DELINEATING THE VARIOUS AGROCLIMATIC ZONES OF KERALA AND IDENTIFYING THE CROPPING PATTERNS FOR THE DIFFERENT ZONES

By

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THESIS

submitted in partial fulfilment of

the requirement for the degree

Master of Science (Agriculture)

Faculty of Agriculture

Kerala Agricultural University

Department of Agronomy

COLLEGE OF HORTICULTURE

Vellanikkara - Trichur

1986

D E C L A R A T I O N

I hereby declare that this thesis entitled "Delineating the various agroclimatic zones of Kerala and identifying the cropping patterns for the different zones" is a bonafide record of research work done by me during the course of research and this thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any other university or society to me.

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C E R T I F I C A T E

Certified that this thesis entitled "Delineating the various agroclimatic zones of Kerala and identifying the cropping patterns for the different zones" is a record of research work done independently by Mr. Karmachandran K.M. under my guidence and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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C E R T I F I C A T E

We the undersigned members of the advisory committee of Mr. Karmachandran K.M. a candidate for the degree of Master of Science in Agriculture with major in Agronomy agree that the thesis entitled "Delineating the various agroclimatic zones of Kerala and identifying the cropping patterns for the different zones" may be submitted by Mr. Karmachandran K.M. in partial fulfilment of the requirement for the degree.

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To My Parents

A C K N O W L E D G E M E N T

I wish to place on record, my deep sense of gratitude to Dr. P. Balakrishna Pillai, Chairman of my Advisory Committee and Professor, Department of Agrometeorology for his inspiring guidance, sustained interest and constructive criticism throughout the period of investigation and preparation of the manuscript.

I also wish to express my gratitude to the members of my advisory committee Sri. A.V.R. Kesava Rao, Assistant Professor, Department of Agrometeorology, Dr. C. Sreedharan, Professor and Head, Department of Agronomy and Sri. V.K.G. Unnithan, Associate Professor, Department of Agricultural Statistics for the timely advice and keen interest they showed in this investigation.

I am extremely thankful to Dr. P. K. Gopalakrishnan, Associate Dean, College of Horticulture for providing the necessary facilities in time to carry out the study.

I express my sincere thanks to Sri. M.V. Sasidharan, Professional Assistant, Meteorological

Centre, Trivandrum for his advices which resulted in the acquisition of rainfall data in time and to Sri. George H. Hargreaves, Utah State University for sending the publications necessary for this study.

I am grateful to Sri. P.S. Nair for his keen interest and valuable advice for the completion of this study.

I am indebted to Sri. Sunny Philip, Agricultural Extension Officer, Canara Bank, Pollachi, for his sincere help in collecting Parambikulam data.

My sincere thanks are due to Sri. M.G.K. Nair, Dr. Shravankumar V. and Sri. Muraleedharan of the Centre for Earth Science Studies (CESS), Trivandrum, Smt. Sreedevi Amma, Additional Director, Directorate of Economics and Statistics, Trivandrum, Sri. Julius Joseph, Meteorologist, Meteorological Centre, Trivandrum, Sri. Prabhakaran, Superintendent, 'A' Section, Land Revenue Division, Revenue Board, Trivandrum and Sri. Premachandran, Assistant Director of Agriculture, Soil Survey Branch, Department of Agriculture, Trivandrum for the kind consideration and helps extended to me.

I am extremely thankful to the officers of the institutions like Geological Survey of India, Trivandrum, research stations of Kerala Agricultural University, Project offices of Idukki, Edamalayar and Parambikulam Projects, Vidyuth Bhavan, Trivandrum and the Directorate of Economics and Statistics, Trivandrum for their whole hearted co-operation.

The encouragement and support of the staff and students of the Departments of Agronomy and Agrometeorology and my friends have helped me a lot in completing this investigation and I shall ever be grateful to them.

My father, mother and sister have always been a constant source of encouragement to me in completing this study.

I gratefully acknowledge the financial assistance of the Government of Kerala during the period of my study.

My sincere thanks are due to Sri. Sidharthan. P.S. for typing this thesis neatly.

Above all, I thank God for the blessings showered upon me, without which this work would not have been possible.

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CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

Figure No.

LIST OF ABBREVIATIONS

AE	Actual Evapotranspiration
CV	Coefficient of Variation
I_a	Aridity Index
ICAR	Indian Council of Agricultural Research
I_h	Humidity Index
I_{ma}	Index of Moisture Adequacy
MAI	Moisture Availability Index
MAR	Moisture Availability Regime(s)
M.S.L.	Mean Sea Level
N.E. Monsoon	North-East Monsoon
P	Precipitation
PD	Dependable Precipitation
PE	Potential Evapotranspiration
S.W. Monsoon	South-West Monsoon
WD	Water Deficit
WS	Water Surplus
A_{Fl}	Dry - Forest loam
B_{Rl}	Semi dry - Red loam
B_{La}	Semi dry - Laterite
B_{Al}	Semi dry - Alluvium
B_{Bs}	Semi dry - Black soil

B_{Fl}	Semi dry - Forest loam
C_{Rl}	Sub humid - Red loam
C_{La}	Sub humid - Laterite
C_{Al}	Sub humid - Alluvium
C_{Sa}	Sub humid - Saline
C_{Fl}	Sub humid - Forest loam
D_{La}	Humid - Laterite
D_{Al}	Humid - Alluvium
D_{Go}	Humid - Greyish Onattukara
D_{Sa}	Humid - Saline
D_{Fl}	Humid - Forest loam
E_{La}	Per humid - Laterite
E_{Fl}	Per humid - Forest loam
F_{La}	Wet - Laterite
F_{Fl}	Wet - Forest loam

INTRODUCTION

INTRODUCTION

Kerala is predominantly an agricultural state. The total cropped area in Kerala is approximately 2,861,700 hectares. But the per head holding is only 0.09 ha. and this is very low when compared to the world average of 4 to 5 hectares. Seventy per cent of the population is engaged in agricultural activities one way or the other, and thus agriculture constitutes the key sector of the economy of the state. It, therefore, becomes evident that the improvement of economy of the state depends to a considerable extent on the development of agriculture.

Agriculture and weather science are very closely related. This is because the growth of plants or animals is primarily influenced by the physical condition of the environment in which they live. Therefore, knowledge of the interaction of weather and crop production becomes unavoidable in agricultural planning. The importance of this is being increasingly appreciated since the past few decades.

Crop combination is the most important aspect of study in Agricultural Meteorology for

rural planning. Due to the high density and annual rate of growth of population, it becomes necessary to produce more. Since the extent of the usable area is limited (indeed, it is gradually diminishing as days go by), it becomes imperative that cultivation has to be intensive, so as to increase productivity. One of the ways of achieving this is to determine the most appropriate crop combination and adopting the same with efficiency. Such a policy entails the identification of the proper and optimal combinations of environmental factors suitable for the chosen crop combination, the study of which will be of considerable help in planning developmental activities, especially of the rural areas.

The need for a systematic delineation of agroclimatic zones of the state and adoption of suitable cropping patterns is more urgent today than at any time in the history of this state. This is essential for ensuring the most rational use of land and increasing productivity per unit area per unit time.

Regionalisation on the basis of agroclimatic parameters is one way of bringing about homogeneity in

areas for identifying the key constraints that inhibit the process of development. Identification of such constraints is necessary for undertaking relevant programmes for agricultural development and prescribing recommendations of improved varieties. Suitable cropping pattern identified for each of the zones can be a valuable tool in planning production strategies.

The National Commission on Agriculture (1976) demarcated homogeneous agroclimatic zones of Kerala. Rainfall patterns formed the basis of demarcation. But under the conditions prevailing in Kerala it was found inadequate to explain the variations in agroclimatic conditions and the existing cropping patterns. The geological formation and the resultant physiographical features have tremendously influenced the rainfall and topography which in turn led to the evolution of soil complexes, cropping patterns and other potentials for agricultural development of the state. In designing cropping patterns for an area the critical agronomic conditions are to be identified. Such critical factors are temperature, availability of sunlight, seasonal moisture availability and drainage conditions

during the rains. Combinations of these factors are critical for a cropping pattern to flourish. It is true that while suggesting suitable cropping patterns economic criteria will also have to be given due attention, apart from the agronomic possibilities.

Hargreaves (1975) suggested an agro-climatic classification considering the length of the growing season based on the Moisture Availability Index (ratio of 75% probability rainfall to the potential evapotranspiration). It is felt that this classification will be most appropriate with some modification and hence it is adopted in the present study of delineation of agroclimatic zones of Kerala and identification of cropping patterns.

Considering all these aspects the present study was taken up with the following objectives.

(i) To demarcate the state into various agroclimatic zones.

(ii) To identify cropping patterns.

(iii) To examine the suitability of existing cropping patterns.

(iv) To suggest modification/improvements in the existing cropping pattern, in the light of the above.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Literature pertaining to the delineation of agroclimatic zones and identification of cropping patterns are briefly reviewed in this chapter.

2.1. Potential Evapotranspiration

The widely accepted concept of potential evapotranspiration (PE) was put forth by Thornthwaite (1948) and Penman (1948) independently.

Thornthwaite (1948) defined potential evapotranspiration as 'the maximum amount of water that would evaporate and transpire from a thickly vegetated extensive territory with no deficiency of water for full use at any time'.

Penman et al. (1956) defined it as the 'evaporation from an extended surface of short green crop, actively growing, completely shading the ground of uniform height and not short of water'. Given these strict conditions Penman argues that evapotranspiration will be primarily determined by climatic factors with some differences due to different albedos and stomatal resistance.

The definitions were synthesized by Rosenberg (1974) as follows: potential evapotranspiration is

the evaporation from an extended surface of short green crop which fully shades the ground, exerts little or negligible resistance to the flow of water, and is always supplied with water. PE cannot exceed free water evaporation under the same weather conditions. ETM is the real maximum evapotranspiration; a special case of the real evapotranspiration ETR. These quantities are ordered in magnitude according to ETR $\leq$ ETM $\leq$ PE.

The biological and physical importance of evapotranspiration in climatic delineation has been described by Thornthwaite (1948). He developed an equation for estimating potential evapotranspiration.

Sanderson (1950) measured the daily evaporation at Toronto over a vegetated soil surface and found that the ETP (PE) predicted by the Thornthwaite formula compared favourably with measured values.

Palmer and Havens (1958) provided a graphical solution for Thornthwaite's equation.

Computed values of thermal efficiency (same as PE) for several Indian stations according to Thornthwaite formula were first reported by Subrahmanyam (1956 a).

Subramaniam and Rao (1980) reported that the

work on the measurement of evapotranspiration using various devices such as atmometers, evaporation pans, lysimeters, evapotrons, etc. began simultaneously with the development of the physics of evaporation. They have mentioned that, with the instruments having their own limitations and high cost, it was difficult to cover measurements for large areas and consequently several workers began estimating PE values from climatological data. Their studies show that the PE values computed using the Thornthwaite formula were in better agreement in perhumid (in Vengurla), humid (in Bombay) and subhumid (in Chanda) climates whereas the deviations were more from semiarid and arid climates.

Subrahmanyam and Hemamalini (1977) computed thermal efficiency values for thirteen stations in Andhra Pradesh.

2.2. Dependable Precipitation

Information on mean rainfall has little value in rainfed agriculture. For understanding the probability of success in cropping, one must consider the assured rainfall received in three out of four years, which is otherwise known as dependable precipitation (PD), dependable rainfall or 75 per cent probability rainfall.

Hargreaves and Vogler (1984) have discussed several methods which are useful in quantifying precipitation in a particular area and pointed out that mean or average rainfall is not a reliable index for technology transfer in agriculture. They reported that some form of probability distribution should be employed, and for purposes of planning irrigation and agricultural developments the 75 per cent probability of assured rainfall had been used as dependable rainfall (PE). They have further stated that a simple ranking of rainfall amounts to determine the 75 per cent probability produced good results, particularly for records of 20 years length or more.

Dependable precipitation is defined as the amount that is normally equalled or exceeded three fourths of the time (Hargreaves, 1982). It is the 75 per cent statistical probability of occurrence (or exceedence) of rainfall.

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

Use of probabilities of monthly total rainfall for agronomic purposes has been reported (Manning, 1956; Balaca and Sridharan, 1966).

Use of initial and conditional rainfall probabilities for obtaining agronomically relevant information (Virmani et al. 1978) has been reported.

Venkataraman (1978), based on weekly rainfall probabilities, suggested that in Satara, Sangli and Ahmed Nagar, Kharif crops can be raised only under irrigation.

2.3. Water Balance

Thornthwaite (1948) evolved a book keeping procedure from which it is possible to calculate actual evapotranspiration (AE), water surplus (WS) and water deficit (WD), by camparing PE and rainfall.

Thornthwaite and Mather (1955) revised assumptions and methods of computations of the book keeping procedure. They also defined two indices Humidity Index (I_h) and Aridity Index (I_a) as WS/PE and WD/PE respectively both expressed as percentages.

The water balance of India according to these modified concepts was discussed by Subrahmanyam (1956 b).

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

Subrahmanyam et al. (1980) presented the climatic water budget for Andhra Pradesh as a whole.

Subramaniam and Rao (1979 & 1980) studied the broad scale patterns of water balance for Rajastan with particular reference to its latitudinal and longitudinal variation.

Subramaniam and Rao (1981) compared the spatial distribution of annual I_{ma} with crop combination maps for Maharashtra.

Subramaniam and Murthy (1982) calculated the climatic water balances of 5 stations of Kerala state. They also classified climates of Kerala both on thermal and moisture regimes following Thornthwaite's scheme.

Water balance and crops in Karnataka was presented by Subramaniam and Rao (1982). They calculated climatic water balance elements and water balance indices for all the meteorological stations in the state. They compared the general distribution of crops and I_{ma} to identify the limits for certain crops.

Swaminadhan and Shanthakumari (1983) studied water balance for selected stations in Madurai district of Tamil Nadu to find out the water surplus/deficit and to suggest the cropping season. They proposed to suggest suitable cropping seasons for the district.

Vinayak (1983) studied water balance elements and indices for 6 stations in Kerala for finding the impact of soil moisture conditions on crop yields.

Monthly and weekly water balances of a dry sub humid coastal station of Andhra Pradesh, Chirala were presented by Subramaniam and Rao (1985). They used the concept of aridity to identify the drought years with different intensities and also delineated water availability periods.

2.4. Moisture Availability Index

Hargreaves (1971) defined the MAI as the

dependable precipitation divided by potential evapotranspiration. He gave equations and methods for its computation.

Hargreaves (1983) suggested MAI as a convenient indicator of water available from rainfall. He reports that the values of MAI can be used for the following purposes:

1) to determine the desirability and/or economics of various cropping systems and practices, including plant densities, fertilization rates and surface drainage methods,

2) to suggest the type or method of surface drainage that will produce the best results; and

3) as a valuable criterion for agricultural technology transfer.

According to Hargreaves et al. (1985), 'A value of MAI of 0.33 or less for one month during the crop growing season is considered to be a danger signal. Production will probably drop below an economic level. This will depend to an important degree both upon the crop grown and upon the corresponding crop growth stage. If the average MAI value for the crop growing season is less than 0.50, then the use of

fertilizers may not be economical. This will also depend upon the crop grown and upon the level of other inputs. Whenever a monthly value exceeds 1.20 or 1.33 then there is indicated to be a need except for rice, of good natural or artificial drainage'. They further state that under rainfed conditions an estimate of water balance is essential for determining potential crop production and that the moisture availability index provide an estimate of the climatic water balance.

High-lighting the usefulness of MAI in evaluating the contribution of rainfall to agricultural production and in agricultural technology transfer, Hargreaves and Vogler (1984) have mentioned that MAI can be calculated for 7, 10, 15 day and one month periods.

2.5. Agroclimatic Classification

In recent years the topic of agroclimatic classification has assumed immense importance in the field of applied climatology. Attempts to classify climates were made from time to time by several workers in the past.

Köppen (1936) divided the world climate into five principal groups (A to E) taking temperature as

the main criterion for classification.

In his paper on 'Problems in the classification of climates' Thornthwaite (1943) emphasised the need for a rational approach in the classification of climatic types for different purposes. Thornthwaite himself amply fulfilled this need later (Thornthwaite, 1948) by proposing a scheme based on fundamental considerations of thermal and moisture effectivities. He used precipitation and potential evapotranspiration in classifying the climate and estimating the soil water balance. Thornthwaite and Mather (1955) took into account monthly mean precipitation and estimated potential evapotranspiration using temperature and water holding capacity of the soil.

A complete classification of the climates of India and the neighbourhood according to the above scheme of Thornthwaite was reported by Subrahmanyam (1956 a).

Subrahmanyam and Ram Mohan (1960) have classified the south-west coast of India under monsoon climate. Subrahmanyam et al. (1965) found that according to the final scheme of Köppen (1936), Kerala comes under monsoon climate.

Emphasising the reasons and need for

classifying climates, Virmani (1980) states that there are two functions of climatic classification. First to identify, organise and name climatic types in an orderly fashion and stimulate the revelation and formulation of relationships within the climatic population. Second to serve as a base for application of technology, for the interpretation of resources as classified and delineated on soil climatic maps and for the transfer of experience. He has further stated that an infinity of combinations of primary and secondary climatic elements could in principle be created by factorial combination and thus, there would be a philosophic problem of reducing the continiua to a finite number of discrete units or classes, and that the global climatic classifications being primarily conceptual, there would be inherent artificiality of boundaries.

Gadgil and Joshi (1980) have stated that it might not be possible for two places to have identical climate. According to them the objective of climatic classification is to group the innumberable individual climates in such a way that all those having certain characteristics in common belong to one class.

Subrahmanyam and Hemamalini (1979) presenting

the moisture regime of climate of Andhra Pradesh remark that the thermal efficiency of the climate in a tropical country like India is more than adequate to support dense forest types of vegetation. According to them it is only the moisture regime that determines the vegetational development.

Subramaniam and Murthy (1963) classified the climates of Kerala into tropical monsoon and tropical savanna type climates. According to this a small portion of Calicut and Cannanore districts, over 50 per cent of Kottayam and Alleppey districts, entire Quilon and Trivandrum district come under tropical savanna and the rest under tropical monsoon type of climate. They calculated water balance elements and indices of 5 stations in Kerala according to Thornthwaite's scheme of classification (1955). It is reported to be found that a major part of Cannanore comes under perhumid (A) type of climate. Trivandrum, a part of Kottayam, narrow strip of Kozhikode and Cannanore districts come under moist subhumid type (C_2) and the rest of the state come under humid (B) type of climate.

Troll (1965) classified the tropical climates on the basis of broad rainfall groups in relation to

potential evapotranspiration. A humid month is defined as a month with mean rainfall exceeding PE. It appears (Walter et al. 1975) that Troll defined a humid month as any month with mean monthly rainfall (R, in m.m) exceeding twice the mean monthly average temperature (T in °C), i.e. $R \geq 2T$ following Gaussen (1954).

Papadakis (1966) used mean annual minimum temperature, frost free season, average daily maximum or minimum temperature for the key months and periods of the year, water balance and the occurence of dry and wet seasons in classifying the climate. His classification is much oriented towards agriculture and crop requirements with the limiting criteria chosen to represent values of significance for crop plants. Papadakis (1975) gave further description of the climatic restraints, soil limitations, farming systems and possibilities in dry tropics and sub-tropics.

Describing the characters of the tropical climate, Virmani et al. (1980) have stated that rainfall in the tropics varied from practically zero to more than 8000 m.m. per year, some areas receive 400 m.m. per month which under any circumstance exceed the monthly evapotranspiration, and on the other hand,

tropical deserts receive no precipitation in any month of most years. The presence of climatic types with alternating wet and dry seasons with one or two rains per year, in between the above two extremes, is also indicated. They also stated that quantification of climate for agricultural production should be based upon the ability of the climate to meet crop demand for water and the suitability of the thermal regime.

Williams and Masterton (1980) point out that for agricultural development planning, adequate assessment of the agroclimatic reasources is an essential prerequisite. According to them the agroclimatic zonation work in Sao Paulo State, Brazil (Estado de Sao Paulo, 1974, 1977) is an outstanding example for such an assessment.

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

Nair (1973 a) proposed an alternative

approach to the delineation of agroclimatic regions and identification of cropping patterns in Kerala in the committee on agroclimatic zones and cropping patterns appointed by the Government of Kerala.

The committee on agroclimatic zones and cropping patterns, in their report (Anonymous, 1974) have delineated thirteen agroclimatic zones in Kerala based on variations in rainfall, altitude, topography and soil. However, the study was carried out in the absence of adequate data based on scientific investigation.

