agricultural Statistics of Kerala - 1989-90, (1991) : Dept. Of Economics and Statistics, Govt. of Kerala, p. 12

Agricultural Statistics of Kerala - 1990-91, (1992) : Dept. Of Economics and Statistics, Govt. of Kerala, p. 12

*Ameen, M., (1956) : Land Use Survey of Delhi State, Proc. International Geographical Seminar, Aligarh.

*Ananthakrishnan,R., Selvam, M.M., and Chellappa, R., (1965) : Seasonal variation in the precipitable water vapour in the atmosphere, *Indian Journal of Met.Geophys.*,Vol.16, No.1.pp 371-385.

Basu, D.N., and Kashyap, S.P., (1996) : Agro-Climatic Regional Planning, Vol.1 - Concepts and Applications, Concept Publishing Co., New Delhi, p. 370.

Basu, D.N., and Kashyap, S.P., (1996) : Agro-Climatic Regional Planning, Vol. I I - Themes and Case Studies, Concept Publishing Co., New Delhi, p. 340.

*Bhatia , S.S., (1965) : Patterns of Crop Cocentration and Diversification in India, *Ecomomic Geography*, Vol. 41.

Bhatia, S.S., (1967) : A New Measure of Agricultural Efficiency in Uttar Pradesh, India., *Economic Geography*, Vol. 43.

Bharatdwaj, O.P., (1961) : Land Use in the Lowlands of the Beas int the Dist.Jullunder-Doab, *National Geographical Journal of India*, Vol. 7, No. 4.

Campbell, James.c., (1987) : Mapping the Land - Aerial Imagery forLand Use Interpretation, Scientific Publishers, Jodhpur.

Centre for Earth Science Studies, (1984) : Resource Atlas Of Kerala, Trivandrum.

*Champion, H.G., (1936) : A Preliminary Study of the Forest types of India and Burma, Govt. of India Press, New Delhi.

*Chatterjee, S.P., (1953) : Land Utilization Survey in India, *Observer*, No.1.

Chowdhury,A.,and Rao, G.A., (1978) :Climatic Change and Wheat Yield in Nort-Western parts of India, In "Climate Change and Food Production",Takahashi,K.,andYoshino,M.M.,(ed), pp. 125-135.

Coleman, A., (1961) : The Second Land Use Survey- Progress and Prospects, *Geographycal Journal*, 127, pp 168-186

Coppock, C. J., (1964) : Crop, Livestock and Enterprise Combination in England and Wales, *Economic Geography*, 40, pp. 65-81.

Coutinho, O., and Sharma, T.C., (1989) : Disparity in Crop Yield in Uttar Pradesh - A dignostic inquiry, *Annals*, NAGI, Vol. 9, No.2. pp.28-39.

Das, M.M., (1982) : Agricultural Land Use and Cropping Pattern in Assam, *Geographical Review of India*, Vol. XLIV, No.4.

Das, J.C., Mehra, A.K., and Madnani, M.L., (1971) : Forecasting theYield of Principal Crops in India on the basis of Weather - Paddy /Rice, *Indian. J. Met. Geophys.*, Vol. 22, pp 47-58

Dhillon, S.S., Sharma, R.L., and Singh, Jasbir., (1986): A Classification of Indian Agriculture into Major Systems, Spectrum of Modern Geography, Concept, New Delhi, pp. 364-378.

*Doi, Kikuzazu., (1959) : The Industrial Structure of Japaneese Perfectures, Proc. International Geographical Union, Regional Conference in Japan, pp. 310-316.

Domrös, M., (1978) : Aspects of Recent Rainfall Fluctuations with Regard to Land Utilization in Sri Lanka, In "Climate Change and Food Production", Takahashi, K.,and Yoshino, M.M.,(ed), pp.101-110

*Enyedi,G.Y.,(1964) : Geographical Types of Agriculture,Budapest, Applied Geography in Hungary.

Farm Guide- 1976, (1976) : Farm Information Bureau, Govt. Of Kerala, Trivandrum, p.135.

Fein, J.S., and Pamela, L Stephens, (ed), (1987) : Monsoons, John Wiley, New York.

