VEGETATION MAPPING AND ANALYSIS OF ERAVIKULAM NATIONAL PARK OF KERALA USING REMOTE SENSING TECHNIQUE

*Thesis submitted in partial fulfilment of the requirement for the degree of **Doctor of Philosophy** of the Cochin University of Science and Technology*

By

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DECLARATION

I, **P.K. SURESH BABU**, hereby declare that the thesis entitled **VEGETATION MAPPING AND ANALYSIS OF ERAVIKULUM NATIONAL PARK OF KERALA USING REMOTE SENSING TECHNIQUE** submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Enviornmental studies is my original work and has not previously formed the basis for the award of any Degree, Diploma, Associateship, Fellowship or any other similar title.

Place: Peechi

Date: 05-09-1998.

P.K. SURESH BABU

CERTIFICATE

This is to certify that the thesis entitled **VEGETATION MAPPING AND ANALYSIS OF ERAVIKULUM NATIONAL PARK OF KERALA USING REMOTE SENSING TECHNIQUE** is based on the original work done by **Mr. P.K. SURESH BABU,** in Kerala Forest Research Institute, Peechi from registration to submission, that this work has not previously formed the basis for the award of any Degree, Diploma, Associateship, Fellowship or any other similar title and that it represents entirely an independent work on the part of the candidate.

Place: Peechi
Date: 05-09-1998

Dr. A.R.R. Menon
Supervisor

Dedicated to

My

Grandfather

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CHAPTER I

INTRODUCTION

1.1 Forests

The natural resources, essential for human development and survival are getting depleted and destroyed at an alarming rate. The growing human population and their requirements for food and energy resulted in overexploitation of natural resources. This indiscriminate use of our resources will definitely lead to complete depletion of our natural resources in the nearest future.

Forests and wild life are the two most important natural living resources. In addition to food and shelter, they provide wood for cooking, timber for construction, cellulose and pulp for the production of paper *etc.*

They also have other important crucial ecological roles to play such as, maintaining and sustaining the supply of oxygen, by absorbing carbon dioxide, combating air pollution, regulating water resources, controlling water and wind erosion, mitigating floods and droughts, conserving genetic diversity and wildlife and providing recreational facility to public *etc.* (Pal, 1982). Any damage or depletion of forests and wildlife may cause irrepairable imbalance to the natural ecosystem.

The results of forest resources survey conducted by FAO (1975) and UNEP (1980) indicate that the forests then covered a total of 3.6 million hectares. This is equivalent to 27.7 % of the global land area. Forests of the tropical countries and territories cover about 1.94 billion ha. representing 53 % of the global forest area. About one half of it was tropical moist forest. The worlds decreasing forest resources covers a total of about 3.4 billion ha.

This is equivalent to 27 % of the global land area. In India, National Forest Policy (1952) recommended that one third of the geographical area to be reserved for forest cover (Govt of India, 1980). However, the recent Survey reports of Forest Survey of India, Dehra Dun (FSI, 1993) show an estimated forest cover of 6,40,107 km^2, which is 19.47 percent of the total geographical area (Anon, 1993).

1.2. Tropical forests

Tropical forests cover a total area of approximately 19 million.km^2. (14 % of the world's area) which is slightly less than half of the world's forested area. They are all located in the developing countries of the world and for the countries concerned they represent an important resource, both from production and conservation point of view (Howard and Lanly, 1975).

Tropical forest environment is quite different from the temperate ones in which almost all the developed countries are located. Tropical ecosystems, endowed with remarkably high level of biological diversity, habitat, heterogeneity, are facing massive degradation and alteration due to intense development oriented,anthropogenic activities (Suraj, 1997).

1.3 . Western Ghats

The Western Ghats, which is one of the nine biogeographic regions of India, comprise an area of approximately 1.6 lakhs km^2 stretching as a narrow belt over a distance of 1600 km. from Tapti valley in Gujarat to Kanyakumari in Tamil Nadu. The Western Ghat regions are reported to support nearly 4000 species of flowering plants. Out of 1.6 lakh km^2, Kerala accounts for about 22,000 km^2 (60 %). The Western Ghats mountain chain of Kerala state has time immemorial been reported for a rare abundance of endemic flora and fauna.

The Western Ghats possess various types of tropical forests ranging from the wet evergreen to dry deciduous. On higher elevation it also holds montane sub tropical and montane temperate forests. The upper reaches of the Western Ghats are considered as one of the most diverse and interesting biomes in India (Nair, 1994).

1.4 Indian subcontinent

The Indian region ($8^{0}\,30'$ N Lat. and $60^{0}\,97.5'$ E Long) with a total area of thirty two million hectares is very rich in biological diversity. In fact, India is one of the twelve centres of diversity and origin of several cultivated plants in the world. It is estimated that about forty five thousand species of plants occur in India alone. The flowering plants comprise fifteen thousand species, of which, five to seven thousand five hundred species are endemic. The region is rich in fauna, containing about sixty five thousand species of animals. Among these, fifty thousand species are insects, four thousand of molluscs, six thousand and five hundred birds and three hundred and forty mammals. This richness in biological diversity is due to extreme variations of climatic and altitudinal conditions coupled with varied ecological habitats (Sharma, 1993).

The Indian subcontinent is one of the richest centres of tropical genetic resources of plants. About 11 % of the known plant species of the world are special to the Indian subcontinent.

1.5. High altitude region

In geographical terms the high altitudes of south India fall within the tropical and sub tropical latitudes. However, the cold prevailing in the higher altitude suggests affinity with the temperate zones high altitude.

High altitude region is an exceptional world apart from its endemic flora and fauna. A peculiar kind of ecosystem known as shola -grassland ecosystem has evolved in the high altitudes. The Nilgiris, north of the Palakkad gap, Anamalai south of the Palakkad gap, Palani- Kodaikanal hills east of the Anamalai and Agasthamalai towards extreme south are important shola-grassland regimes. Each of these regime is considered as unique ecological entity, many plant species being endemic (Kunhikrishnan, 1991). The Eravikulam National Park is situated in the high ranges of Southern Western Ghats of Idukki district, Kerala, having an elevation up to 2695mts. with an average base elevation of 2000mts. The major geomorphological feature like rocks and cliffs render the area more inaccessible in some localities.

1.6. Eravikulam National Park- A Unique Ecosystem

Eravikulam National Park consists of an unique shola-grassland ecosystem which has remained stable and in ecological equilibrium for many decades, implying that the vegetational types are highly developed and attained stability under same climatic regime. According to Clementsian concept (1916), two distinct vegetation types can not form climax in a same regional climate. The successional status of grasslands have been a subject of much controversy over the years. Ranganathan (1938) held the view that the grasslands of the Nilgiris represent climax vegetation just like shola vegetation, contrary to the view of sub climax held by many researchers (Champion, 1936; Bor, 1938; Shankaranarayanan, 1958; Gupta, 1960; Gupta and Sankaranarayanan, 1962; and Chandrasekheran, 1962). Moreover, worlds largest population (more than 50 %) of endangered Nilgiri tahr (*Hemitragus hylocrius*, Ogliby) exist in the National Park.

1.7. Conservation and Management

The impact of population growth has a direct effect on forest ecosystem, which is passing through a critical phase of ecological stress. Therefore, conservation and judicious management of actual flora and fauna through ecologically viable conservation strategies are essential for sustainable management of National Parks and Wildlife Sanctuaries.

Wildlife is an integral part of the various ecosystems and it is very closely linked with the vegetal cover, which is one of the most important elements of the ecosystem. Any quantitative change such as the extent, density *etc.* and qualitative change from primary to the secondary type, will have a definite bearing on the wildlife.

The vital importance of protecting the environment and of preserving the precious gifts of nature intact has been realised only in recent times, and the role played by forests, plants, trees, leaves and greenery in general in maintaining the earth's atmosphere pure and healthy have been fully recognised today. But by the time we awakened to protect the natural forests a considerable portion of our valuable forest cover of the earth had already vanished.

In India, at present, there is a tremendous regression in the forest area and a very impoverishment of the wild animals. Much of the wildlife once widely distributed are now seen in certain pockets only. Hence *in situ* conservation of wildlife is a necessity. In order to conserve the natural flora and fauna, it is suggested that a minimum of 5% of the geographical area should be conserved as Protected Areas (PA). *In situ* conservation through a well planned protected area network has to be a predominant conservation strategy. This calls for maintenance of Wildlife Sanctuaries and National Parks rich in genetic diversity in their pristine form.

Kerala has a rich tradition in the field of nature conservation. The first sanctuary viz. Periyar Wildlife Sanctuary was constituted in the year 1977 and thereafter a series of sanctuaries and National Parks have been established (Karunakaran, 1986). At present there are twelve Wildlife Sanctuaries and two National Parks covering an area of 2315 km^2. This comes about 6% of total land area and about 24.61 % of the forest cover of Kerala (KFD, 1991).

1.8. Remote Sensing

The tropical scenario is one in which the population is expected to double by the year 2000 AD. The world population by 2000 AD is expected to be 7000 million people as against 3700 million now, whereas the population level was only 1000 million about 150 years ago. Eighty five percent increase in population will be expected in the next 25 years, and it is going to occur in a region in which possibly 90% of the usable land is already in use and forested lands are rapidly decreasing . This rapidly changing world constitutes therefore a reason *prima facie* for intensifying vegetal study in a quicker pace using remote sensing technology. Remote sensing supplemented with ground truth provide a very satisfactory method of obtaining several types of forest management information, which by other methods is outdated before the data can be fully used or is too expensive to collect (Howard,1976).

By the advancement of this technology, in recent years the use of remotely sensed data for land resource mapping and evaluation has increased, mainly because of the ability to supply enormous amount of information in the quickest possible time, free access of the data and availability of digital image processing facility in the regional Remote Sensing Service Centres of different parts of India.

Remote sensing is the technique of deriving information about objects on the surface of the earth with out physically coming into contact with them.

It concerns with electromagnetic energy from sun and its interaction with earth's features. But, quite often, similar spectral reflectance by different earth features and dissimilar spectral reflectance by similar earth features create spectral confusion leading to misclassification. These problems can be overcome by systematic ground truth information.

Remote sensing data can be interpreted either visually by using the characteristic spectral signatures such as tone, texture *etc.*, or digitally with the help of computers. Digital image processing involves pattern recognition technique, which classify the image data into different forest types on the basis of radiance information. The difference in the reflectance of different forest crown cover classes basically depend on spatial, spectral, radiometric and temporal resolutions but the difference in spectral radiance of each forest category becomes the basis for the identification and differentiation on satellite image.

Remote sensing data has the following advantages over conventional systems:

a. Data availability

b. Cost

c. Time frame

d. Repetivity and synoptic coverage

The basic principle of remote sensing lies in the acquisition of spectral signature of the objects at a distance and its interpretation. The different stages in Remote sensing are:

1. Origin of electromagnetic energy (sun, transmitter carried by the sensor).
2. Transmission of energy from the source to the surface of the earth and its interaction with the intervening atmosphere

3.Interaction of the energy with the earth's surface

(reflection/absorption/transmission or self emission)

4. Transmission of the reflected / emitted energy to the remote sensor placed on the platform.

5. Detection of the energy by the sensor, that is converting it into photographic image or electrical output.

6. Transmission /recording of the sensor output.

7. Pre processing the data for sensor output.

8. Collection of ground truths and collateral information.

9. Data processing and interpretation (Deekshatulu and Joseph, 1991)

Every object in nature has its own distribution of reflected, emitted and absorbed radiation. These spectral characters (spectral signatures) are used to distinguish one from another or to obtain information about size, shape *etc.*

The reflected, scattered. re-emitted energy in different wave length intervals vary according to the nature of the object and environmental conditions at the point of observation. It is known that a vegetation community, whether heterogen ous or homogenous, density of a single species or group of species and canopy cover tend to influence the reflectance properties within the field of view of the sensor thereby causing variation in the spectral response. The major factors influencing the spectral response are atmosphere, Sun's azimuth angle, (angle between Sun and horizontal plane at the point of observation), view angle of the sensor and geometry of the object. In the case of vegetation, in addition to the above factors, transmissions through leaves, number of cellular layers in the leaf, texture of upper epidermis, arrangement of leaves, nature of background (soil, moisture status, leaf litter, under growth) and topographic effects like slope, aspect of the target in relation to the solar azimuth and reflectance of the target itself influence the reflectance properties.

1. 9. Significance of the study

For the optimal utilisation of land resources, information on physical, ecological and socio-economic conditions of the area should be comprehensive and up to date. At present there is no detailed vegetation map of the study area, which is essential for effective management of any Protected Area.

The information on the structural status of the permanent vegetation such as quantitative aspects and floristic composition is essential for the better and effective decision making.

Spatial distribution, composition, economic and ecological properties of vegetation in different cover classes and the pattern of their changes *etc* are pre-requisites for planning, utilisation and management of Wildlife Sanctuaries and National Parks. Vegetation map is one of the best ways to represent above mentioned information. High altitude shola and grassland vegetation of the Western Ghats is a fragile ecosystem about which at present there is no detailed information. It has been emphasised that current mapping and monitoring technology is insufficient to cater to the needs of forest managers and environmentalists.

Vegetation maps are required for planning, exploration, reconnaissance, and management of pre-investment surveys and also useful in land management, National Park service, geological surveys and other planning procedures.

Knowledge on the spatial and temporal status of shola and grassland vegetation supplemented with phytosociological data could be used as the basis for more scientific management.

Information with respect to grassland, it's quality and distribution is of prime need to wildlife managers and for taking conservation measures in National Parks (Roy *et al.*, 1991). Information about the spatial status and distribution pattern of vegetation types and their changes are necessary for planning, utilisation and management of the National Parks. Vegetation classification and mapping have been considered significant in deriving basic information in the ecosystem conservation and management of wildlife (Muller-Dombois and Ellenberg, 1984). In order to monitor and manage the protected areas like Sanctuaries, National Parks and Biosphere Reserves, a thorough knowledge of structural and functional aspects are essential.

To meet such an inevitable need of management, the present study has been undertaken and it includes broadly two aspects *viz*. Vegetation mapping, and Vegetation Analysis.

1.10. Objectives

In the absence of detailed land cover map and the structural data of the tree vegetation of the Eravikulam National Park, a study with the following objectives . . under taken.

1. To map the vegetation in large scale (1:25,000), medium scale (1:50,000) and small scale (1: 100,000) using remote sensed data products like Aerial photographs, Satellite imageries and Digital data.
2. To estimate the area of different land cover classes.
3. To prepare contour map, slope map and drainage map of the study area as supplementary information.
4. Phytosociological Analysis of the forest vegetation.
5. To study the spatial distribution pattern of shola forests.

CHAPTER II

REVIEW OF LITERATURE

2.1. History of vegetation mapping

A general overview of vegetation of India was obtained through the forest type map prepared initially by Champion (1936) and subsequently revised by Champion and Seth (1968). They classified the vegetation based on bioclimatic attributes. This map prepared at a scale of 1:14,000,000 approximately is undoubtedly of immense significance for perceiving the climatic relationships, properties and spatial distribution of different vegetation types in the country. Preservation of the same thematic information at a larger scale of 1: 2,000,000 was then brought out in Forest Atlas of India (1973).

Although Champion and Seth's (1968) system of classification, because of its simplicity, is widely used, several drawbacks in the classification scheme adopted and the way mapping was done, have been pointed out.(Puri *et al.*, 1983). Further, the practical utility of such maps are limited in scope, because the map represents geographical distribution of potential forest type which is likely to develop in a region in the absence of any human interference, rather than representing the attributes of actual vegetation as existing at present. Concept of potential vegetation becomes somewhat hypothetical where natural vegetation was dramatically altered in the past. In addition, it is now being increasingly realised that management of natural vegetation needs to be looked, not in isolation, but in combination with other alternative landuses in a broad perspective of integrated resource management. Vegetation/land cover classification and mapping along these lines have been attempted for southern part of the country by French Institute of Pondichery jointly with Govt.Dept. (Legris and Meher-Homji , 1968). The main map at a scale of 1: 1,000,000 depicts, important features of natural vegetation and introduced/transformed land cover types like, agriculture and plantations.It is accompanied by six inset maps (at 1:5,000,000 scale) showing other environmental features, like relief, geology, bioclimate, land use, agricultural region and potential vegetation types. Such maps provide more information than the earlier ones mentioned but the scale is too small to provide detailed information for planning and management. Meher-Homji (1978) prepared the forest map of Peninsular India in 1:1,000,000 scale along this line.

2.2. Remote sensing

2.2.1. Role of aerial photographs in vegetation mapping.

Basic idea about the use of aerial cameras for forestry purposes started during 18^{th} and first half of the 19^{th} century. The inventions of aerial cameras, different types of lenses, sensitive bases to record the images, the image processing techniques and the air-born platform developed during this time, boosted the trend. The practical application of aerial photographs and photogrammetry depended on the developement of the gelatin emulsion by Maddox in 1871, and roll film by Eastman in 1885 and air plane by Wright brothers in 1903. The first aerial photograph from the plane was taken by Wilber Wright in 1909.

The use of air planes in forest stand mapping started in 1919 at Canada. Wilson (1920) was the pioneer in this field. In 1924, the Irrawaddy delta in Burma was mapped from the air (Blandford, 1924). Vertical aerial photography in the 1920's in Burma, Indonasia, Papua-New Guinea, Zambia *etc* provided the begining of remote sensing in tropical forest lands (Bourne, 1931). The general principles of remote sensing have been described by Avery (1967), FAO (1973), Simmonet (1983), Curran (1985) and Sharma (1986).

In India, the pioneers of the Indian Remote sensing programme were the two eminent scientists, Vikram Sarabhai and Homi Bhabha. Prof: P.R. Pisharati, father of Indian Remote Sensing, organised the first successful mission of early detection of coconut wilt disease in 1970 by Remote sensing techniques using a Soviet aircraft, US equipment and Indian scientist.

In India, however, the survey work using aerial photographs started in 1924 for delta mapping. In Indian subcontinent, this technique was first used in Sri Lanka in 1947. The regular survey started in Asian countries during the period of 1950-60's. Since 1925, aerial photographs are in use in India for preparation of topographical maps. Since 1965, for Pre- Investment Survey of Forest Resources, aerial photographs were used for forest type mapping and inventories in India. Opening of the Indian Photointerpretation Institute (IPI) in Dehra Dun was a major break through in this field. With the opening of IPI, the photointerpretation technique was more popularised and subsequently many organization,like Forest Survey of India (FSI), started photointerpretation works.

Nowadays airborne recording techniques are not only restricted to aerial photography, where reflected radiations in the visible and near infra red parts of the spectrum is utilised, but also other sensors developed subsequently such as SLAR (Side Looking Air Borne Radar), Thermal infra red line scanner and Multi Spectral Scanner. These instruments have opened new vistas in application forestry. These sensor developments, in composition with orbital satellite technology have given way to new developments in resource evaluation.

The application of remote sensing and aerial photography particularly to India were discussed in detail by Singh (1970), Maselekar (1974) and Tomer (1976). Tiwari (1977) pointed out the use of stratified photo maps to estimate timber.

A comparative evaluation of land use and forest type classification and mapping, using aerial photographs with conventional ground stock mapping was carried out by Tiwari (1978). Use of aerial photography in stock mapping in India was started by Tiwari (1978) and Shedha (1978).

Colour infrared photography became universally popular, although its potential use in forestry was referred to earlier (Spurr, 1948). Application and studies of infra red colour photography were also undertaken by many researchers (Fritz, 1967 and Benson and Siems, 1970).

Vegetation mapping using 1:10,000 scale B&W panchromatic aerial photographs has been carried out in the western part of Kanha National Park (Roy *et al.*, 1986). Changes taking place in the vegetation cover of Kanha National Park has been identified on the aerial photographs and mapped by Shetha *et al.*, (1986).

Versteegh (1968) prepared forest cover type map of Bastar in Madhya Pradesh in 1:25,000 scale using B&W aerial photographs. Gupta and Abichandini (1968) conducted air photo analysis of plant communities in relation to edaphic zones in the arid zone of western Rajastan. Tomar (1968) prepared a manual for photointerpretation for tropical forests of Kerala and Tamil Nadu. Aerial photographs have been used for forest and landuse identification in South, Central and North India (Tomar, 1969).

Tomar (1971) suggested 1:25000 to 1:30,000 scale aerial photographs for forestry studies in Himalayan region with special reference to Jammu and Kashmir. Van and Joshi (1972) conducted a reconnaissance survey of the forests in Doon Valley with the aid of aerial photographs and identified about 15 land cover classes in 1: 60,000 scale aerial photographs. Seth (1972), Van and Joshi (1972) discussed the scope of photointerpretation in Indian Forestry. Seth and Tomar (1973) used 1: 60,000 scale B&W aerial photographs for volume class stratification for forest inventories. Tomar and Maslekar (1974) proposed a land use/forest type classification for aerial photo interpretation. Tomar and Maslekar (1974) used aerial photographs for mapping and survey.

FAO (1975) proposed a forest cover monitoring programme for tropical forests. Maslekar (1977) assessed young teak plantations of Attappadi range, using 1:10,000 B&W aerial photographs. Shedha (1978) emphasized the role of aerial photographs in the preparation of forest maps. Tiwari (1978) made a comparative evaluation of cost, time and accuracy of forest and land use maps prepared from 1:15,000 B&W aerial photographs and ground stock maps in Tehri Garwal, Himalayas and found aerial photomap was cost effective and more detailed information content. Shedha (1981) compared forest maps prepared by ground and aerial photomethods for Gudem Reserve Forest, Andra Predesh. Mathur *et al.*, (1984) correlated soil and land use types of a part of Terai and Bhabas forest of Utter Predesh by using aerial photographs.