Hargreaves (1971) defined various degrees of moisture adequancy or deficit in statistical terms in such a manner as to provide a standard description of moisture adequacy for agricultural production. He also suggested defixation of climatic classification for arid zones. Hargreaves (1975) showed a broad relationship between M-I and moisture deficit classification.

Hargreaves (1983) has suggested that a better understanding and use of climatic information should be an integral part of attempts to increase agricultural production in developing countries. He further stated that in very mountaneous countries with complex patterns

of rainfall regimes and wide variations in temperature, useful agroecological zoning requires many data points and large scale mapping.

Hargreaves and Vogler (1984) suggested that in technology transfer in agriculture water resources should be considered in combination with energy and soil characteristics.

Hargreaves et al. (1965) have reported that when the climatic and phenologic requirements (of crops) are met, the temperature and radiation determine limits to crop production. In their attempt towards zonation of different areas in India, a small mountaneous area to the east of Kerala was not zoned, as rainfall is variable and does not fit into the criteria used for other zones. They have stated that agrotechnology transfer between similar conditions had frequently been successful. They have proposed the following conditions for similarity in climatic conditions.

1) Rainfall similar in amount, distribution and intensity.
2) The values of PE approximately equal.
3) The mean values of temperature nearly the same.

4) The differences between mean maximum and mean minimum temperatures nearly equal; and

5) Latitude and day length not too different for crops that are sensitive to this factor.

Virmani (1980) pointed out that the assessment of land for agricultural potential is one of the primary uses of information on climatic classification and that it should be based on the information on soils and climate, since within a 'climatic type' several 'soil types' are likely to occur and any land use potential based on climatic parameters alone is not likely to be meaningful.

2.6. Cropping Patterns

National Commission on Agriculture (1976) defined cropping pattern as the distribution of crops in a taluk area whose total area is 70 per cent or higher of the gross cropped area and is the same over two or three adjoining taluk areas. For limiting the number of crops constituting a pattern, the commission has considered only those crops which individually occupy 10 percent or more of the gross cropped area of

the taluk. Trial computations by the commission have shown that the number of crops thus obtained in a cropping pattern hardly exceeds five.

Thornthwaite and Mather (1955) termed the ratio of actual evapotranspiration (AE) to potential evapotranspiration (PE) as the Index of Moisture Adequacy (I_{ma}) which is expressed as percentage. They reported that the values of I_{ma} vary with the available soil moisture.

Various water balance parameters were studied in relation to cropping patterns in India. Subrahmanyam et al. (1963) found that the distribution of I_{ma} agreed fairly with the cropping pattern of some of the major crops in the Indian subcontinent. Further studies on regional basis had been made by various researchers.

In their paper 'Water balance and crops in Karnataka', Subramaniam and Rao (1982) observed that in the case of kharif jowar good yields can be expected in places where I_{ma} is more than 70 per cent.

Subramaniam and Rao (1985) worked out the various water balance elements in different parts of Rajastan. Their study indicated the need for change in the existing cropping pattern.

Subramaniam and Rao (1979) attempted to relate seasonal I_{ma} and cropping pattern of 4 deltaic districts of Andhra Pradesh.

Swaminadhan and Sundarameenakshi (1985) calculated water surplus and water deficit for Ramanathapuram, a draught prone district of Tamil Nadu. Based on the water balance analysis and cropping pattern, suggestions were given for planning and development of agricultural resources.

Water balance studies on Trivandrum and its vicinity by Subramaniam and Vinayak (1982) indicated an assured level of moisture adequacy over 60 per cent enabling support of various crops requiring high moisture level.

Subramaniam and Rao (1984) who compared the general distribution of crops and I_{ma} to identify the limits for certain crops observed that in case of Kharif jowar good yields could be expected in places where the I_{ma} is more than 70 per cent.

The committee on agroclimatic zones and cropping patterns, in their report (Anonymous, 1974) have remarked that the existing cropping patterns are the cumulative effort of the generations of farmers who through trial and error have evolved a system based on natural resource

endowments as latitude, rainfall, topography, soil etc. and that the configuration of these factors influence in evolving a singular agronomic environment where a particular cropping pattern fits in.

According to Nair (1973 b) who put forward an approach towards designing the optimum cropping patterns for Kerala, one has to look into the basic characteristic of the environment complex and juxtapose the agronomic requirements of crops to obtain the optimum crop combinations suited for the region.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present work was undertaken with the object of delineating the various agroclimatic zones of Kerala and identifying the cropping patterns.

3.1. Collection of Data

3.1.1. Data on Geography and Topography.

Data regarding latitude, longitude and altitude of different places in the state were obtained from the Centre for Earth Science Studies, Trivandrum. Topography map of the state was obtained from the Geological Survey of India, Trivandrum.

3.1.2. Meteorological Data.

Meteorological data were collected from 11 stations of Kerala Agricultural University, 7 stations of India Meteorological Department, and 82 stations maintained by the State Government and other agencies like Idukki, Edamalayar and Parambikulam projects. The available data found useful for the study were collected for the period 1901-80.

Table 1. shows the name, latitude and longitude of the stations under present study as well as the period of data used for agroclimatic classification.

Table 1. Stations and data used in agroclimatic classification

Name of station	+ + Latitude °N	+ + Longitude °E	Period of data available
(1)	(2)	(3)	(4)
Kasaragod	12°31'	74°59'	1901-80
			1979-81 *
Hosdurg	12°18'	75°06'	1901-80
Payyannur	12°06'	75°12'	1901-80
Taliparamba	12°03'	75°21'	1901-80
Irikkur	11°58'	75°33'	1901-80
Cannanore	11°52'	75°22'	1901-80
Telechery	10°45'	75°30'	1901-80
Mananthody	11°48'	76°01'	1901-80
Ambalavayal	11°38'	76°13'	1961-83 **
Vythiri	11°33'	76°02'	1901-80
Kuttiyadi	11°40'	75°49'	1901-80
Badagara	11°36'	75°35'	1901-80
Quilandi	11°27'	75°42'	1901-80
Calicut	11°15'	75°47'	1901-80
			1931-80 *
Nilambur	11°17'	76°14'	1901-80
Manjeri	11°07'	76°08'	1902-80
Thirurangadi	11°03'	75°55'	1901-80
Perinthalmanna	10°58'	76°14'	1901-80
Ponnani	10°47'	75°55'	1901-80
Mannarghat	10°59'	76°28'	1901-80
Cherpulassery	10°52'	76°19'	1901-80
Parali	10°48'	76°33'	1901-80
Pattambi	10°48'	76°12'	1973-83 *
Ottappalam	10°47'	76°23'	1901-80

Table 1. (continued)

(1)	(2)	(3)	(4)
Palghat	10°46'	76°39'	1901-80
			1951-80 *
Chittur	10°42'	76°44'	1901-80
Alathur	10°38'	76°33'	1906-50
Thalappilly	10°40'	76°15'	1907-80
Chowghat	10°34'	76°03'	1901-50
Ollukkara	10°32'	76°16'	1961-84 **
Trichur	10°31'	76°13'	1901-80
Triprayar	10°22'	76°08'	1901-50
Mukundapuram	10°15'	76°10'	1907-80
Cranganore	10°13'	76°12'	1907-80
Malayattur	10°12'	76°31'	1905-80
Parur	10°09'	76°13'	1901-80
Perumbavur	10°07'	76°29'	1901-80
Alwaye	10°07'	76°21'	1916-80
Neriyamangalam	10°03'	76°47'	1935-80
Ernakulam	9°59'	76°17'	1901-80
Cochin(B)	9°58'	76°14'	1931-80 *
Fort Cochin	9°58'	76°14'	1901-80
Muvattupuzha	9°58'	76°35'	1901-80
Marayur	10°16'	77°09'	1916-80
Munnar	10°06'	77°04'	1916-80
Devikulam	10°04'	77°06'	1905-80
Santhampara	9°58'	77°14'	1908-50
Velur	9°54'	76°50'	1961-80
Chinnar	9°52'	77°06'	1908-50
Karikode	9°50'	76°40'	1901-80
Idukki	9°51'	76°55'	1978-85 *
Vandenmedu	9°43'	77°08'	1929-80
Kumily	9°35'	77°10'	1908-50
Peermade	9°34'	76°59'	1908-80

Table 1. (Continued)

(1)	(2)	(3)	(4)
Vaikom	9°45'	76°24'	1901-30
Ettumanur	9°40'	76°34'	1901-30
Palai	9°36'	76°45'	1901-30
Kottayam	9°35'	76°32'	1901-30
			1973-83 *
Kanjirappally	9°34'	76°47'	1905-50
Changanacherry	9°27'	76°33'	1901-30
Arulutty	9°52'	76°20'	1906-30
Shertallai	9°42'	76°20'	1901-30
Alleppey	9°33'	76°20'	1941-50
			1951-80 *
Ambalapuzha	9°23'	76°22'	1901-30
Chengannur	9°19'	76°37'	1901-30
Haripad	9°17'	76°27'	1901-30
Mavelikara	9°15'	76°32'	1901-30
Kayamkulam	9°11'	76°30'	1905-30
Thiruvalla	9°23'	76°33'	1901-30
Pathanamthitta	9°16'	76°46'	1905-30
Konni	9°13'	76°51'	1905-30
Adoor	9°09'	76°44'	1901-30
Karunagappally	9°04'	76°32'	1901-30
Kottarakkara	9°01'	76°46'	1901-30
Punalur	9°00'	76°55'	1901-30
			1961-80 *
Aryankavu	8°59'	77°10'	1905-30
Quilon	8°53'	76°36'	1905-30
Nilamel	8°50'	76°53'	1946-80
Paravoor	8°47'	76°40'	1905-30
Ponmudi	8°45'	77°07'	1951-80

Table 1. (Continued)

(1)	(2)	(3)	(4)
Varkala	8°43'	76°42'	1946-80
Attingal	8°42'	76°49'	1901-80
Nedumangad	8°36'	77°00'	1901-80
Trivandrum	8°29'	76°57'	1901-80
			1931-80 *
Neyyattinkara	8°23'	77°05'	1901-80
Parassala	8°20'	77°09'	1905-80

* Temperature data

** Temperature and rainfall data

Others : Rainfall data

+ + Source: Centre for Earth Science Studies, Trivandrum.

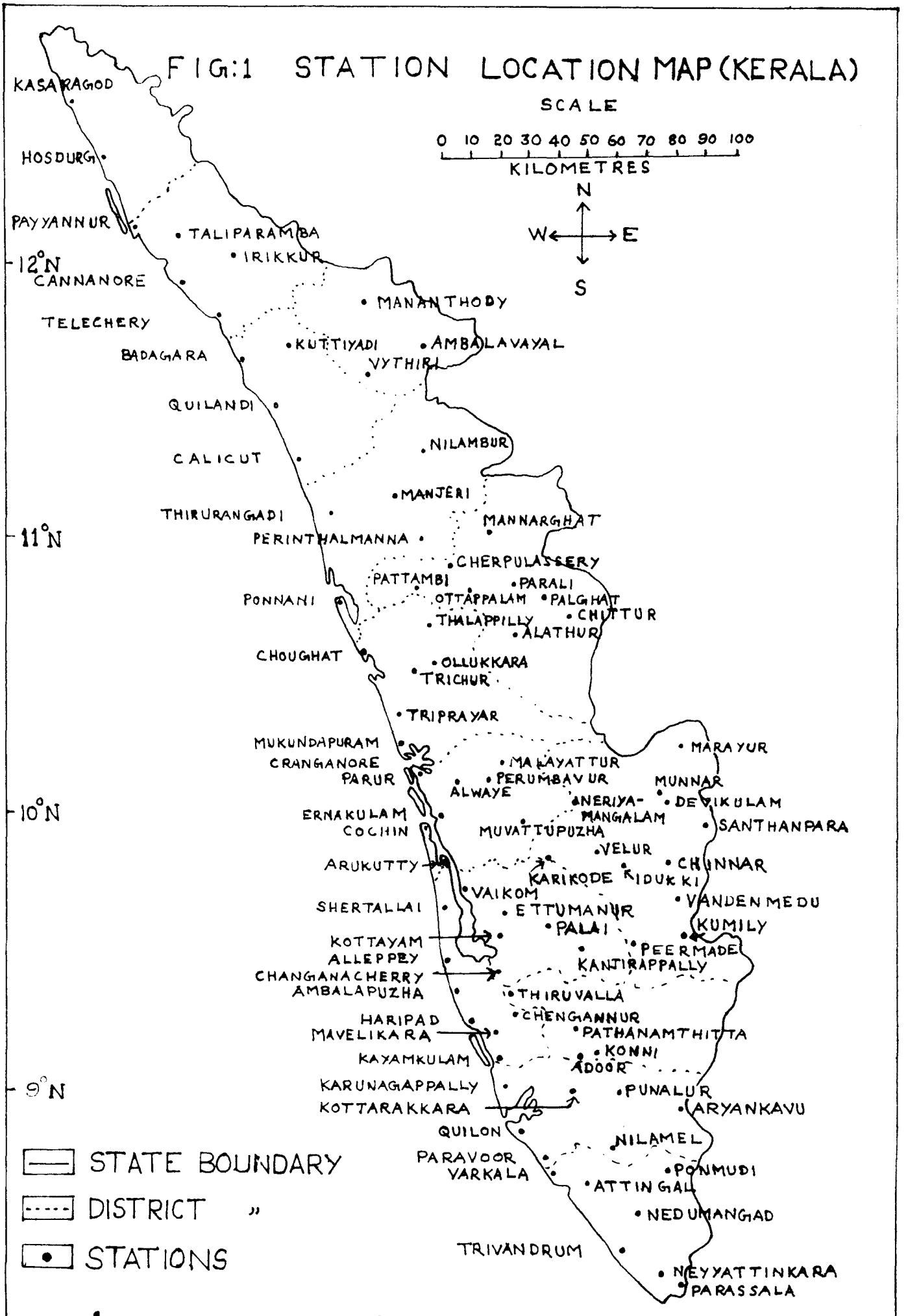


FIG:1 STATION LOCATION MAP (KERALA)
SCALE
0 10 20 30 40 50 60 70 80 90 100
KILOMETRES
N
W
E
S
KASARAGOD
HOSDURG
PAYYANNUR
TALIPARAMBA
IRIKKUR
12°N
CANNANORE
MANANTHODY
TELECHERY
KUTTIYADI
AMBALAVAYAL
BADAGARA
VYTHIRI
QUILANDI
NILAMBUR
CALICUT
MANJERI
THIRURANGADI
MANNARGHAT
11°N
PERINTHALMANNA
CHERPULASSERY
PATTAMBI
PARALI
PONNANI
OTTAPPALAM
PALGHAT
THALAPPILLY
CHITTUR
ALATHUR
CHOUGHAT
OLLUKKARA
TRICHUR
TRIPRAYAR
MUKUNDAPURAM
MARAYUR
CRANGANORE
MALAYATTUR
PARUR
PERUMBAVUR
MUNNAR
ALWAYE
NERIYA-MANGALAM
DEVIKULAM
10°N
ERNAKULAM
COCHIN
MUVATTUPUZHA
SANTHANPARA
VELUR
ARUKUTTY
CHINNAR
KARIKODE
IDUKKI
VAIKOM
VANDENMEDU
SHERTALLAI
ETTUMANUR
PALAI
KUMILY
KOTTAYAM
PEERMADE
ALLEPPEY
KANJIRAPPALLY
CHANGANACHERRY
AMBALAPUZHA
THIRUVALLA
CHENGANNUR
HARIPAD
PATHANAMTHITTA
MAVELIKARA
KONNI
KAYAMKULAM
ADOOR
9°N
KARUNAGAPPALLY
PUNALUR
KOTTARAKKARA
ARYANKAVU
QUILON
NILAMEL
PARAVOOR
VARKALA
PONMUDI
ATTINGAL
NEDUMANGAD
TRIVANDRUM
NEYYATTINKARA
PARASSALA
STATE BOUNDARY
DISTRICT "
STATIONS

Fig.1. depicts the location of the stations with district boundaries.

Data on humidity and wind speed were collected from the publication of India Meteorological Department (Anonymous, 1967). Sunshine data were collected from the Scientific Report of India Meteorological Department (Rao and Ganesan, 1971).

Mean temperature data for Cannanore, Ponnani and Quilon were obtained from the publication of Utah State University (Hargreaves et al. 1985).

3.1.3. Crop and Soil Data.

Crop data available at the Directorate of Economics and Statistics, Trivandrum and soil data available at the Soil Survey Wing, Department of Agriculture, Trivandrum at the village level were collected.

3.2. Methodology

3.2.1. Temperature.

The mean monthly maximum and minimum temperatures were computed for different stations, from which mean monthly temperatures were calculated.

Temperatures of the hottest month and the coldest month, and the mean annual temperature range were computed and discussed.

3.2.2. Relative Humidity and Wind Speed.

The monthly and annual means of relative humidity for 7 IMD stations are computed and discussed.

The monthly and annual values for average wind speed for different stations are tabulated and discussed.

3.2.3. Sunshine.

Mean daily duration of bright sunshine and maximum possible hours of sunshine are presented and discussed for 5 stations i.e. Kasaragod, Pattambi, Ollukkara, Kayamkulam and Trivandrum.

3.2.4. Rainfall.

The monthly rainfall data collected for about 80 years were tabulated station wise. Mean monthly rainfall for each of the 12 months as well as the mean annual rainfall for all the stations was computed. Mean seasonal rainfall for four seasons were also computed following India Meteorolo-

gical Department. The four seasons are as follows.

	Season	Period
1)	Winter	January and February
2)	Summer	March to May
3)	S.W. Monsoon	June to September
4)	N.E. Monsoon	October to December

Spatial variation of mean rainfall and its coefficient of variation for all the seasons and the year are diagramatically presented.

The rainfall received at 75 per cent probability level was used for classifying the agro-climates of Kerala. The rainfall received at 75 per cent probability level known as dependable rainfall (P) is the minimum rainfall expected to be received in 3 out of 4 years. A simple ranking method as described by Doorenbos and Pruitt (1977) and Oldeman and Frere (1982) was used for the computation of dependable rainfall for the stations in Kerala. The method is as follows:

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

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

Where, n = Number of records.

The rank number which has a probability level of 75 per cent was calculated. The rainfall record corresponding to this rank number gave the dependable rainfall.

The monthly values of dependable rainfall found in this manner were used for computing the MAI on monthly basis and subsequently for classifying agroclimates.

3.2.5. Potential Evapotranspiration (PE).

The concept of potential evapotranspiration put forward by Thornthwaite (1948) is widely accepted and utilised in various fields like climatic classification, water balance and others.

Thornthwaite considered temperature and possible number of sunshine hours for the estimation of potential evapotranspiration. The formula given by Thornthwaite for unadjusted potential evapotranspiration (e) is as follows:

$$e = 1.6 \left(\frac{10\ t}{I}\right)^{a}$$

where e = Monthly unadjusted potential evapotranspiration in cm/month,

t = Mean monthly temperature in °C,

I = annual heat index $(\sum_{i=1}^{12} i)$,

i = Monthly heat index and is equal to $(t/5)^{1.514}$

and a = non linear function of the heat index, approximated by expression,

$$a = 0.000000675\ I^3 - 0.0000771\ I^2 + 0.01792\ I + 0.49239.$$

The unadjusted potential evapotranspiration (e) so obtained is for average 12 hours of sunshine and 30 day month. The values can be adjusted by multiplying with a correction factor depending on the latitude and season.

The main advantage of Thornthwaite's method is that PE can be estimated if mean temperature data is available. Because of the simplicity of the method and relatively low data input, Thornthwaite's method is used in this study.

The monthly mean temperatures for 15 stations were first plotted on a map of Kerala from which the mean temperatures for all the raingauge stations were

interpolated, keeping in mind the altitude of the stations. Following Thornthwaite's method, computation of unadjusted potential evapotranspiration (e), was carried out which was later adjusted by multiplying with a correction factor depending on the latitude and season, to obtain corrected PE for all the months at each station.

3.2.6. Water Balance Studies.

All the water balance elements ie. actual evapotranspiration (AE), water surplus (WS) and water deficit (WD) were computed by the revised book keeping procedure of Thornthwaite and Mather (1955). The field capacity of the soil to hold moisture was assumed considering the type of soil and vegetation on the lines suggested by Thornthwaite.

Water balance indices such as humidity index (I_h), and aridity index (I_a) were calculated making use of the following formulae:

(1) Humidity Index $I_h = \frac{WS}{PE} \times 100$

(2) Aridity Index $I_a = \frac{WD}{PE} \times 100$

The water balance elements and indices for

14 stations in Kerala on annual basis are presented and discussed.