Gadgil, Sulochana., (1995) : Climate Change and Agriculture- An Indian Perspective,*Current Science*,Vol.69, No.8, pp 649-659.

Goonerate, W., (1978) : Recent Climatic Fluctuations and Food Problems in Sri Lanka, In "Climate change and Food Production",Takahashi,K.,andYoshino,M.M.,(ed).pp.111-122.

Gupta, N.L., and Gurjar, R.K., (ed), (1993) Sustainable Development, Vol. I I, Rawat Publications, Jaipur. P.278.

Haseena, Raghavan., (1996) Impact of Climatic Variability and Droughts on the Crop Yields in Kerala, Unpublished P.hD. thesis ,Cochin University of Science and Technology.

Indian Council of Agricultural Research, (1992) : Hand Book Of Agriculture. P. 1303.

Jain, R.C., Agrawal, Ranjana., and Jha, M.P., (1980) : Effects of Climatic Variables on Rice Yield and its Forecast, *Mausam*, Vol.31, No.4, pp 591-596.

James, M.E., (1991) : Studies on Space-Time Variables of Hydrometeorological Parameters Over Kerala State, unpublished Ph.D. thesis, Cochin University of Science and Technology.

Kaur, Dhian., (1991) : Changing Patterns of Agricultural Land Use - A spatial Analysis of Bist Doab - Punjab, Rawat Publications, Jaipur. p.216.

Kerala Agriculture University, (1993) Package of Practices, Recommendations 'Crops'. Thrissur.

Kerala State Gazetteer, (1986) : Kerala Gazetteers, Trivandrum.

Kerala State Land Use Board, (1991) : Agriculture in Kerala : A Retrospect - An analytical study.

Kerala State Land Use Board, (1995) : Land Resources Of Kerala State

Koeppen, W., (1900) : Versuche einer Klassification der Klimate, *Geogr. Zeitscher*, Band 6, pp 593-611 and 657-679.

Kuniyal, J.C., (1987) : Crop Concentration and Diversification in Naini Tal District, UP Himalaya, *The Natonal Geographical Journal*, Vol.X X X I I I, No. 2., pp 160-167.

*Learmonth, A.T.A., (1962) : Sample Villages in Mysore State in India, Liverpool, United Kingdom.

Mavi, H.S., (1986) : Introduction to Agrometeorology, Oxford and IBH Publ.Co.Pvt.Ltd., New Delhi. p.281.

Mavi, H.S., Singh, G., Mathauda, S.S., Singh, R., Mahi, G.S., and Jhorar, O.P., (1993) : Climate Change and Wheat Yield in the Punjab (India), Proc. Symp. on Climate Change, National Disasters and Agricultural Strategies, BAU, Beijing, pp 58-65.

Mishra, B.N., (1990) : Land Utilization Management in India, Chugh Publications, Allahabad. p.322.

Mohammed, Ali., and Amani, K.Z., (1985) : Regional Imbalances in Growth Levels of Rice Production in India, The Geographer, Vol.X X X I I., No.2., pp.56-68.

Mohammed, Noor., (ed.) (1981) : Perspectives in Agricultural Geography - Land Use and Planning, Vol. 3, Concept Publishing Co. New Delhi. 533.

Mohan, R., and Gupta, R.P., (1985) : Land Use Classification of the Area around Jaipur using Landsat Data, *The National Geographical Journal*, Vol. X X X I, No. 1, pp. 39-43.

Mowla, K.G., (1978) : Relation between Climate and Rice Production in Bangladesh, In "Climate change and Food Production",Takahashi,K., and Yoshino, M.M., (ed.), pp. 137-146.

Nair, K.S., (1987) : Hydrometeorological Studies of Kerala State in relation to Western Ghats, unpublished Ph.D. thesis, Cochin University of Science and Technology.

National Remote Sensing Agency, (1989) : Manual of Nation-wide Land use/ Land Cover mapping using Satellite Imagery, part 1.

Natarajan, S., Gajbe, M.Y., and Manchanda, M.L., (1986) : Land Use Study in Mewat Area, Haryana, using Remote Sensing Techniques, *Photonirvachak*, Vol.14, No.1.