Madhavanunni *et al.*, (1985) prepared forest cover map of a part of Godavari basin using B&W aerial photographs of 1:25,000 scale. Rekha Ghosh (1989) prepared drainage map of Eastern India from aerial photographs. Menon (1988) used 1:15,000 B&W aerial photographs for vegetation mapping in Attappadi region, Kerala. In this, more than 20 units were mapped. Porwal and

Roy (1991) used 1:10,000 B&W aerial photographs for mapping Kanha National Park, Madhya Pradesh. Five sublandscapes and physiographic units, four forest vegetation types, four crown closure classes, under storey components *etc* were also distinguished in the study.

Fang (1980) discussed the use of aerial photographs and Landsat imageries in forest inventory in China. Ibrahim *et al.*, (1986) discussed the use of aerial photographs in Malaysian forestry. Ibrahim and Hashim (1990) mapped and classified mangrove forests by using 1:40,000 aerial photographs in Malaya. Tiner (1990) used high altitude photographs for inventorying wet lands in the United States. Aerial photographs of two different dates were used to monitor changes in Sinharaja forest, Srilanka (Banyard and Fernando, 1992).

2.2.2. Role of Satellite imagery in vegetation mapping

The applications of satellite imagery for forestry related purpose is relatively new. The era of satellite remote sensing began with the launching of Landsat 1 in July 1972 by NASA, United States. The first Indian Remote Sensing satellite (IRS 1A) was launched in April 17, 1986. Recent research indicates that optical mechanical scanning is applicable to the identification of forest tree species (Olson, 1970).

Quantitative changes in forest cover and effects of fire were successfully done using satellite remote sensing techniques with special reference to Bandipur National Park and Mudumalai Wildlife Sanctuary, (Madhavanunni *et al.*, 1986). Prince (1985) has already used satellite data successfully for studying and monitoring range conditions in Botswana.

In 1983, the forest cover maps of India were prepared by NRSA for the period 1972-75 and 1980-82. Lal *et al.*, (1990) assessed the extent and location of deforestation in Kodagu district, Karnataka using 1:2,50,000 Landsat MSS data.

The application of IRS 1A data in forestry was discussed by Madhavanunni *et al.*, (1991). Porwal and Roy (1992) used 1:50,000 Landsat TM FCC for delineation and mapping of heterogen. ous forests of Western Ghats, Kerala and estimated as overall accuracy as 88.33 percent.

Roy *et al.*, (1992) used 1:50,000 Landsat TM FCC for mapping Chanaka Wildlife Sanctuary, Ores and compared it with aerial photomap. Application of remote sensing for ratten resources survey was done by Nandakumar and Menon (1992). Roy *et al.*, (1993) mapped tropical forests of Andaman islands using Lands at TM FCC of 1:50,000 scale and identified nine land cover classes.

Habitat assessment of Kaziranga National Park using remote sensing was studied by Parihar, Panigrahi and Lahar in 1986. Spectral relationship of grasslands to its biomass in Kanha National Park (MP) has been evaluated (Roy *et al.*, 1991).

New remote sensing tool called imaging spectrometer (Airborne visible/infra red imaging spectrometer AVIRIS) and its application in ecology, geology and oceanography were described by Greggvane and Goetz, (1993).

Varghese *et. al.*, (1996) prepared bamboo stock mapping using remote sensed data. Suraj *et. al.*, (1996) prepared a land cover map of a part of Chimmony Wildlife Sanctuary, Kerala. Mapping of high altitude shola grasslands of some part of Eravikulam National Park were carried out by Sureshbabu *et al.*, (1997).

2.2.3 Digital image processing

For digital mapping Landsat data were used by Dodge and Bryant in 1976. The area of hard wood/soft wood and total forested area were compared with existing records. Bryant *et al.*, (1980) used Landsat digital data for forest mapping and compared it with aerial photographs. Computer classification of data from Landsat has resulted in measurements and maps of forest types for two New Hampshire Countries (Arthur and Emily, 1976). Studies on spectral separability of cover classes were done by many researchers. Spectral separability analysis of various tropical forest cover classes as recorded on Landsat MSS data were carried out for two test areas of Northeastern India (Ashbind Singh, 1987).

Adeneyi (1985) prepared land cover map of a semi arid area of Nigeria using Landsat digital data. Skidmore *et al.*, (1987) used digital Landsat data for forest mapping in Australia. In India, digital mapping were carried out by several workers. Kachhwaha (1983) used Landsat digital data for forest mapping. Singh and Khan (1989) used digital data for change detection studies. Ashbindu Singh (1990) integrated digital data with ancillary data to improve supervised classification. Menon and Sashidhar (1990) evaluated different digital techniques for land cover mapping. Menon (1991) mapped rubber area using IRS data. Menon and Ranganadh (1992) used IRS data for mapping Silent Valley region.

Vegetation indices from AVIRS data were used to evaluate spatial patterns of vegetation type, productivity and potential physiological activity by John *et al.*, (1993)

2.3. Vegetation studies.

Ecology began to be formalised as a discipline in Europe in the late 1800. In 1866 E.H. Haeckel coined the term Ecology (Egerton,1962). In 1905 F.E. Clements published the first American book on Ecology, "**Reseaech methods in Ecology**". The first formal textbook of Plant Ecology by Weaver and Clements' was brought out in 1929.

Based on various ecological aspects, ecosystem studies are carried out on different levels *viz*. community structure and composition (Synecology), functions of component species (Autecology), cycle of material components like Carbon, Nitrogen, Water, flow of energy *etc*. Primary step in any synecological study is the classification of vegetation.

Classical reviews of vegetation classification are those given by Stebbing (1922), Champion (1936), Razi (1955), Chandrasekharan (1962) and Champion and Seth (1968). Of these, most widely accepted forest classification system is that of Champion (1936) and Champion and Seth (1968).

Meher-Homji (1984) recognised 14 phytogeographic zones of India based on bio-climatic parameters, of which 11 are in Peninsular India and three pertain to the Himalayas and the Andaman and Nicobar islands. The eleven zones encompass twenty nine vegetation types.

Succession is considered as a process of ecosystem development (Odum, 1969). Tansley (1920) termed succession for the community development. Clements (1916) advocated the successional theory, which reveals that the vegetation undergoes a constant orderly change of species in a particular area, over a period of time, *i.e.* vegetation emerges, develops and attainsclimax state.

Quantitative sampling methods in small areas or quadrats were introduced in a few of the earlier studies of American vegetation (Pound and Clements, 1898). Quadrat sizes for different vegetation types vary accordingly. The minimal area of quadrat was standardised by species/area curve method (Cain, 1938). The increase in number of species with increase in area was first scientifically treated by Jaccard (1912) followed by Brawn-Blanquet (1932), Cain (1938), Misra and Puri (1954), Oosting (1956), Misra (1968), Singh *et al.*, (1984), Basha (1987), Subhash *et al.*, (1987), Pascal (1988) and Roy (1993).

The degree of presence of a species in a unit area (quadrat) is termed as constancy (Du Rietz, 1930). Raunkiaer (1934) developed the concept of frequency and formulated the law of frequency based on percentage frequency. Raunkiaer (1934) developed the frequency analysis, based on the presence or absence of species in a number of quadrats. Basal area is used as an index of dominance by Curtis (1959). Density, frequency, abundance, IVI *etc.* were worked out by Phillip (1959) and Muller-Dombois and Ellenberg (1974).

The concept of maturity index was developed by Pichi-Sermoli (1948). Only very few studies have been conducted in India. Maturity index values of undisturbed and disturbed evergreen, semi evergreen and moist deciduous forests in Attappadi were worked out (Menon and Balasubramanyan, 1985)). Roy *et al.*, (1993) found that the tropical forests of Andaman was moderately mature.

Distribution of species is one of the most important aspects of vegetation that has attracted many ecologists (Fracker and Brischle, 1944; Whitford, 1948; Ashby, 1948 and Cole, 1949). Whitford (1948) used the ratio of abundance and percentage frequency as a measure of contagiousness among the plants. In most of the cases, abundance/frequency value less than 0.025 indicates regular distribution, 0.025 to 0.05 random and more than 0.05 contagious (Curtis and Cottom, 1956).

Gleason (1936 & 1939) proposed the continuum concept. Curtis and McIntosh (1951) modified this concept. Continuum index value helps in evaluating the environmental influence over the vegetation. Since the publication of the Jaccard's formula, it has undergone several quantitative and qualitative modifications which are widely accepted (Gleasan, 1920; Ellenberg, 1956; Pandeya, 1961 and Sorenson, 1948).

The concept of community co-efficient was put forward by Jaccard (1912) in order to compare two plant communities. Jaccard's formula was modified later on by Gleason, (1920), Sorenson, (1948) and Ellenberg, (1956).

Diversity index derived from information theory, has been widely used in recent work of ecologists. Shannon Weaner equation (1949) has been widely applied to quantify anything that came to hand particularly species diversity. (Simpson, 1949) proposed another index to study the floristic diversity and concentration of dominance.

Diversity and dominance in man made forests were worked out by Srivastava (1986). Pande *et al.*, (1988) had conducted a comparative vegetation analysis of four plantations. They stated that with stand maturity, the higher density value the higher is the species richness.

Diversity index is higher for tropical forests for young (5.06) and old (5.4) while for the temperate forests, it is between 1.16 to 3.4 (Knight 1975), Braun, 1950, Monk, 1967 and Risser and Rice 1971).

Concentration of dominance values for temperate vegetation ranges between 0.16 to 0.99 (Whittaker and Niering, 1965, Rissern and Rice, 1971). In the case of tropical forests, concentration of dominance is 0.06 (Knight, 1975).

Higher rate of concentration of dominance is due to lower rate of evolution and diversification of communities in plantation ecosystems. The same have been reported for temperate vegetation (Connel and Orias, 1964 and Simpson, 1964).

Concentration of dominance varied from 0.15 to 0.22 for trees, 0.18 to 0.3 for saplings and 0.14 to 0.21 for shrubs (Joshi and Tiwari, 1990); 0.89 to 0.308 (Joshi and Behera, 1991)and 0.14 to 0.155 (Pathak *et al.*, 1993) for mixed tropical forests of Orissa.

Phytosociological works in Kerala are rather scanty. Some of the important publications are Singh *et al.*, (1984) for Silent Valley. Basha (1987) for the evergreen forests of Silent Valley and Attappadi; Pascal (1988) for evergreen forests of Western Ghats. KFRI (1980) conducted a phytosociological study in Attappadi reserved forests. Menon and Balasubramanyan (1985) for Trichur Forest Division and Pascal and Pelissier (1996) for tropical evergreen forests of southwest India.

Singhal *et al.* (1986) analysed vegetation of woody species of some forests of Chakrata Himalayas and Singhal and Soni (1989) analysed woody species of Musoori. Srivastava (1986) studied diversity and co-dominance of man made forests . Laxmi *et al.*, (1987) studied Phytosociology on Machhlad subwatershed of Pauri Garhwal, UP. Singhal and Sharma (1989) worked on Phytosociology of high level alluvial sal forests and Gangetic tropical moist deciduous forests of Doon Valley.

General nature of vegetation such as density, frequency, abundance and constancy have been analysed for major forest divisions *viz.* Gir, Girnar, Bhavnager and Rajkot Jamnagar divisions of Saurashtra by Menon and Shah (1981). Influence of forests on various environmental aspects such as, rainfall, soil erosion, watershed management, air pollution , wind, climate, energy and recreational aspects were reviewed by Menon (1982)

In addition to these, many studies have been made on phytosociological aspects of forest vegetation (Joshi and Behera, 1990; Sushil Kumar *et al.*, 1991; Room Singh *et al.*, 1991; Lata and Bisht, 1991 and Dani *et al.*, 1991)

2. 3.1 High altitude Shola and Grass land ecosystem

Chandrasekharan (1962) classified high altitude vegetation of Western Ghats as wet temperate forests and montane grasslands. According to Champion and Seth (1968), the vegetation of montane region of south India can be classified into Southern montane wet temperate forest (2A/C), Southern subtropical hill forest (8A/C), Southern montane wet scrub (2A/ds1) and Southern montane wet grassland (2A/DS2). Gadgil and Meher-Homji (1984) classified these forests under the biogeographic region of wet evergreen forests of Western Ghats and vegetation type as montane shola.

Even though there is much controversy over the status of shola-grassland vegetation since 1938, only a very few studies have been conducted on high altitude shola grass land vegetation with special reference to South India. The successional status of grasslands have been subjected to much controversy over the years. Ranganadhan (1938) held the view that the grass land of the N ilgiri representsclima vegetation just like that of shola vegetation, contrary to the view of subclimax as held by many workers (Champion, 1936; Bor, 1938; Shankaranarayan, 1958; Gupta, 1960; Gupta and Sankaranarayan, 1962; Chandrasekharan, 1962; Noble, 1967 and Lakshmanan, 1968).

Shetty and Vivekanandan (1971) made an attempt to document the vascular flora of Anamudi and adjacent areas. Rice (1984) studied the ecology and behaviour of Nilgiri tahr in Eravikulam National Park. Sreekumar and Nair (1986) attempted to document the grasses of Eravikulam National Park. Easa (1996) studied prey-predater relationship in Eravikulam National Park. Srivastava (1994) has shown the re-establishment of the shola forests in grasslands of upper Palani hills

No phytosociological study has been conducted in Eravikulam National Park other than Shibu Jose *et al.*, (1994). According to him grass lands are steady state vegetation maintained by edaphic features.

CHAPTER III

STUDY AREA

3.1. Location

The study was conducted in Eravikulam National Park, Kerala that represents one of the unique high altitude shola-grassland ecosystems in the Western Ghats. This park is also famous for sustaining the largest population of Nilgiri Tahr (*Hemitragus hylocrius*, Ogliby), an endangered mountain goat endemic to south India.

Eravikulam National Park lies between 10 ^{0} 5' to 10 ^{0} 20' N Lat. and 77^{0} to 77^{0} 10 ' E Long. falling along the crest of the Western Ghats in the High Ranges. The entire area falls within Devikulam Taluk of Idukki district, Kerala (Fig. 1).

3.2. Boundaries

The notified boundaries of the study area are as follows:

East: The old Kannan Devan Hill produce village boundary along the ridge through Kattumudi and Perumalmalai.

South: Northern bounderies of Chattamunnar, Nemakkad and Vaguvarai estates of Tata Tea Ltd.

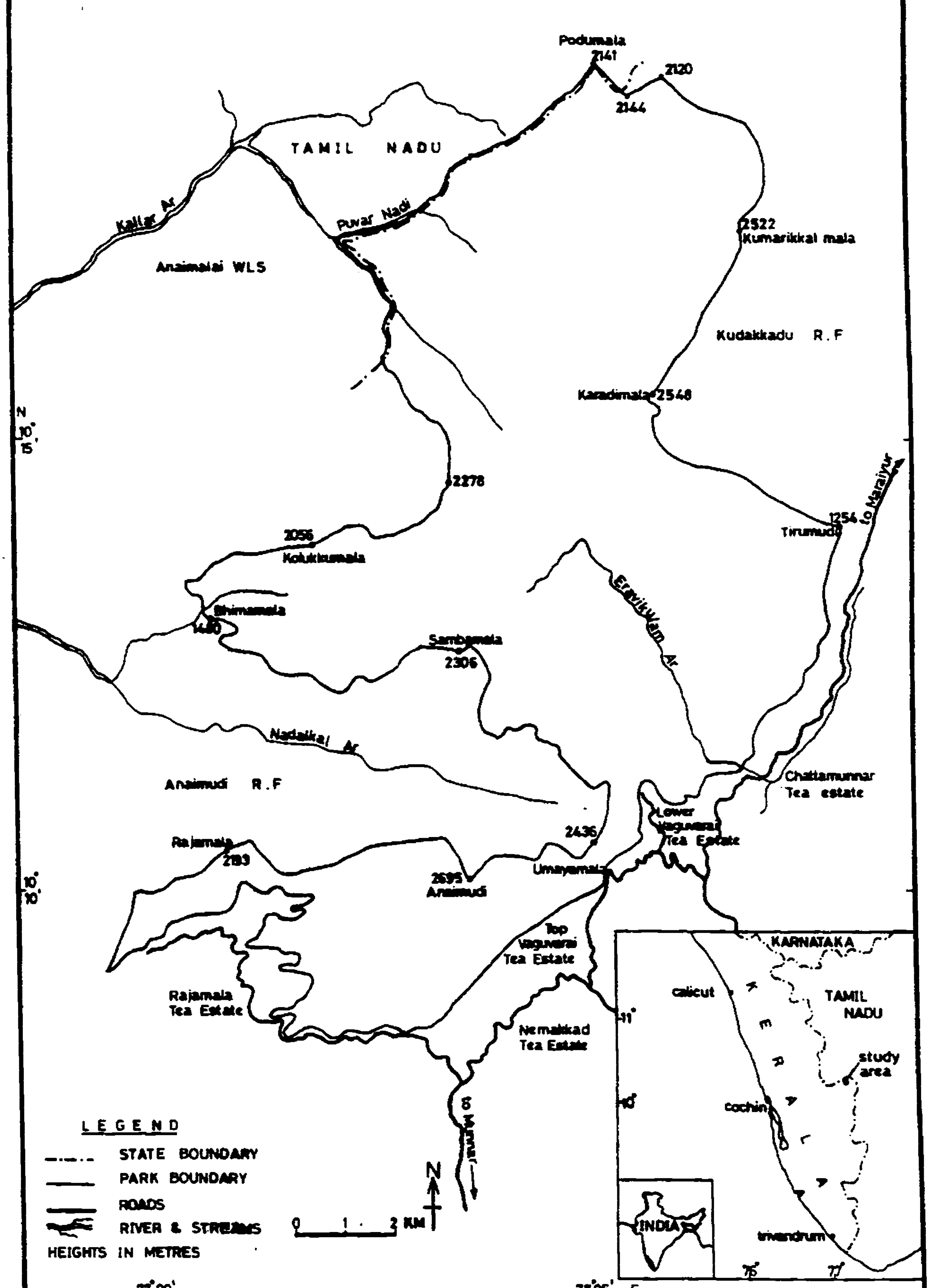
West: Old Kannan Devan Hills produce village boundery along the ridges through Rajamalai, Sambamalai and Kollukumalai

North: The boundary coincides with the interstate boundary between Tamilnadu and Kerela at an elevation of 1689 mts.

3.3. Transportation

The nearest town is Munnar, which is accessible by road from Cochin and Kottayam, which are 135 km and 148 km respectively. The nearest airport is Cochin, which is 135 km, and the nearest railhead is Alwaye, which is 115 km away from the National Park,

Fig.1 ERAVIKULAM NATIONAL PARK-LOCATION



The southern part of park (Tourism zone) is accessible by road. From the east, entry to the park is through Vaguvarai tea estate. A trail is connecting Vaguvarai to Eravikulam Hut in the centre of the plateau and further to Puvar in the northern sector of the park.

3.4. Geomorphology

The main body of the National Park is composed of high rolling plateau with an average elevation of 2000mts and most of the peaks on the plateau rise from 100 to 300m above it (plate 1a & b). The main plateau is divided roughly into half from north- west to southeast by the Turnur's valley. Anamudi peak is situated in the southern corner of the park, the highest point in Peninsular India. There are three mountain ridges radiating from the peak, *viz*. Anamalai towards north, Palani to the east and Cardamom hills to the southwest. The lowest point is 1400m. There are steep cliffs at many places. The Park is drained by numerous small perennial streams and forms the catchments of Chinnar and Pambar rivers, which flows into Tamil Nadu.

3.5. Geology

The geological formations in the Eravikulam National Park are pre cambian metamorphic rocks represented by charnockite, garnet, silliminite gneises. garnet biotic gneises, hornblende biotic gneises, granetic gneises, migmatit es and granites. A few dolomite dykes are seen traversing the country rocks mainly in the foothill zones of the Western Ghats in Eravikulam National Park. Following geological formations are represented: foliated granite and pink granite gneises, Hornblende gneises, hornblende biotic, quarts-mica gneises (composite) and cole granulate with patches of limestone.

3.6. Edaphic characters

The soil profile is characterised by a reddish brown surface horizon to a very duskyred lower horizon. The accumulation of organic C, N, P and K

Plate 1a. Undulating terrain of rolling grassland

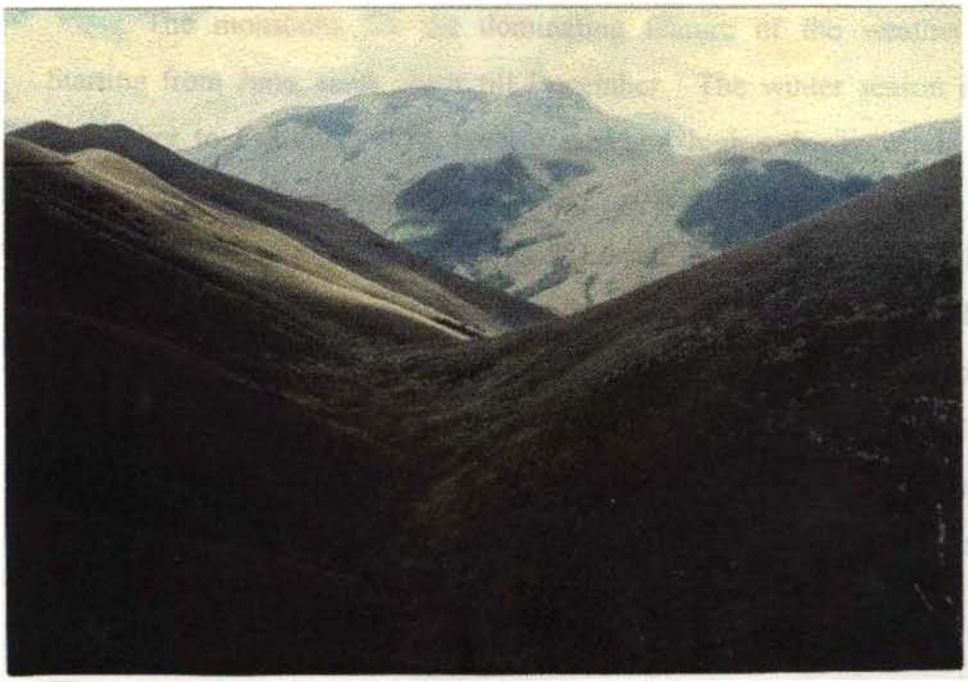


Plate 1b. Characteristic geomorphology of the study area

was marked in the surface horizons. The shola soil registers a relatively higherorganic carbon ranging from 4.79 to 22.48 %. The respective values of grassland profile were 1.31 % to 18.88 %. The soil pH in shola and grassland are almost similar. Total N, P and k levels are also higher in the shola forests. (Shibujose *et al.*, 1994)

3.7. Climate

3.7.1. Temperature

During March and April, the absolute temperature varies between a maximum of 27 ^{0} C. and a minimum of 13 ^{0} C. During December and January the minimum temperature falls as low as 10 ^{0} C. The high diurnal variation in temperature in the tropical latitude due to altitudinal influence brings about the ecological peculiarities. The ombrothermic graph for the year 1993 and 1994 are given in figure 2 and 3.