3.2.7. Moisture Availability Index.

The moisture availability index (MAI) provides an estimate of the climatic water balance which is essential for determining potential crop production under rainfed conditions. The MAI is a moisture adequacy index at the 75 per cent probability level of precipitation occurence. It is defined as the dependable precipitation (PD) divided by potential evapotranspiration (PE) and is computed as follows:

$$MAI = \frac{PD}{PE}$$

Monthly values of MAI were computed for all the stations adopting this method.

3.2.8. Agroclimatic classification.

Many attempts have been made in the past to classify climate to find out agricultural potential of a region by various researchers such as Thornthwaite (1948), Hargreaves (1971, 1975) and Papadakis (1966).

Most of them are based on annual, seasonal or monthly rainfall and average temperature.

In the present study the method suggested by Hargreaves (1975) was used for the agroclimatic classification.

Hargreaves showed a broad relationship between MAI and moisture deficit classification, which is given as follows:

MAI	Moisture deficit classification
0 - 0.33	Very deficit
0.34 - 0.67	Moderately deficit
0.68 - 0.99	Somewhat deficit
1.00 - 1.33	Adequate moisture
$\geqslant$ 1.34	Excessive moisture

The moisture deficit classification was used as a concrete base for classifying agroclimates of Kerala. However, the classification has been extended by including one more class namely 'Wet' with MAI above 1.67 keeping in view of the wet climates of Kerala.

Hargreaves (1971) suggested a defixation of climatic classification for arid zones. The defixation is based on the length of the period of moisture

availability and it fails to identify the different agroclimates existing in Kerala because, no station with MAI in the range 0.00 - 0.33 for all the months could be identified with the available data input.

Hence, it is felt that a new rational criterion for defixation of agroclimates have to be evolved. The present study proposes a classification of moisture availability regimes (MAR) which is felt to be more rational, scientific and realistic and is as shown in Table 2. It is used hereafter in this thesis as a broad classification of the agroclimates of Kerala.

Table 2. Classification of moisture availability regimes

Sl. No.	Criteria	Moisture Availability Regime (MAR)	Symbol
(1)	(2)	(3)	(4)
1.	6 or more months with MAI in the range 0.00 - 0.33	DRY	A
2.	5 or more consecutive months with MAI above 0.33	SEMI-DRY	B
3.	5 or more consecutive months with MAI above 0.67	SUB-HUMID	C
4.	5 or more consecutive months with MAI above 0.99	HUMID	D
5.	5 or more consecutive months with MAI above 1.33	PER-HUMID	E
6.	5 or more consecutive months with MAI above 1.67	WET	F

The type of soil play a vital role in crop production. When the moisture availability regimes (MAR) were superimposed over a soil map of Kerala various agroclimatic zones were obtained. The suitability of the agroclimatic zones for crop production is discussed.

3.2.9. Cropping Patterns.

In the present study, cropping pattern for each taluk was worked out from the village level crop data by the method discribed by National Commission on Agriculture (1976). To facilitate analysis and to have a broad picture of crop distribution of the state, the crops and their areas were coded using crop symbols and numerical subscripts.

The codes for crops are as follows:

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

The percentage area of crops are denoted as follows:

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

For example, the code Pd_2 shows that paddy occupies 50 to 69% of the gross cropped area.

When the same distribution of crops was found to hold good for two or more adjacent taluks, a pattern was obtained. The various cropping patterns thus obtained are discussed in relation to the agroclimatic zones, with special reference to the suitability of the cropping patterns to the different zones.

The suitability of cropping patterns was examined with the following procedure. First, the

cropping patterns followed in each agroclimatic zone were found out from the maps. Then the suitability of the agroclimatic zones for following the cropping patterns was examined based on the developments in agricultural science.

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

The present study was undertaken for delineating the various agroclimatic zones of Kerala and identifying the cropping patterns for the different zones. The meteorological data and soil and crop data received from the various departments and stations are discussed in this chapter.

4.1. Area Under Study

4.1.1. Geographical Features of Kerala State.

Kerala is one among the smallest states in India with an area of 38,864 sq. km. It is a narrow strip of land lying on the western side of the western ghats and it lies between 8°17'30" and 12°47'40" North latitudes and 74°51'57" and 77°24'47" East longitudes. The state is bounded on the north and north-east by Karnataka state. The eastern and southern limits are boardered by Tamil Nadu state and the Arabian Sea washes the shore in the west. The majestic western ghats form the physical limit on the east. The length of the sea coast and the maximum breadth of the state are 580 km and 120 km respectively. 50 per cent of the total geographical area is above 75 m above M.S.L.

4.1.2. Physiography.

The state of Kerala is highly uneven in topography due to the varigated features of mountains, hills, valleys and slopes. On the basis of physiographic features the state is distinguished into three broad divisions namely highland, midland and lowland, each of them running parallel from north to south.

4.1.2.1. Highland.

The highland is mountaneous and has an undulating surface. The range in elevation is 1000 to 1500 m above M.S.L. The western ghats is traversed by several passes of which the Palghat gap is well known.

4.1.2.2. Lowland.

The low land is a strip ofland running along the coast and is not more than 30 km in width at any point. This area is low with level topography and is characterised by marine land forms consisting of beach ridges and beaches with swamps and lagoons. In several places they are liable to be flooded during monsoon.

4.1.2.3. Midland.

Sandwiched between the lowland and highland lies the midland region. The elevation generally observed in this area is below 100 m above M.S.L. As one moves from the ghats towards the west the hills become flat with milder slopes and the dales become wider.

4.1.3. Rivers, Back Waters and Drainage.

There are 44 rivers in the state of which 41 are west flowing. The east flowing rivers are the tributories of the Cauvery. One of the striking features of the state is the continuous chain of lagoons and back waters extending along the coastal region. They stretch from the northern to the southern end and all are interconnected by cannals, both natural and manmade. Because of the undulating topography, majority of the area enjoy a good drainage system except the low lying areas.

4.2. Agroclimatic Features

The climatic elements and soil type of an area have an important role in providing congenial conditions for crop growth as they together

determine the agroclimatic features of a locality. The climatic and soil fatures of Kerala are discussed as follows.

4.2.1. Climatic Features.

The most important climatic elements are rainfall, temperature, humidity, wind, sunshine etc. All these have their own significance in the life of crops. The healthy growth of the plants, their high yield etc. depend upon certain optimum values of these climatic elements. The study of these elements in Kerala is therefore of great importance.

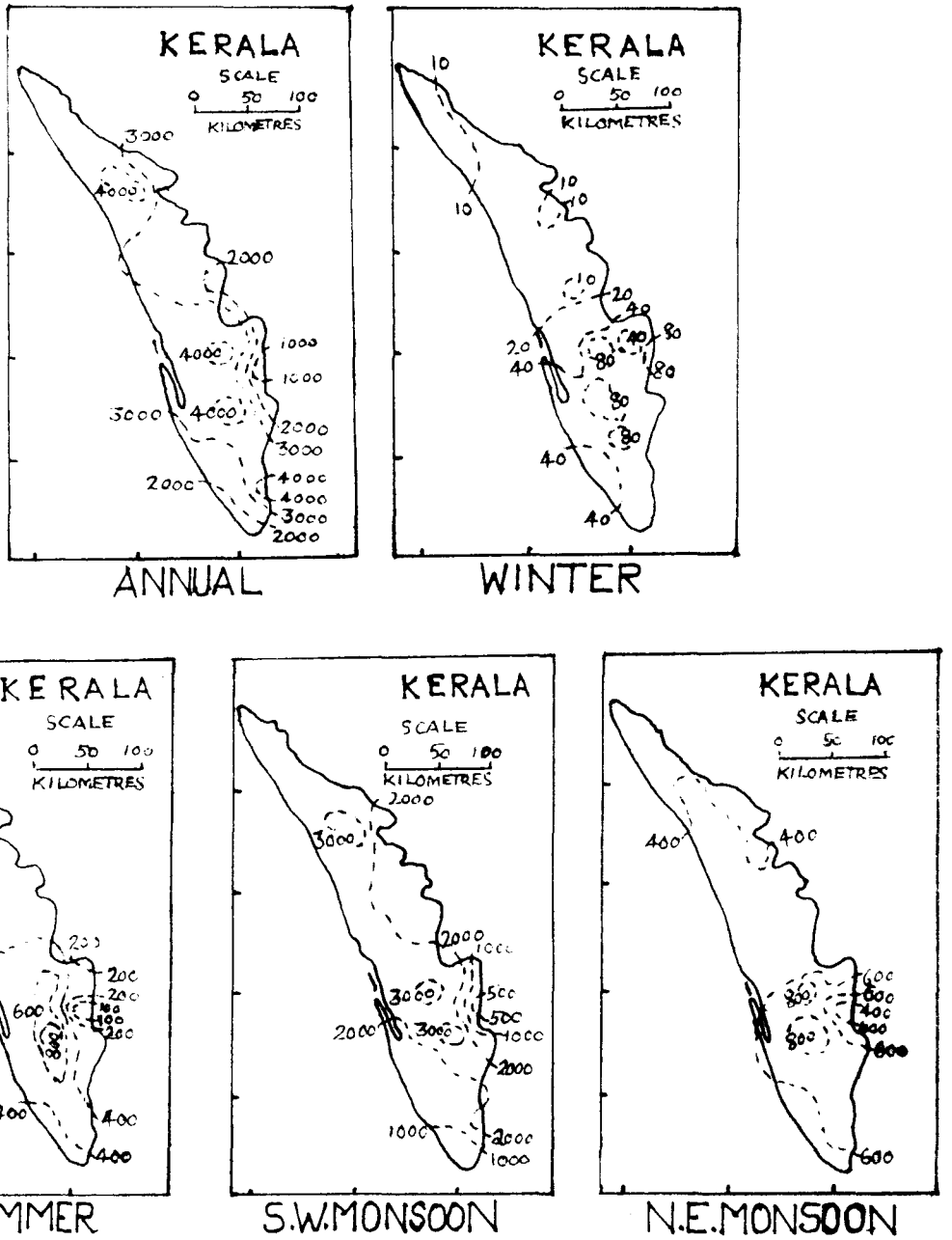
4.2.1.1. Rainfall.

The average rainfall for Kerala was computed from the mean annual rainfall for 91 stations and was found to be 2908 mm. The spatial distribution of seasonal and annual rainfall and the coefficient of variation are discussed below.

4.2.1.1.1. Spatial Distribution.

The spatial distribution of annual and seasonal rainfall in the state is shown in Fig 2. It shows that there are two distinct zones of rainfall. In general the annual average rainfall

FIG: 2 SPATIAL DISTRIBUTION OF ANNUAL AND SEASONAL RAINFALL(*mm*)

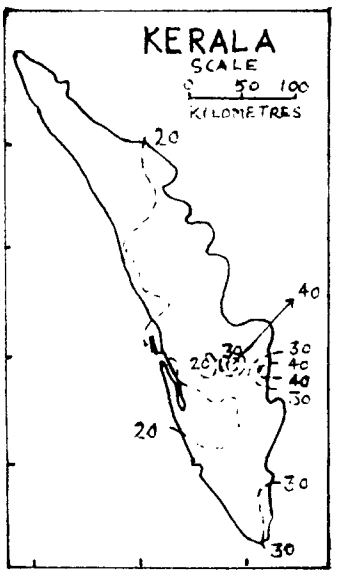


increases from south to north. However there are 4 pockets of high annual rainfall exceeding 4000 mm in the state. They are in and around the areas such as Wynad, Neriamangalam, Idukki project and Ponmudi. Chinnar and surroundings in the leeward side of the western ghats receive only 665 mm of annual rainfall and may be considered as a special area. Chinnar and Parassala are the two stations which do not receive even 600 mm rainfall in any season.

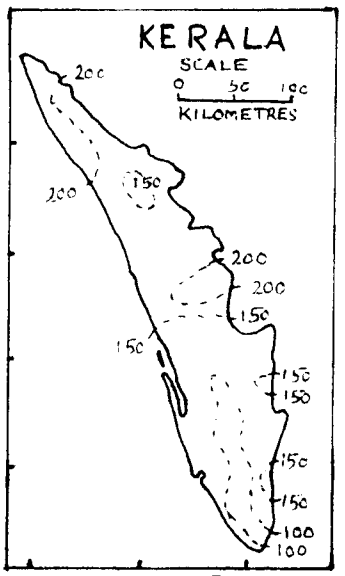
The rainfall during the south-west monsoon shows a similar trend as that of the annual rainfall. Rainfall during the north-east monsoon season increases from north to south. In winter the state receive very low rainfall which in general, increase slightly from north to south. During summer the State receive a good amount of rainfall which is found to increase from both northern and southern parts of the state to the central part of Travancore with a maximum of 850 mm at Kanjirappally.

Palai and Kanjirappally receive less rainfall than the surrounding stations during the S.W. monsoon season. In winter and N.E. monsoon they get the highest rainfall of all the stations in the state. This phenomenon may be studied in depth for

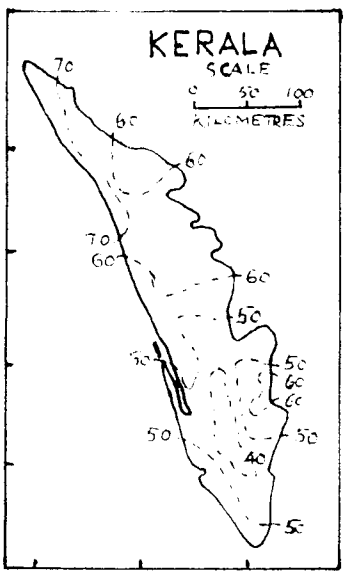
FIG:3 SPATIAL DISTRIBUTION OF COEFFICIENT OF VARIATION (%) OF RAINFALL



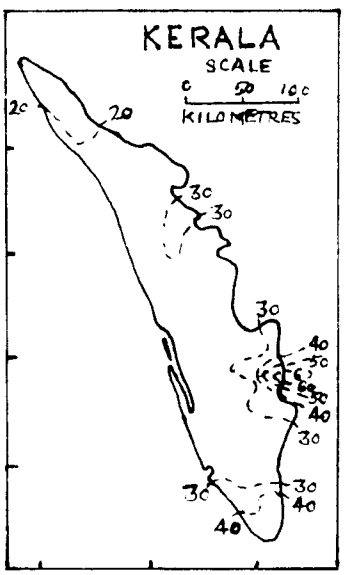
ANNUAL



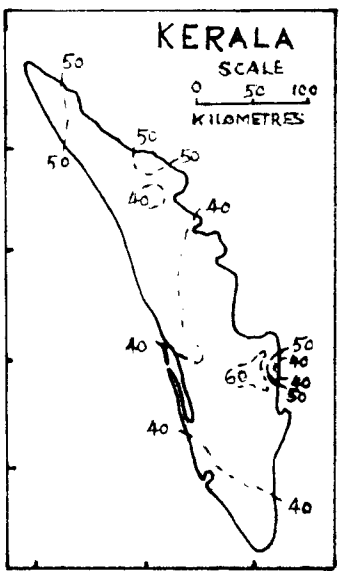
WINTER



SUMMER



S.W. MONSOON



N.E. MONSOON

a better understanding of the rainfall climatology of the area.

4.2.1.1.2. Coefficient of Variation.

The spatial distribution of annual and seasonal coefficient of variation of rainfall for the state is shown in Fig. 3. In general the annual CV increases from north to south. Velur and Chinnar have the highest CV (44%) while Calicut has the lowest value (14%).

During S.W. monsoon season CV shows a similar trend and the areas with high CV are Chinnar and Palghat. Rainfall probability on a weekly basis may be carried out in these areas for future work.

In N.E. monsoon and winter CV is found to increase from south to north. In summer there is slight increase of CV from south to north.

The annual CV for a station is smaller than the CV for the seasons.

4.2.1.2. Temperature.

The temperature of the hottest month, temperature of the coldest month and the annual

temperature range for 9 stations in the state are given in Table 3.

Table 3. Temperature of the hottest month, temperature of the coldest month and the annual temperature range for 9 stations in Kerala.

Station	Average temperature of the hottest month °C	Average temperature of the coldest month °C	Annual temperature range °C	Period for which the computation in based
(1)	(2)	(3)	(4)	(5)
Calicut	29.5	25.0	10.9	1931-60
Pattambi	30.2	25.9	17.3	1973-83
Palghat	30.9	25.4	15.2	1951-80
Cochin	28.9	26.0	8.2	1931-80
Idukki	26.1	22.0	10.5	1983-85
Kottayam	29.2	26.5	12.4	1973-83
Alleppey	29.4	26.0	10.1	1951-80
Punalur	29.4	26.1	16.2	1961-80
Trivandrum	28.8	26.2	10.2	1941-60

The monthly average of minimum temperature is lowest in Idukki (19.1°C) and the monthly average of maximum temperature is highest in Palghat (37.5°C).

The monthly average of daily temperature is lowest in Idukki (22.0°C) while it is highest in Palghat (30.9°C).

Table 3 shows that, there is not much difference either in the temperatures of the hottest month or coldest month among the stations in Kerala. However, regarding the annual temperature range Cochin has a range of 8.2°C, where as Palghat, Pattambi and Punalur in the midland have a range about twice this value.

4.2.1.3. Humidity.

The mean daily relative humidity (%) computed on monthly, and annual basis for 7 stations in the state is shown in Table 4.

Table 4 . Mean daily relative humidity for 7 stations in Kerala

Station	Period for which data is available	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Calicut	1961-80	68	71	72	73	78	86	91	89	86	82	76	70	79
Palghat	1961-80	57	51	55	64	79	82	86	86	81	79	72	64	70
Cochin	1961-80	6[illegible]	69	71	73	7[illegible]	85	88	86	83	81	77	70	77
Kottayam	1973-82	74	73	71	75	78	85	87	85	82	82	83	76	79
Alleppey	1961-80	69	73	71	75	80	87	90	89	86	83	79	73	80
Punalur	1961-83	63	61	67	76	79	83	86	85	82	85	82	73	78
Trivandrum	1961-80	68	69	72	77	83	84	83	84	82	84	81	73	78

The table shows that among the stations Alleppey has the highest mean annual relative humidity (80%) while Palghat has the lowest value (70%). All the stations recorded the highest mean relative humidity in June, July, or August while the lowest is recorded in January, February or March. The monthly means of the relative humidity recorded in the state vary from 51% (Palghat) to 91% (Calicut).

4.2.1.4. Wind.

The average wind speed for 5 different stations are given in Table 5.

Table 5. Average monthly and annual wind speeds for 5 stations in Kerala

Station	January	February	March	April	May	June	July	August	September	October	November	December	Annual
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Calicut	9.4	11.4	12.3	12.6	12.5	9.8	9.2	8.9	8.7	8.2	8.1	8.3	10.0
Palghat	11.3	9.3	8.5	9.3	11.8	13.0	13.3	13.6	11.9	8.7	7.6	10.9	10.8
Cochin	.0	9.3	10.6	10.7	10.9	9.1	9.6	9.9	9.1	7.8	6.7	7.1	9.1
Alleppey	9.3	10.7	12.4	12.3	13.6	12.6	12.0	11.1	10.1	10.4	9.1	8.5	11.0
Trivandrum	5.1	5.9	6.6	7.8	9.2	9.6	10.9	11.2	10.4	7.3	5.8	4.8	7.9

Source: India Meteorological Department, Poona.

The table shows that all the coastal weather stations such as Alleppey, Cochin and Calicut have recorded greater wind speeds. The wind speeds recorded at Palghat were as high as the coastal stations. The monthly average of wind speed is lowest (4.8 kmph) in Trivandrum (in December) while it is highest (13.6 kmph) in Palghat (in August) and Alleppey (in May).

4.2.1.5. Sunshine.

Sunshine over Kerala is presented using the available data for 5 stations namely Kasaragod, Pattambi, Ollukkara, Kayamkulam and Trivandrum. Table 6 shows (1) the mean daily duration of sunshine in hours and (2) maximum possible hours of sunshine.

The table shows that all the stations are having maximum sunshine hours from January to March. During this period the sunshine received by all the stations is between 8 and 10 hours. From June to November the mean daily sunshine hours is very low and ranges between 2.8 and 8 hours.

Kasaragod has the lowest (11.4 hours in December) and the highest (12.8 hours in June and July) values of the maximum possible hours of sunshine.