National Agricultural Research Project, (1989) : Status Report of the Southern Zone, Vol.I, Kerala Agricultural University, Thrissur, p.323.

National Agricultural Research Project, (1989) : Status Report of the Southern Zone, Vol. I I & I I I Kerala Agricultural University, Thrissur, p.237.

National Agricultural Research Project, (1989) : Status Report of the Northern Zone, Vol. I I & I I I, Kerala Agricultural University, Thrissur, P.73.

National Agricultural Research Project, (1992) : Status Report of the Central Zone, Vol. I I & I I I, Kerala Agricultural University, Thrissur, P.293.

Oram, P.A., (1985) : Sensitivity of Agricultural Production to Climate change, Climate Change, Vol. 7, No. 2. pp 129-152.

Parry, M.L., and Carter, T.R.,(ed) (1988) : The Impact of Climate on Agriculture. Vol.2, Assessments in Semi-arid Regions, N.T.Konijin, Kluwer, Dordrecht.

Prakasa Rao, V.L.S., (1956) : Land Use Survey in India- its Scope and Some Problems, Proc. of the International Geographical Seminar, Aligarh.

Raghavaswami, V., (1983) : Land Capability Classes, Land Use and Population Distribution, *Annals*, NAGI, Vol.I I I, No. 2., pp.1-14

Raina, A.N., (1963) : Observations on Soils and Land Utilization in Kashmir, *Geographical Review of India*, Vol. 25, No. 3.

Ramakrishna, G.V.S., and Yadav, M.D., (1984) : Variation in Crop Production Efficiency in Indian Arid Districts, *National Geographical Journal of India*,Vol. X X X., No.3.,pp.173-185.

Ramaniah, Y.V., and Reddy, N.B.K., (1986) : Land Use Orientation in Andhra Pradesh, *Annals*, NAGI,Vol. V I, No.2. pp 57-60.

Ram Mohan, H.S., and Maria, Juliet., (1983) : Classification of the Monsoon Climates of the World, Proc. Symp. on Water Balance and National Development, Waltair, pp 83-92.

Ram Mohan, H.S., and Subrahmanyam, V.P., (1983) : Application of Water Balance Concept in Agricultural Planning and Operation in South India, *The National Geographical Journal of India*, Vol. X X I X, No.1-2, pp 30-34.

Rao, Appa G., (1983) Estimation of Wheat Yields Over Punjab using District and State Models, *Mausam.* Vol.34, No.3. pp 275-280

Rao, M.S,. and Kalavathy, K., (1983) : Water Balance and Cropping Pattern in Madurai District, Tamilnadu, *The Indian Geographical Journal,* Vol. LVIII, No.2, pp. 172-182.

Rasmidatta, V., (1978) : The Climatic Fluctuation and Problems in Crop Production in Thailand, In "Climate Change and Food Production",Takahashi, K., and Yoshino M.M., (ed). pp 147-153.

Saha, K.R., and Mooley, D.A., (1978) : Fluctuations of Monsoon Rainfall and Crop Production, In, "Climate Change and Food Production", Takahashi, K., and Yoshino M.M., (ed), pp. 73-80.

Sastri, A.S.R.A.S., Ramakrishna, Y.S., and Bhandari, C.S.,(1982) : Drought Climatology of Guhiya Catchment in Rajasthan, *National Geographical Journal of India,* Vol. X X V I I I Part 3 & 4, pp 146-148.

Saravanan, E., (1994) Agroclimatological Studies of Kerala State For Application in Land Use Planning, Unpublished Ph.D. thesis, Cochin University of Science and Technology.

Sawant, S.B., and Gadgil, A ., (1983) : Factors Affecting Agricultural Efficiency in India, *National Geographer,* Vol.XV I I I, No.1., pp.107-113.

Seasons and Crop Report of Kerala State - 1981-82 & 1982-83, (1985) : Department of Economics and Statistics, Govt. of Kerala, p. 139.