3.7.2. Rainfall

The monsoons are the dominating feature of the weather cycle. Starting from June, rains occur till December. The winter season is from December to February. The lashing rain and high velocity winds (55-60 km/hr) and poor visibility during monsoon period make the area totally inaccessible. The average rainfall is 581.6 cm as per 1994 record. During winter months the wind blows lighter when it blows from east and gains strength when it blows from west during monsoon times. The maximum precipitation is in the month of July and minimum in January (Figs 2 & 3). Incoming solar radiation is very poor during the monsoon period due to heavy mist and cloud. But during summer the insolation is high throughout the area.

Fig.2. Monthly distribution of Rainfall and Temperature of Eravikulam National Park in 1993

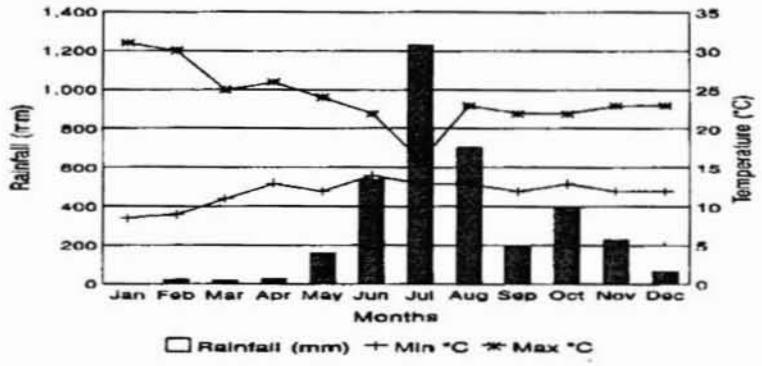


Fig.3. Monthly distribution of Rainfall and Temperature of Eravikulam National Park in 1994

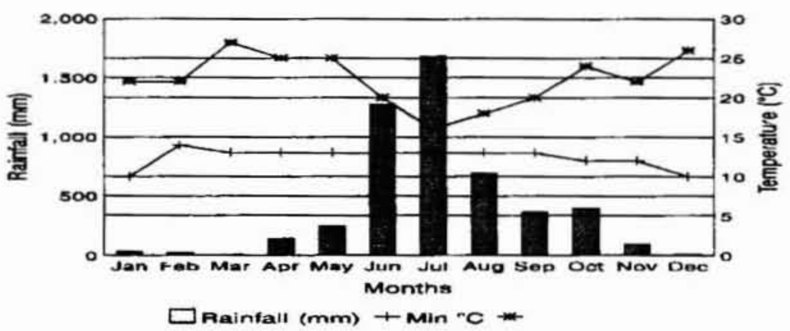
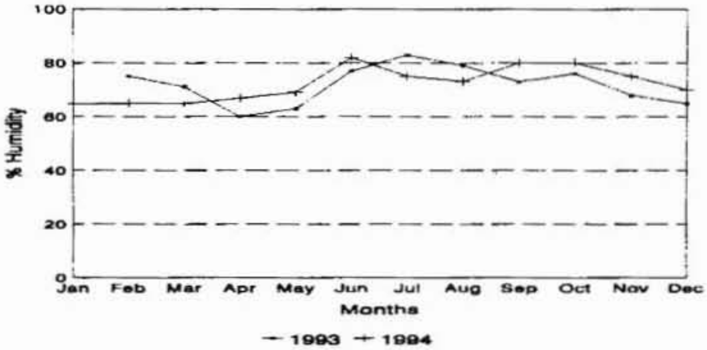


Fig.4. Percentage Humidity of Eravikulam National Park 1993 and 1994



3. 7.3. Humidity

Humidity varies with season. Humidity is always above 60% and during rainy season it reaches above 80%. The winter days are marked by very low humidity (Fig 4).

3.8. Ecology

Eravikulam National Park is a unique shola and grassland ecosystem. Here two distinct vegetation types such as shola forests and grasslands are juxtaposed with each other unlike the Clementsian concept of succession. There has been much controversy over the years about the successional status of these high altitude grasslands. According to one school of thought, both shola and grasslands are climaxes in the same climatic conditions. The other view is that, only shola is the climax vegetation and grassland is only sub-climaxe maintained through the successive fire, frost and grazing.

3.9. Vegetation

Vegetation types of Eravikulam National Park consists of Shola forests (Southern montane wet temperate Forest), Transition forests (Southern Subtropical Hill Forest), Evergreen forests (West Coast Tropical Evergreen Forest) and Grasslands (Southern montane wet temperate Grassland) and Scrub Savannah.

3.9.1. Montane wet temperate forests (Shola)

It is an evergreen forest (temperate rain forest) often appear as stunted evergreen and classified as montane wet temperate forests by Champian and Seth (1968). Shola forests are characterised by short bole trees rarely exceeding 6m. height. The crowns are usually very dense and rounded with entire, coriaceous leaves, which tend to be reddish of varying degrees when young, giving a range of colours, as if the most conspicuous feature of the type. The branches are clothed with mosses, ferns and other epiphytes and woody climbers are common. There is no marked differentiation in canopy layers as in the tropical evergreen forest but there is a continuous series from under-shrub to shrub and to shola trees. There is considerable admixture of species. The forest is usually found in patches in protected pockets or declivities in the rolling grassland (Shetty and Vivekanandan, 1971). They occur as numerous, isolated, compact, sharply defined and usually small woods, interspersed with vast stretches of grasslands. The dominant species in the shola forests are *Syzygium arnottianum*, *Mahonia leschenaultii*, *Maesa indica*, *Litsea ligustrina etc.* Lauraceae and Myrtaceae are the dominant families.

3.9.2. Subtropical hill forests

Evergreen forests of this type are found in the transitional zone between montane wet temperate forests and tropical wet evergreen forests. The trees are smaller ranging from 10-15m height. The type is characterised by a mixture of species of both tropical evergreen forests and montane wet temperate forests. The common species are *Syzygium cuminii*, *Biscophia javanica*, *Canarium strictum*, *Ardisia rhomboidea*, *Cedrella toona*, *Eurya nitida*, *Persia macrantha*, *etc.*

3.9.3. West coast tropical evergreen forests

The West Coast tropical evergreen forests are characterised by a bewildering multiplicity of lifeforms and overpowering preponderance of greenness. This contains a luxurious growth of evergreen trees of different sizesand shapes arranged in a serial tier. The top canopy is formed of tall trees of 45m height or even more and the canopy is almost unbroken. This type of forest is seen in the lower elevation of National Park and it confined to a small area.

3.9.4. Grasslands

In India grasslands constitute one of the major biomes. Grasslands cover more than 60% of the area. In Kerala, grasslands extends over an area of about 200 Km^2 (Anon, 1991). These high altitude grasslands are extensive and consist a complex of grasses, herbs and under-shrubs. The dominant species of these grasslands are *Chrysopogon zeylanicus*, *Arundinella fuscata*, *Dichanthium polyptychum*, *Eulalia pheothrix etc.* The common non-grass species in the grasslands are *Anaphalis* spp, *Swertia* spp, *Hypericum mysurensis*, *Phlebophyllum kunthianum*, *Eupatorium* spp, *Viola* spp and the fern, *Pteridium aquilinum.*

3.9.5. Scrub

Extensive patches of *Phlebophyllum kunthianum* and *Pteridium acquilinum* are present in certain areas, which constitute the scrub vegetation of the area.

3.10. Fauna

Carnivores, herbivores and omnivores are the major mammalian fauna found in the National Park. Among the herbivores, the first and foremost is the Nilgiri Tahr (*Hemitragus hylocrius*) which occupies the highlands and rocky regions of the National Park. Other herbivores are the Sambar and barking deer, which are found in sholas and Gaur in low-lying grasslands. Malabar giant squirrel is another arboreal found in the sholas. Elephants constitute a migratory population and do not occupy a permanent station. Among the carnivores the main species are tiger, panther and wild dogs which occupy both the open grasslands and shola forests. Small Indian and jungle cat are also seen in the sholas. Among the omnivores, Sloth Bear, Nilgiri langur, and Wild Boar are found mainly in the sholas and on the fringes. The avifauna includes the Kestral, Blackbird, Nilgiri Pipit, Black

Winged Kite, Nilgiri White Eye, Bush Lark, Emerald Dove, Wood Pigeon, and Jungle Crow.

3.11. Socio-economic status

A small population of tribals called Mudhuvas inhabit the eastern part of the Park. They are staying in their hamlets called kudi (Lakkam kudi), situated in the boundary of Eravikulam National Park. About thirty families and two hundred individuals are engaged in cultivating lemon grass and collection of minor forest produces from the adjoining forest areas. A few of them are working with the Forest Department as temporary protection mazdoors. Some of them are engaged temporarily as fire watchers during the fire season. Educational and health facilities are available in the nearby villages. Literacy rate is very low among them.

3.12. History

The area was resumed by the Kerala Govt under the Kannan Devan Hill Produce Act (Resumption of lands) 1971. This was declared as Sanctuary in 1975 by a notification (G.O. No.8907/Fm/375/AD dt. 31-3-75) and again declared as National Park in 1978 by another notification (G.O. No.92368/Fm/3/76/AD dt. 31-3-78, because of its outstanding ecological, floral, geomorphological and zoological significance.

The National Park is highly important to the country because it supports the largest population of the Nilgiri Tahr existing in the world now. Nilgiri Tahr is a highly endangered species and included in schedule I of the Wildlife (Protection) Act 1972. This is the only place where a viable population of Tahr exists without any outside interference. Anamudi peak (2695m), the highest point south of the Himalayas falls in the southern part of the Park.

Tribal people sparsely inhabited the area and little was known about it before tea estates were started late in the 19^{th} century. Mention has been made about Shola-grassland ecosystem in ancient Tamil literature. Early plantation managers found the area now known as Eravikulam National Park as cold and unsuitable for raising plantation. Rather than converting such areas, they retained the wild state of those areas for outdoor sports. The High Range game preservation association managed those areas and kept the carrying capacity of the area to the optimum level so that highland remained in its original condition. The High Range game preservation association managed the area till 1975, when it was declared as a Sanctuary.

CHAPTER IV

METHODOLOGY

4.1. Vegetation Mapping

4.1.1. Data used

4.1.1.1. Aerial photographs

Aerial photography is defined as the science of making photographs from the air for studying the surface of the earth. In almost all studies on natural resources, aerial photographs are used as basic material and hence they play an important role in resource mapping. The main use of aerial photography are, for pictorial representation, photointerpretation and photogrammetric survey of natural resources. In the present study black and white aerial photographs were used with following specifications.

Type: Vertical, Panchromatic Black & White

Scale: 1: 15,000

Camera: RMK 15/23

Focal length: 15.3

Year: 1990

Format size: 23 x 23 cm

Nature of print: Glossy, Single weight

Overlap: Foreword 60 to 80 %

Lateral 10 to 40 %

Direction of flight: South to North

Film: Kodak xx aerographic, panchromatic black and white 2405

Filter: D 12 x 256

4.1.1.2. Satellite data products.

The Indian Remote Sensing Satellite IRS 1A and 1B, LISS 2 data in the form of false colour composites and computer compatible tapes were used for the study. The data products were procured from National Remote Sensing, Agency (NRSA), Hyderabad.

4.1.1.2.1. False Colour Composites

False Colour Composites are the photographic enlargement of the Satellite data with appropriate rectification. If the pre- processed data is in digital form, it is converted into an image by etching a photographic film using a computer based photo write system. FCC are generated by combining the data contained in three different spectral bands into an image by assigning blue , green and red colour to the data in three spectral bands respectively, during the exposure of a colour negative. The choice of band combinations can be determined depending upon the application. Various types of FCC's are available depending upon their pre-processing of the raw data. Here only standard and geocoded data products were used. An FCC imagery is generated by combining IRS bands of 2,3,4 (2 in blue, 3 in green and 4 in red) which enables the identification of vegetation types effectively.

4.1.1.2.1.1. Geocoded FCC

When the image data is referenced with respect to a geographic co-ordinate system, it is called geo coded data The geo coded data involves higher level of corrections based on system corrections or on ground control points (GCP). A GCP is one whose image location on the geographic coordinate system is known. These sub scenes will have a coverage of 15' X 15' (Latitude X Longitude) analogous to 1:50,000 scale of topographic maps of Survey of India (28 km^2 approx.). System corrected geo-coded data will have a location accuracy of 1.5kms while GCP based corrections will give even up to 24 km.

Specifications of the geo coded FCC used for the present study are

Sensor: IRS 1B L2 A2

Band: 2,3,4.

Scale: 1:50000

Year: Feb, 1993

Resolution: 36.25

Path: 25

Row: 61

4.1.1.2.1.2. Standard FCC

Standard FCC involves corrections based on geometric and radiometric features only. In the present study Standard FCC, with following specifications are used:

Sensor:IRS 1A LISS 2 A2

Band: 2,3,4

Scale: 1:1,25000

Year: 1990

Resolution: 36.25

Path: 25

Row: 61

4.1.1.2.3. Computer compatible tapes

The satellite data in digital form for analysis and interpretation on computer based systems are available as magnetic media such as CCT's, Catridge tapes, Floppy diskettes and Digital audio tapes.

CCT's of following specifications were used for digital image processing :

Sensor: IRS 1 A LISS 2 A2

Band: 2,3,4.

Year: 23-12-88.

Path: 25

Row: 61

4.1.1.3. Collateral data

The collateral or ancillary data is the secondary data pertaining to the area of interest other than remote sensed data. The Survey of India topo sheets 58 F/3 and F/4 on 1:50,000 scale, Management Plan of Eravikulam National Park *etc.* are used as collateral data. To transfer the details from aerial photographs a base map is prepared from Survey of India topo sheets 58 F/3 and F/4.

4.1.2. Analysis and interpretation of Remote Sensed data

The following steps were involved in the present study.

4.1.2.1 Data acquisition

Aerial photography in India is controlled and co-ordinated by the Survey Of India (SOI) . Once the scale and type of the photographs are indicated, Survey of India designs the photographic specifications and places the order for photography to one of the three flying agencies *viz.* the Indian Air Force, M/s ari survey company Ltd. Dum Dum and NRSA, Hyderabad ..

For the present study aerial photographs and Satellite data products were procured from National Remote Sensing Agency (NRSA), Hyderabad.

4.1.2.2. Reconnaissance survey

Information regarding the study area viz. geology, geomorphology, climate, soil conditions, drainage, vegetation *etc.* were collected from available records. For the preliminary study, important land features were marked in the aerial photographs. Reconnaissance surveys were conducted with aerial photographs and SOI maps. During the field trips, ground features were correlated with photographic images with the help of pocket stereoscope.

4.1.2.3. Photo analysis

The air photo analysis includes the following major steps.

4.1.2.3.1. Preparation of Photointerpretation key

A characteristic or a combination of characteristics that enable the identification of an object on an image is called an interpretation key (Sabins, 1978). On the basis of information collected during reconnaissance survey, a photointerpretation key was prepared following Tomar (1968).

4.1.2.3.2. Marking the boundary of the study area

Aerial photographs are laid out in a mosaic form on a table and the boundary of the study area was marked.

4.1.2.3.3. Annotation of aerial photographs

Important features identified on aerial photographs were annotated with the help of Survey of India Topo maps.

4.1.2.3.4. Preparation of aerial photographs for interpretation.

Image interpretation is an act of detection of the land cover classes using photographic data. This includes the following procedures:

The principal points were marked by intersecting the line joining the opposite fiducial marks (index marks rigidly connected with camera lens which form images on negative). Marks were so adjusted that the intersection of lines from opposite fiducial marks defines the principal point (Tomar, 1968).

The principal point is transferred to the adjoining photograph stereoscopically. This point is called conjugate principal point. Then the flight line is marked by joining the principal point and conjugate principal point of adjoining photographs. The effective area (central part of the photograph delimited by bisectors of overlaps with adjacent photographs on vertical photograph) was marked on each photograph.

4.1.2.3.5. Aerial photointerpretation

Interpretation of objects on aerial photographs was done with the help of photointerpretation key prepared according to the fundamental photoelements like tone, texture, pattern, shape, size shadow location and association. (Tomar, 1968)

4.1.2.4. Photoelements

4.1.2.4.1. Tone

Object of colour have different qualities of light reflectance and therefore, appear in varying shades of gray on aerial photographs.

4.1.2.4.2. Texture

Texture is characteristic dependent on the coarseness or smoothness of the image. Texture is more useful in identification of larger groups of objects like tree stands. Branching habits and age of a tree decide the texture of trees.

4.1.2.4.3. Pattern

Pattern is a repetition or spatial arrangement of objects like Orchards, Plantations *etc.* in a characteristic of man made objects.

4.1.2.4.4. Shape

Each object has its own shape, and this helps in identifying the object. The shape of tree is important in identifying the species in the aerial photograph.

4.1.2.4.5. Size

Size of an object imaged depends upon the object size, scale of aerial photograph and resolving power of camera. The crown size of a tree is important element in forestry.

4.1.2.4.6. Shadow

Shadows mainly depend upon the time of the photography and direction of flight. Shadows falling on ground helps in knowing the shape of the crown and even length of shadow is useful in height determination. However, shadows are not always useful and at many times obscure ground details. Normally, shorter shadows are preferred in photointerpretation.

4.1.2.4.7. Location

Topographic locations and relative elevations helpful in identifying objects.

4.1.2.4.8. Association

Location and association are not objects characteristic but denotes its immediate surrounding.

Each locality with its own vegetation composition determines the method of photointerpretation. Striking variety of the vegetation in different parts of the world necessitates adoption of different interpretation methods in forestry (Tomer and Maslekar, 1974).

4.1.2.5. Visual interpretation of satellite imagery

Tone, colour, texture, site/location *etc.* were used as parameters in visual interpretation. Based on the photoelements, an interpretation key was prepared. Photostratification scheme is adopted as shown by Roy *et al.*, (1991). The methodology used was the monoscopic visual interpretation of the satellite imagery.

4.1.3. Field checking

The units delineated on the aerial photographs and satellite imageries were compared with ground details at random to verify the correctness of interpretation and to check the doubtful areas.

4.1.4. Preparation of thematic maps

Once the interpretation of aerial photographs/satellite imageries was completed, the interpreted details were transferred to base map using Optical pantograph. Scale and tilt correction were made wherever necessary. Base maps were prepared from Survey of India topo sheets.

4.1.4.1. Fair map preparation and printing

Fair mapping was done on a transparent film. The details of aerial photo/satellite imagery interpreted were transferred on the base maps. From these base maps, fair maps were prepared. The transparent fair maps were used for making photocopies.

4.1.5. Area estimation

Area estimation of different cover classes in the aerial photographs and satellite imagery maps were carried out using Planix 2000 digital planimeter.

4.1.6. Digital Image Processing

IRS 1A LISS 2 data procured in CCT's were used for digital image processing by using VIPS-32 software available at Regional Remote Sensing Service Centre, Bangalore. Various stages involved in the image processing are as follows:

4.1.6.1. Collection of ground truth information

As pre-requisite, ground truth information is essential for digital image processing with a desired level of classification accuracy. Very meagre information is available regarding the spectral differentiability of shola forests and different grassland communityies. Sufficient training set information were collected representing each of the thematic classes available. Since the area represents a vast physiographic diversity, multiple training sets for a specified thematic class were gathered so as to incorporate cover spectral variations of vegetation type class arising as a result of varied illumination conditions.

4.1.6.2. Feature selection

The main function of image processing is the optimization of raw video data for the particular interpretation task. This includes the elimination of redundant data by feature selection *i.e.*, the selection of only those attributes from the raw data which are sufficient for class identification.

4.1.6.3. Image enhancements

The image enhancements were preferred to improve the visual interpretability of the image in contrast to a specific application. Some of the common image enhancement techniques employed are Stretching and Enhancement of digital data.

Stretching optimizes contrast such that the features of interest are separated from others. For this the first step is to create an image histogram, which describes statistical distribution of gray levels on an image in terms of the number of pixels comprising each gray level. One simple way to increase contrast is to expand the original gray level to fill the total image of the recording/display system. For example an area has a radiance value from 30 to 70 for a band. The radiance value 0 is assigned to value 30 and a radiance value of 255 is assigned to 70 and the stretching of the radiance values of other pixels are done accordingly. Enhancement includes the following major steps:

a. The average radiance value of a group of pixel is calculated.
b. The deviation of radiance values from the normal is calculated and doubled or increased suitably.