Table 6 . Sunshine over Kerala

I - Mean daily duration of sunshine in hours based on available data upto 1965

II - Maximum possible hours of sunshine

Station		Jan.	Feb.	Mar.	Apr.	May.	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual mean of sunshine
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Kasaragod	I	9.3	9.4	9.3	8.9	6.5	3.2	2.8	4.2	5.6	6.6	8.0	8.9	6.9
	II	11.5	11.7	12.0	12.4	12.7	12.8	12.6	12.5	12.2	11.8	11.5	11.4	12.1
Pattambi	I	9.6	9.6	9.3	8.4	6.1	3.3	2.8	4.3	6.0	6.1	7.9	9.0	6.8
	II	11.6	11.8	12.1	12.4	12.6	12.7	12.7	12.2	12.2	11.9	11.6	11.5	12.1
Ollukkara	I	9.2	9.1	9.4	8.3	5.7	3.3	3.1	3.9	5.1	6.2	7.5	8.5	6.6
	II	11.6	11.8	12.5	12.3	12.6	12.7	12.7	12.5	12.2	11.9	11.6	11.5	12.1
Kayamku-lam	I	9.4	9.5	9.4	8.4	5.9	4.3	4.4	5.1	6.4	6.4	7.5	8.4	7.1
	II	11.6	11.8	12.1	12.3	12.5	12.6	12.6	12.4	12.2	11.9	11.7	11.6	12.1
Trivan-drum	I	7.3	8.5	8.3	6.7	5.9	3.7	4.1	5.3	5.9	5.5	5.9	7.4	6.3
	II	11.7	11.9	12.1	12.3	12.5	12.6	12.6	12.4	12.2	11.9	11.7	11.6	12.1

Rao and Ganesan (1971).

Source: India Meteorological Department, Poona.

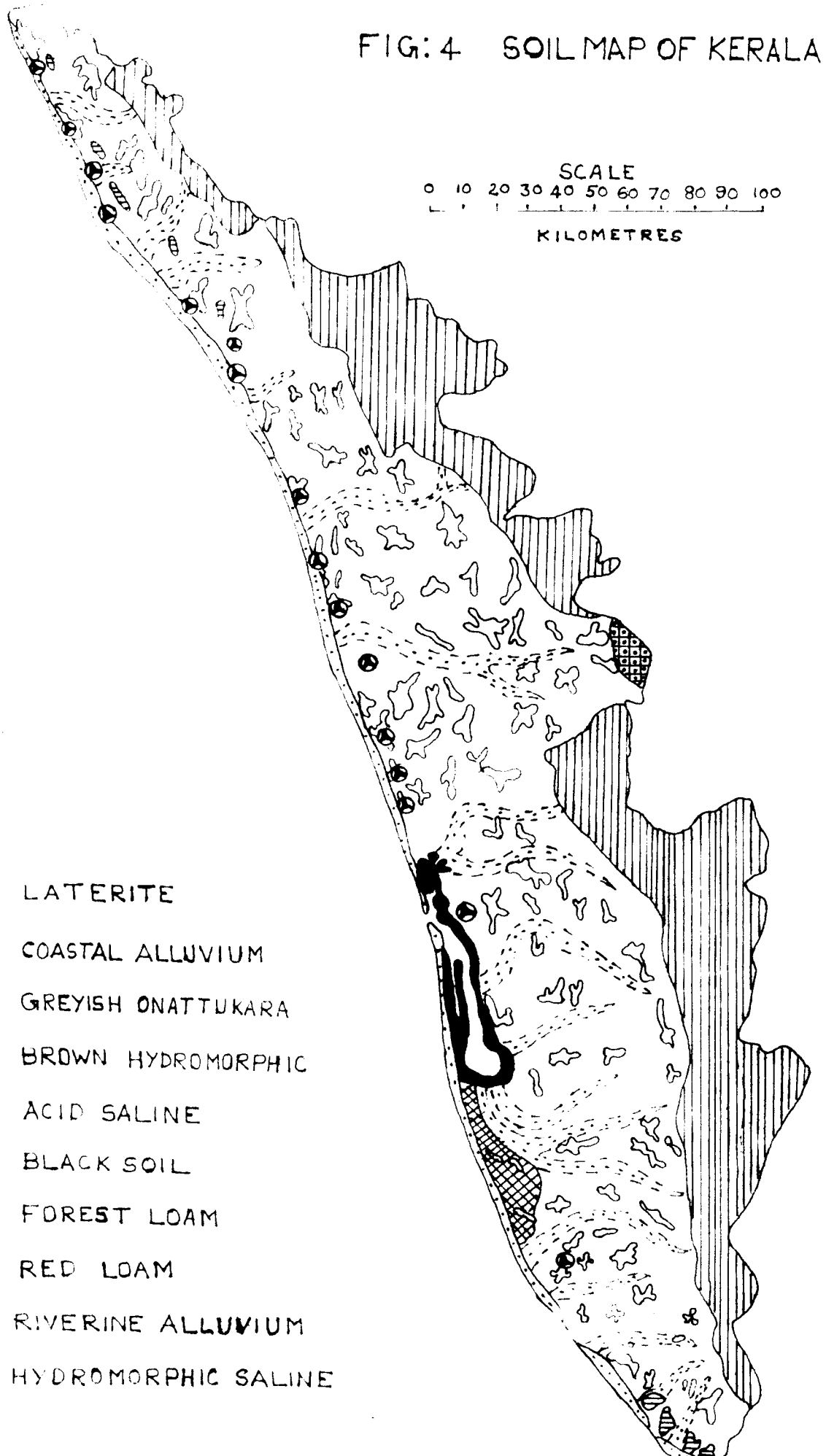
4.2.2. Soils.

On the basis of morphological features and physicochemical properties, the soils of the state have been classified by the Soil Survey Branch, Dept. of Agriculture, Kerala State, into ten broad groups as shown below.

(1) Red loams
(2) Laterites
(3) Coastal alluvium
(4) Riverine alluvium
(5) Greyish Onattukara
(6) Brown hydromorphic
(7) Hydromorphic saline
(8) Acid saline
(9) Black soils and
(10) Forest loams.

The distribution of these soil types is shown in the soil map of Kerala (Fig. 4). The important characters, limitations and management needs of the soil groups compiled by Soil Survey Branch, Department of Agriculture (Anonymous, 1978) are summarised below.

FIG: 4 SOIL MAP OF KERALA



4.2.2.1. Red Loams.

These soils possess favourable physical properties. They are mostly observed on gently to moderately sloping areas and hence soil erosion is not much of a hazard.

4.2.2.2. Laterites.

The laterite soils in general are well drained, low in all essential plant nutrients and organic matter. The choice of crops is limited, depending on effective soil depth. The laterite layer is exposed in some areas due to erosion. In some other areas a hard indurated surface crust develops. Laterite soils are distributed on a wide range of slope classes.

4.2.2.3. Coastal Alluvium.

The coastal alluvium is distributed all along the coast. It consists of sandy soils very low in natural fertility. In some places high water table during monsoon periods limits the choice of crops. Water holding capacity of these soils is low. During summer crop losses due to drought are also common. These soils are located in level areas where erosion

is seldom a problem except for sea erosion observed in some area.

4.2.2.4. Riverine Alluvium.

These are moderately well drained soils distributed mainly on the banks of rivers and tributories. They occur on flat to gently sloping lands. They are light to medium textured with good physical properties and good productivity.

4.2.2.5. Greyish Onattukara.

This is the characteristic soil type of Onattukara areas. They occur in flat to gently sloping areas and are highly porous with limited capacity for retaining water and fertilizers. The surface texture vary from loamy sand to sandy loam and the coarse fraction increases with depth. Water table during summer goes down to 10' in dry land and down to 5' in wet lands. In rainy season water table comes almost near to the surface.

4.2.2.6. Brown Hydromorphic.

The brown hydromorphic soils occupy the typical paddy growing areas commonly referred to as wet lands. They occur on flat to gently sloping

lands mostly in valleys. These soils exhibit wide range in chemical, physical and morphological characteristics. Drainage is the major problem, hence, choice of crops is limited. Provision for drainage to remove excess water has to be given in these areas. The important crop is paddy.

4.2.2.7. Hydromorphic Saline.

The saline soils occupy areas adjacent to the coast and are subjected to periodical inundation by sea water causing salinity hazards. In other characteristics they closely resemble the brown hydromorphic soils.

4.2.2.8. Acid Saline.

The acid saline soils have developed under hydromorphic conditions and include the Kari, Kayal and Karappadam soils of Kuttanad. The area faces the problems of toxic accumulation of acids and salts under prolonged waterlogged condition and hazards due to salinity.

4.2.2.9. Black Soils.

The black soils occur in a limited area

only in Chittur taluk of Palghat District. These soils are heavy clays and crack in summer due to shrinkage. They are alkaline in reaction. They occur on flat to gently sloping lands.

4.2.2.10. Forest Loams.

The forest loams constitute nearly 25% of the land area of the state. These soils are characterised by a surface layer rich in organic matter. They are generally acidic, rich in nitrogen, but poor in bases due to heavy leaching. Important crops cultivated in these soils are rubber, tea, coffee and cardamom. In areas where forests are denuded, adequate protection against erosion has to be provided before taking up cultivation.

4.2.3. Important Crops of Kerala and their Adaptation to Environmental conditions.

Scientific examination of the adaptability of crops to various environmental conditions is helpful in identifying the suitability of the various places for potential agricultural production. An attempt has therefore, been made to examine the adaptation of important crops (in terms of area) of Kerala to the environmental conditions prevailing.

The area occupied by 12 important crops of Kerala during the year 1982-83 is as follows (source: Directorate of Economics and Statistics, Trivandrum):

	Important crops	Gross cropped area (ha)	% of gross cropped area
1.	Rice	740086	25.86
2.	Coconut	682281	23.84
3.	Rubber	271200	9.48
4.	Tapioca	233010	8.14
5.	Cashew	142339	4.97
6.	Pepper	106143	3.71
7.	Coffee	62368	2.18
8.	Mango	60201	2.10
9.	Arecanut	59604	2.08
10.	Jackfruit	58870	2.06
11.	Cardamom	54423	1.90
12.	Tea	35021	1.22
	Total	2505546	87.54

The 12 important crops (each occupying an area above 30000 hectares) altogether occupy 2505546 ha (87.54%) of the total cropped area of 2861702 ha in the state.

Climatic and soil conditions favouring the

growth of the 12 important crops of Kerala have been examined earlier by various scientists, and researchers. However, the suggestions given are too vast and space consuming to be included in this thesis. Hence the important and relevant points of their suggestions are tabulated in Table 7 for an easy examination of the environmental conditions for the growth of the crops, at the same time taking care to avoid misinterpretation of the information obtained through reference.

Table 7. Environmental conditions for the growth of important crops of Kerala

Crop	Source	Altitude above M.S.L.	Temperature	Rainfall	Soil	General statements
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rice	Aiyer(1944)	0-1524 m.		Minimum 635 mm in a season.	Any type.	Grow in wide range of conditions.
	Potti(1978)		Minimum 20°C		Grows in all soils with pH 3.5 - 9.	Rice is a water loving crop. Optimum humidity is 43%
	ICAR (1980)	Below sea level to 1979 m above M.S.L.	Maximum 35°C		pH 3-10	
Coconut	ICAR (1980)	0-900m in areas near equator	Mean annual temperature of 27°C with a diurinal variation of 6° to 7°C is optimum.	Well distributed rainfall of 100-225 cm per annum is congenial. Stands higher rainfall if soil is well drained.	All types with good drainage.	Frost and low humidity adversely affect the crop.

Table 7. (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rubber	ICAR(1980)	0-600 m.	21-35°C is optimum.	A fairly distributed annual rainfall of not less than 200cm is optimum.	Well drained and deep.	Requires a warm, humid, equable climate. It can withstand a dry spell of 1-2 months.
Tapioca	Aiyer(1944)	0-914.4 m.	Does not stand much cold.	It can stand very heavy rainfall even upto over 100".	Well drained soils.	In the plains and tracts with moderate rainfall the crop requires irrigation.
	Potti(1978)	Up to 800m if free of fog.	Stands very hot conditions.	Stands heavy rainfall.	All types of soils with good drainage.	Warm, humid climate. Does not perform well in the shade. Strong wind cause lodging.
	Onwueme (1978)		Mean temperature of 25-29°C is best.	Also in dry areas with rainfall as low as 50cm/year.	Poorly drained, stony and saline soils are unsuitable.	
Cashew	ICAR(1980)	0-300m.		Grows in areas with 50-400 cm annual rainfall.	All types of soil with good drainage.	

Table. 7. (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Aravindakshan (1978)	Economic upto 850 m. in Kerala.	Grows in high temperature. Cold and frost are harmful.	250-375cm per annum is optimum.	Well drained laterite soil is the most suited. Heavy, ill drained soil is not good.	Grows even in barren lands. Very dry climate adversely affect its productivity.
	Annonymous (1978)					Breaks the hard indurated surface crust developed on the laterite soils.
Pepper	ICAR(1980)	0-1200m.	Tolerates a range of 10-40°C.	250cm (annual) isideal.	Well drained clay loam soil is best.	Pepper is a plant of humid tropics.
	Aiyer(1944)	-do-		At least 152cm.	Red loams and sandy loams largely lateritic in type.	Requires shade.
Coffee	ICAR(1980)	500-1000m for Robusta and 1000-1500m for Arabica.	Grows well between 12°C and 36°C.	1250-3000mm	Deep, friable, porous, rich in organic matter, moisture retentive, slightly acidic, pH 6 - 6.5.	

Table 7. (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mango	ICAR(1980)	0-1500 m.		Withstands fairly dry conditions and heavy rainfall.	Wide range of soils.	
	Bose(1985)	0-1400 m.	Does well in a range of 24°C to 27°C. 48°C is the upper limit.	25cm-250cm.	Deep, well drained soils. Saline and alkaline conditions are not congenial.	Frequent rains or high humidity (over 80%) during flowering period is not good.
Arecanut	ICAR(1980)	0-1000 m.	Flourishes well at 15-38°C.		A variety of soils deep and well drained.	Does not withstand extremes of temperature and wide diurinal variations.
	Nair(1978)	0-920 m.	21-27°C is suitable. Requires a cool atmosphere.	75-500 cm of well distributed rainfall.	-do-	The crop is sensitive to high temperature, so, supplemental irrigation is needed in low rainfall areas.

Table 7. (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Jack fruit	ICAR(1980)		Cold and frost are harmful.			Humid hill slopes and warmer plains are suitable.
	Bose(1965)	0-1500 m.	Grows in warm arid and humid plains and in humid slopes.		Wide variety of soils with good drainage.	
Cardamom	ICAR(1980)	600-1500m is best.	10-35°C is best.	Well distributed and more than 150 cm per annum is best.	Forest loam and lateritic soils.	Thrives best in warm, humid, tropical forests.
Tea	ICAR(1980)	0-2460 m.		Varies between 125-750 cm per annum in the tea growing areas in India.	All types of well drained and deep soils of pH 4 to 6 are suitable.	Requires warm and moist climate.
	Aiyer(1944)	0-6000 feet.	11-38°C is the range. Average temperature of 21°C is most favourable.	152-178cm is most favourable if well distributed. It may go even up to 900 cm.	Tea soils in India are acidic.	

4.3. Water Balance

Though the rainfall is the main source of water supply to plants, the plants do not depend on rainfall alone, as the moisture in the soil is also utilized. The growth of crops is uninhibited if the water available to the plant is balanced against the loss of water through the crop. This loss of water can be estimated by using the concept of potential evapotranspiration. The net water available to crops through soil moisture is estimated by water budgeting technique by knowing the precipitation and potential evapotranspiration. Even though the Thornthwaite's equation is complicated to work out the potential evapotranspiration, using nomogram and tables, the calculations of PE from temperature data were done for stations in Kerala.

The water balance elements rainfall (P), potential evapotranspiration (PE), actual evapotranspiration (AE), water surplus (WS) and water deficit (WD), and also the water balance indices such as humidity index (I_h), aridity index (I_a) and the index of moisture adequacy (I_{ma}) of 14 representative stations in the state on an annual basis are given in Table 8.

Table 8 . Water balance elements and indices for 14 stations in Kerala on annual basis

Stations	Rain-fall (P)mm	PE mm	AE mm	WS mm	W D mm	I_h (%)	I_a (%)	I_{ma} (%)
Kasaragod	3568	1696	1282	2286	414	134.8	24.4	75.6
Cannanore	3192	1724	1282	1910	442	110.8	25.6	74.4
Manantbody	3294	1171	1029	2195	142	187.4	12.1	87.9
Calicut	3343	1724	1393	1950	331	113.1	19.2	80.8
Ponnani	2927	1698	1281	1646	417	96.9	24.6	75.4
Chittur	1607	1750	1136	471	614	26.9	35.1	64.9
Ollukkara	2036	1722	1340	1496	382	86.9	22.2	77.8
Munnar	3620	862	821	2807	41	325.6	4.8	95.2
Cochin	3116	1710	1394	1722	316	100.7	18.5	81.5
Kottayam	3176	1757	1538	1638	219	93.2	12.5	87.5
Alleppey	3181	1720	1478	1703	242	99.0	14.1	85.9
Punalur	2929	1730	1569	1360	161	78.6	9.3	90.7
Quilon	2279	1679	1442	837	237	49.9	14.1	85.9
Trivandrum	1833	1708	1444	389	264	22.8	15.5	84.5

The table shows that PE varies from 862 mm of Munnar to 1757 mm of Kottayam. The table also shows that the annual PE values for all the stations stand well above 1500 mm except for the two stations in the high land i.e. Munnar and Mananthody. This shows the effect of altitude on the temperature and PE of a place. It is also seen from the table that the AE varies from 821 mm of Munnar to 1569 mm of Punalur. The coastal stations Kasaragod, Cannanore, Calicut, Ponnani, Cochin, Alleppey and Quilon have AE value between 1280 mm and 1400 mm. Among the stations Trivandrum has the lowest water surplus of 389 mm and Munnar has the highest water surplus of 2807 mm. At the same time Munnar shows the lowest water deficit of 41 mm while Chittur shows the highest water deficit of 614 mm. The value of I_h ranges from 22.8% of Trivandrum to 325.6% of Munnar. The I_a varies from 4.8% of Munnar to 35.1% of Chittur.

The annual value of I_{ma} vary from 64.9% of Chittur to 95.2% of Munnar. It is interesting to note that though there is a general increase in annual average rainfall from south to the north of Kerala the stations situated north of Cochin except Mananthody, have I_{ma} values less than 81% while the rest of the stations have I_{ma} values more than 81%.

4.4. Agroclimatic Classification of Kerala.

The moisture availability regimes of Kerala were delineated based on the moisture availability indices of different places (Appendix I) following the method suggested by Hargreaves (1971, 1975) and the newly evolved defixation for Kerala. The moisture availability regimes (Fig.5) were then super imposed over the soil map of Kerala (Fig.4) to get the agroclimatic zones of Kerala (Fig.6).

4.4.1. Moisture Availability Regimes of Kerala.

It can be seen from Fig. 5 that all the 6 moisture availability regimes (MAR) namely A,B,C,D,E and F proposed in the chapter 'Materials and Methods' are found in the state. All are discussed below. A major part of the state lies under the C, D and E types of MAR.