Seasons and Crop Report of Kerala State - 1983-84, (1986) : Department of Economics and Statistics, Govt. Of Kerala, p.104

Seasons and Crop Report of Kerala State - 1984-85, (1987) : Department of Economics and Statistics, Govt. of Kerala, p.117

Seasons and Crop Report of Kerala State - 1985-86, (1987) : Department of Economics and Statistics, Govt. of Kerala, p.127.

Seasons and Crop Report of Kerala State - 1986-87, (1988) : Department of Economics and Statistics, Govt. of Kerala, p.102.

Seasons and Crop Report of Kerala State - 1987-88, (1992) : Department of Economics and Statistics, Govt. of Kerala, p. 102.

*Sen, A.K., (1957) : Land and Agricultural Planning in Matpalsa, Birbhum, *Geographical Review of India*, Vol. 19, No.4..

Sen, Chandra., (1986) : Land Use Patterns in Hills of Uttar Pradesh - An Ecological Abuse, *The National Geographical Journal of India*, Vol. X X X I I , No.2.

Shafi, M., (1960) : Measurement of Agricultural Efficiency in Uttar Pradesh, *Economic Geography*, Vol. 36 pp 296-305.

Shafi, M., (1960) : Field Works in Land Use Research under Indian Conditions, Bombay Geographical Magazine, 8 & 9 (1).

Shafi, M., (1972) : Measurement of Agricultural Productivity of the Great Plains, The Geographer, Vol. 19, pp 4-13.

Shafi, M., (1984) Agricultural Productivity and Regional Imbalances - A Study of Uttar Pradesh, Concept Publishing Co., New Delhi.

Sharma, J.K., (1987) : Agricultural Land Utilization Planning and Development of Dharwad Taluk (Karnataka), *National Geographical Journal of India*, Vol. X X I I I., No.2. pp. 143-153.

Sharma, S.C., (1991) : Land Use Survey in Tarai Tract- A Study of Eastern Uttar Pradesh, Concept Publishing Co., New Delhi. p.386

Sharma, T.S., and Coutinho, O., (1983) : Growth of Irrigation and Its Impact on Crop Land Use and Crop Yield in Karnataka, Annals, NAGI, Vol. I I., No.2., pp.13-22.

Singh, Jasbir., Sandhu, Devinder Singh., and Gupta, Jai Prakash., (1990) : Dynamics of Agricultural Change - An Agricultural Atlas of India, Oxford and I B H, New Delhi.

Singh, Jasbir., and Dhillon, S.S., (1994) : Agricultural Geography, Tata Mc Graw Hill Publishing Co., New Delhi. P.443.

Singh, Surendra., (1982) : Identification and Phasing of Agricultural Developments in Rohlkhand, Uttar Pradesh, *National Geographical Journal of India*, Vol.X X V I I I , parts 1&2, pp.28-36.

Sohal, K.S., (1993) : Changes in Intensity of Cropping In Punjab, In "Sustainable Developmnt",Gupta, N.L.,and Gurjar, R.K.,(ed).

Srivastava, S.L., (1983) Regional Disparities in Agricultural Development in Madhya Pradesh, Indian Journal of Regional Science, Vol. X V., pp. 55-60

Statistics For Planning - 1980, (1981) : Bureau of Economics and Statistics, Govt. of Kerala, p.290.

Statistics For Planning - 1983, (1984) : Directorate of Economics and Statistics, Govt. of Kerala, p. 381.

Statistics For Planning - 1988, (1988) : Directorate of Economics and Statistics, Govt. of Kerala, p.302.

*Subrahmanyam, V.P., (1956) The Water Balance of India According to Thornthwaite's Concept of Potential Evapotranspiration, *Annals of American Geographers*, Vol. 46, No.3, pp 300-311.

Subrahmanyam, V.P., (1956) : Climatic types of India according to the Rational classification of Thornthwaite, *Indian Jr. Met. Geophy*, Vol. 7, No.3, pp. 253-264.

Subrahmanyam, V.P., (1958) The Climatic Types of India in Relation to the Distribution of Natural Vegetation, *Indian Geographer*, Vol. 2 & 3 No. 1 & 2. pp 1-12.

Subrahmanyam, V.P., and Subramaniam, A.R., (1964) : Application of Water Balance Concept for a Climatic Study of Droughts in South India, *Indian Jr. Met. Geophys.*, Vol.15, No.3. pp 393-402.