The enhancement techniques are extensively used in digital image processing as a first step, after rectifying the scene to improve the quality of an image for easy recognition of various earth features including forest classes. Digital techniques have been found to be more satisfactory than the photographic techniques for image enhancement because of the precision and flexibility in digital image processing.

For the purpose of forest mapping contrast enhancements are attempted for optimum use in the field studies. This technique expands the range of brightness values in an image so that the image can be efficiently displayed in a manner desired by the analyst. After keen observation of certain known areas of different forest categories, one can decide the optimum stretching parameters to locate/identify various earth features correctly.

4.1.6.4. Data analysis

The function of digital image analysis is scene segmentation into the required classes and their identification.

The bands 4,3 and 2 in red, green and blue colour respectively was used for preliminary appraisal of the study area and for False Colour Composite generation. An area of approximately 512x1024 pixel size was selected for processing at a stretch. The digital analysis consists of three main activities:

1. Location of sample segment in the image
2. Generation of training signature of various features and

4.1.6.5. Classification of sample segments

For locating sample segments in the image the starting scan line and pixel of each sample segments are required. VIPS-32 software system was used to derive this information. Using image co ordinates, sample segments of scan lines and 512 X 1024 pixels were extracted from digital data. Extracted sample segment used for digital analysis.

To classify sample segments, it is necessary to generate training segments for various features identified during ground truth collection. Different steps involved in generating training signatures are ;

1. Marking the training windows for various features by locating ground truth sites in the image.
2. Generation of signature for training windows,
3. Testing the separability of training signature
4. Modification in training windows if required
5. Finalization of training signature

4.1.6.6. Classification

There are two basic approaches to pattern recognition *viz*; supervised and unsupervised classification. The former is based on knowledge of ground truth sample of each class on which the classifier can be trained, the latter is based on interactive clustering of the input data without training the classifier on ground samples. Since the ground truths are available supervised classification is preferred in the present study. Various algorithms are used for supervised classification. Maximum likelihood classifier.has been adopted.

4.1.6.6.1. Maximum likelihood Classifier

For digital image analysis supervised classification using maximum likelihood algorithm was adopted. The maximum likelihood classifier uses both the variance and covariance of the training set data to calculate the probability of known pixels occurring in all the classes, the unknown pixel would be assigned to the most likely class or labeled as 'reject' if the probability values are below a particular threshold value fixed by the analyst.

The redundancy in the raw data was assessed through correlation matrix. Spectral seperability of the defined classes were assessed by comparing the mean and standard deviation values. A minimum denorm (normalized difference between two means *i.e* difference between means of two classes/sum of standard deviation of two classes) with a value of 1 was considered as the threshold to indicate seperability of two classes under consideration in a given feature. Eighty five percent purity of training sets, as assessed through back classification (*i.e*, 85% pixels of a training set get classified in the theme class which was assigned to it.), was taken as a threshold for final selection of training sets and computation of training statistics.

4.1.7. Preparation of drainage , contour and slope map

A drainage map was prepared using 1: 15000 black and white aerial photographs and Survey of India topo sheets.

A contour map of the study area was prepared based on Survey of India topo sheets. The slope map of the area was also prepared by using Wentworth (1936) method. Area under different slope categories and their respective percentage were also calculated using digital planimeter.

4.2. Vegetation analysis

With a view to study the phytosociology of vegetation in Eravikulam National Park, a thorough reconnaissance survey was carried out initially to assess the overall floristic and structural characteristics of the permanent vegetation so as to design the sampling procedure and intensity.

Based on reconnaissance survey major vegetation types were identified. The entire National Park consists of mainly of Shola-Grassland vegetation which is similar in composition and structure on visual observation. The other vegetation types representing are, Southern sub tropical hill forest, West coast tropical evergreen forest, and Scrubs. All these types together constitute only less than 10% of the National Park area.

The community structure of the grassland varies with place to place. It is observed that *Chrysopogon zeylanicus* is present in almost all areas and occupies a dominant place in all communities.

Scrub lands are seen in certain localities as patches and *phlebophyllum kunthianus* and *Pteridium acquilinum*. constitute the major species of it.

4.2.1. Sampling

Based on strata identified on aerial photographs, stratified random sampling was carried out in the area to study the vegetation types, their composition and structural features. The entire Park falls under the same climatic zone. The vegetation type, altitude and accessibility are the chosen criteria for selecting the sample plots. The whole area was divided into seven localities for quadrat studies.

4.2.2. Census quadrat method

Phytosociological analysis of tree layer (>15 cm gbh) of selected localities were made by census quadrat method (Ousting, 1956). Ten quadrats of $10m^2$ size were randomly laid down in each locality. (Menon and Balasubramanyan, 1985 and Shibu Jose *et al.*, 1994) and to characterize the floristic composition and structure of vegetation, thus covering a sampling area of $1000m^2$ in each locality and to cover $7000m^2$ of total sampling area in the study area. According to an earlier study (Shibu Jose *et a.l*, 1994) the species- area curve reaches a plateau at $2500m^2$ indicating the adequacy of the sampled area. Misra and Puri (1957) pointed out that for general ecological studies, the size and number of quadrats to be examined in a community are not much important.

The boundaries of the quadrats were marked using bamboo sticks and ropes. Girth at breast height (gbh) of all trees of 15 cm and above were measured using measuring tape.

The sampling intensity in the grasslands could be reduced to minimum, as homogenous grassland communities were mapped based on its spectral reflectance properties in digital image processing. Randomly selected quadrats of size 4mx2m were laid in different grassland types which were previously identified through remote sensing. In each grassland types 10 quadrats were taken and percentage frequency of each species.calculated Frequency of non grass species were also noted.

Since the percentage frequency of species is widely applied as a measure in the vegetation study, it is used to find out the species composition and dominant communities of grassland.

4.2.3. Quantitative analysis of the vegetation

From quadrat studies, the data on density (D), percentage frequency (%F), abundance (AB), basal area (BA), relative basal area (RBA), relative frequency (RF), relative density (RD), and important value index (IVI) *etc.* are calculated as per the following formula (Gates, 1949; Misra and Puri, 1954; Curtis, 1959; Phillips, 1959; Misra, 1968; Muller-Dombois and Ellenberg, 1974; Ambasht, 1988).

4.2.3.1.Density

Density is an expression of numerical strength of a species in a community and can be calculated as follows

$$\text{Density (D)} = \frac{\text{Total number of individuals}}{\text{Total number of quadrats}}$$

4.2.3.2. Relative density

It is the study of numerical strength of a species in relation to total number of individuals of all species and can be calculated as:

$$\text{Relative density (RD)} = \frac{\text{No. of individuals of species}}{\text{No. of individuals of all species}} \times 100$$

4.2.3.3. Frequency

Indicates the number of sampling units in which a given species occurs and then expresses the distribution or dispersion of various species in a community.

$$\text{Frequency (F)} = \frac{\text{Number of quadrats of occurrence}}{\text{Total number of quadrats studied}}$$

4.2.3.4. Percentage frequency

The composition of different vegetation units frequency is expressed in terms of "Percentage values " or" Frequency index".

$$\text{PF} = \frac{\text{Number of quadrats of occurrence}}{\text{Total number of quadrats studied}} \times 100$$

4.2.3.5. Relative frequency

Relative frequency is calculated as:

$$\text{Relative frequency (RF)} = \frac{\text{Number of occurrence of the species}}{\text{Number of occurrence of all species}} \times 100$$

4.2.3.6. Abundance

It is an appreciation of the number of individuals of different species in a community per quadrat in which they occur and calculated as follows:

$$\text{Abundance (AB)} = \frac{\text{Total number of individuals}}{\text{Number of quadrats of occurrence}}$$

4.2.3.7. Basal area

This is regarded as an index of dominance of a species. Higher the basal area, greater the dominance. The average basal area and the relative basal area were calculated out of the average diameter of the stem at the breast height using the following formula.

$$\text{Basal area (BA)} \quad (\text{GBH})^2/4$$

4.2.3.8. Relative basal area

$$\text{Relative basal area (RBA)} = \frac{\text{Basal area of the species}}{\text{Total basal area of all species}} \text{ X 100}$$

4.2.3.9. Important value index

A total picture of the ecological status of a species with respect to community structure can be obtained only by synthesizing the percentage values of Relative density, Relative frequency and Relative basal area. These when added together give the IVI based on which the association is derived.

Important value index (IVI) = Relative density + Relative frequency +Relative basal area

The IVI of each family is calculated by adding the IVI of all species of that family.

The mean density, mean abundance, mean frequency, mean important value index of different species and the percentage IVI value of each species with respect to the total IVI value of the locality as a whole are calculated separately for each locality to establish the stand relationships.

4.2.3.10. Family importance value

The family importance value was calculated as shown by Keel *et al*, (1993).

FIV = Relative density + Relative diversity + Relative dominance.

$$\text{Relative density} = \frac{\text{Number of individuals of the species}}{\text{Total number of individuals in the sample}} \times 100$$

$$\text{Relative diversity} = \frac{\text{Number of species in the sample}}{\text{Number of species in the sample}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Basal area of the family}}{\text{Total basal area of the in the sample}} \times 100$$

4.2.3.11. Law of frequency

The concept of frequency in vegetation study was originally developed by Raunkiear (1934). The vegetation was divided into five frequency classes (Raunkiar, 1934)

Class A: 0-25 % frequency

Class B: 21-40 % frequency

Class C: 41-60 % frequency

Class D: 61-80 % frequency

Class E: 81-100 % frequency

The nature of vegetation (homogeneity/heterogeneity) was worked out using Raunkiar's (1934) low of frequency which states

$$A > B > C <=> D < E$$

where A, B, C, D and E are various frequency classes.

4.2.3.12. Distribution

Distribution of species is one of the important aspects of ecological studies, which has attracted attention of a number of ecologists (Cole, 1946; Frackler and Brischle, 1944; Witford, 1948 and Ashby, 1948). Abundance/frequency ratio was worked out to study the nature of distribution of species.

4.2.3.13. Maturity index

A great deal of work has been done in India and abroad regarding the successional status of the forest ecosystem (Puri and Jain, 1961). To know more about the structural aspects of the vegetation, especially the successional status of the vegetation, the maturity index (MI) value for each locality was worked out. The term maturity index (MI) was first coined by Pichi- Sermolli (1948) to assess the status of the community in relation to successional stages. The maturity index is calculated by using the formula

$$\text{Maturity index (MI)} = \frac{\text{Total frequency percentage of a locality}}{\text{Total number of species present}}$$

4.2.3.14. Community Co- efficient

To assess the overall similarity of different locality with respect to species diversity, 'the index of similarity' is worked out. The study is based on the "community coefficient concept" (Jaccard 1912). It is based on the presence/absence relationship between the number of species common to two areas and total number of species. Thus, it expressesthe ratio of the common species to all species found in the vegetation (Muller-Dombois and Ellenberg, 1974)

The community Co efficient is expressed in terms of similarity index. Sorenson's (1948) modified formula for similarity index is followed here because it is mathematically more satisfactory in terms of statistical probability.

$$IS = \frac{2C}{A+B} \times 100$$

Where,

C = the number. of species common to two relives

A = the total number.of species in relive A

B = the total number of species in relive B

4.2.3.15. Continuum concept

For calculating the continuum index (Curtis and McIntosh, 1951), each species is assigned a climax adaptation number based on the important value index (IVI) ranging from 1-10 for species at both ends. A high adaptation number means better adaptation to all environmental conditions present in terminal stands To assess the position of a single stand, the important value index of different species present in the stand were weighed against their adaptation number. These values are added to give the total value for a stand, which is the continuum index of the locality

4.2.3.16. Diversity index

Community diversity is the most direct measure of ecosystem fitness. The study of diversity is the study of variation in the number of different ecological circumstances. Diversity can be used as a measure of environmental constraints at play. It has therefore been suggested that the 'Index of Diversity' can be an indication of the relative importance of the factors that are affecting the population balance as a whole. Diversity is composed of two distinct components, *viz.* the total number of species and how the abundance data are distributed among the species. First component refers to the richness and the second component is evenness or equitability. A number of indices have been proposed to measure species richness, which are independent of the sampling size. Two well known richness indices are follows:

$$R1 = \frac{S-1}{\ln(n)} \quad \text{(Margalef, 1958)}$$

$$R2 = \frac{S}{\sqrt{n}} \quad \text{(Menhinick, 1964)}$$

There are an infinite number of diversity indices (Peet, 1974). Here some of diversity numbers presented by Hill (1973) are the easiest to interpret ecologically. As the diversity index is a combined value, the index has major limitations and with just the value of diversity index is impossible to say that relative importance of species richness and evenness. There fore a series of diversity numbers by Hill (1973) are made use to assess the community ecologically.

Hill's family of diversity numbers is derived from the following formula:

$$NA = \sum_{i=1}^{S} (P2)\ N/1=A \quad \text{where,}$$

P= proportion of individuals belong to the i th species.

Hill (1973) had shown that 0^{th}, 1^{st} and 2^{nd} order of these diversity (A=0,1,2) of the above equation coincides with of the most important measure of diversity, as:

N0 = S where 'S' is the total number of species.

N1 = H = Shannon wiener index

N2 = $1/\lambda$ where λ is the Simpson's index.

To analyse this (Hills diversity number) Simpson's Index and Shannon weiners Index are needed.

Simpsons index (1949) $= (Pi)^2$

where Pi is the proportional abundance of the i th species given

by Pi = ni/N, i = 1,2,3,-----S

Shannon wiener index $H = \sum [\ Pi_{ln}(Pi)\ ]$

Evenness indices: A number of indices have been used to quantify evenness composition of diversity. A series of 5 indices are used. They are expressed as a ratio of hills numbers (Alatalo, 1981).

Evenness index E1= ln (N1)/ ln (N0) (Pielou, 1975 and 1977)

E2= N1/N0 (Shelden, 1969)

E3= N1-1/N0-1 (Heip, 1974)

E4= N2/N1 (Hill, 1975)

E5= N2-1/N1-1 (Alatalo, 1981)

General Species diversity is calculated using the concept of information theory by Shannon Wiener (1949) which is modified by Margalef.(1958)

The formula is

$$\text{Diversity index } H = \sum \frac{n1}{N} \log \left(\frac{n1}{N}\right)$$

Where n1 = Number of individuals of a species

N = Total number of individuals of all species

4.2.3.17. Concentration of Dominance

Measured by Simpson's Index (Simpson, 1949)

$$CD = \left(\frac{n1}{N}\right)^2$$

Where, n1 and N are the same as for diversity index.

4.2.3.18. Constancy

The presence or absence of a species in a stand is a measure of regularity or distribution of a species in different stands of an association. It is generally expressed in a scale of 1-5 based on (Pandeya, *et. al.*, 1968)

4.2.4. Study of structural composition of Grasslands

Census quadrat techniques were adopted to study the structural composition of grasslands. Randomly selected quadrats of 4m X 2m size were laid in different grassland community types, which were previously identified using digital image technique. Occurrence and non occurrence of species were noted and studied in each quadrat to find out the dominant communities of the grassland.

4.2.5. Spatial distribution pattern of shola forests

The altitudinal heights of each shola patches were located to study the distribution of shola forests. This is done by overlay the contour map on to the vegetation map and noting the contours bisecting the shola. If more than one contour bisect or touches the shola the average of the contour value was taken. The entire area of National Park is divided into altitudinal classes of 100m intervals. The occurrence of number of shola patches in each altitudinal classes was found out. Area of each shola was measured using digital planimeter to study the size in relation to its distribution. The shola forests were classified into different area classes. The area classes of shola forests were formulated in such a way that maximum accuracy is obtained. The frequency of sholas in each area classes were found out.

CHAPTER V

RESULTS AND DISCUSSION

5.1. Vegetation Mapping

5.1.1. Results

Vegetation maps in three different scales *viz.* a detailed large-scale map of 1:25,000, medium scale of 1:50,000 and a small scale of 1:1,00,000 were prepared.

5.1.1.1. Large scale map prepared from Aerial photograph.

A detailed large scale vegetation map has been prepared from 1:15,000 pan chromatic black and white aerial photographs (Fig. 5). A total of nine land cover classes were identified (Table 1) on visual interpretation of data. A flow chart for forest cover mapping through visual interpretation technique is given Figure 6.

Tonal variation of different land cover classes like, West coast tropical evergreen forest, Subtropical hill forest and Shola forests on aerial photographs could be distinguished and hence delineated accurately.

The smallest unit delineated in the aerial photograph are 5mm x 5mm size Photostratification scheme based on fundamental photo elements is adopted to prepare a density wise classification.

Fig.5. In pauch at the back of the thesis

Fig. 6. Flowchart for visual interpretation of forest cover mapping

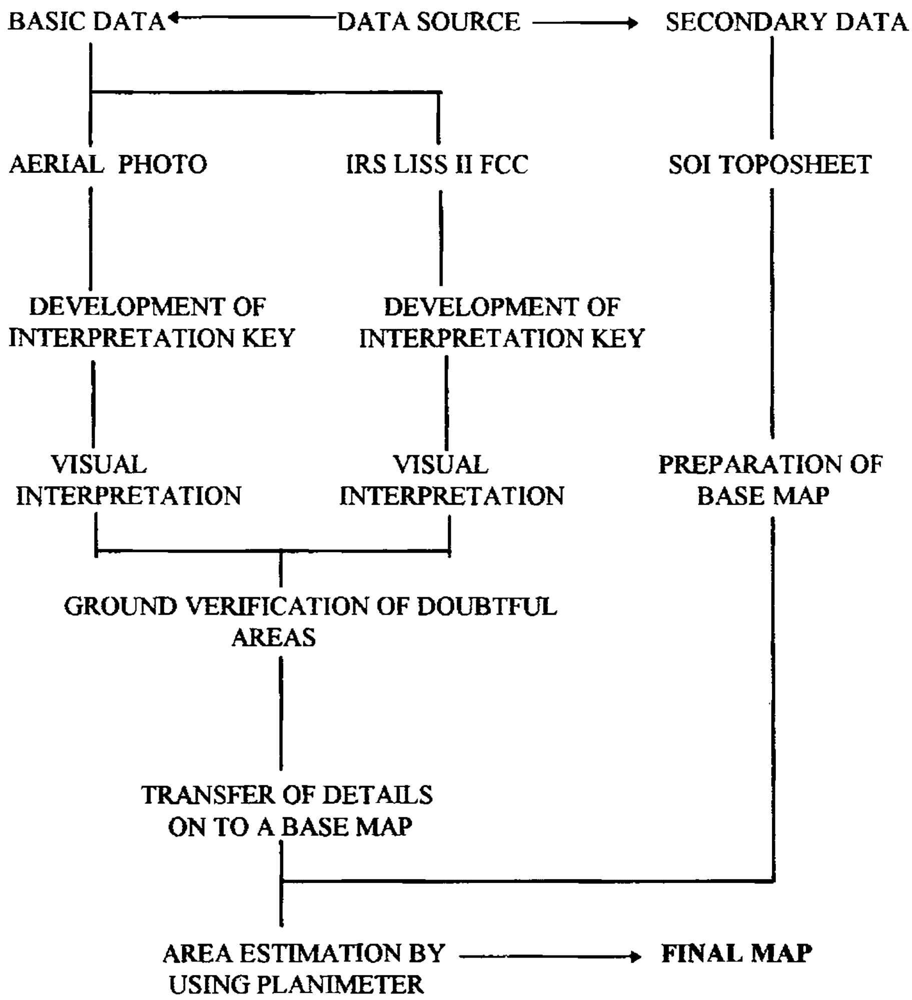


Table 1. Comparison of thematic information in the map prepared through visual interpretation of Aerial photograph, Satellite imageries and digitally classified output.

Aerial photograph	Geocoded FCC	Standard FCC	Digitally classified output
Shola Crown cover Law(1-25 %) Medium (26-50) High (>50)	Shola Crown cover Low (1-25 %) Medium (26-50) High (>50)	Shola Crown cover Low (1-25) Medium (26-50) High (>50)	Shola merged with evergreen and subtropical forests.
Evergreen	Not distinguished	Not distinguished	Not distinguished
Sub Tropical Hill forest	Sub Tropical Hill Forest	Not distinguished	Not distinguished
Grassland	Grassland	Grassland	Grassland classified into three
Tea Wattle	Tea Wattle	Tea Wattle	Tea Not distinguished
Scrub	Scrub	Scrub	Scrub
Habitation	Not distinguished	Not distinguished	Not distinguished
Rock	Rock	Rock	not distinguished

Density stratification of Shola forests into three density classes was achieved based on its tonal contrast. The density classes followed are, 1. Low density shola (Crown cover 1-25%) 2. Medium density shola (26-50%) and (3) a high density shola (crown cover >50%). Image interpretation key for different land cover classes using panchromatic black and white aerial photographs were also prepared (Table 2).

5.1.1.2. Medium scale Vegetation map prepared from geocoded FCC

Geocoded FCC of IRS LISS 2 data has been used for the preparation of medium scale (1:50,000) vegetation map (Fig. 7). The advantage of using geocoded FCC is that it has been prepared after geometric and radiometric correction to the geographic orientation of the real north so that while interpretation the ground control points can be traced easily by using Survey of India toposheets.