4.4.1.1. Dry (A).

Here MAI is in the range of 0.00 - 0.33 for six or more months. On the lines of Hargreaves et al. (1985) it may be stated that this is a danger signal as production will drop below an economic level during the six months and that

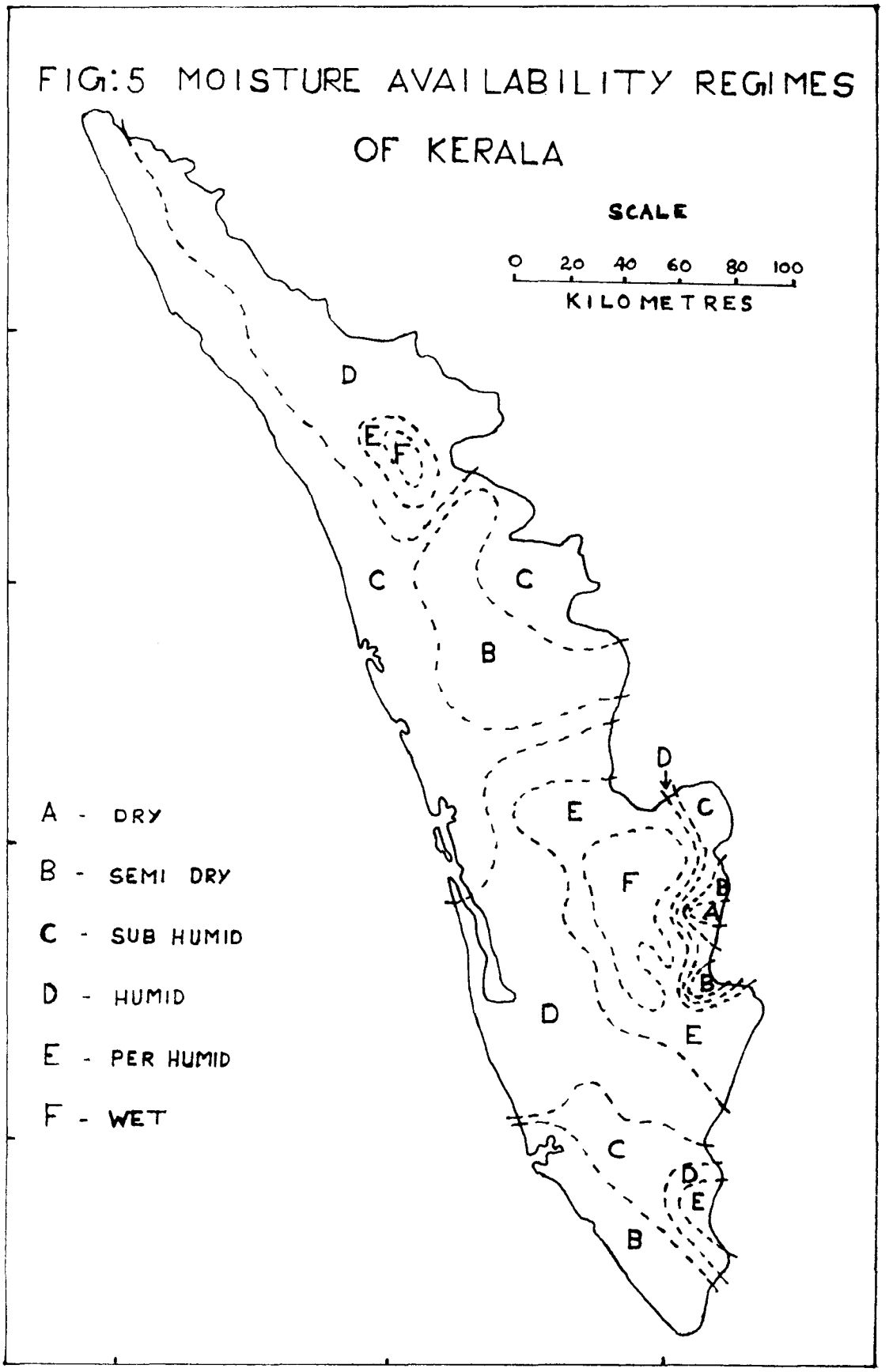


FIG:5 MOISTURE AVAILABILITY REGIMES
OF KERALA
SCALE
0 20 40 60 80 100
KILOMETRES
A - DRY
B - SEMI DRY
C - SUB HUMID
D - HUMID
E - PER HUMID
F - WET

application of fertilizers may not be economical during this period. Provision for irrigation is a must for economic crop production during the six months, in this regime.

4.4.1.2. Semi-Dry (B).

The semi dry (B) type is characterised by moisture availability index (MAI) above 0.33 for 5 or more consecutive months. Application of fertilisers may not be economical during the months with MAI below 0.50 (Hargreaves et al. 1985). Crop which can withstand moderate drought and not having high water requirement survive in this zone.

4.4.1.3. Sub-Humid (C).

The areas under this type have 5 or more consecutive months with MAI above 0.67. It may be stated following Hargreaves et al. (1985) that fertilisers can be applied during the five months. Crops with moderate to high water requirement can flourish in this regime.

4.4.1.4. Humid (D).

The areas of this type have 5 or more consecutive months with MAI above 0.99. This zone

appears to be congenial for almost all the important crops of Kerala.

4.4.1.5. Per-Humid (E).

Perhumid type is characterised by 5 or more consecutive months with MAI above 1.33. Hargreaves et al. (1985) suggested that whenever a monthly value of MAI exceeds 1.33 there is a need, except for rice, of good natural and artificial drainage. Hence, proper drainage is a must for crops except rice in this zone during the five months.

This is also a zone suitable for almost all the important crops in Kerala, particularly plantations and spices. In general crops with high water requirement flourish well in the per-humid type of moisture availability regime.

4.4.1.6. Wet (F).

It comprises of areas having 5 or more consecutive months with MAI above 1.67. Hargreaves et al. (1985) suggest that good natural or artificial drainage is needed for crops except rice during the five months with MAI above 1.67. Crops with very high water requirement grow well in this type of MAR.

A variety of crops are grown in all the six types of MAR in Kerala. With supplemental irrigation crops with high moisture requirements can be grown in the dry and semi dry MAR types. However, inaddition to moisture availability there are several factors which limit the choice of a crop for a particular place, like temperature, altitude, humidity, sunshine, soil type and adaptation of crops to various environmental conditions. These factors also have to be considered while suggesting a crop to a particular area. An attempt to fulfil this requirement is made while discussing the agroclimatic zones of Kerala.

4.4.2. Agroclimatic zones of Kerala.

It has been mentioned that there are 10 types of soils and 6 moisture availability regimes in the state.

The soil types that are similar in terms of their origin, properties or suitability to certain crops were grouped with the intention that the grouping should make the agroclimatic classification simple. At the same time, care was taken so that the basic characters of the component soil types are properly represented by the corresponding soil groups.

The brown hydromorphic soils have been formed as a result of transportation and sedimentation of material from adjoining hill slopes and also through deposition by rivers.(Anonymous, 1970). In Kerala they are found scattered in laterite soils. So they are considered here along with laterite(s). As coastal alluvium and riverine alluvium soils are dominated by sand fraction, they are grouped as alluvial soils or alluvium. The greyish alluvial soils of Onattukara, because of their very low organic matter content, low fertility, immature profile and suitability to crops like sesamum, are considered seperately. Red loams stand apart because of its congenial physical properties for the growth of coconut palms. Forest loams are found mainly in forests and high altitude areas. Acid saline and hydromorphic saline soils have salinity as a common problem and they are grouped as saline soils. Black soil is unique in properties like alkalinity and high water holding capacity and hence it is considered as such.

These 7 soil groups, i.e. red loams (Rl), laterites (La), alluvial soils or alluvium (Al), greyish Onattukara (Go), saline soils (Sa), black soils (Bs) and forest loams (Fl) are considered

for identifying the agroclimates of Kerala.

When the 6 moisture availability regimes were super imposed over the 7 soil groups 20 agroclimatic zones were found to be present in Kerala, out of the 42 possible combinations (Table 9). They are Dry-Forest loam (A_{Fl}), Semi dry-Red loam (B_{Rl}), Semi dry-Laterite (B_{La}), Semi dry-Alluvium (B_{Al}), Semi dry-Black soil (B_{Bs}), Semi dry-Forest loam (B_{Fl}), Sub humid-Red loam (C_{Rl}), Sub humid-Laterite (C_{La}), Sub humid-Alluvium (C_{Al}), Sub humid-Saline (C_{Sa}), Sub humid-Forest loam (C_{Fl}), Humid-Laterite (D_{La}), Humid-Alluvium (D_{Al}), Humid-Greyish Onattukara (D_{Gc}), Humid-Saline (D_{Sa}), Humid-Forest loam (D_{Fl}), Per humid-Laterite (E_{La}), Per humid-Forest loam (E_{Fl}), Wet-Laterite (F_{La}) and Wet-Forest loam (F_{Fl}).

The agroclimatic zones and the areas under each zone are as follows:

1. Dry-Forest loam (A_{Fl}) : Easternmost part of Udumbanchola (in and around Chinnar).
2. Semi dry-Red loam (B_{Rl}) : Isolated pockets in Trivandrum and Neyyanttinkara taluks.
3. Semi dry-Laterite (B_{La}) : (1) Places excluding the coastal parts, river beds and red loam

Table 9 . Agroclimatic zones of Kerala

Moisture availability regimes	Soil types						
	Rl	La	Al	Go	Sa	Bs	Fl
A							A_{Fl}
B	B_{Rl}	B_{La}	B_{Al}			B_{Bs}	B_{Fl}
C	C_{Rl}	C_{La}	C_{Al}		C_{Sa}		C_{Fl}
D		D_{La}	D_{Al}	D_{Go}	D_{Sa}		D_{Fl}
E		E_{La}					E_{Fl}
F		F_{La}					F_{Fl}

A - Dry

B - Semi dry

C - Sub humid

D - Humid

E - Per humid

F - Wet

Rl - Red loams

La - Laterites

Al - Alluvium

Go - Greyish Onattukara

Sa - Saline soils

Bs - Black soils

Fl - Forest loams

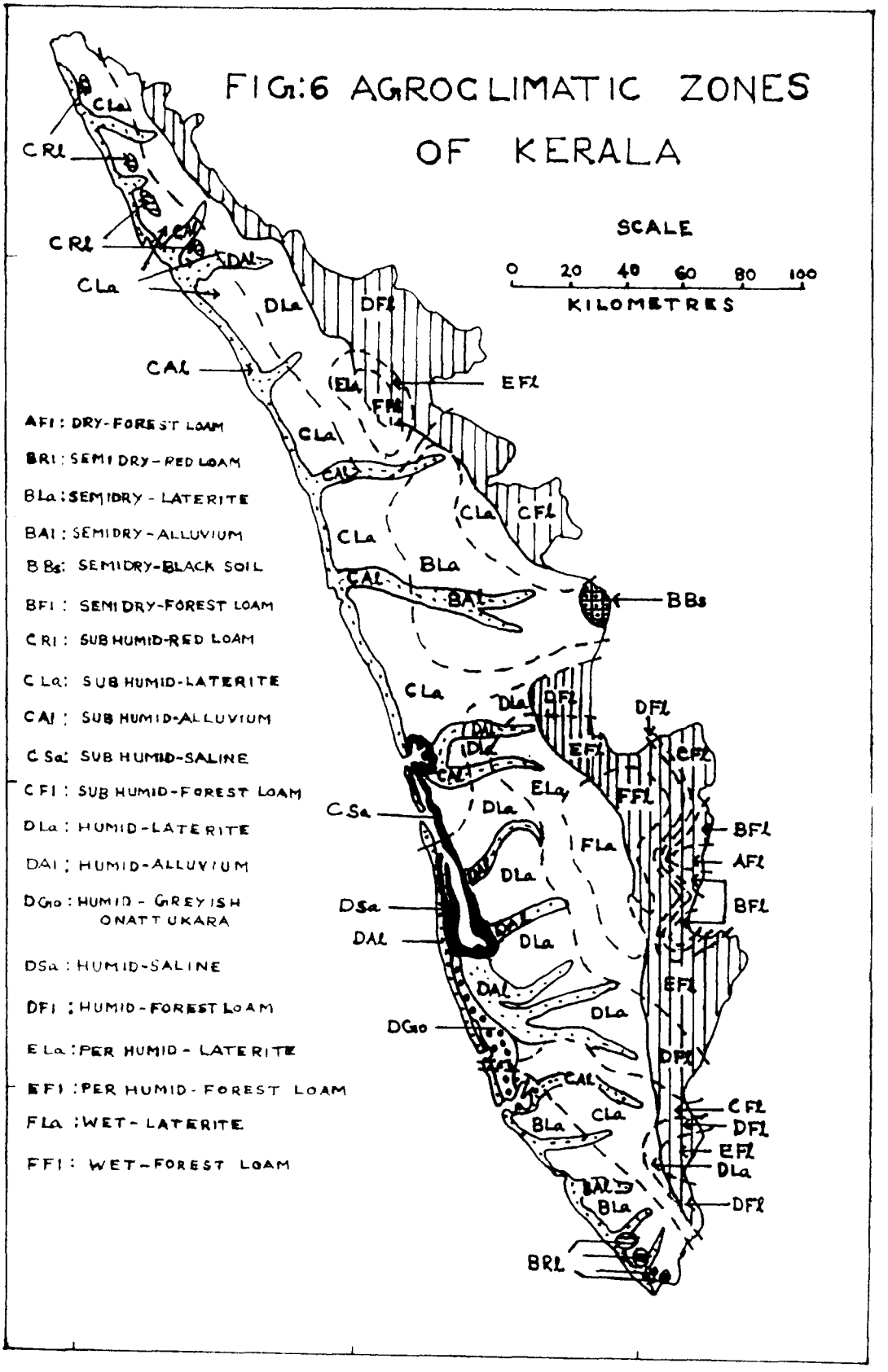


FIG:6 AGROCLIMATIC ZONES OF KERALA
SCALE
0 20 40 60 80 100
KILOMETRES
AFl : DRY-FOREST LOAM
BRl : SEMI DRY-RED LOAM
BLa : SEMIDRY - LATERITE
BAl : SEMIDRY - ALLUVIUM
BBs : SEMIDRY-BLACK SOIL
BFl : SEMI DRY-FOREST LOAM
CRl : SUB HUMID-RED LOAM
CLa : SUB HUMID-LATERITE
CAl : SUB HUMID-ALLUVIUM
CSa : SUB HUMID-SALINE
CFl : SUB HUMID-FOREST LOAM
DLa : HUMID-LATERITE
DAl : HUMID-ALLUVIUM
DGo : HUMID - GREYISH ONATTUKARA
DSa : HUMID-SALINE
DFl : HUMID-FOREST LOAM
ELa : PER HUMID - LATERITE
EFl : PER HUMID - FOREST LOAM
FLa : WET - LATERITE
FFl : WET-FOREST LOAM

soils of the area comprising of : Quilon, Chirayinkil and Trivandrum taluks; western three fourth of Neyyanttinkara taluk; and western part of Nedumangad taluk.

(2) Places excluding the river beds of the area comprising of: Perintalmanna taluk; parts of Ernad, Mannarghat, Ottappalam, Talappilly, Alathur, Chittur and Palghat taluks; and north-east corner of Trichur taluk.

4. Semi dry-Alluvium (B_{Al}) : (1) River beds and coastal areas of Quilon, Chirayinkil, Trivandrum and Neyyattinkara taluks.

(2) River beds of Ottappalam, Talappilly, Palghat and Alathur taluks.

5. Semi dry-Black soil (B_{LS}) : Easternmost part of Chittur and Palghat taluks.

6. Semi dry-Forest loam (B_{Fl}) : (1) Kumily and surroundings Peermed taluk.

(2) Areas north, west and south of A_{Fl} area in Udumbanchola taluk.

7. Sub humid-Red loam (C_{Rl}) : Isolated patches in Kasaragod, Hosdurg and Taliparamba taluks.

8. Sub humid-Laterite : (1) Places excluding coastal (C_{La}) parts, river beds and red loam soils of the area comprising of: Cannanore, Tirur, Ponnani, Choughat and Parur taluks; western parts of Kasaragod, Hosdurg, Taliparamba, Tellicherry, Badagara, Quilandy, Kozhikode, Ernad, Ottappalam, Talappilly, Trichur, Mukundapuram and Alwaye taluks; northern half of Kanayannur taluk; narrow strips of Alathur and Chittur taluks; southern part of Ernad taluk; a central strip of Mannarghat taluk; and northern part of Palghat taluk.

(2) Places excluding coastal parts and river beds of the area comprising of: Kannathur and Kottara-kkara taluks; Western part of Pathanapuram taluk; and a narrow central strip of Neyyattinkara and Nedumangad taluks.

9. Sub humid-Alluvium : Coastal areas and river beds (C_{Al}) in the two regions under C_{La}.

10. Sub humid-Saline (C_{Sa}) : Pokkali lands in the coastal parts of Parur, Kanayannur and Cochin taluks.

11. Sub humid-Forest loam (C_{Fl}) : (1) Easternmost parts of Ernad and Mannarghat taluks.

(2) A small area in and around Marayur in Devikulam taluk.

(3) A small area in and around Aryankavu of Pathanapuram taluk.

12. Humid-Laterite (D_{La}) : (1) Parts excluding river beds in an area composed of: Central halves of Kasaragod, Hosdurg, Taliparamba, Tellicherry, Quilandi and Kozhikode taluks; eastern half of Badagara taluk; and a narrow strip of Ernad taluk.

(2) Parts excluding river beds in an area comprising of: Central half of Mukundapuram taluk ; eastern half of Alwaye taluk; southern half of Kanayannur taluk; western half of Kunnathunad taluk; western halves of Meenachil, Kanjirappilly and Pathanamthitta taluks; and eastern halves of Chengannur and Mavelikkara taluks.

(3) A narrow strip of Nedumangad taluk west of Ponmudi.

13. Humid-Alluvium : River beds of the taluk areas (D_{Al}) described under D_{La} + western part of Chengannur and Mavelikkara taluks + Coastal areas of Shertallai, Ambalapuzha and Karthikappally taluks.

14. Humid-Greyish Onattukara : Greyish Onattukara (D_{Go}) soils in Mavelikkara, Karunagappilly and Karthikappally taluks.

15. Humid-Saline : Areas with acid saline soils (D_{Sa}) around Venbanad lake.

16. Humid-Forest loam : (1) North west strip of Ernad (D_{Fl}) taluk; eastern three fourth of South Wynad and North Wynad taluks; eastern parts of Kasaragod, Hosdurg, Taliparamba and Tellicherry taluks; and forest area near Parambikulam.

(2) South east part of Pathanamthitta taluk; north east part of Pathanapuram taluk; a narrow strip south of Aryankavu; a narrow strip south of Ponmudi; the easternmost part of Neyyattinkara taluk; and a narrow transition zone between the C_{Fl} and E_{Fl} zones of Devikulam, Udumbanchola and Peermed taluks.

17. Per humid-Laterite (E_{La}) : (1) A strip of land comprising of: westernmost side of South Wynad; easternmost part of Quilandi taluk; and its adjoining area in Ernad taluk;

(2) Eastern half of Kunnathunad taluk; western part of Devikulam and Thodupuzha taluks; major portion of Kothamangalam taluk; and an eastern strip of Meenachil and Kanjirappally taluks.

18. Per humid-Forest loam (E_{Fl}) : (1) A narrow western strip of South Wynad taluk; and north central strip of Ernad taluk.

(2) Easternmost part of Mukundapuram taluk; northern and east-central parts of Devikulam taluk; western part of Udumbanchola taluk; southern and central part of Peermed taluk; and north east part of Pathanamthitta taluk.

19. Wet-Laterite (E_{La}) : Neriamangalam; a part of Devikulam taluk near Neriamangalam; a central strip of Thodupuzha taluk; easternmost parts of Kanjirappally and Meenachil taluks; and western part of Peermed.

20. Wet-Forest loam (F_{Fl}) : (1) A small pocket in and around Vythiri.

(2) A pocket consisting of the central part of Devikulam taluk; easternmost part of Thodupuzha taluk; and a small northern part of Peermed taluk.

Besides these, a few minor agroclimatic zones, were also found in Kerala. They are found in isolated patches and/or occupying comparatively small area and/or found in the transition zones of the moisture availability regimes. Hence, they are not assessed.

4.4.2.1. Grouping of Agroclimatic Zones of Kerala.

An attempt was made to identify the agroclimates suitable for the crops and group the agroclimates in a cluster. The specialities of moisture availability regimes and soil groups were considered in the process. The predominant crops and the suitable agroclimates are given in Table 10.

Table 10. Predominant crops and suitable agroclimatic zones in Kerala

Sl. No.	Main crop	Suitable agroclimate
(1)	(2)	(3)
1.	Mainly rice	
	a) Mainly rainfed rice	$C_{La}, C_{Al}, C_{Sa}, D_{La}, D_{Al}, D_{Sa}, D_{Go}$
	b) Mainly rainfed and irrigated rice	$C_{La}, C_{Al}, C_{Sa}, D_{La}, D_{Al}, D_{Sa}, D_{Go}$ + B_{La}, B_{Al}, B_{Bs}.
2.	Mainly coconut	$B_{Rl}, B_{Al}, B_{La}, C_{Rl}, C_{Al}, C_{La}, D_{Rl}, D_{Al}, D_{La}$,
3.	Mainly plantations other than cocomut (Rubber, Tea, Coffee, Cocoa & Spices)	$F_{Fl}, F_{La}, E_{Fl}, E_{La}, D_{Fl}, D_{La}$.

The 'mainly rice' area accounts for 67.84% of rice area and 69.27% of rice production in the state, while the 'mainly coconut' areas cover 48.46% area and 48.69% production of coconut in the state. Areas growing 'mainly plantations other than coconut' contribute 54.65% area and 59.57% of production of those crops in the state.

From Table 10 it is possible to find out the important crops suitable for a particular agroclimatic zone. For example, the crops suitable for the agroclimate C_{La} can be found out from Table 10 as (1) rainfed rice, (2) irrigated rice and (3) coconut. Similarly the major crops suitable for each of the agroclimates given in the table can be found easily. The information on crops and agroclimates obtained in this manner, when combined with the details of information on crops, and soils mentioned earlier, it facilitates an easy and rational examination of the suitability of the existing cropping patterns. It is also possible to suggest by this way the need for any change in the existing cropping pattern.