Subrahmanyam, V.P., Subba Rao, B., and Subramaniam, A.R.S., (1965) : Koeppen and Thornthwaite's System of Climatic Classification as Applied to India, *Annals of Arid Zone*, Vol. 4, No. 1, pp. 46-55.

*Subrahmanyam, V.P., (1967) : The Problems of the Incidence and spread of Continental droughts, Report on WMO / IHD Project, Rep. No. 2., Geneva.

*Subrahmanyam, V.P., and Sastri, C.V.S., (1969) : Some Aspects of Drought Climatology of Dry Sub Humid zones of South India, J.Met.Soc.Japan, Vol. 47, pp 239-249.

*Subrahmanyam, V.P., (1972) : Water Balance an Eco-Climatic Planning, Publications in Climatology, Centron, New Jercey, pp.46-57

Subrahmanyam, V.P., and Ram Mohan, H.S., (1980) : Classification of Monsoon Climates and the Stability of their Moisture

Regime,Stat.Climate.Dev.in Atmos.Sci., Elsevier Pub.Vol.13, pp. 335-348.

Subrahmanyam, V.P., (!982) : Water Balance and Its Application with Special Reference to India, Andhra University Press, Waltair. P.102.

Subrahmanyam, V.P., (ed.) (1983) Cotributions to Indian Geography, III, General Climatilogy, Heritage Publications, New Delhi, p. 329.

Subrahmanyam, V.P., (ed.) (1983) : Cotributions to Indian Geography, IV, Applied Climatilogy, Heritage Publications, New Delhi, p. 223.

Subramaniam, A.R., and Raju, Narasimha P.A., (1987) : Water Requirements of Crops in North Coastal Andhra, *Mausam*, Vol.38, No.1. pp 59-62.

Subramaniam, A.R., and Srimannarayana, T., (1991) : Climatic Studies of Madhya Pradesh, Trans. Inst.Indian Geographers, Vol.13, No.1,pp 73-81.

Swaminathan, M S., (1987) Abnormal Monsoons and Economic Consequences - The Indian experience, In "Monsoons", Fein, J.S., and Stephen, Pamela L., (ed.). Pp .121-133.

Takahashi, K., and Yoshino, M.M., (1978) : Climate Change and Food Production, University of Tokyo Press, Tokyo.

Tanaka, M., (1978) : Synoptic Study on Recent Change in Monsoon Asia and its Influence on Agricultural Production, In "Climata Change and Food Production", Takahashi, K., and Yoshino, M.M., (ed.).

Thomas, D., (1963) : Agriculture in the Wales During Napoleonic Wars, Cardiff, University of Wales Press.

Thompson, Louis M., (1986) Climate Change, Weather Variability and Corn Production, *Agronomy Journal*, Vol.78, pp 649-653.

*Thornthwaite, C.W., (1948) An Approach towards a rational Classification of Climate, *Geographical Review*, Vol.38, No.1.pp 55-94.

*Thornthwaite, C.W., and Mather, J.R., (1955) : The Water Balance Publication in Climate, Lab.Climat. Centerton, N.J., Vol.8, No.1.

Vidyanath, V., (1986) : Agricultural Regionalisation of Andhra Pradesh, *Annals*, NAGI, Vol. V I, No2. Pp 49-56.

Virmani, S.M., (1991) : Statistics and Agroclimate Assessment, Proc. National Symp. Stat. Methodology for Dyrland Agri., CRICA, Hyderabad.

Venkitaraman, S., and Krishnan, A., (1992) : Crops and Weather, ICAR, New Delhi, p.586.

Venkitaraman, S., and Rahi, A.K., (1983) Influence of Temperature Climatology on Productivity of Wheat Crop in India, *Mausam*, Vol.34, No.1.

Yoshino, M.M., (ed.) (1984) : Climate and Agricultural Land Use in Monsoon Asia, University of Tokyo Press, Tokyo.

Weaver, J.C., (1954) : Crop Combination Regions in the Middle West, *Geographical Review*, X L I V, pp 176-181.

* Not referred to in original