Fig.7

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(prepared from 1:50,000 IRS 1B LISS 2 geocoded imagery of 1993)

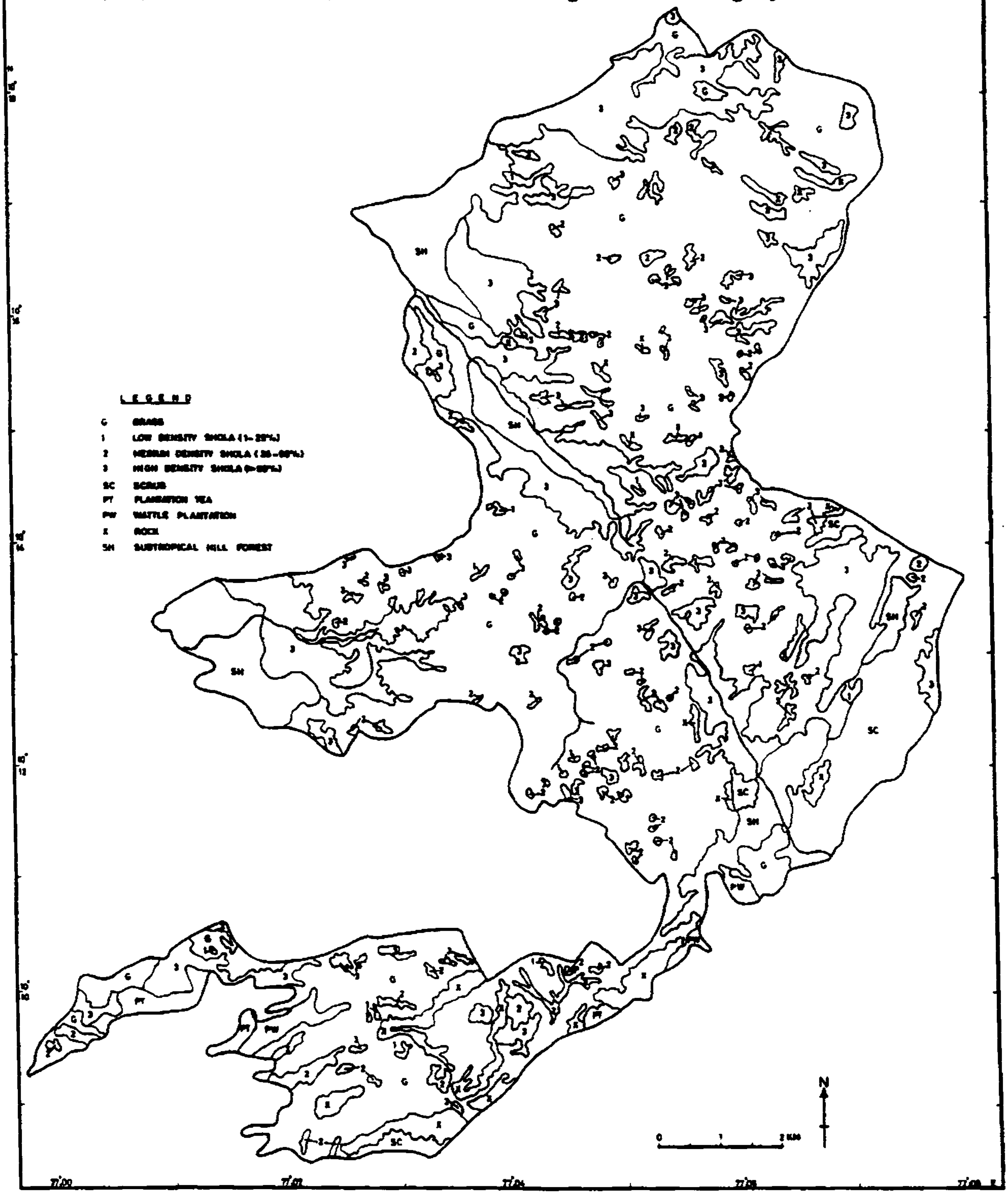


Table 2. Image Interpretation key for different land cover classes using Pan-chromatic B & W Aerial photographs.

Symbol	Cover type	Tone	Texture	Pattern	Association
E	Evergreen Forest (1A C4)	Grayish dark	Course	Contiguous	Hill slopes
SH	Sub Tropical Hill Forest (8A C1)	Dark	Fine	Contiguous	Slope descending from the plateau
S	Shola Forest (11A C1)	Deep dark	Medium	Non contiguous	Glens, hollows, valleys
G	Grassland (11A DS2)	White	Fine	Contiguous	3 & 5
SC	Scrub (11A DS1)	Grayish white	Course	Patchiness	
PT	Tea plantation	Dark gray	Fine	Distinct arrangements	
PW	Wattle plantation	Grayish	Medium	Distinct crown shape	
H	Habitation	Yellowish white	Course	Distinct appearance	
X	Exposed rock	Light gray	Rough	Scattered	
W	Water body	Dark black	Fine	Distinct	

Features discernible in geocoded FCC are almost comparable with aerial photographs (Table. 1). The peculiar vegetation type like shola and grassland vegetation where minute shola patches are interspersed with vast spreading grasslands were found to be more difficult to interpret in satellite imageries. This can be overcome to some extent by using high resolution LISS 2 data. West coast tropical evergreen forests could not be distinguished. Smallest units of sholas are merged with the adjacent features in most cases. An accuracy level of nearly 75% was worked out. Shola forests were classified based on their density, into three classes, viz. low density (1-25 % crown cover), medium density (26-50 %) and high density (> 50%)

Comparative account of different vegetation classes, obtained through various data products used, are given in table 1. An image interpretation key for land cover classes using IRS data is also prepared (Table. 3).

Table 3. Image Interpretation key for landcover mapping using IRS FCC

Sl	Symbol	Cover type	Tone	Texture	pattern
1	S	Shola	Dark red	Fine	Non contiguous
2	E/SH	Evergreen Types	Bright red	Medium	Contiguous/Non contiguous
3	G	Grassland	Light gray	Fine	Non contiguous
4	SC	Scrub	Yellowish gray	Mottled	Patchiness
5	H	Habitation	Bluish gray	Course	Distinct appearance
6	PT	Tea plantation	light red	Medium	Distinct arrangements
7	PW	Wattle plantation	Slightly dark red	Medium	Distinct arrangements
8	X	Rock	Grayish	Course	Scattered

5.1.1.3. Small scale Vegetation map prepared from standard FCC

For a small scale (1:1,00,000) vegetation map, standard FCC (1:1,25,000) of IRS LISS 2 data were used (Fig. 8). Land cover classes delineated (Table 1).

Subtropical hill forest and West coast evergreen forest could not be identified. Shola forests are classified based on their density into three as in the case of geocoded FCC and aerial photograph.

5.1.1.4. Vegetation map prepared from Digital image processing.

Digitally classified output of the study area are given in Plate 2. The initial reconnaissance survey during the study realised the highly heterogeneous nature and distribution of grassland communities. Based on the spectral differentiability, grassland communities of Eravikulam National Park are classified into three types.

Grassland community type 1 occupies comparatively less area and mostly seen in the lower elevation of Rajamala and in some parts of the center of the Park. Grassland community type 2 occupies more or less equal area as the grassland community type 3. It occupies the north western part of the National Park and Anamudi area. Grassland community type 3 is seen mostly on the northeastern side of the National Park (Plate 2).

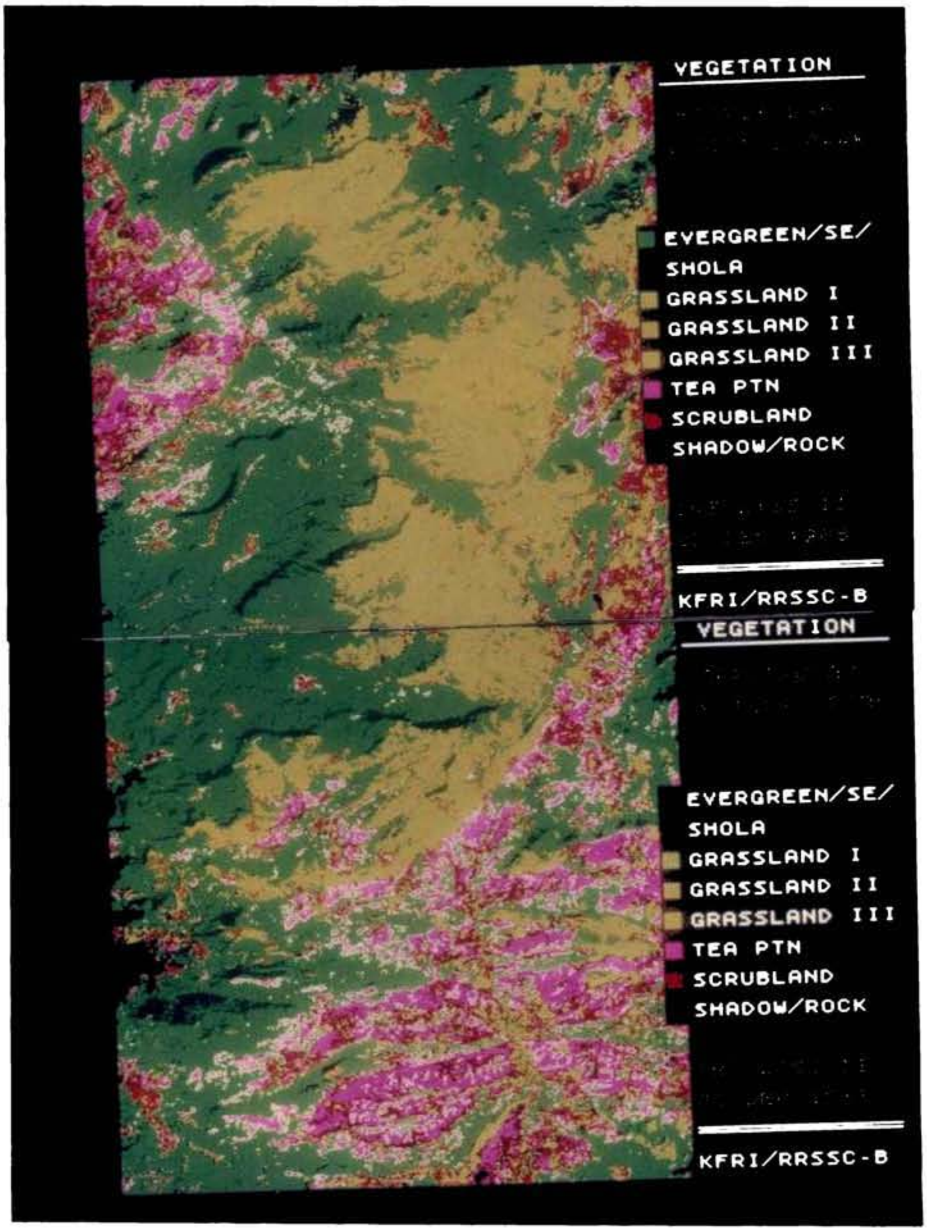


Plate 2. Eravikulam National Park - Digital classified output

Confusion matrices were generated to study the number of pixels going into each class and classification accuracy was estimated to 75% (Table 4). Subtropical hill forest and west coast tropical evergreen forests, Tea and Wattle plantations could not be distinguished from shola forests. A flowchart for digital image processing technique is also prepared (Fig. 9.).

Table 4. For accuracy evaluation of Digital image processing, Confusion matrix developed showing percentage of pixell going into different classes

	GR1	GR2	GR3	E	SH	PT	SW	SC	R	P
GR1	90.23	3.76	5.26	0	0	0	0	0	0.7	100
GR2	4.72	79.53	14.96	0	0	0	0	0	0.7	100
GR3	6.34	10.56	80.23	0	0	0	0	0	2.0	100
E	0	0	0	77.54	10.3	7.72	0	0	0.2	100
SH	0	3.13	0	0	89.0	0	6.25	0	1.5	100
PT	0	0	0	13.17	0	86.1	0	0.35	0.3	100
SW	0	0.56	0	0.56	11.7	0	85.4	0	1.6	100
SC	0	0	1.76	0	0	0	0	98.0	0	100

GR1, GR2, GR3- Grassland type 1, type 2, type 3; E- Evergreen; SH- Shola; PT- Tea plantation; SW- Shadow; SC- Scrub, R- Reject pixel, P- Total pixel.

5.1.1.5. Drainage map, Slope map and Contour map

For better management of Wildlife Sanctuaries and National Parks, ancillary information such as drainage map, contour map and slope map are necessary. A contour map showing contours with 100m. interval has been prepared (Fig 10). Based on the contour information a slope map was also prepared. Six slope categories were identified. The slope category above 30° has minimum area and the slope class $15\text{-}20^{\circ}$ has the maximum area (fig 11). Drainage map in 1:50,000 has also been prepared based on aerial photographs and SOI toposheets (Fig 12).

5.1.1.6. Land cover classes

Vegetation classes obtained through different data products used are given (Table 1). Major vegetation types in the study area are grasslands and shola forests (Plate 3a). In addition to these some transition forests are seen in

ERAVIKULAM NATIONAL PARK - LANDCOVER

Fig.8 (prepared from 1:1,25,000 IRS 1A LISS 2 imagery of 1990)

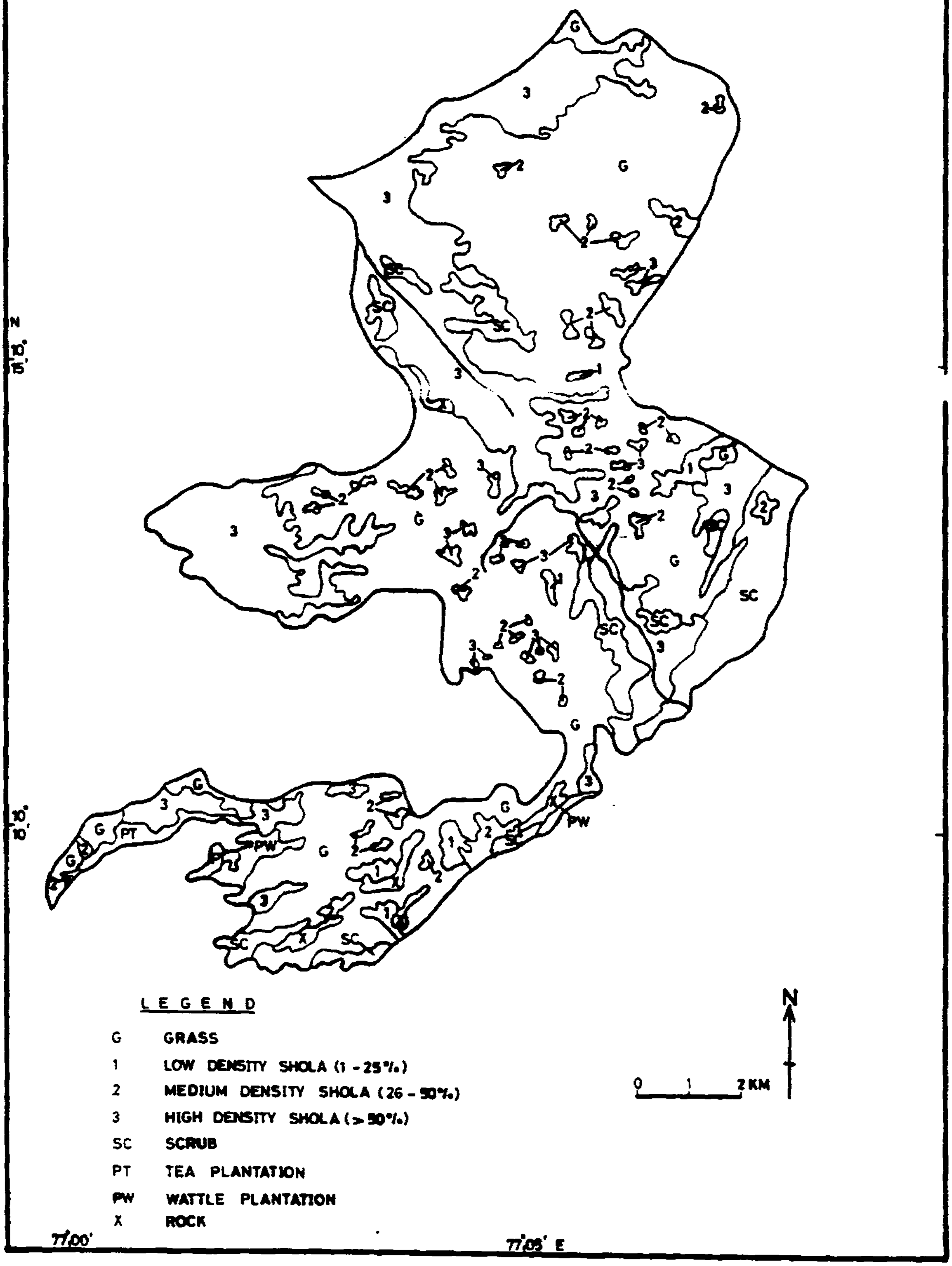


Fig. 9. The details of software and commands used for digital analysis of IRS digital data

IRS - CCT

VIPS Compatable Reformating

< LOAIRS >

Display on Pericolour

< LOADIM >

Stretching and FCC creation

< SAVIM >

Histogram creation

< HISTO >

Supply of ground truth information

with training sets

< GTRUTH >

Class statistics calculation

<CLSTAT >

Separability among classes

Generation of confusion matrices

< SEPAR >

Choose subset of classes for each segment

Classification of each sample segment

< CLASSEG >

Reject pixels-----------Yes--------------More classes

No ------------------------------------ No

Class pixel

Percentage class average ---------------- x 100

Data pixel

the lower elevation i.e., Southern subtropical hill forest, between 1200m and 1700m elevation. A few patches of west coast tropical evergreen forests are also seen. Area of each vegetation class obtained through different data are given in Table 5. Around 60% of the area is covered with grasslands and about 25% consists of shola forests.

5.1.1.7. Area estimation of different cover types

Area of each vegetation type estimated through different data products are given in Table 5. Total area of National Park is estimated at 112 km^2.

Table 5. Area estimation of different land cover classes obtained through different remote sensed data (area in km^2)

Cover class	Aerial photo	Standard FCC	Geocoded FCC
Shola Total	19.95 (17.81%)	32.67 (29.17%)	28.6 (25.53%)
Low dense	0.36 (0.32%)	1.56 (1.39%)	0.72 (0.41%)
Medium dense	3.41 (3.05%)	2.78 (2.48%)	3.20 (2.55%)
High dense	16.17 (14.44%)	28.33 (25.29%)	24.67 (22.02%)
Grassland	65.44 (58.42%)	67.15 (59.95%	66.58 (59.44%)
Evergreen	0.20 (0.18%)		
Sub Tropical Hill Forest	9.47 (8.45%)	-	4.39 (3.91%)
Scrub	8.45 (7.58%)	8.98 (8.01%)	5.74 (5.13%)
Tea plantation	0.74 (0.66%)	0.99 (0.89%)	0.91 (0.81%)
Wattle Plantation	0.99 (0.88%)	0.94 (0.84%)	0.88 (0.77%)
Habitation	0.11 (0.10%)	-	-
Rock	6.57 (5.86%)	1.24 (1.11%)	3.01

5.1.1.7.1. Grassland

About 60% of the National Park is covered by grassland. Grassland comprises 58.43, 59.96, and 59.45 km^2 in map prepared from Aerial photograph, standard FCC and Geocoded FCC, respectively. In digital image processing, three different community types of grasslands were identified based on their characteristic spectral radiance value. Total grasslands delineated from the digitally classified out put is about 78.25 km^2.

5.1.1.7.2. Shola

The area of shola forest estimated are 17.81, 29.17 and 29.46 km^2 from aerial photographs, standard FCC and geocoded FCC respectively.

5.1.1.7.3. West coast tropical Evergreen

In the study area a small stretch of west coast tropical evergreen forests is located in the lower elevation of the northeastern part of National Park, which could be distinguished from shola forests in aerial photographs. At the same time it is merged with shola forests in Satellite data products.

5.1.1.7.4. Southern subtropical hill forest

In the National Park about 9.45 km^2 of subtropical hill forests are estimated from aerial photographs and 4.39 Km^2 are estimated from Geocoded FCC. These forests are seen in the transition zone between low elevation evergreen forests and high elevation shola forests. This type of forest constitutes about 8.46% of the total area of National Park.