4.5. Cropping Patterns of Kerala

The cropping patterns present in the state

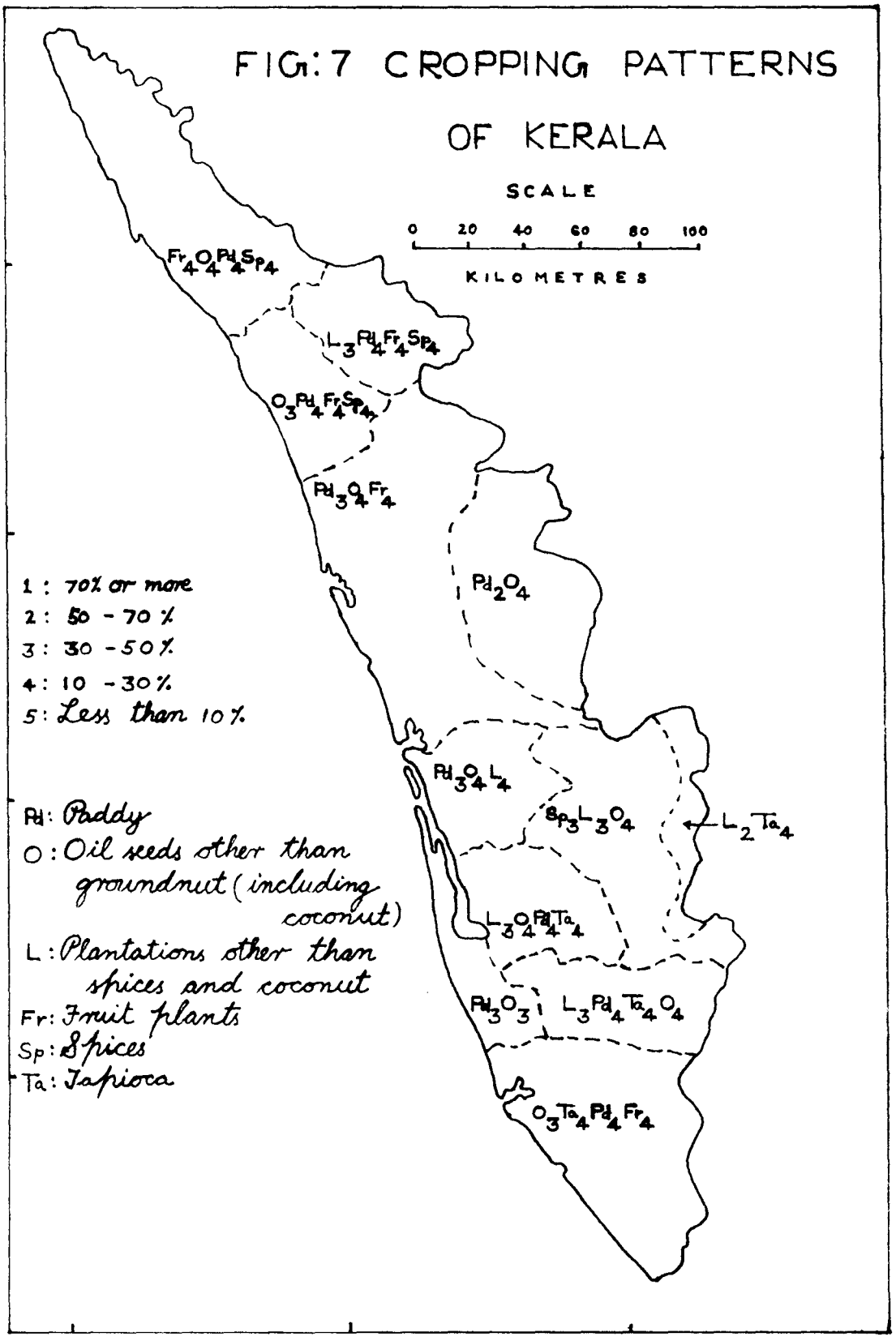


FIG: 7 CROPPING PATTERNS
OF KERALA
SCALE
0 20 40 60 80 100
KILOMETRES
$Fr_4O_4Pd_4Sp_4$
$L_3Pd_4Fr_4Sp_4$
$O_3Pd_4Fr_4Sp_4$
$Pd_3O_4Fr_4$
Pd_2O_4
$Pd_3O_4L_4$
$Sp_3L_3O_4$
L_2Ta_4
$L_3O_4Pd_4Ta_4$
Pd_3O_3
$L_3Pd_4Ta_4O_4$
$O_3Ta_4Pd_4Fr_4$
1 : 70% or more
2 : 50 - 70 %
3 : 30 - 50 %
4 : 10 - 30 %
5 : Less than 10 %
Pd : Paddy
O : Oil seeds other than groundnut (including coconut)
L : Plantations other than spices and coconut
Fr : Fruit plants
Sp : Spices
Ta : Tapioca

were found out according to the method suggested by National Commission on Agriculture (1976) and as described in the chapter 'Materials and Methods'. The cropping patterns of the state found out based on the 1982-83 data given by the Directorate of Economics and Statistics, Trivandrum, are presented in Fig. 7. The figure shows that there are 12, cropping patterns in Kerala. They may be put under 3 major groups named (1) mainly rice, (2) mainly coconut and (3) mainly plantations other than coconut.

The cropping patterns falling under each of the three major groups are as shown below.

Major group	Cropping pattern	Places under the Cropping pattern
1. Mainly rice	$Pd_3 O_4 Fr_4$	Malappuram district & Trichur "
	$Pd_2 O_4$	Palghat "
	$Pd_3 O_4 L_4$	Ernakulam "
	$Pd_3 O_3$	Alleppey "
2. Mainly coconut	$Fr_4 O_4 Pd_4 Sp_4$	Cannanore "
		& Kasaragod "
	$O_3 Pd_4 Fr_4 Sp_4$	Kozhikode "
	$O_3 Ta_4 Pd_4 Fr_4$	Quilon "
		& Trivandrum "

3. Mainly plantations other than coconut	L_3 Pd_4 Fr_4 Sp_4	Wynad district
	Sp_3 L_3 O_4	Major part of Idukki district
	L_2 Ta_4	Eastern halves of Devikulam, Udumbanchola and Peermed taluks in Idukki district.
	L_3 O_4 Pd_4 Ta_4	Kottayam district
	L_3 Pd_4 Ta_4 O_4	Pathanamthitta district.

4.C. Suitability of Cropping Patterns to Agroclimatic Zones.

Once the cropping patterns are identified, it is essential to examine the suitability of the cropping patterns to the agroclimatic zones, so as to obtain relevant information for optimum use of natural resources. With this objective the suitability of the existing cropping patterns to the different agroclimatic zones were examined based on the information on the environmental conditions for the growth of various crops. Each of the agroclimatic zones, are discussed hereafter in relation to the cropping patterns followed in each zone.

4.6.1. Dry-Forest loam (A_{F1}).

This is prevailing in and around Chinnar. The altitude of Chinnar station is 600 m above M.S.L. The annual rainfall received at the station is 665 mm on an average. The rainfall received during winter, summer, S.W. monsoon season and N.E. monsoon season are 43 mm, 90 mm, 166 mm and 376 mm respectively. Average temperature of the hottest month is 26.1°C and that of the coldest month is 22.0°C with a temperature range of 10.5°C.

The cropping pattern followed in this zone is L_2 Ta_4. The important crops included under the cropping pattern are (1) plantation crops other than spices and coconut and (2) tapioca. The very low rainfall does not satisfy the environmental conditions required for the crops as suggested by ICAR (1980)Kerala Agricultural University (1983), and Aiyer (1944). Tapioca however may survive (Table 7). Certain millets which can thrive well under very low rainfall and soil moisture conditions are suitable for this agroclimatic zone. Groundnut can also be grownin this zone (Anonymous, 1978).

4.6.2. Semi dry-Red loam (B_{R1}).

This agroclimate is found in and around

Vellayani. The altitude of Vellayani station is less than 64 m above M.S.L. The annual average rainfall for the stations nearby Vellayani is in the range of 1379-1824 mm. The average rainfall received at the stations during the winter, summer, S.W. monsoon and N.E. monsoon seasons are in the range of 33-47 mm, 311-361 mm, 895-924 mm and 457-540 mm respectively. The average temperature of the hottest month is 28.8°C and the average temperature of the coldest month is 26.2°C. The temperature range for the area is 10.2°C. The annual relative humidity is around 70 %, and January is the month with the lowest value of mean monthly relative humidity (66 %).

The cropping pattern followed in this zone is O_3 Ta_4 Pd_4 Fr_4. The important crops are coconut, tapioca, paddy and fruit plants such as mango and cashew. From Table 7 it can be concluded that this agroclimatic zone is suitable for growing coconut, tapioca, paddy, mango and cashew. Cotton, groundnut and pulses can also be grown in this zone (Anonymous, 1974).

4.6.3. Semi dry-Laterite (B_{La}).

This agroclimate is prevailing in

two different regions i.e. (1) the B_{La} area near Trivandrum (2) the B_{La} area around Palghat.

In the 1st area the cropping pattern followed is O_3 Ta_4 Pd_4 Fr_4. Here the environmental conditions are almost same as in the zone B_{R1} except for the type of soil. The soil type laterite also is found to support the cultivation of important crops such as coconut, tapioca, paddy and the fruit crops like mango and cashew (Table 7). So, this area is suitable for the cropping pattern followed.

The 2nd area has altitude in the range of 10-192 m above M.S.L. The average annual rainfall is in the range of 1680-2937 mm. The average rainfall received during Winter, Summer, S.W. monsoon and N.E. monsoon seasons are 9-21 mm, 189-338 mm, 1161-2140 mm and 312-498 mm respectively. Average temperature of the coldest month is 25.4 - 25.9°C. The mean temperature range is between 15.2°C - 17.3°C. The annual mean relative humidity at Palghat is 70%, and February is the month with lowest value of mean relative humidity (51%).

The cropping patterns of the 2nd zone

are Pd_2 O_4 and Pd_3 O_4 Fr_4. The important crops are paddy, coconut and fruit crops like cashew and mango. This is an important paddy growing tract of Kerala despite the fact that only S.W. monsoon season receives rainfall sufficient to meet the requirement of rainfed paddy as described by Aiyer (1944). The winter and summer crops are raised mainly with the help of assured irrigation from Malampuzha and Peechi irrigation projects and from other sources. Potti (1978) has mentioned that high productivity is reportedly maintained when the relative humidity is 43%. Palghat has the lowest mean annual relative humidity in the state. The mean monthly relative humidity is less than 70% for six months from December to May with February having the lowest value of 51%. All these have made this a potential paddy growing area. Coconut cannot tolerate low humidity (ICAR, 1980). The easternmost part of this area has low relative humidity and a distinct reduction in the number of coconut palms and an increase in the population of Palmyra palms are observed in this part. The soil and climatic conditions are favourable for the growth of cashew and mango as mentioned by Anonymous (1978) and ICAR (1980).

Among the 4 important crops included in this

cropping pattern paddy, cashew and mango are found suitable for the Palghat area of the agroclimate B_{La}. Coconut is not as suitable as the other crops for the less humid eastern part of this area.

It is reported (Anonymous, 1974) that cucurbits, pulses, groundnut, yams, dioscorea, pepper, nutmeg, cinnamon, sweet potato, soyabean, cotton, horsegram, sesamum and foddergrass can also be grown in the zone B_{La}.

4.6.4. Semi dry-Alluvium (B_{Al}).

The climatic features of this zone are almost same as described under B_{R1} and B_{La}. However, a slightly higher relative humidity and more availability of water for irrigation due to the proximity to sea or river, are the added characters of this zone. The cropping patterns found in these areas are O_3 Ta_4 Pd_4 Fr_4 and Pd_2O_4. Paddy, coconut, tapioca, mango and cashew are the important crops. The climate and the soil types do not put limitation to the growth of these crops (Table 7). It is reported that cucurbits, pulses, groundnut, yams, dioscorea, pepper, nutmeg, cinnamon, sesamum, foddergrass, sweet potato, soyabean, cotton and horsegram can also be grown in this zone (Anonymous, 1974).

4.6.5. Semi dry-Black soil (B_{Bs}).

The cropping pattern of this zone is $Pd_2\ O_4$. The important crops are paddy, groundnut, cotton and coconut. The altitude of the area is around 67 m above M.S.L. The annual rainfall is 1607 mm. The rainfall during S.W. monsoon can meet the requirement of paddy described by Aiyer (1944) for one season. The irrigation available from the Parambikulam-Aliyar project is used for growing rice in the other seasons. The temperature and relative humidity of this zone are similar to that of the Palghat region of the zone B_{La}.

The area is well suited for growing paddy if the availability of water is ensured. This zone satisfy the requirements of cotton mentioned by ICAR (1980) and Anonymous (1978) and that of groundnut mentioned by Nair (1978). The soil type and relative humidity are not in agreement with the requirements of coconut described by ICAR (1980).

Crops like millets should be given more importance in this zone. It is reported (Anonymous, 1974) that sugarcane and pulses can also be grown in this zone.

4.6.6. Semi dry-Forest loam (B_{F1}).

Kumily is the only station in this zone where meteorological data is available. The average annual rainfall received at the station is 1751 mm while the average rainfall during S.W. monsoon, is above 635 mm. The altitude of the station is 823 m above M.S.L. and hence, the temperature of this area is similar to that of Idukki station.

The cropping pattern followed in this agroclimatic zone is L_2 Ta_4. The important crops are tapioca, tea, coffee and rubber. The agro-climatic zone satisfy the soil and climatic requirements of tapioca, tea and coffee but does not fully satisfy the requirement of rubber (Table 7).

Millet, vegetables and groundnut can also be grown in this zone (Anonymous, 1974).

The temperature, rainfall, humidity, wind, sunshine and day length of Kerala discussed under the climatic features of Kerala and the Table 7 show that the places under C, D, E and F moisture availability regimes (except the C_{F1} area near Marayur) are climatically suitable for growing the

majority of the important crops of Kerala. The climatic requirement of the crops such as paddy, coconut, rubber, tapioca, cashew, pepper, coffee, mango, arecanut, cardamom, tea, ginger, cocoa, banana and sesamum described by ICAR (1980), Aiyer (1944), Potti (1978), Aravindakshan (1976), Narayanan (1976), Pillai (1978), Nair (1976) and Kerala Agricultural University (1983) are existing in these places. Bose (1965) points out the suitability of jack tree for humid climates. Hence, jack tree can be considered to be suitable for D, E and F types of MAR. These crops may be grown in these places if the altitude and soil types are in agreement with the crops' requirements. This conclusion makes the examination of the suitability of various crops to different agroclimatic zones simple.

4.6.7. Sub humid-Red loam (C_{R1}).

This is seen in isolated patches in Kasaragod and Cannanore districts. The altitude of the areas is less than 300 m above M.S.L. The cropping pattern is Fr_4 C_4 Pd_4 Sp_4. The important crops are coconut, cashew, paddy, rubber, pepper and arecanut. These crops are suitable for the C type

of MAR if the altitude and soil type permit their growth. Table 7 shows that the altitude and soil type are suitable for growing these crops.

It is reported (Anonymous, 1974) that vegetables, pulses, banana, fodder/grass, ginger, nutmeg and pineapple can also be grown in this zone.

4.6.8. Sub humid-Laterite (C_{La}).

The places under this zone are situated at elevations below 300 m above M.S.L. The cropping patterns are Fr_4 O_4 Pd_4 Sp_4, O_3 Pd_4 Sp_4 Fr_4, Pd_3 O_4 Fr_4, Pd_3 O_4 L_4, L_3 Pd_4 Ta_4 O_4 and O_3 Ta_4 Pd_4 Fr_4. The important crops are paddy, coconut, cashew, rubber, pepper, arecanut, tapioca and mango.

These crops can be grown in the C type of MAR if the altitude and the soil type permit. The soil conditions and altitude of this zone are suitable for these crops (Table 7). Hence, the suitability of the crops is confirmed.

Vegetables, pulses, banana, fodder/grass, ginger, nutmeg, pineapple, sweet potato, groundnut and cinnamon can also be grown in this zone (Anonymous, 1974).

4.6.9. Sub humid-Alluvium (C_{Al}).

The altitude of this zone is less than 300 m above M.S.L. and the soil types are coastal alluvium and riverine alluvium.

The climatic conditions, cropping patterns and important crops of the zone C_{Al} are same as that of the zone C_{La}. The crops have already been found suitable for the climatic conditions in the zone C_{La} and hence, suitable for the climatic conditions of the zone C_{Al} also. The soil and altitude requirements for the growth of these crops exist in this, confirming the suitability of the crops to this zone (Table 7).

However, tapioca should not be planted either in places having extremely high water table or where there is stagnation of water. Vegetables, pulses, banana, fodder grass, ginger, nutmeg, pineapple, sweet potato, groundnut, cinnamon, sesamum and cucurbits can also be grown in this zone (Anonymous, 1974).

4.6.10. Sub humid-Saline (C_{Sa}).

This zone is found mainly in the areas with acid saline soils in the coastal parts of Trichur

and Ernakulam districts. The hydromorphic saline soils found in small isolated patches also come under this zone. The altitude is near M.S.L. The main cropping patterns are Pd_3 O_4 Fr_4 and Pd_3 O_4 L_4.

The important crops are paddy and coconut. The climatic conditions of this zone are in the same range as mentioned under C_{La} and thus suitable for growing these crops. The soils and altitude of this zone are also suitable for growing them (Table 7).

Prawn culture can also be carried out in the rice fields of this zone when rice is not grown (Anonymous, 1974).

4.6.11. Sub humid-Forest loam (C_{Fl}).

The cropping patterns found in this zone are Pd_3 O_4 Fr_4, Pd_2 O_4, L_2 Ta_4 and O_3 Ta Pd_4 Fr_4. The important crops are pepper, tea, cardamom, tapioca and paddy. The climatic data available are found to be inadequate for a meaningful examination of the suitability of the cropping patterns of this zone. Hence, a detailed study of this zone with a denser network of meteorological stations (which is not possible at present) is necessary for examining the suitability of the crops to this zone.

4.6.12. Humid-Laterite (D_{La}).

The main cropping patterns in this zone are Fr_4 O_4 Pd_4 Sp_4, O_3 Pd_4 Sp_4 Fr_4, Pd_3 O_4 L_4, L_3 O_4 Pd_4 Ta_4 and L_3 Pd_4 Ta_4 O_4. The important crops are paddy, coconut, tapioca, rubber, arecanut, pepper, cocoa, ginger, cashew, mango, jack and banana. The altitude (not exceeding 300 m above M.S.L.), soil types (laterites or brown hydromorphic) and the moisture availability regime (Humid) are found to be suitable for these crops based on Table 7.

Vegetables, nutmeg, cashewnut, fodder grass and pineapple can also be grown in this zone (Anonymous, 1974).

4.6.13. Humid-Alluvium (D_{Al}).

The altitude of all the places in this zone is less than 300m above M.S.L. The climatic condition and cropping patterns of this zone are within the same range as that of the zone D_{La}. The important crops are paddy, coconut, tapioca, arecanut, cocoa, mango and banana. Referring to Table 7 and Kerala Agricultural University (1983) it can be seen that these crops are suitable for this zone. Pulses, cucurbits, groundnut, ginger, pepper, nutmeg, cinnamon, sesamum and fodder grass also can be grown in this zone (Anonymous, 1974).

4.6.14. Humid-Greyish Onattukara (D_{GO}).

This agroclimate is found in the greyish alluvial soils of the Onattukara areas. These soils occur in flat to gently sloping land and are highly porous with limited capacity for retaining water and fertilizers. Altitude of this zone is less than 30 m above M.S.L.

The two main cropping patterns of this zone are Pd_3 O_3 and O_3 Ta_4 Pd_4 Fr_4. The important crops grown in this agroclimatic zone are paddy, coconut, sesamum and tapioca. Considering that the moisture availability regime D supports the growth of these crops, and based on the soil and climatic requirements of these crops described by ICAR (1980), Aiyer (1944) and Potti (1978), it may be stated that they are suitable to this zone. Sesamum can be grown here when there is no prolonged heavy rainfall (October to May). Tapioca may be grown by ensuring a soil condition with no stagnation of water in the root zone. Cow-pea, vegetables, groundnut, pulses and fodder grass can also be grown in this zone (Anonymous, 1974).

4.6.15. Humid-Saline (D_{Sa}).

This agroclimatic zone is found in the saline

soils around the Vembanad lake. The soil is mainly acid saline. The altitude of the places in this zone ranges from 3 m below M.S.L. to a few meters above M.S.L. The important cropping pattern in this zone is Pd_3 O_3. The most important crops are paddy and coconut.

The climatic conditions in this zone are similar to that of the zone D_{La}. It is reported that these soils are suitable for the cultivation of paddy and that coconut is also found to thrive well in reclaimed 'Kayal' lands (Anonymous, 1978). Hence these crops are suitable for this zone. Colocasia also can be grown in this zone (Anonymous, 1974).

4.6.16. Humid-Forest loam (D_{F1}).

The altitude of the places in the zone ranges from 30[illegible] to 1200 m above M.S.L. The important cropping pattern is L_3 Pd_4 Pr_4 Sp_4.

The important crops are coffee, tea, pepper, cardamom, rubber, ginger, paddy, mango and jack. The moisture availability regime and the soil type are suitable for growing these crops. The altitude also favours the growth of these crops except mango and jack. Mango and jack do not tolerate cold and hence,

they are suitable only for the lower elevations of this zone. Vegetables, potato and sugarcane can also be grown in this zone (Anonymous, 1974).

4.6.17. Per humid-Laterite (E_{La}).

The cropping patterns found in this zone are $Pd_3\ O_4\ Fr_4$, $Pd_3\ O_4\ L_4$, $Sp_3\ L_3\ O_4$, $L_3\ O_4\ Pd_4\ Ta_4$ and $S_3\ Ta_4\ Sp_4\ Fr_4$. The important crops are paddy, coconut, tapioca, rubber, pepper, arecanut, cocoa, mango, jack, cashew, ginger and banana. The altitude of the zone does not exceed 600 m above M.S.L. As the MAR is perhumid the crops suitable for E type of MAR are suitable to this zone provided the altitude and the soil types agree. Considering the altitude and soil types of this zone and also taking into account the environmental conditions required for the important crops revealed by Table 7, Potti (1978), Aiyer (1944) and Kerala Agricultural University (1983) it is concluded that the crops are suitable for this zone.

Vegetables, pulses, nutmeg, cinnamon, clove and fodder grass can also be grown in this zone (Anonymous, 1974).

4.6.18. Per humid-Forest loam (E_{Fl}).

In general the altitude of the places in this zone is within the range of 300-1200 m above M.S.L. with the majority of the areas below 900 m above M.S.L. Other climatic conditions are almost similar to that of the zone E_{La}. So the crops suitable for the zone E_{La} can be considered suitable for this zone also depending on their adaptation to different altitudes and soils.

The important cropping patterns in this zone are L_3 Pd_4 Fr_4 Sp_4, Pd_3 O_4 Fr_4, Sp_3 L_3 O_4, L_3 Pd_4 Ta_4 O_4 and O_3 Ta_4 Pd_4 Fr_4. The important crops grown in this agroclimatic zone are paddy, coconut, tapioca, pepper, tea, coffee, cocoa, and cardamom. The environmental conditions described by ICAR (1980), Kerala Agricultural University (1983) and Aiyer (1944) show that paddy and pepper are well suited for the zone, and that coconut, tapioca and cocoa can be grown economically upto about 900 m above M.S.L. The soil and climatic conditions described by ICAR (1980) further helps to understand that this zone is suitable for tea, coffee, and cardamom.

Vegetables, potato and sugarcane can also be grown in this zone (Anonymous, 1974).

4.6.19. Wet-Laterite (F_{La}).

The altitude of the various places in this zone varies from 60 to 1020 m above M.S.L. and the majority of the areas are below 600 m above M.S.L. The soil types are laterite and brown hydromorphic.

The important cropping pattern in this agroclimatic zone is Sp_3 L_3 O_4. The important crops are cardamom, tea, coffee, rubber, pepper, tapioca, ginger and paddy. The altitude and soil conditions described in Table 7 show that all these crops are suitable for this zone. As mentioned earlier the climatic conditions of F type M.R is suitable for growing these crops. Rubber grows well up to 600 m above M.S.L. and at higher elevations cardamom is better.

Pulses, banana, coconut, nutmeg, cinnamon, clove, cocoa and arecanut can also be grown in this zone (Anonymous, 1974).

4.6.20. Wet-Forest loam (F_{Fl}).

The altitude of this zone is 300-1600 m above M.S.L. The important cropping patterns are L_3 Pd_4 Fr_4 Sp_4 and Sp_3 L_3 O_4. The important crops

of this zone are cardamom, tea, coffee, pepper, tapioca and paddy. The F type of MAR is suitable for growing these crops. The soil and climatic conditions described in Table 7, show that cardamom, tea, coffee, pepper and paddy are suitable for this zone and that tapioca may be grown in the zone only up to an altitude of 800 m above M.S.L.

Vegetables, potato and sugarcane can also be grown in this zone (Anonymous, 1974).

The present study has laid out 6 moisture availability regimes and has identified 20 agroclimatic zones and 12 cropping patterns of Kerala. Hargreaves et al. (1985) have pointed out the problems faced by crops at different levels of MAI. His suggestions can be applied to the agroclimates of Kerala to arrive at the following conclusions. As the dry (A) type of moisture availability regimes are characterised by 6 or more months with MAI below 0.33, great care is required during the six months for economic crop production in such areas. Fertilizers should not be applied during this period unless irrigation is assured. The perhumid (E) and wet (F) types of moisture availability regimes are characterised by 5 or more months with MAI above 1.33. There is a need, except

for rice, of good natural and artificial drainage in such areas.

There is no exaggeration to say that about 50% of cultivation of tapioca in Kerala is done on slopes which in most parts of the world would be considered unsuitable for cultivation. It is widely accepted that the cultivation of tapioca cause soil erosion. This is true for low rainfall areas too, as one or two heavy showers are sufficient to cause considerable erosion. Considering the economy and food problems of the state it may not be wise to stop tapioca cultivation, but proper soil conservation measures have to be taken up when tapioca is grown on the slopes, especially of the subhumid (C), humid (B), perhumid (E) and wet (F) types of moisture availability regimes.

SUMMARY

5. SUMMARY

The present study was carried out for delineating the various agroclimatic zones of Kerala and for identifying the cropping patterns for the different zones.

Meteorological data were collected for 11 stations of Kerala Agricultural University, 7 stations of India Meteorological Department and 82 stations maintained by the State Government and other agencies. Soil and crop data were collected for the whole state. Results of the analyses of various data are summarised as follows:

5.1. Agroclimatic Features

The meteorological data collected consist of data on rainfall, temperature, humidity, wind and sunshine.

The average annual rainfall for the state is 2908 mm. The spatial distribution maps show that the annual and S.W. monsoon rainfall increase from south to north, while N.E. monsoon rainfall increases from north to south. During winter it increases slightly from north to south. During summer the

rainfall is found to increase from both northern and southern parts of the state to Central Travancore. Among the stations, Chinnar shows the lowest mean annual rainfall of 665 mm. There are four pockets of high annual rainfall exceeding 4000 mm. They are in and around Wynad, Neriamangalam, Idukki and Ponmudi.

Studies on the coefficient of variation of annual and seasonal rainfall show that the annual, S.W. monsoon, N.E. monsoon and winter values show a reverse trend when compared to the spatial distribution of mean rainfall. The summer values increase slightly from south to north. In general, the annual CV for a station is smaller than the CV for the seasons. Annual CV is lowest at Calicut (14%) while it is highest at Velur and Chinnar (44%).

Analysis of temperature data shows that the monthly average of minimum temperature is lowest in Idukki (19.1°C) while the monthly average of maximum temperature is highest in Palghat (37.5°C). Cochin has a temperature range of 8.2°C, whereas Palghat, Pattambi and Punalur have a range about twice this value.

The highest mean annual relative humidity in the state was observed in Alleppey (80%) while Palghat has the lowest value (70%). The highest relative humidity was observed in June, July or August while the lowest is in January, February or March. The monthly means of relative humidity vary from 51% (Palghat) to 91% (Calicut).

Palghat, Alleppey, Cochin and Calicut have recorded highest wind speeds in the state.

Mean bright sunshine hours in the state vary from 8 to 10 hours during January to March, while the values are very low and ranges between 2.8 and 8 hours during June to November. Maximum possible hours of sunshine vary from 11.4 hours (in December) to 12.8 hours (in June and July).

The soil data obtained from the Soil Survey Branch, Department of Agriculture, Trivandrum, revealed that there are 10 broad groups of soils. They are (1) red loams, (2) laterites, (3) coastal alluvium, (4) riverine alluvium, (5) greyish Onattukara, (6) brown hydromorphic, (7) hydromorphic saline, (8) acid saline, (9) black soils and (10) forest loams. The important characters, limitations and general management needs of the soil groups outlined by Soil

Survey Branch, Department of Agriculture (Anonymous, 1978) were summarised.

5.2. Water Balance and Agriculture

The water balance elements such as potential evapotranspiration (PE), actual evapotranspiration (AE), water surplus (WS) and water deficit (WD) and also the water balance indices such as humidity index (I_h), aridity index (I_a) and index of moisture adequacy (I_{ma}) of 14 representative stations in the state were computed on annual basis.

PE varies from 862 mm (Munnar) to 1757 mm (Kottayam) among these stations. Its distribution confirms the effect of altitude on PE. AE varies from 821 mm (Munnar) to 1569 mm (Punalur). The coastal stations have AE values between 1200 mm and 1400 mm. Water surplus varies from 389 mm (Trivandrum) to 2807 mm (Munnar). Water deficit ranges from 41 mm (Munnar) to 614 mm (Chittur). The values of I_h range from 22.8% at Trivandrum to 325.6% at Munnar. I_a varies from 4.8% at Munnar to 35.1% at Chittur. The annual I_{ma} varies from 64.9% at Chittur to 95.2% at Munnar. Among these 14 stations, those situated north of Cochin (except Manantbody), have I_{ma} values less

than 81% while the rest have values more than 81%.

5.3. Agroclimatic Classification

Monthly values of moisture availability index (MAI) were computed as the ratio of 75% probability rainfall to potential evapotranspiration. Six moisture availability regimes (MAR) were proposed and delineated following the guidelines of Hargreaves (1971 & 1975). The moisture availability regimes are as follows:

Sl. No.	Criteria	Moisture Availability Regime(MAR)	Symbol
1.	6 or more months with MAI in the range 0.00 - 0.33	DRY	A
2.	5 or more consecutive months with MAI above 0.33	SEMI-DRY	B
3.	5 or more consecutive months with MAI above 0.67	SUB-HUMID	C
4.	5 or more consecutive months with MAI above 0.99	HUMID	D
5.	5 or more consecutive months with MAI above 1.33	PER-HUMID	E
6.	5 or more consecutive months with MAI above 1.67	WET	F

The soil types of Kerala were clustered together in terms of their orgin, properties and suitability to crops so as to form 7 soil groups.

The soil groups are as follows:

Soil group	Symbol	Constituent soil types
Red loams	Rl	Red loams
Laterites	La	Laterites, Brown hydromorphic
Alluvial soils	Al	Coastal alluvium, Riverine alluvium
Greyish Onattukara	Go	Greyish Onattukara
Saline soils	Sa	Acid saline, Hydromorphic saline
Black soils	Bs	Black soils
Forest loams	Fl	Forest loams

20 agroclimatic zones were identified by superimposing the 6 moisture availability regimes over the 7 soil groups. They are A_{Fl}, B_{Rl}, B_{La}, B_{Al}, B_{Bs}, B_{Fl}, C_{Rl}, C_{La}, C_{Al}, C_{Sa}, C_{Fl}, D_{La}, D_{Al}, D_{Go}, D_{Sa}, D_{Fl}, E_{La}, E_{Fl}, F_{La} and F_{Fl}.

5.4. Cropping patterns

Crop data obtained from the Directorate of

Economics and Statistics, Trivandrum, was processed and it was found that there are 12 major important crops in Kerala (each occupying an area more than 30000 ha). They are rice, coconut, rubber, tapioca, cashew, pepper, coffee, mango, arecanut, jackfruit, cardamom and tea which altogether occupy 87.54% of the gross cropped area.

The cropping patterns resent in the state were identified according to the method described by National Commission on Agriculture. The crops and their areas were coded using crop symbols and numerical subscripts respectively.

The codes for crops are as follows:

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

The area of crops are denoted as follows:

Area coverage (% of gross cropped area)	Numerical subscripts
70 or more	1
50 - 69	2
30 - 49	3
10 - 29	4
less than 10	5

It was found that there are 12 cropping patterns in the state. They are put under three major groups. The 3 major groups, the individual cropping patterns and the places coming under them are given below.

Major group	Cropping pattern	Places under the cropping pattern
1. Mainly rice	$Pd_3O_4Fr_4$	Malappuram district
		& Trichur "
	Pd_2O_4	Palghat "
	$Pd_3O_4L_4$	Ernakulam "
	Pd_3O_3	Alleppey "
2. Mainly coconut	$Fr_4O_4Pd_4Sp_4$	Cannanore "
		& Kasaragod "
	$O_3Pd_4Fr_4Sp_4$	Kozhikode "

	$O_3Ta_4Pd_4Fr_4$	Quilon district & Trivandrum "
3. Mainly plantations other than coconut	$L_3Pd_4Fr_4Sp_4$	Wynad district
	$Sp_3L_3O_4$	Major part of Idukki district.
	L_2Ta_4	Eastern halves of Devikulam, Udumbanchola and Peermed taluks in Idukki district.
	$L_3O_4Pd_4Ta_4$	Kottayam district
	$L_3Pd_4Ta_4O_4$	Pathanamthitta "

5.5. Suitability of Cropping Patterns

The environmental conditions prevailing in the 20 agroclimatic zones were examined and the suitability of the cropping patterns for each agro-climatic zone were discussed. The soil and climatic conditions favouring the growth of the various crops suggested by various scientists, researchers and authors were also considered for this purpose.

An examination of the climatic conditions of

Kerala revealed that, all the places coming under the moisture availability regimes C, D, E and F (except the C_{F1} area near Marayur) are climatically suitable for growing the majority of the important crops of Kerala i.e. paddy, coconut, rubber, tapioca, cashew, pepper, coffee, mango, arecanut, cardamom, tea, ginger, cocoa, banana and sesamum. These crops may be grown in these places provided the altitude and soil type are in agreement with the crops' requirements.

The information obtained by examining the suitability of the cropping patterns for each of the 20 agroclimatic zones are summarised as follows.

It is found that the cropping patterns existing in almost all the agroclimatic zones are suitable for the zones. Very few crops were found unsuitable for these zones. Coconut do not appear to be suitable for Semi dry-Black soil (B_{Bs}) zone and the eastern parts of Semi dry-Laterite (B_{La}) zone in Palghat. Rubber is not a congenial crop for Semi dry-Forest loam (B_{F1}) zone. Mango and jack are not suitable for the high altitude areas of Humid-Forest loam (D_{F1}) zone. Coconut, tapioca and cocoa are suitable only up to 900 m above M.S.L. in the Per

humid-Forest loam (E_{Fl}) zone. In Wet-Laterite (F_{La}) zone rubber grows well upto 600 m above M.S.L., while cardamom is a better crop for the higher elevations of the zone. Tapioca is not suitable for areas 800 m above M.S.L. in the Wet-Forest loam (F_{Fl}) zone. It is also found that the important crops except tapioca of the Dry-Forest loam (A_{Fl}) zone appear to be not suitable for the zone. It is felt that a detailed study with a denser network of meteorological stations is necessary for examining the suitability of crops to the zone Sub humid-Forest loam (C_{Fl}).

It also appears that crops such as millets with low water requirement should be given more importance in the zones Semi dry-Black soil (B_{Bs}) and Dry-Forest loam (A_{Fl}).

Great care is required for six months for economic crop production in areas with Dry (A) type of MAR. There is a need, except for rice, of good natural and artificial drainage in areas with Per-humid (E) and Wet (F) types of MAR.

In order to reduce the soil erosion caused by growing tapioca, it is suggested that proper soil

conservation measures have to be taken up when tapioca is grown on the slopes, especially of the subhumid (C), humid (D), perhumid (E) and Wet (F) types of moisture availability regimes.

5.6. Suggested Future Work

The present study is of pioneering nature in the sense that data from about 100 stations in the state were collected for a period of 80 years and a rational scheme of agroclimatic classification is applied. It is hoped that this will contribute to the development of better cropping systems and practices.

However, the climate and crop data are not available in the form and length required for a more realistic analysis. Weekly water balance and water availability periods may give a better insight to the agroclimatic potential of the state. Future work is, hence, suggested based on weekly data. Crop specific agroclimatic classification may also be attempted. Kerala is a landmass of variable topography and it is felt that the present network of agromet stations is not enough to bring out the various agroclimatic conditions of the state. Hence a denser network of agromet stations is the urgent need for developing a data source for future work.

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* Original not seen.

APPENDICES

APPENDIX - I

Moisture availability index (MAI) (on monthly basis)

Stations	Months											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Ponmudi	0.00	0.00	0.07	0.64	0.88	3.78	3.92	1.53	2.90	4.90	1.12	0.00
Varkala	0.00	0.00	0.09	0.30	0.91	1.91	1.55	1.06	0.55	1.20	0.51	0.06
Attingal	0.00	0.00	0.03	0.41	0.58	1.74	1.33	0.61	0.38	1.14	0.61	0.05
Nedumangad	0.00	0.00	0.14	0.68	0.66	1.51	1.29	0.72	0.55	1.57	0.95	0.14
Trivandrum	0.01	0.00	0.05	0.46	0.64	1.39	1.04	0.54	0.38	1.27	0.76	0.12
Karunagappally	0.00	0.00	0.02	0.37	0.91	2.52	2.11	1.11	0.66	1.36	0.61	0.07
Punalur	0.00	0.06	0.25	0.98	0.88	2.50	2.66	1.62	0.87	2.19	1.08	0.04
Kottarakkara	0.00	0.00	0.05	0.51	0.63	2.42	2.65	1.37	0.81	1.50	0.70	0.07
Aryankavu	0.00	0.00	0.18	0.36	0.29	2.35	2.16	1.50	0.74	1.75	0.99	0.17
Quilon	0.00	0.00	0.05	0.46	0.82	2.79	1.77	0.90	0.56	1.25	0.72	0.02
Nilamel	0.00	0.00	0.09	0.75	0.60	2.39	1.80	1.18	0.53	1.64	0.39	0.00
Paravoor	0.00	0.00	0.01	0.28	0.61	1.97	1.20	0.56	0.35	1.07	0.52	0.00
Pathanamthitta	0.00	0.05	0.28	0.87	1.24	2.74	2.84	1.90	1.16	2.20	0.96	0.14
Konni	0.00	0.05	0.35	1.12	1.10	2.84	3.11	2.15	1.11	2.07	0.92	0.10
Adoor	0.00	0.00	0.14	0.12	0.74	2.42	2.63	1.65	0.94	1.65	0.88	0.11
Thiruvalla	0.00	0.00	0.06	0.42	0.82	3.02	2.74	1.82	1.12	1.47	0.89	0.09

Appendix - I (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Arukutty	0.00	0.00	0.04	0.35	0.86	3.91	3.83	2.02	1.31	1.49	0.72	0.04
Shertallai	0.00	0.00	0.03	0.38	0.85	3.08	3.09	1.74	1.32	1.36	0.64	0.05
Alleppey	0.00	0.07	0.06	0.44	0.89	2.80	3.94	1.88	1.63	1.01	0.39	0.10
Ambalapuzha	0.00	0.02	0.07	0.42	0.80	3.01	2.79	1.36	1.15	1.55	0.85	0.17
Chengannur	0.00	0.00	0.09	0.67	0.60	2.76	2.98	2.02	1.22	1.82	1.09	0.11
Haripad	0.00	0.00	0.09	0.30	0.81	3.01	2.70	1.61	1.12	1.70	0.79	0.17
Mavelikara	0.00	0.00	0.09	0.48	0.82	3.41	3.01	1.92	1.37	1.84	0.87	0.12
Kayamkulam	0.00	0.00	0.07	0.37	0.82	2.44	2.13	1.24	1.01	1.24	0.78	0.04
Vaikom	0.00	0.00	0.04	0.32	0.73	3.54	3.38	1.87	1.27	1.22	0.51	0.07
Palai	0.00	0.01	0.24	1.16	1.12	3.43	3.67	2.67	1.20	1.99	1.33	0.19
Ettumanur	0.00	0.00	0.11	0.48	0.73	3.31	3.37	2.15	1.09	1.26	0.57	0.07
Kottayam	0.00	0.00	0.08	0.48	0.90	3.23	3.46	1.90	1.31	1.65	0.81	0.11
Kanjirappally	0.00	0.02	0.51	1.11	1.45	3.92	3.79	2.69	1.36	2.52	1.17	0.19
Changanacherry	0.00	0.00	0.09	0.57	0.84	3.04	3.13	1.95	1.21	1.64	0.87	0.10
Chinnar	0.00	0.00	0.00	0.04	0.12	0.20	0.12	0.06	0.09	0.57	0.49	0.07
Marayur	0.00	0.00	0.00	0.28	0.41	0.72	1.47	0.72	0.72	1.28	1.23	0.26
Munnar	0.00	0.00	0.08	0.95	1.33	5.97	11.32	0.85	2.56	2.47	0.91	0.00
Devikulam	0.00	0.00	0.00	0.81	1.35	5.18	7.00	3.56	2.20	3.09	1.23	0.10
Vandenmedu	0.00	0.01	0.05	0.74	0.37	2.71	3.58	2.71	1.36	1.96	0.92	0.19
Kumily	0.00	0.00	0.19	0.28	0.27	1.87	2.17	0.99	0.49	1.51	1.03	0.24