5.1.1.7.5. Scrub

About 7.59% (8.46 Km^2) of the area are covered by scrubs. The estimates of scrubs obtained in different data products are 7.56, 8.02 and 5.13 respectively out of total area of 112 Km^2

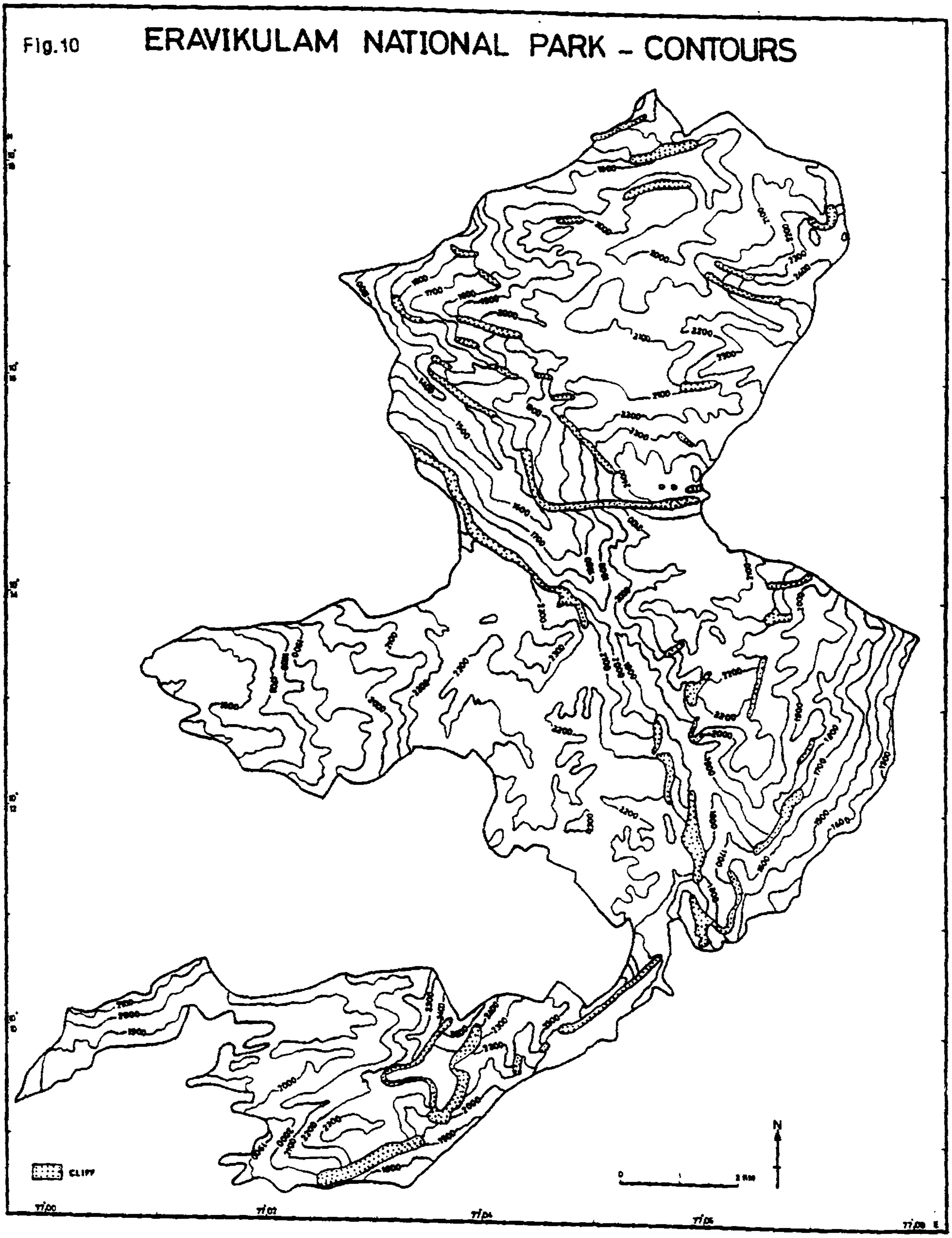


Fig.10
ERAVIKULAM NATIONAL PARK - CONTOURS
CLIFF
N

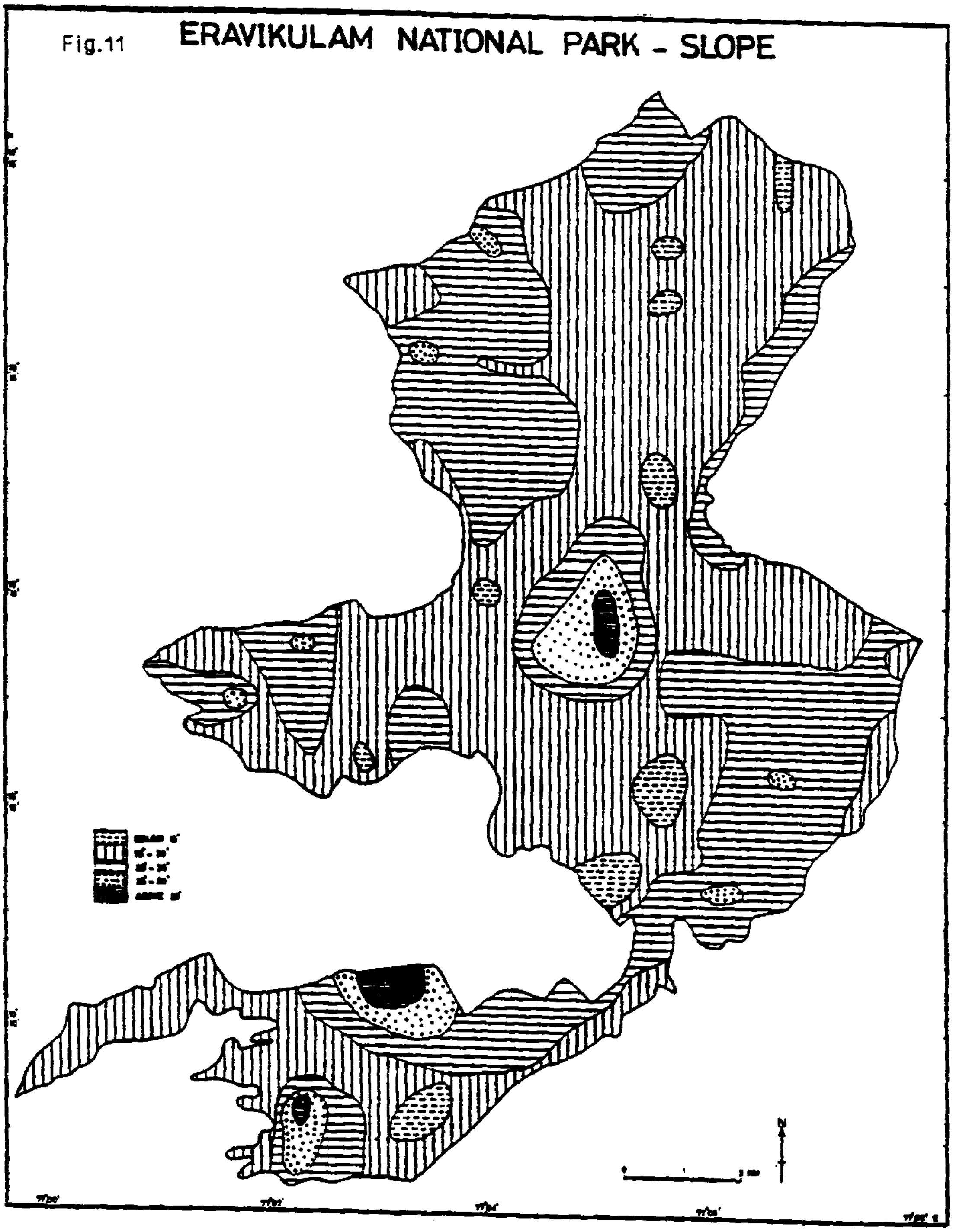
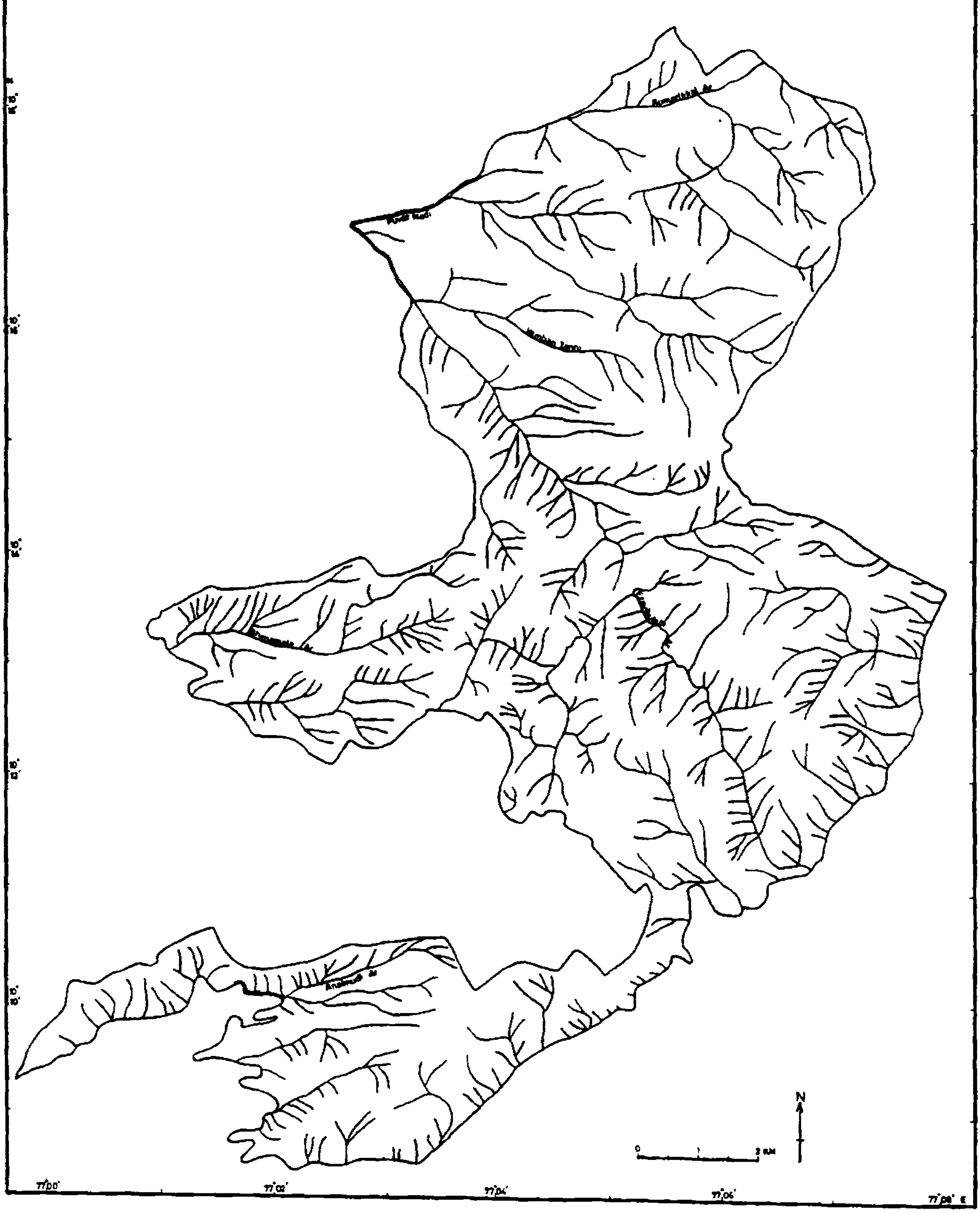


Fig.11 ERAVIKULAM NATIONAL PARK - SLOPE

Fig.12 ERAVIKULAM NATIONAL PARK - DRAINAGE



5.1.1.7.6. Plantation

Tea plantations were found encroaching in the southwest boundary of National Park near Pettimudy estate plantations. Similarly in the lower Vaguvarai region also, some wattle plantations are seen inside of the Park boundary. Total area covered by plantations is 1.74 Km^2. (1.5 % of the total area).

5.1.1.7.7. Habitation

Some tribal settlements (Muduvakudi) is found inside the National Park near Lackam tea estate (Plate 3b). The area of settlement is about 0.11 Km^2.

5.1.1.7.8. Rock

Rocks and cliffs are some of the important geomorphologic features in the National Park. Based on aerial photographs the area covered by rocks are 5.868% of the total area.

5.1.2. Discussion

The vegetation maps prepared by remote sensing techniques were the first of its kind for the Eravikulam National Park. As per the management plan, Eravikulam National Park, covers an area of about 97 Km^2. Area estimation carried out using Digital Planimeter after overlaying existing boundaries gave an area of 112 km^2. Plantations like Tea and Wattle were found inside the South west boundary of National Park near Pettimudi Tea estate.

Vegetation/Land cover classification and mapping have been attempted for the southern part of India by French Institute, Pondichery, Jointly with Government Departments (Legris and Meher-homji, 1968). Their main map at a scale of 1:1000000 depicts important features of natural vegetation and land cover types such as, agricultural and plantations but are in a scale too small to convey information appropriate for planning and management.

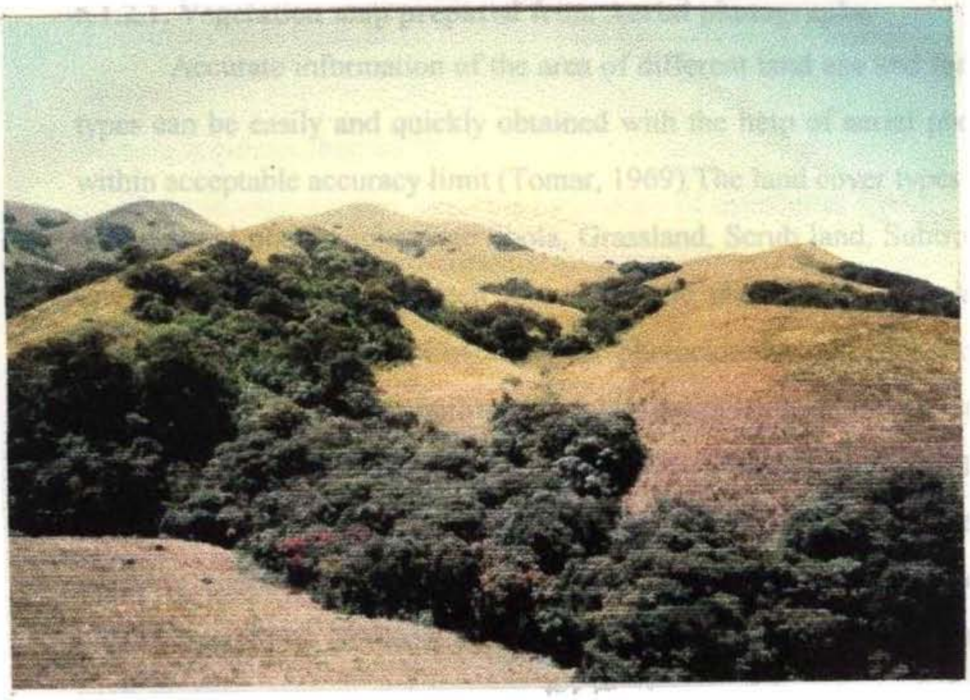


Plate 3a. A view of shola - grassland vegetation

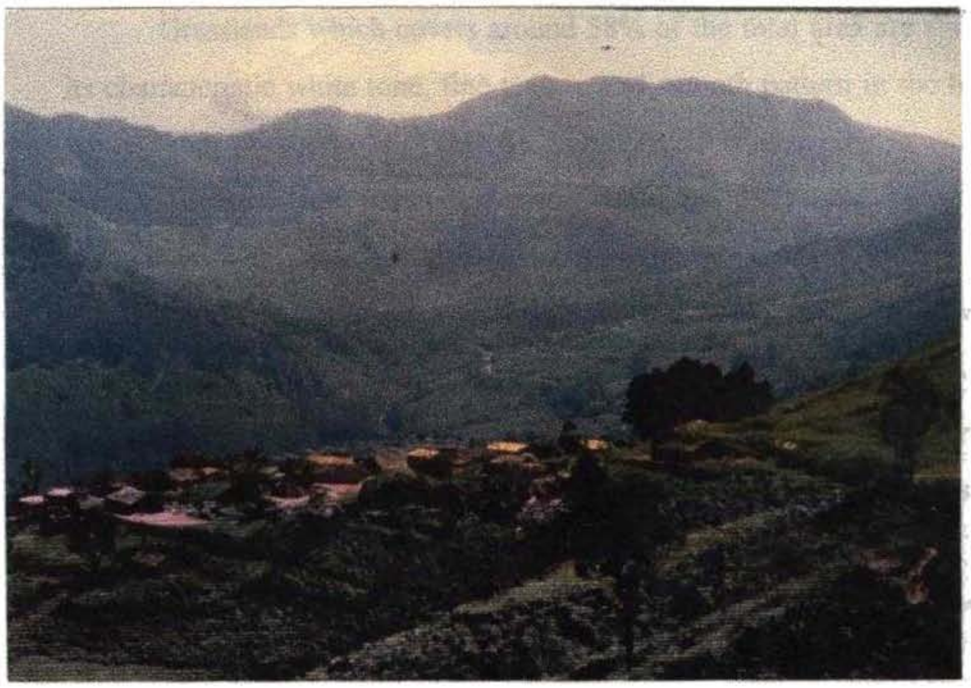


Plate 3b. Tribal settlement at Lakkam (Muduva Kudi)

5.1.2.1. Vegetation map prepared from Aerial photographs

Accurate information of the area of different land use and forest cover types can be easily and quickly obtained with the help of aerial photographs within acceptable accuracy limit (Tomar, 1969).The land cover types observed on the aerial photographs were Shola, Grassland, Scrub land, Subtropical hill forest, low elevation evergreen forests, Wattle plantations, Tea plantations, Habitations and Rocks. Characteristic photoelements of each land cover feature in the study area facilitates proper delineation of the cover classes. The tonal variations between shola forests and subtropical hill forests as well as that of evergreen forests are found to be very little. Hence, the delineation of cover classes was much more difficult task. Altitude, topography, and phytogeographical elements were considered along with the photoelements such as, tone, texture and location for the proper delineation of these forest types. Much care has been taken for correct delineation of shola patches which are ranging from 1 to 300 ha. and are intermixed with the grasslands. During the cover class delineation from the aerial photograph, 1ha was the smallest size of shola that could be easily delineated.

Grasslands which covers around 58% of the total area are shown with its characteristic white tone, fine texture and smooth pattern in the black and white aerial photographs (Table 8). Scrub lands with a greyish white tone, medium texture and medium pattern could be delineated properly from grasslands. The common species composition of scrub lands are *Phlebophyllum kunthianum, Eupatorium adenophorum, Pteridium acquilinum. etc.*

Using black and white aerial photographs the vegetation types *viz.* shola, sub tropical hill forest and evergreen forests are classified into three density classes based on its tonal contrast. Density stratification was done at three levels *viz.* low density (crown cover 1-25%), medium density (26-50%) and high density (>50%). It fails to provide further classification due to following reasons.

1. Narrow stratification of forests based on density is not possible when the crown
closure is greater than 60 %.
2. Shola forests mapped were the admixture of numerous species. No single species dominates. In such a case it is impossible to obtain a pure signature of species formation.

This density classification is contrary to the general forest density categories used by the Forest Survey of India. According to them forests have been categorised into three types on the basis of percentage crown density *i.e.*,

1. Dense or closed forest - >40%
2. Open forest - 10-40%
3. Degraded forest - <10 %

Such a classification is more effective in general forest mapping of entire country. In order to map a small area that too a protected National Park where density stratification is more important for its management, high, low and medium density classification is adopted instead of dense, open and degraded classification of FSI.

Aerial photographs are in use in India since 1925 and has been in use in forest survey since 1965 (Preinvestment survey of forest resources). More recently large scale aerial photographs have provided useful data for quantitative estimation of change in vegetation cover and density (Poulton, 1975) A comparative evaluation of land use and forest type classification and mapping with aerial photographs *viz.-a-viz.* conventional ground stock mapping was carried out by Tiwari (1978). The Forest Survey of India, the Indian Institute of Remote sensing, some state forest departments and forest development corporations have been regularly using aerial photo interpretation and remote sensing techniques for vegetation and soil mapping (Shedha, 1982).

Roy *et al.* (1986) studied considerable structural detail about existing vegetation such as structure, spacing, plant life form and species relationships with the help of aerial photographs and emphasized the necessity of multistage approach of remote sensing technology. Use of aerial photography in forestry is well established (Hilderbrandt, 1986). The main reason for the continuing reliance of the aerial photographs as an essential data base for resource analysis lie in its proven worth, its versatility and its low cost (Menon, 1988). He emphasized that the aerial photographs are having three dimensional effect which gives better resolution for stratifying vegetation types based on photoelements, and the density, height, composition of species *etc.* are well distinguished on it. Aerial photographs provides feasibility to visualise the landscape in a three dimensional perspective and so as to classify the vegetation on the basis of dominant emergent tree species. Vegetation mapping using 1:10,000 scale B&W panchromatic aerial photographs has been carried out in the Western part of Kanha National Park (Roy, 1986). An examination of recent literature indicates that aerial photos are widely used for vegetation mapping and resource evaluation (Monasterio-Hardin *et al*, 1989, Sureshkumar, 1990; Porwal and Roy, 1991). In tropical forests, density stratification can be performed within a reliable level of accuracy with 1:15,000 scale photographs (Menon, 1990 and Porwal & Roy 1992).

Panchromatic black and white aerial photography still remains universally as the most important medium of photointerpretation and photogrammetric mapping. This is in general due to its lower cost (resulting from a greater number of days per year suitable for aerial photography and the much wider tolerance of the film to incorrect exposure) and to the exacting requirements of sophisticated mapping equipements. In highly undulating terrain like Western Ghats, where our study area falls, aerial photographs are better for forestry mapping purposes than any other satellite products.

5.1.2.2. Vegetation Map prepared from Geocoded FCC.

IRS LISS 2 Geocoded FCC is equally comparable with the aerial photographs since it has better ground resolution (36.25). Grasslands were observed in light grey tone with fine texture and were distinguished from scrub lands of its characteristic yellowish tone with medium texture (Table 3). The units of West coast tropical evergreen forests could not be delineated as it shows the similar photoelements of subtropical hill forests. The evergreen and semi evergreen forests are not distinguishable in remotely sensed data due to mixing of spectral signature (Menon, 1990).

The smaller size of some shola forest patches often appeared as a small reddish dark spots in the satellite imagery, and even very small units were merged with the adjacent units which may ultimately affect the result of the vegetation map.

Spatial resolution is one of the most important parameters deciding the potential application of satellite data. IRS LISS 2 data having a better spatial resolution of 36.25m is adequate for vegetation studies. An FCC imagery generated by combining IRS bands 2,3, and 4 enables the identification of vegetation type effectively. Qualitative changes in the forest cover and effects of fire were successfully monitored using satellite remote sensing techniques at Bandipur National Park and Mudumalai Wildlife Sanctuary (Madhavanunni *et al*, 1986). With the advancements in satellite remote sensing technology with respect to, scanning technique, spatial and spectral resolution; broad based vegetation type stratification have been reported with space platforms also (Benson and De-Gloris, 1985 and Tucker *et al.*, 1985). The use of geocoded FCC in the preparation of medium scale vegetation map with maximum accuracy is a well established fact.