Appendix - I (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Peermade	0.00	0.00	0.17	0.47	0.66	7.78	8.83	5.08	2.94	3.53	1.43	0.05
Santhanpara	0.00	0.01	0.07	0.42	0.44	1.89	2.19	0.88	0.64	2.56	1.77	0.37
Velur	0.00	0.05	0.00	0.57	0.41	2.94	3.14	2.40	1.05	1.13	1.00	0.00
Karikode	0.00	0.00	0.17	0.88	1.18	4.38	4.47	2.80	1.52	2.44	0.92	0.09
Malayattur	0.00	0.00	0.16	0.65	0.79	3.82	4.09	2.76	1.40	1.67	0.66	0.01
Parur	0.00	0.00	0.00	0.24	0.64	3.34	3.24	1.98	1.01	0.93	0.36	0.00
Perumbavur	0.00	0.00	0.01	0.32	0.60	3.81	3.95	2.50	1.10	1.64	0.53	0.01
Alwaye	0.00	0.00	0.01	0.25	0.70	4.16	4.15	2.25	0.91	1.37	0.49	0.00
Muvattupuzha	0.00	0.00	0.08	0.55	0.91	3.73	3.93	2.60	1.20	2.01	0.80	0.08
Ernakulam	0.00	0.00	0.02	0.29	0.97	3.88	3.38	1.94	0.95	1.48	0.50	0.02
Cranganore	0.00	0.00	0.00	0.22	0.89	3.90	3.80	1.98	1.26	1.11	0.44	0.00
Mukundapuram	0.00	0.00	0.00	0.16	0.75	3.92	4.26	1.95	0.83	1.10	0.31	0.00
Trichur	0.00	0.00	0.00	0.15	0.72	4.01	4.18	2.36	0.89	1.23	0.30	0.00
Thalappilly	0.00	0.00	0.00	0.17	0.55	3.40	4.17	2.13	0.53	1.01	0.39	0.00
Ollukkara	0.00	0.00	0.00	0.13	0.46	2.61	4.66	2.19	0.77	0.90	0.20	0.00
Chowghat	0.00	0.00	0.00	0.29	0.87	4.42	3.92	1.82	1.05	1.24	0.57	0.00
Triprayar	0.00	0.00	0.00	0.18	0.90	4.35	4.25	1.92	0.96	1.27	0.42	0.00
Alathur	0.00	0.00	0.00	0.13	0.35	2.34	4.08	1.61	0.46	1.02	0.43	0.00
Palghat	0.00	0.00	0.00	0.15	0.33	1.94	3.89	1.77	0.53	0.95	0.46	0.00
Parali	0.00	0.00	0.00	0.27	0.41	2.38	4.24	2.01	0.65	1.47	0.23	0.00

Appendix - I (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Ottappalam	0.00	0.00	0.00	0.26	0.48	2.94	4.01	2.00	0.58	1.24	0.47	0.00
Cherpulassery	0.00	0.00	0.00	0.35	0.49	2.75	4.08	1.77	0.63	1.23	0.51	0.00
Mannarghat	0.00	0.00	0.00	0.37	0.58	2.65	4.60	2.04	0.77	1.57	0.52	0.00
Chittur	0.00	0.00	0.00	0.13	0.24	1.55	3.00	1.35	0.41	0.67	0.28	0.00
Perinthalmanna	0.00	0.00	0.00	0.26	0.40	2.62	4.29	1.78	0.59	1.49	0.61	0.00
Ponnani	0.00	0.00	0.00	0.29	0.70	3.73	3.80	1.80	0.99	1.16	0.51	0.00
Manjeri	0.00	0.00	0.00	0.32	0.49	3.49	4.84	2.02	0.64	1.18	0.41	0.00
Thirurangadi	0.00	0.00	0.00	0.14	0.52	3.58	4.46	1.90	0.83	0.99	0.33	0.00
Nilambur	0.00	0.00	0.00	0.13	0.39	3.05	4.69	1.85	0.56	1.10	0.29	0.00
Calicut	0.00	0.00	0.00	0.16	0.62	4.48	5.36	2.16	0.72	1.00	0.46	0.00
Quilandi	0.00	0.00	0.00	0.09	0.65	4.10	5.48	2.28	0.70	0.82	0.30	0.00
Badagara	0.00	0.00	0.00	0.16	0.64	4.66	5.60	2.62	0.82	0.77	0.30	0.00
Kuttiyadi	0.00	0.00	0.00	0.35	0.83	5.71	7.02	4.04	1.29	1.62	0.71	0.00
Vythiri	0.00	0.00	0.05	0.62	0.76	7.85	13.57	6.08	2.10	2.15	0.55	0.05
Telechery	0.00	0.00	0.00	0.10	0.48	4.65	5.51	2.39	0.61	0.70	0.20	0.00
Cannanore	0.00	0.00	0.00	0.04	0.48	4.73	5.53	2.43	0.85	0.72	0.19	0.00
Irikkur	0.00	0.00	0.00	0.13	0.54	4.32	6.54	3.54	1.04	1.19	0.35	0.00
Taliparamba	0.00	0.00	0.00	0.07	0.46	4.74	6.33	2.94	0.97	0.94	0.32	0.00
Payyannur	0.00	0.00	0.00	0.06	0.44	5.23	6.21	2.93	0.99	0.76	0.21	0.00
Hosdurg	0.00	0.00	0.00	0.03	0.42	5.70	6.03	2.93	1.07	0.77	0.22	0.00
Kasaragod	0.00	0.00	0.00	0.06	0.46	5.47	5.93	3.18	1.17	0.78	0.23	0.00

APPENDIX - II

Seventy five percent probability rainfall (mm) and potential evapotranspiration (mm) (on monthly basis)

Stations	Item	Months											
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Ponmudi	x	0	0	6	61	83	299	290	113	212	358	83	0
	y	75	72	92	96	94	79	74	74	73	73	74	75
Varkala	x	0	0	14	48	144	256	206	140	76	168	69	8
	y	138	128	153	159	159	136	133	132	139	140	134	138
Attingal	x	0	0	4	65	94	238	178	81	52	160	83	7
	y	139	129	155	159	161	137	134	132	137	140	135	138
Nedumangad	x	0	0	22	109	106	215	172	96	74	218	127	19
	y	135	130	159	160	161	142	133	133	134	139	133	133
Trivandrum	x	1	0	8	72	103	202	142	74	52	175	103	17
	y	139	130	156	157	161	145	136	136	137	138	135	136
Karunagapally	x	0	0	3	59	144	233	279	145	92	192	83	10
	y	140	128	155	161	159	132	132	131	140	141	135	139
Punalur	x	0	2	40	159	146	362	354	220	122	309	142	6
	y	136	138	162	163	165	145	133	136	140	141	131	138

Appendix - II (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Kottarakkara	x	0	0	8	83	102	331	353	181	113	212	92	10
	y	139	132	161	162	162	137	133	132	140	141	132	134
Aryankavu	x	0	0	27	56	46	315	270	109	101	240	129	23
	y	110	114	149	157	161	134	128	126	136	137	130	134
Quilon	x	0	0	7	74	130	360	234	117	79	176	97	3
	y	138	127	152	160	158	129	132	130	140	141	134	138
Nilamel	x	0	0	15	121	98	325	239	155	74	229	51	0
	y	138	132	160	162	164	136	133	131	139	140	132	138
Paravoor	x	0	0	1	45	97	260	160	74	48	150	70	0
	y	138	128	153	159	159	132	133	131	139	140	134	138
Pathanamthitta	x	0	6	45	140	204	397	369	249	162	312	127	18
	y	136	133	160	161	165	145	130	131	140	142	132	133
Konni	x	0	7	56	181	181	412	408	280	156	294	121	13
	y	135	137	161	162	165	145	131	130	140	142	131	132
Adoor	x	0	0	23	19	122	341	349	215	131	235	116	14
	y	136	137	162	161	165	141	131	130	140	142	132	133
Thiruvalla	x	0	0	9	68	135	453	387	240	157	310	119	12
	y	140	136	161	162	165	150	141	132	140	143	134	136

Appendix - II (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Arukutty	x	0	0	6	57	140	571	506	271	170	210	98	6
	y	140	133	160	161	163	146	132	134	130	141	137	138
Shertallai	x	0	0	5	62	140	449	408	232	169	192	88	7
	y	140	134	160	162	164	146	132	133	128	141	137	139
Alleppey	x	0	9	10	72	147	417	516	250	206	142	53	14
	y	141	135	162	163	165	146	131	133	126	141	137	140
Ambalapuzha	x	0	3	12	68	131	428	366	181	140	218	117	24
	y	141	132	161	163	164	142	131	133	127	141	137	140
Chengannur	x	0	0	15	108	97	409	393	264	171	258	146	15
	y	140	133	162	161	163	148	132	131	140	142	134	136
Haripad	x	0	0	15	49	131	418	354	212	145	239	107	24
	y	141	130	160	162	162	139	131	132	129	141	136	139
Mavelikara	x	0	0	14	77	133	494	397	253	185	260	118	16
	y	140	130	160	162	163	145	132	132	135	141	135	137
Kayamkulam	x	0	0	11	60	132	329	281	163	136	175	105	6
	y	140	129	157	161	161	135	132	131	135	141	135	139
Vaikom	x	0	0	6	131	119	527	467	254	170	173	69	10
	y	140	132	159	160	164	149	136	136	134	142	135	139

Appendix - II (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Palai	x	0	1	37	185	181	514	514	352	168	202	176	26
	y	135	132	154	160	162	150	140	132	140	142	132	135
Ettumanur	x	0	0	17	77	119	500	479	293	151	179	76	10
	y	140	134	157	160	164	151	142	136	138	142	134	140
Kottayam	x	0	0	13	76	148	491	509	260	183	237	108	15
	y	141	138	159	160	165	152	147	137	140	144	134	140
Kanjirappally	x	0	2	78	178	234	560	500	355	191	356	152	28
	y	134	130	153	160	161	143	132	132	140	141	130	131
Changanacherry	x	0	0	14	91	139	459	451	259	169	235	117	14
	y	140	134	161	161	165	151	144	133	140	143	134	138
Chinnar	x	0	0	0	5	18	20	11	5	8	54	46	6
	y	95	97	129	136	150	98	93	90	94	94	93	87
Marayur	x	0	0	0	32	50	62	119	57	58	105	100	20
	y	76	82	109	114	123	86	81	79	81	82	81	77
Munnar	x	0	0	7	84	121	424	747	445	169	168	60	0
	y	66	65	84	88	91	71	66	65	66	66	66	66
Devikulam	x	0	0	0	65	109	347	438	317	134	198	76	6
	y	63	60	77	80	81	67	62	61	61	64	62	62

Appendix - II (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Vendammedu	x	0	1	5	79	42	222	353	203	105	153	71	14
	y	73	78	102	107	114	82	77	75	77	78	77	74
Kumily	x	0	0	22	35	36	170	187	82	43	131	89	20
	y	80	89	117	124	135	91	86	83	87	87	86	82
Peermade	x	0	0	18	53	80	661	706	396	235	286	114	4
	y	76	81	107	113	121	85	80	78	80	81	80	77
Santhanpara	x	0	1	7	45	51	157	171	66	50	202	138	28
	y	74	78	103	108	116	83	78	75	76	79	78	75
Velur	x	0	5	0	80	64	294	311	216	136	128	117	0
	y	100	100	145	140	157	100	99	90	130	113	117	131
Karikode	x	0	0	26	140	190	617	581	367	198	341	122	12
	y	131	120	153	160	161	141	130	131	130	140	132	132
Malayattur	x	0	0	25	104	126	542	532	359	182	234	87	1
	y	132	130	152	160	160	142	130	130	130	140	131	132
Parur	x	0	0	0	38	103	488	431	263	131	131	49	0
	y	138	133	160	160	161	146	133	133	130	141	136	137

Appendix - II (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Perumbavur	x	0	0	2	51	97	545	517	328	143	230	70	2
	y	132	130	154	160	161	143	131	131	130	140	133	134
Alwaye	x	0	0	2	40	113	599	504	297	119	195	66	0
	y	135	131	158	160	161	144	131	132	131	141	134	136
Muvattupuzha	x	0	0	12	86	147	529	515	341	156	281	107	10
	y	132	130	153	160	161	142	131	131	130	140	133	133
Ernakulam	x	0	0	3	47	157	566	449	260	124	208	69	3
	y	138	132	159	160	162	146	133	134	131	141	137	137
Cranganore	x	0	0	0	35	144	569	506	263	162	156	60	0
	y	138	133	160	160	161	146	133	133	129	141	136	137
Mukundapuram	x	0	0	0	25	121	573	566	259	106	155	42	0
	y	138	133	160	160	161	146	133	133	128	141	136	137
Trichur	x	0	0	0	24	118	585	544	312	119	173	40	0
	y	137	136	163	163	163	146	130	132	134	141	135	135
Thalappilly	x	0	0	0	28	92	497	534	277	73	144	52	0
	y	137	135	167	167	168	146	128	130	139	143	135	133
Ollukkara	x	0	0	0	22	76	381	587	289	105	127	27	0
	y	137	137	165	167	166	146	126	132	137	141	134	134

Appendix - II (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Chowghat	x	0	0	0	46	139	645	521	238	131	175	77	0
	y	137	134	161	161	160	146	133	131	125	141	135	137
Triprayar	x	0	0	0	29	144	635	561	253	122	179	57	0
	y	138	133	160	160	160	146	132	132	127	141	136	137
Alathur	x	0	0	0	23	59	337	490	206	64	147	58	0
	y	143	140	172	172	170	144	120	128	138	144	136	135
Palghat	x	0	0	0	26	55	277	451	220	74	139	64	0
	y	143	143	174	173	169	143	116	124	140	147	139	139
Parali	x	0	0	0	45	70	343	504	251	90	207	30	0
	y	141	135	169	165	170	144	119	125	138	141	133	135
Ottapalam	x	0	0	0	45	82	426	497	252	81	180	64	0
	y	139	137	171	170	170	145	124	126	140	145	137	139
Cherpulassery	x	0	0	0	57	83	393	514	221	88	174	66	0
	y	133	136	164	163	170	143	126	125	139	142	133	135
Mannarghat	x	0	0	0	53	99	371	557	247	101	220	67	0
	y	124	135	158	142	170	140	121	121	132	140	130	130
Chittur	x	0	0	0	22	41	220	348	168	57	99	39	0
	y	143	144	175	174	170	142	116	124	140	147	139	139

Appendix - II (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Perinthalmanna	x	0	0	0	42	68	372	540	222	80	208	80	0
	y	133	139	161	160	168	142	126	125	136	140	131	132
Ponnani	x	0	0	0	46	112	545	505	234	122	164	68	0
	y	137	135	162	161	159	146	133	130	123	141	134	137
Manjeri	x	0	0	0	48	82	488	605	251	85	167	54	0
	y	132	134	160	151	169	140	125	124	133	141	133	133
Thirurangadi	x	0	0	0	23	89	519	575	245	108	141	45	0
	y	136	133	160	159	170	145	129	129	130	143	135	136
Nilambur	x	0	0	0	19	66	427	567	224	73	154	38	0
	y	131	130	155	150	170	140	121	121	130	140	130	131
Calicut	x	0	0	0	26	105	659	692	281	101	144	63	0
	y	137	132	159	164	170	147	129	130	140	144	136	136
Quilandi	x	0	0	0	15	111	615	713	297	98	117	40	0
	y	137	133	160	163	170	147	130	130	140	143	135	136
Badagara	x	0	0	0	26	108	685	733	340	115	110	40	0
	y	137	132	161	162	170	147	131	130	140	142	134	136
Kuttiyadi	x	0	0	0	49	149	731	978	485	172	227	92	0
	y	130	130	160	140	170	128	129	120	133	140	130	131

Appendix - II (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Vythiri	x	0	0	5	67	84	683	1018	468	174	185	45	4
	y	80	79	102	108	111	87	75	77	83	86	82	83
Telechery	x	0	0	0	16	81	684	727	311	85	100	27	0
	y	137	134	162	162	170	147	132	130	140	142	134	136
Cannanore	x	0	0	0	7	82	696	736	316	119	102	25	0
	y	137	134	162	161	170	147	133	130	140	141	133	136
Irikkur	x	0	0	0	20	92	613	857	436	138	167	46	0
	y	125	131	160	153	170	142	131	123	133	140	131	132
Taliparamba	x	0	0	0	11	78	682	836	373	133	133	43	0
	y	132	132	161	156	170	144	132	127	137	141	133	134
Payyannur	x	0	0	0	10	75	769	838	381	138	108	20	0
	y	133	132	160	161	170	147	135	130	139	142	134	136
Hosdurg	x	0	0	0	5	71	843	820	378	147	110	29	0
	y	128	127	156	150	171	148	136	129	138	142	134	135
Kasaragod	x	0	0	0	10	78	809	818	410	160	112	31	0
	y	124	123	152	161	171	148	138	129	137	143	135	135

x = 75% probability rainfall (mm)

y = Potential evapotranspiration (mm)

DELINEATING THE VARIOUS AGROCLIMATIC ZONES OF KERALA AND IDENTIFYING THE CROPPING PATTERNS FOR THE DIFFERENT ZONES

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ABSTRACT OF A THESIS

submitted in partial fulfilment of

the requirement for the degree

Master of Science (Agriculture)

Faculty of Agriculture

Kerala Agricultural University

Department of Agronomy

COLLEGE OF HORTICULTURE

Vellanikkara - Trichur

1986

ABSTRACT

An investigation was carried out for delineating the various agroclimatic zones of Kerala and for identifying the cropping patterns for the different zones. Meteorological data were collected from 100 stations in Kerala. Soil and crop data were collected for the whole state.

The agroclimatic features of Kerala were studied. The water balance elements and indices of 14 representative stations in the state were computed and presented on annual basis. Six moisture availability regimes (MAR) were proposed and delineated following the guidelines of Hargreaves (1971 & 1975).

Twenty agroclimatic zones were identified by superimposing the six moisture availability regimes over seven soil groups. The zones are (1) Dry-Forest loam (A_{Fl}), (2) Semi dry-Red loam (B_{Rl}), (3) Semi dry-Laterite (B_{La}), (4) Semi dry-Alluvium (B_{Al}), (5) Semi dry-Black soil (B_{Bs}), (6) Semi dry-Forest loam (B_{Fl}), (7) Sub humid-Red loam (C_{Rl}), (8) Sub humid-Laterite (C_{La}), (9) Sub humid-Alluvium (C_{Al}), (10) Sub humid-Saline (C_{Sa}), (11) Sub humid-Forest loam (C_{Fl}), (12) Humid-Laterite (D_{La}), (13) Humid-

Alluvium (D_{Al}), (14) Humid-Greyish Onattukara (D_{Go}), (15) Humid-Saline (D_{Sa}), (16) Humid-Forest loam (D_{Fl}), (17) Per humid-Laterite (E_{La}), (18) Per humid-Forest loam (E_{Fl}), (19) Wet-Laterite (F_{La}) and (20) Wet-Forest loam (F_{Fl}). Twelve cropping patterns of the state were also identified.

Suitability of the existing cropping patterns for the agroclimatic zones were examined. It is found that the cropping patterns existing in almost all the agroclimatic zones are suitable to the zones. Coconut is not suitable for B_{Bs} zone and the eastern parts of B_{La} zone, while rubber is not congenial for the zone B_{Fl}. Mango and jack are not suitable for the high altitude areas of D_{Fl} zone. Coconut, tapioca and cocoa are suitable only up to 900 m above M.S.L. in the zone E_{Fl}. In F_{La} zone rubber grows well up to 600 m above M.S.L., while cardamom is better for higher elevations. Tapioca is not suitable for areas 800 m above M.S.L. in the zone F_{Fl}. The important crops except tapioca are unsuitable for A_{Fl} zone. It is felt that a detailed study with a denser network of meteorological stations is necessary for examining the suitability of crops to the zone C_{Fl}. Crops such as millets with low water requirement should be given more

importance in the zones like B_{Bs} and A_{Fl}.

Dry (A) type MAR demands great care of crops at least for six dry months. Perhumid (E) and Wet (F) types of MAR demand proper drainage for crops except rice. Proper soil conservation measures have to be taken up when tapioca is grown on the slopes, especially of the Sub humid (C), Humid (D), Perhumid (E) and Wet (F) types of moisture availability regimes.