5.1.2.3. Vegetation map prepared from standard FCC

A small scale vegetation map of 1:1,000,00 scale is generally meant for the reconnaissance survey of the area. A small scale map will enable us a quick and ready appraisal of the area within a minimum time and space. A standard FCC of IRS 1A LISS 2, of scale 1:1,25,000 was used for the purpose. Synoptic coverage repetitive and availability of near real time data of satellite remote sensing are some of advantages over aerial photographs. The units of Sub tropical hill forest, Evergreen forest and some of rocky patches were merged with the units of shola forests. At the same time, grasslands could be delineated with almost maximum accuracy and comparable with the map prepared from aerial photographs. This emphasizes that especially for, mapping of high altitude shola grassland vegetation, small scale imagery is not sufficient to extract maximum information. Three density classes have been achieved in the density stratification scheme. According to Madhavanunni *et al.* (1991), in LISS 2 imagery when interpreted, to delineate broad forest types and stratification, two to three categories were identified on the basis of density. During the process of delineation of land cover classes, the very minute shola patches could not be identified. This is often mixed with adjacent land cover types. The capacity to extract fairly accurate information pertaining to relatively homogenous primary forests using IRS data is well established (Madhavanunni *et al.*, 1991). Prince (1984) has already used satellite data successfully for studying and monitoring range condition in Botswana.

5.1.2.4. Vegetation map prepared from Digital Image Processing

Vegetation/land cover classes, digitally distinguishable and corresponding themes interpreted on aerial photograph are tabulated (Table 1) The CCT processed output was of a very small scale (1:2,50,000) and hence density stratification was not done.

The forest types like, sholas, subtropical hill forests, and evergreen forests showed similar spectral signature and hence can not be separated during classification. They merged together into single unit as evergreen forest.

The spectral separability of grasslands were more prominent, since sufficient number of training sites were given and accordingly, the grassland communities of Eravikulam National Park were classified (Plate 2). The overall accuracy as per the percentage of pixels going into different classes shows 86%(Tab 4).

For effective management and ecosystem conservation of grassland resources, a community wise mapping is essential. The knowledge on the distribution pattern of various types of grassland communities is a pre-requisite for management.

Information with respect to grassland, its quality, distribution *etc.* are of prime need to wildlife managers for taking conservation measures in National Parks (Roy *et al*, 1991).

In India, the studies on grasslands using remote sensing technique were undertaken by many workers. Grassland mapping and monitoring of Banni, Katchch (Gujarat) has been done using remote sensing data by Jadhav *et al.*, (1993). Roy *et al.*, (1991) studied the spectral reflectance and potentiality of grasslands in Kanha National Park using the remote sensing data. He used hybrid colour composite generated by using LANDSAT MSS band 4, 5 and 7/5 for identification of various types of grasslands. In the study, he classified grasslands based on physiognomy, ecological set up and dominant grasses present. Such a physiognomic classification is irrelevant to the high altitude grasslands of Eravikulam National Park where in almost all areas *Chrysopogon zeylanicus* is a dominant species.

Traditional methods of identifying and classifying different grasslands in such a vast area of rolling terrain like Eravikulam National park is a difficult task. In *lieu of* conventional methods, modern technique like, digital image processing was used for quick and accurate classification of grassland vegetation.

A detailed investigation is required to assess the factors determining the distribution patterns of these grassland communities and is beyond the scope of this study. Computerised image processing has considerable potential in forest mapping. It not only helps to reduce the high volume of image data and speed up the interpretation process, but also permits the more accurate and consistent analysis of multispectral images (Kalensky and Wightman, 1976)

Visual interpretation has inherent drawbacks of subjectivity and does not provide technology for regular monitoring as an operational basis. Therefore it is necessary to develop technology based on digital processing. The percentage mixing of pixels of different grass communities were evaluated and the classes with more than 75% purity were selected for final classification (Table 4)

Many pixels in an image contains a mixture of surface cover classes, for example, grass and underlying soil (Tucker and Miller, 1977). As the mixture proportions change from pixel to pixel, the spectral vector changes. Thus an overlap is created between the individual signature of the mixed classes. This mixing is particularly troublesome in same applications (Robert, 1983).

The qualitative approach is one such method through which the overall classification accuracy can be assessed. This is done by ratioing the number of points found correctly on the classified image to that of total number of points checked in the field multiplied by 100. This gives the total accuracy of the classified output in percentage.

The quantitative approach is one that estimates the amount of mixing among different training sets defined in the ground truth and the classes in the classified output by generating " confusion matrix" to check errors of omission and commission and finally the overall classification accuracy. While the interpretation of single image by manual methods is largely based on spatial patterns, digital image processing methods are based exclusively on spectral signatures recorded by the multispectral sensors. More over the spectral signature of vegetation are not constant but are changing with the phenological conditions as well as locality features.

5.1.2.5 Drainage, Slope and Contour map

The information on drainage networking system gathered from Survey of India toposheets on 1:50,000 scale, was updated by using geocoded satellite imagery pertaining to post-monsoon period. Major rivers in the study area are Anamudi Ar in the southern side of the Park, Eravikulam Ar in the eastern side, Bhimamala Ar in the western side and Puvar Nadi and Kumarikkal Nadi in the north. The isolated sholas act like sponges giving out water throughout the year.

The wetlands and marshes which fall within the valley act as potential sources of water for many streams. The interspersed sholas also act as the perennial source of water for many streams. They are well spread throughout the National Park which inturn facilitates the origin of many cascading streams. Effective protection of shola and marshes also facilitates proper watershed management. Drainage network helps in delineation of watersheds and for suggesting various water harvesting structures and soil conservation measures. The concept of watershed as a planning unit for development of land and resource has gained importance since 1974 when the Ministry of agriculture, Govt. of India initiated various developmental programmes like, Drought Prone Area Programme (DPAP), Desert Development Programme (DDP), Hill Area Development Programme (HADP) *etc.*

Slope, aspect and altitude are important parameters from land resource point of view, of these, slope is very vital one for land irrigabality and land capability assessment. Five categories of slopes were identified in the study area (Fig 11). Maximum area covered is under the 15^0 to 20^0 slope category, followed by 20^0 to 25^0 indicating an undulating terrain of rolling grasslands. The slope range class between 15^0 to 25^0 sustains the large area in the unique ecosystem of shola - grasslands in Eravikulam National Park.

The contour map prepared gives an idea regarding the altitudinal ranges of the area which varies from 1300 to 2695m Average base elevation of the National Park is around 2000m. and the highest peak (2695m) Anamudi is situated in the southern side of the plateau.

5.1.2.6. Area Estimation

The total area of Eravikulam National park, estimated in the present study is 112 km^2. As per management plan of National Park and other available literature the total area of the park was only 97 km^2. The boundary of National Park is not demarcated properly. The boundary is clearly defined only where it is coinciding with inter-state boundary. In some areas distinction between National Park, reserved forest, tea estates etc. is vague. The park boundary is not clear along the eastern side with Chattamunnar estate, Perumal mala and Pettimudi estate.

Here demarcated the original Park boundary by using survey of India toposheets, aerial photographs and government notification and later estimated the total area using digital planimeter.

The information of aerial photographs were transferred in to the Park boundary and it is found that in certain areas encroachment of plantations such as tea and wattle have taken place.

5.2. Vegetation Analysis

5.2.1. Results

The following five vegetation types (Champion and Seth, 1968) are recognized from the area and structural aspects of three major types, *viz*. Shola forests, Subtropical hill forests and Grasslands were worked out using phytosociological methods.

1. Shola forest (Southern montane wet temperate forest)
2. Grassland (Southern montane wet temperate grassland)
3. transition forest (Southern subtropical hill forest)
4. Evergreen forest (Southern west coast evergreen forest)
5. Scrub

5.2.1.1. Shola Forest

Three types of montane temperate forests are recognised by Champion and Seth (1968).

1. Montane wet temperate forests
2. Himalayan moist temperate
3. Himalayan dry temperate

The montane wet temperate forests occur both in northern and southern forms and are without conifers, unlike the Himalayan moist temperate types. The wet types are mostly confined to the south Indian hills and in the eastern Himalayas, respectively called the southern wet and northern wet types.

Shola forests of south India is classified as southern montane wet temperate forests (Champion and Seth, 1968). In the montane region of most tropical mountains, sometimes at a less, sometimes at a greater altitude above sea level, the tropical rain forest is replaced by temperate rainforest. The trees in it are evergreen and they never have plank buttresses. They have smaller or thicker leaves than trees in tropical rain forest. These are the residual forests confined to the sheltered sites such as valleys, glens, hollows and depressions where moisture availability is more. They occupy a limited area generally occurring as gallery forests along water courses. These are essentially edaphic formations on rich soils and are relatively humid throughout the year.

5.2.1.1.1. Floristics

There is no marked differentiation of upper storey and lower storey of the vegetation.*Syzygium arnottianum, Cinnamomum wightii* and *Elaeocarpus oblongus* are the common species available. The other species are *Schefflera racemosa, Linocera ramiflora, Litsea wightiana* etc. The lower storey contains small twisted trees of 7-10m hight. Common species are *Ternstroemia japonica, Symplocos spp, Microtropis ramiflora etc.* The shrubby layer is very dense when it is undisturbed. Common species are *Phlebophyllum kunthianus, Psychotria anamalayana and Lasianthus venulosus.* The dominant species according to their IVI values are given in Table. 6. The most dominant species of shola forests are *Syzigium arnottianum, Mahonia leschenaultii, Maesa indica* and *Cinnomomum wightii.* Maximum number of species (10) is represented by Lauraceae followed by Rubiaceae (4), Myrtaceae(3) and Celastraceae(3).

A total of 888 trees of above 15 cm. GBH belonging to 50 species were enumerated from the 7,000 m^2 sampling area. This is equivalent to the density of 1268 individuals/ha.. Highest percentage of density (6.86) was recorded by *Maesa indica* followed by *Microtropis ramiflora* (6.62), Average basal area of shola forests of Eravikulam National Park is 25 sq. m./ha, of which 20.74 % is constituted by *Syzygium arnottianum.* Dominant species which recorded maximum IVI are *Syzygium arnottianum, Mahonia leschenaultii* and *Maesa indica, Cinnamomum wightii* (Table 6). Phytosociological data of each locality are given (Tables 7-13).

Table 6. Mean values of abundance density basal area frequency and IVI of Shola forest in different localities of Eravikulam National Park

No.	Name of species	AB	D	BA	PF	IVI
1	*Syzygium arnottianuum*	1.28	0.81	677.89	54.28	30.24
2	*Mahonia leschnaultii*	1.60	0.52	159.35	42.85	16.02
3	*Measa indica*	2.02	0.87	84.64	47.14	15.03
4	*Cinnamomum wightii*	1.23	0.54	249.17	35.71	14.90
5	*Microtropis ramiflora*	1.24	0.84	147.97	35.71	14.05
6	*Garcinia combogia*	1.20	0.52	153.13	25.71	11.35
7	*Litsea wightiana*	1.21	0.47	95.16	28.57	10.30
8	*Ilex wightiana*	0.14	0.01	7.10	1.42	9.95
9	*Actinodaphne bourdilloni*	1.14	0.470	97.83	30.00	9.93
10	*Elaeocarpus recurvatus*	0.90	0.25	193.11	20.00	9.45
11	*Ternatroemia japonica*	0.65	0.50	117.92	21.42	9.37
12	*Euonymus angulatus*	1.42	0.35	141.97	18.57	9.28
13	*Litsea ligustrina*	1.02	0.31	141.90	22.85	9.22
14	*Ligustrum perrottettii*	1.08	0.38	105.68	21.42	8.69
15	*Ilex denticulata*	0.95	0.24	152.82	17.14	8.65
16	*Symplocos spicata*	1.19	0.37	99.16	20.00	8.23
17	*Eurya nitida*	1.39	0.32	101.76	17.84	7.65
18	*Rhododendron arboreum*	1.33	0.15	254.61	10.00	7.63
19	*Turpinia nepalensis*	1.09	0.20	156.58	14.28	7.31
20	*Ixora notoniana*	1.48	0.70	69.04	25.71	7.08
21	*Daphniphyllum glaucescens*	1.19	0.37	76.46	17.14	7.01
22	*Schefflera recemosa*	1.52	0.34	82.39	17.14	6.89
23	*Ardisia rhomboidea*	0.70	0.280	37.85	21.42	6.39
24	*Symplocos pendula*	0.75	0.24	123.93	12.80	6.26

No.	Name of species	AB	D	BA	PF	IVI
25	*Lasianthus venulosus*	1.57	0.25	95.30	12.85	6.15
26	*Psychotria anamallayana*	0.77	0.28	27.84	24.28	6.11
27	*Microtropis microcarpa*	0.57	0.04	19.93	17.14	4.85
28	*Eugenia spp.*	0.57	0.10	96.84	7.14	3.76
29	*Lasiosiphon eriocephalus*	0.44	0.15	35.74	10.00	3.68
30	*Linocera macrophylla*	0.60	0.14	32.18	11.42	3.24
31	*Litsea glabrata*	0.46	0.15	24.95	10.00	3.07
32	*Pithecellobium subcoriacium*	0.45	0.27	13.92	8.57	2.86
33	*Vaccinium leschnaultii*	0.57	0.14	16.76	11.42	2.86
34	*Cinnamomum perrottetii*	0.40	0.10	29.10	7.14	2.74
35	*Meliosma wightii*	0.42	0.05	61.12	5.71	2.46
36	*Dodonaea viscosa*	0.61	0.15	9.06	5.71	2.35
37	*Neolitsea foliosa*	0.17	0.08	24.04	7.14	2.20
38	*Pittosporum neighrrense*	0.85	0.08	36.36	2.85	2.00
39	*Tarenna monosperma*	0.50	0.08	11.64	4.28	1.66
40	*Persia macrantha*	0.14	0.04	2.91	4.28	1.05
41	*Rhodomyrtus tomentosa*	0.19	0.05	3.68	4.28	1.02
42	*Allophyllus rhomboidea*	0.23	0.07	4.10	4.28	0.99
43	*Gaultheria fragrantissima*	0.28	0.05	2.55	2.85	0.95
44	*Derris brevipes*	0.28	0.02	18.57	2.85	0.93
45	*Debregeasia longifolia*	0.42	0.04	49.72	2.85	0.88
46	*Alseodaphne semicarpifolia*	0.14	0.01	18.18	1.42	0.80
47	*Flaucourtia montana*	0.14	0.02	10.22	2.85	0.79
48	*Gomphandra coriacea*	0.21	0.04	2.55	2.85	0.63
49	*Glochidion neilgherrense*	0.14	0.01	7.11	1.42	0.45
50	*Cryptocarya neilgherrenis*	0.14	0.01	4.54	1.42	0.37

Table 7. Phytosociological data of Shola forest

locality:Naikollymala Altitude: 2150 msl

NO.	Species	D	AB	PF	BA	RD	RF	RBA	IVI	AB/F
1	*Syzygium arnottianum*	0.80	1.33	60.00	534.92	7.48	9.09	17.04	33.61	0.02
2.	*Elaeocarpus recurvatus*	0.60	1.20	50.00	296.02	5.61	7.58	9.43	22.62	0.024
3	*Mahonia leschenaultii*	1.10	1.57	70.00	38.50	10.28	10.61	1.23	22.12	0.02
4	*Eurya nitida*	1.20	2.40	50.00	66.91	11.21	7.58	2.13	20.92	0.05
5	*Cinnamomum wightii*	0.90	1.50	60.00	103.10	8.41	9.09	3.28	20.78	0.03
6	*Garcinia cambogia*	0.60	2.00	30.00	286.40	5.61	4.55	9.12	19.28	0.07
7	*Euonymus angulatus*	0.40	1.33	30.00	336.12	3.74	4.55	10.71	19.00	0.04
8	*Symplocos pendula*	1.10	2.75	40.00	81.46	10.28	6.06	2.59	18.93	0.07
9	*Litsea ligustrina*	0.50	1.25	40.00	140.33	4.67	6.06	4.47	15.20	0.03
10	*Lasiosiphon eriocephalus*	0.40	1.33	30.00	215.12	3.74	4.55	6.85	15.14	0.04
11	*Litsea wightiana*	0.60	2.00	30.00	127.29	5.61	4.55	4.05	14.21	0.07
12	*Rhododendron arboreum*	0.40	1.33	30.00	133.73	3.74	4.55	4.26	12.55	0.04
13	*Measa indica*	0.50	1.25	40.00	31.82	4.67	6.06	1.01	11.74	0.03
14	*Pittosporum nilgherense*	0.30	3.00	10.00	127.29	2.80	1.52	4.05	8.37	0.30
15	*Ixora notoniana*	0.20	1.00	20.00	71.60	1.87	3.03	2.28	7.18	0.05
16	*Turpinia nepalensis*	0.10	1.00	10.00	127.29	0.93	1.52	4.05	6.50	0.10
17	*Shefflera racemosa*	0.10	1.00	10.00	127.29	0.93	1.52	4.05	6.50	0.10
18	*Tarenna monosperma*	0.30	3.00	10.00	49.72	2.80	1.52	1.58	5.90	0.30
19	*Actinodaphne bodurdillonii*	0.10	1.00	10.00	97.45	0.93	1.52	3.10	5.55	0.10
20	*Lasianthus venulosus*	0.20	2.00	10.00	49.72	1.87	1.52	1.58	4.97	0.20
21	*Psychotria anamallyana*	0.20	2.00	10.00	35.08	1.87	1.52	1.12	4.51	0.20
22	*Derris brevipes*	0.10	1.00	10.00	62.37	0.93	1.52	1.99	4.44	0.10

Total No. Of species 107
Total No. Of Qtd.occ 66
Total basal area : 3139.53
Basal area of the stand :22.5 m^2/ha

MI : 30
Diversity index : 2.85
Concentration of dominance :0.07

Table 8. Phytosociological data of Shola forest

Locality:Anamudi — Altitude : 2350 msl

NO.	Species	D	AB	PF	BA	RD	RF	RBA	IVI	AB/F
1	*Microtropis ramiflora*	1.20	2.00	60.00	389.82	10.43	8.70	6.79	25.92	0.03
2.	*Rhododendron arboreum*	0.30	3.00	10.00	1089.0	2.61	1.45	18.97	23.03	0.30
3	*Cinnamomum wightii*	0.60	1.50	40.00	630.15	5.22	5.80	10.98	22.00	0.04
4	*Maesa indica*	1.30	2.60	50.00	57.45	11.30	7.25	1.70	20.25	0.05
5	*Ligustrum perrottettii*	1.20	3.00	40.00	206.92	10.43	5.80	3.61	19.84	0.07
6	*Elaeocarpus recurvatus*	0.30	1.50	20.00	717.98	2.61	2.90	12.51	18.02	0.07
7	*Turpinia nepalensis*	0.30	1.00	30.00	548.05	2.61	4.35	9.55	16.51	0.03
8	*Neolitsea foliosa*	0.60	1.20	50.00	168.34	5.22	7.25	2.93	15.40	0.02
9	*Litsea wightiana*	0.60	1.20	50.00	86.63	5.22	7.25	1.51	13.98	0.02
10	*Ardisia romboidea*	0.70	1.40	50.00	28.72	6.09	7.25	0.50	13.84	0.03
11	*Litsea ligustrina*	0.60	1.20	50.00	58.00	5.22	7.25	1.01	13.48	0.02
12	*Mahonia leschenaulti*	0.60	1.50	40.00	62.37	5.22	5.80	1.09	12.11	0.04
13	*Syzygium arnottianum*	0.20	1.00	20.00	357.12	1.74	2.90	6.22	10.86	0.05
14	*Euginia spp*	0.10	1.00	10.00	447.49	0.87	1.45	7.80	10.12	0.10
15	*Lasianthus venulosus*	0.50	2.50	20.00	154.02	4.35	2.90	2.68	9.93	0.13
16	*Symplocos pendula*	0.30	1.50	20.00	127.29	2.61	2.90	2.22	7.73	0.07
17	*Euonymus angulatus*	0.20	1.00	20.00	154.02	1.74	2.90	2.68	7.32	0.05
18	*Gaultheria fragrantissima*	0.40	2.00	20.00	17.90	3.48	2.90	0.31	06.69	0.10
19	*Ilex denticulata*	0.30	3.00	10.00	147.10	2.61	1.45	2.56	6.62	0.30
20	*Simplocos spicata*	0.80	2.00	40.00	71.60	6.96	5.80	1.25	4.01	0.05
21	*Meliosma wightiana*	0.10	1.00	10.00	62.37	0.87	1.45	1.09	3.41	0.10
22	*Actinodaphne bourdillonii*	0.10	1.00	10.00	49.72	0.87	1.45	0.87	3.19	0.10
23	*Glochidion nilghirence*	0.10	1.00	10.00	49.72	0.87	1.45	0.87	3.19	0.10
24	*Derris brevipes*	0.10	1.00	10.00	17.90	0.87	1.45	0.31	2.63	0.10

Total No. Of species : 115
Total No. Of Qtd.occ : 69
Total basal area : 5739.68
Basal area of the stand :25.32 m^2/ha

MI : 28.75
Diversity index : 2.92
Concentration of dominance :0.06

Table 9. Phytosociological data of Shola forest

Locality Umayamala | Altitude: 2100 msl

NO.	Species	D	AB	PF	BA	RD	RF	RBA	IVI	AB/F
1	*Microtropis ramiflora*	2.00	2.22	90.00	389.82	19.61	12.33	6.68	38.62	0.02
2.	*Cinnamomum wightii*	1.10	1.57	70.00	471.68	10.78	9.59	8.08	28.45	0.02
3	*Syzygium arnottianum*	0.20	1.00	20.00	1243.0	1.96	2.74	21.30	26.00	0.05
4	*Ilex denticulata*	0.60	1.20	50.00	357.12	5.88	6.85	6.12	18.85	0.02
5	*Symplocos pendula*	0.30	1.00	30.00	658.79	2.94	4.11	11.29	18.34	0.03
6	*Litsea wightiana*	0.90	1.80	50.00	91.96	8.82	6.85	1.58	17.25	0.04
7	*Ligustrum perrottetii*	0.50	1.25	40.00	240.65	4.90	5.48	4.12	14.50	0.03
8	*Litsea ligustrina*	0.20	1.00	20.00	548.05	1.96	2.74	9.39	14.09	0.05
9	*Mahonia leschenaultii*	0.60	1.20	50.00	42.08	5.88	6.85	0.72	13.45	0.02
10	*Psychotria anamallayana*	0.50	1.00	50.00	49.72	4.90	6.85	0.85	12.60	0.02
11	*Turpinia nepalensis*	0.50	1.67	30.00	127.29	4.90	4.11	2.18	11.19	0.06
12	*Meliosma wightii*	0.20	1.00	20.00	315.75	1.96	2.74	5.41	10.11	0.05
13	*Elaeocarpus recurvatus*	0.40	1.33	30.00	121.00	3.92	4.11	2.07	10.10	0.04
14	*Rododendron arboreum*	0.10	1.00	10.00	447.49	0.98	1.37	7.67	10.02	0.10
15	*Lasianthus venulosus*	0.50	2.50	20.00	97.45	4.90	2.74	1.67	9.31	0.13
16	*Euria nitida*	0.20	1.00	20.00	183.29	1.96	2.74	3.14	7.84	0.05
17	*Persia macrantha*	0.30	1.00	30.00	20.37	2.94	4.11	0.35	7.40	0.03
18	*Ardisia rhomboidea*	0.30	1.50	20.00	62.37	2.94	2.74	0.07	6.75	0.07
19	*Euginia spp.*	0.20	1.00	20.00	103.10	1.96	2.74	1.77	6.47	0.05
20	*Linociera macrophylla*	0.20	1.00	20.00	81.46	1.96	2.74	1.40	6.10	0.05
21	*Symplocos spicata*	0.10	1.00	10.00	127.29	0.98	1.37	2.18	4.53	0.10
22	*Euonymus angulatus*	0.10	1.00	10.00	20.37	0.98	1.37	0.35	2.70	0.10
23	*Maesa indica*	0.10	1.00	10.00	17.9	0.98	1.37	0.31	2.66	0.10
24	*Schefflera racemosa*	0.10	1.00	10.00	17.90	0.98	1.37	0.31	2.66	0.10

Total No. Of species : 102
Total No. Of Qtd.occ : 73
Total basal area : 5835.90
Basal area of the stand : 27.07 m^2/ha

MI : 30.42
Diversity index : 2.83
Concentration of dominance :0.08

Table 10. Phytosociological data of Shola forests

Locality Turners valley Altitude:2,000

NO.	Species	D	AB	PF	BA	RD	RF	RBA	IVI	AB/F
1	*Syzygium arnottianuam*	1.10	1.57	70.00	748.53	8.33	10.61	21.71	40.65	0.02
2.	*Ternstroemia japonica*	1.20	2.00	60.00	389.82	9.09	9.09	11.31	29.49	0.03
3	*Mahonia leschhaultii*	0.40	1.33	30.00	509.15	3.03	4.55	14.77	22.35	0.04
4	*Garcinia combogia*	1.00	2.50	40.00	286.4	7.58	6.06	8.31	21.95	0.06
5	*Ixora notoniana*	1.30	2.60	50.00	127.29	9.85	7.58	3.69	21.12	0.05
6	*Euonia angulatus*	1.40	4.67	30.00	161.10	10.61	4.55	4.67	19.83	0.16
7	*Psychotria anamallayana*	0.70	1.40	50.00	71.60	5.30	7.58	2.08	14.96	0.03
8	*Dodonia viscosa*	1.00	3.33	30.00	49.72	7.58	4.55	1.44	13.57	0.11
9	*Lasiosiphon eriocephalus*	0.70	1.75	40.00	35.08	5.30	6.06	1.02	12.38	0.04
10	*Actinodaphne bourdillonii*	0.50	1.25	40.00	71.60	3.79	6.06	2.08	11.93	0.03
11	*Litsea glabrata*	0.60	2.00	30.00	71.60	4.55	4.55	2.08	11.18	0.07
12	*Cinnamomum perrottettii*	0.30	1.50	20.00	154.02	2.27	3.03	4.47	9.77	7.07
13	*Euginia spp.*	0.40	2.00	20.00	127.29	3.03	3.03	3.69	9.75	0.10
14	*Microtropis microcarpa*	0.30	1.50	20.00	97.45	2.27	3.03	2.83	8.13	0.07
15	*Lasianthus venulosus*	0.20	2.00	10.00	127.29	1.52	1.52	3.69	6.73	0.20
16	*Daphniphyllum glaucescens*	0.20	2.00	10.00	127.29	1.52	1.52	3.69	6.73	0.20
17	*Tarenna monosperma*	0.30	1.50	20.00	31.82	2.27	3.03	0.62	6.22	0.07
18	*Microtropis ramiflora*	0.30	1.50	20.00	25.78	2.27	3.03	0.75	6.05	0.07
19	*Maesa indica*	0.40	4.00	10.00	31.82	3.03	1.52	0.92	5.47	0.40
20	*Schefflera racemosa*	0.20	2.00	10.00	49.72	1.52	1.52	1.44	4.48	0.20
21	*Rhododendron arboreum*	0.20	2.00	10.00	49.72	1.52	1.52	1.44	4.48	0.20
22	*Meliosma wightii*	0.10	1.00	10.00	49.72	0.76	1.52	1.44	3.72	0.10
23	*Debregeasia longifolia*	0.20	2.00	10.00	17.90	1.52	1.52	0.52	3.56	0.20
24	*Elaeocarpus recurvatus*	0.10	1.00	10.00	17.90	0.76	1.52	0.52	2.80	0.10
25	*Ardisia romboidea*	0.10	1.00	10.00	17.90	0.76	1.52	0.52	2.80	0.10

Total No. Of species : 132
Total No. Of Qtd.occ : 66
Total basal area : 3447.51
Basal area of the stand : 26.14m^2/ha

MI : 26.40
Diversity index : 2.95
Concentration of dominance :0.06

Table 11. Phytosociological data of Shola forest

Locality Eravikulam — Altitude: 2100 msl

NO.	Species	D	AB	PF	BA	RD	RF	RBA	IVI	AB/F
1	*Syzygium arnottianum*	0.80	1.60	50.00	717.98	5.76	6.10	18.28	30.14	0.03
2.	*Maesa indica*	1.30	2.17	60.00	286.40	9.35	7.32	7.29	23.96	0.04
3	*Garcinia combogia*	1.20	1.71	70.00	258.47	8.63	8.54	6.58	23.75	0.02
4	*Cinnamomum wightii*	1.10	1.57	70.00	240.65	7.91	8.54	6.13	22.58	0.02
5	*Microtropis ramiflora*	1.20	2.00	60.00	103.10	8.63	7.32	2.62	18.57	0.03
6	*Ixora notoniana*	1.30	2.60	50.00	97.45	9.35	6.10	2.48	17.93	0.05
7	*Sympocos spicata*	0.80	2.00	40.00	198.89	5.76	4.88	5.06	15.70	0.05
8	*Daphniphyllum glaucescens*	1.00	2.50	40.00	127.29	7.19	4.88	3.24	15.31	0.06
9	*Mahonia leschenaultii*	0.70	1.40	50.00	127.29	5.04	6.10	3.24	14.38	0.03
10	*Ilex denticulata*	0.20	1.00	20.00	389.82	1.44	2.44	9.92	13.80	0.05
11	*Litsea wightiana*	0.60	2.00	30.00	183.29	4.32	3.66	4.67	12.65	0.07
12	*Linociera macrophylla*	0.60	1.20	50.00	81.46	4.32	6.10	2.07	12.49	0.02
13	*Euria nitida*	0.40	1.33	30.00	198.89	2.88	3.66	5.06	11.60	0.04
14	*Actinodaphne bourdillonii*	0.20	1.00	20.00	286.40	1.44	2.44	7.29	11.17	0.05
15	*Schefflera racemosa*	0.50	1.67	30.00	127.29	3.60	3.66	3.24	10.50	0.06
16	*Ardisia rhomboidea*	0.60	1.50	40.00	28.72	4.32	4.88	0.73	9.93	0.04
17	*Vaccinium leschenaultii*	0.40	1.00	40.00	49.72	2.88	4.88	1.27	9.03	0.03
18	*Ligustrum perrottetii*	0.20	2.00	10.00	183.29	1.44	1.22	4.67	7.33	0.20
19	*Rhodomyrtus tomentosa*	0.40	1.33	30.00	25.78	2.88	3.66	0.66	7.20	0.04
20	*Euonymus angulatus*	0.10	1.00	10.00	161.10	0.72	1.22	4.10	6.04	0.10
21	*Litsea ligustrina*	0.20	2.00	10.00	31.82	1.44	1.22	0.81	3.47	0.20
22	*Turpinia nepalensis*	0.10	1.00	10.00	22.99	0.72	1.22	0.59	2.53	0.10

Total No. Of species 139
Total No. Of Qtd.occ 82
Total basal area 3928.09
Basal area of the stand 27 m^2/ha

MI : 37.27
Diversity index : 2.88
Concentration of dominance :0.06

Table 12. Phytosociological data of Shola forests

Locality: Rajamala Altitude : 2000 msl

NO.	Species	D	AB	PF	BA	RD	RF	RBA	IVI	AB/F
1	*Ternstroemia japonica*	2.30	2.56	90.00	435.64	12.64	9.89	20.08	38.21	0.02
2.	*Syzygium arnottianum*	1.50	1.67	90.00	644.39	8.24	9.89	13.58	36.11	0.03
3	*Microtropis microcarpa*	2.50	2.50	100.00	42.08	13.74	10.99	1.31	26.04	0.03
4	*Pithecellobium subcoriaceum*	1.90	3.17	60.00	97.45	10.44	6.59	3.04	20.07	0.05
5	*Garcinia combogia*	0.90	2.25	40.00	240.65	4.95	4.40	7.50	16.85	0.06
6	*Actinodaphne bourdillonii*	1.30	2.17	60.00	58.00	7.14	6.59	1.81	15.54	0.04
7	*Maesa indica*	1.20	1.71	70.00	22.99	6.59	7.69	0.72	15.00	0.02
8	*Schefflera racemosa*	1.20	3.00	40.00	127.29	6.59	4.40	3.97	14.96	0.07
9	*Daphniphyllum glaucescens*	1.00	2.50	40.00	140.33	5.49	4.40	4.37	14.26	0.06
10	*Mahonia leschnaultii*	0.40	2.00	20.00	286.40	2.20	2.20	8.92	13.32	0.10
11	*Psychotria anamallayana*	0.60	1.00	60.00	38.50	3.30	6.59	1.20	11.09	0.02
12	*Litsea glabrata*	0.50	1.25	40.00	103.10	2.75	4.40	3.21	10.36	0.03
13	*Symplocos spicata*	0.20	1.00	20.00	198.89	1.10	2.20	6.20	9.50	0.05
14	*Lasianthus venulosus*	0.30	1.00	30.00	127.29	1.65	3.30	3.97	8.92	0.03
15	*Allophyllus rhomboidea*	0.50	1.67	30.00	28.72	2.75	3.30	0.89	6.94	0.06
16	*Pittosporum nilgherence*	0.30	3.00	10.00	127.29	1.65	1.10	3.97	6.72	0.30
17	*Vaccinium leschnaultii*	0.40	2.00	20.00	49.72	2.20	2.20	1.55	5.95	0.10
18	*Alseodaphne semicarpifolia*	0.10	1.00	10.00	127.29	0.55	1.10	3.97	5.62	0.10
19	*Flacourtia montana*	0.20	1.00	20.00	71.6	1.10	2.20	2.23	5.53	0.05
20	*Euria nitida*	0.20	2.00	10.00	97.45	1.10	1.10	3.04	5.24	0.20
21	*Gomphandra coriaceae*	0.30	1.50	20.00	17.90	1.65	2.20	0.56	4.41	0.07
22	*Linocera macrophylla*	0.20	2.00	10.00	62.37	1.10	1.10	1.94	4.14	0.20
23	*Debregeasia longifolia*	0.10	1.00	10.00	31.82	0.55	1.10	0.99	2.64	0.10
24	*Cryptocarya neilgherensis*	0.10	1.00	10.00	31.82	0.55	1.10	0.99	2.64	0.10

Total No. Of species : 182
Total No. Of Qtd.occ : 91
Total basal area : 3208.98
Basal area of the stand :32.75 m^2/ha

MI : 37.92
Diversity index : 2.79
Concentration of dominance :0.08

Table 13. Phytosociolgical data of Shola forest

Locality: Puvar Altitude: 2150 msl

NO.	Species	D	AB	PF	BA	RD	RF	RBA	IVI	AB/F
1	*Syzygium arnottianum*	1.10	1.57	70.00	389.92	9.91	9.21	14.64	33.76	0.02
2.	*Maesa indica*	1.30	1.44	90.00	38.50	11.71	11.84	1.45	25.00	0.02
3	*Actinodaphne bourdillonii*	1.10	1.57	70.00	58.00	9.91	9.21	2.18	21.30	0.02
4	*Litsea ligustrina*	0.70	1.75	40.00	215.12	6.31	5.26	8.08	19.65	0.04
5	*Ligustrum perrottettii*	0.80	1.33	60.00	108.91	7.21	7.89	4.09	19.19	0.02
6	*Ilex dendiculata*	0.60	1.50	40.00	175.74	5.41	5.26	6.60	17.27	0.04
7	*Mahonia leschenaultii*	0.90	2.25	40.00	49.72	8.11	5.26	1.87	15.24	0.06
8	*Elaeocarpus recurvatus*	0.40	1.33	30.00	198.89	3.60	3.95	7.47	15.02	0.04
9	*Symplocos spicata*	0.70	2.33	30.00	97.45	6.31	3.95	3.66	13.92	0.08
10	*Daphniphyllum glaucescens*	0.40	1.33	30.00	140.33	3.60	3.95	5.27	12.82	0.04
11	*Euonymus angulatus*	0.30	1.00	30.00	161.10	2.70	3.95	6.05	12.70	0.03
12	*Turpinia nepalensis*	0.20	1.00	20.00	198.89	1.80	2.63	7.47	11.90	0.05
13	*Ardisia rhomboidea*	0.30	1.00	30.00	127.29	2.70	3.95	4.78	11.43	0.03
14	*Litsea wightiana*	0.60	4.50	40.00	17.90	5.41	5.26	0.67	11.34	0.04
15	*Cinnamomum perrottettii*	0.40	1.33	30.00	49.72	3.60	3.95	1.87	9.42	0.04
16	*Microtropis ramiflora*	0.20	1.00	20.00	127.29	1.80	2.63	4.78	9.21	0.05
17	*Schefflera racemosa*	0.20	1.00	20.00	127.29	1.80	2.63	4.78	9.21	0.05
18	*Cinnamomum wightii*	0.10	1.00	10.00	161.10	0.90	1.32	6.05	8.27	0.10
19	*Euria nitida*	0.30	3.00	10.00	71.60	2.70	1.32	2.69	6.71	0.30
20	*Vaccinium leschenaultii*	0.20	1.00	20.00	17.90	1.80	2.63	0.67	5.10	0.05
21	*Rhododendron arboreum*	0.10	1.00	10.00	62.37	0.90	1.32	2.34	4.56	0.10
22	*Ilex wightiana*	0.10	1.00	10.00	49.72	0.90	1.32	1.87	4.09	0.10
23	*Dodonia viscosa*	0.10	1.00	10.00	17.90	0.90	1.32	0.67	2.89	0.10

Total No. of species 111
Total No. of Qtd.occ 76
Total basal area : 2662.55
Basal area of the stand :14.17 m^2/ha

MI : 33.04
Diversity index : 2.88
Concentration of dominance :0.07

5.2.1.1.2.Density

With respect to the density data, the species which recorded mean density greater than 0.5 are *Maesa indica* (0.87), *Microtropis ramiflora* (0.81), *Cinnamomum wightii* (0.54), *Garcinia cambogia* (0.52), *Mahonia leschenaultii* (0.52), and *Ternstroemia japonica* (0.5) (Table 6).

5.2.1.1.3. Abundance

Among 50 species encountered in the study area 19 species recorded mean abundance value greater than one. These are *Maesa indica* (2.02), *Mahonia leschenaultii*(1.6), *Lasianthus venulosus* (1.57), *Schefflera racemosa* (1.52), *Euonymus angulatus* (1.42), *Eurya nitida*(1.39), *Rhododendron arboreum* (1.33), *Syzygium arnottianum* (1.28), *Microtropis ramiflora* (1.24), *Cinnamomum wightii* (1.23), *Litsea wightiana* (1.21), *Garcinia combogia* (1.2), *Symplocos spicata* (1.19), *Daphniphyllum glaucescens* (1.19), *Actinodaphne bourdillonii* (1.14), *Turpinia nepalensis* (1.09), *Ligustrum perrottettii* (1.08) *Litsea ligustrina* (1.02) and *Ixora notoniana* (1.02). Eight species which recorded mean abundance value of less than 0.2 are *Fla courtia montana* (0.14), *Persia macrantha* (0.14), *Glochi dion neilgherrense* (0.14), *Ilex wightiana* (0.14), *Cryptocarya neilgherensis* (0.14), *Alseodaphne semicarpifolia* (0.14), *Neolitsea foliosa* (0.17) and *Rhodomyrtus tomentosa* (0.19).

5.2.1.1.4. Frequency

With respect to the mean percentage frequency, (Table 6) only one species *viz. Syzygium arnottianum* recorded percentage frequency greater than 50 (54.28) followed by *Maesa indica* (47.14) *Mahonia leschenaultii* (42.85), *Microtropis ramiflora* (35.71), *Cinnamomum wightii* (35.71) and *Actinodaphne bourdillonii* (30). The lowest percentage frequency value (1.42) are recorded by four species such as, *Glochidion neilgherense, Ilex wightiana, Cryptocarya neilgherensis and Alseodaphne semicarpifolia.*

5.2.1.1.5. Basal area

Mean basal area varies with 2.55 to 677.89 among the 50 species encountered (Table 14). *Syzygium arnottianum* is represented by maximum basal area (677.89) followed by *Rhododendron arboreum* (254.61), *Cinnamomum wightii* (249.17), *Elaeocarpus recurvatus* (193.11), *Mahonia* *leschenaultii* (159.35), *Turpinia nepalensis* (156.58), *Garcinia combogia* (153.13), *Ilex dendiculata* (152.82), *Microtropis ramiflora* (149.97), *Euonymus angulatus* (141.97), *Litsea ligustrina* (141.9), *Symplocos pendula* (123.93), *Ternstroemia japonica* (117.92), *Ligustrum perrottetti* (105.68), *Eurya nitida* (101.76). Fifteen species record basal area of more than 100 , and 25 species record basal area more than 50. The lowest basal area (2.55) is represented by *Gaultheria fragrantissima* and *Gomphandra coriacia*, followed by *Persia macrantha* (2.91), *Rhodomyrtus tomentosa* (3.68), *Allophyllus rhomboidea* (4.1), *Cryptocarya neilgherense* (4.54), *Ilex wightiana* (7.1), *Glochiodion neilgherense* (7.11) and *Dodonea viscosa* (9.66). Basal area of individual localities are given in Table 14.

Table 14. Basal area of Shola forests in different localities.

Locality	Basal area
Naikollimala	22.5
Anamudi	25.32
Umayamala	27.07
Turner's Valley	26.14
Eravikulam	27.00
Rajamala	32.75
Puvar	14.17

5.2.1.1.6.Important value index

Wide range of variation is seen among species when we consider their mean IVI. It ranges from 0.37 to 30.24 (Table 6). Only 7 species recorded mean IVI more than 10. These are *Syzygium arnottianum* (30.24), *Mahonia leschnaultii* (16.02), *Maesa indica* (15.03), *Cinnamomum wightii* (14.9), *Microtropis ramiflora* (14.05), *Garcinia cambogia* (11.35), and *Litsea wightiana* (10.3). The most dominant species of shola forests of Eravikulam National Park is *Syzygiun arnottianum*.*Cryptocarya neilgherrense* records the lowest mean IVI value (0.37) followed by *Glochidion neilgherrense* (0.45), *Gomphandra coriacea* (0.63), *Flacourtia montana* (0.79), *Alseodaphne semicarpifolia* (0.8), *Debregeasia longifolia* (0.88), *Derris brevipes* (0.93), *Gaultheria fragrantissima* (0.95) and *Allophyllus rhomboidea* (0.99). While analysing the IVI value of each locality dominant species varies with locality. IVI of different localities are given in Tables 7-13 .

5.2.1.1.7. Family importance value

The highest FIV of shola forest is 53.84 represented by Lauraceae followed by Myrtaceae(37.32) and Symplocaceae (26.96). The details of the number of species, total IVI, relative density, relative diversity, relative dominance and family importance values are given in Table15.

5.2.1.1.8. Constancy

Based on the constancy value it is observed that same species are having different constancy values in different localities. (Table 16). *Mahonia leschenaultii* records the highest constancy value of four in Naikollumala. In Anamudi no species records constancy value more than three. *Microtropis ramiflora* is constantly present in the locality Umayamala along with *Cinnamomum wightii* with a constancy value four. In the Turnurs Valley *Syzygium arnottianum* is the most constant species with a value four. Similarly in Eravikulam highest constancy value recorded is four by *Gaultheria fragrantissima* and *Cinnamomum wightii*. *Syzygium arnottianum*, *Ternstroemia japonica* and *Microtropis microcarpa* are constantly present in Rajamala. *Maesa indica* records the highest value in Puvar.

Table 15. Family Important Values (FIV) of Shola forests

No.	Families	No.of Species	Total IVI	RD	RDIV	RDO	FIV
1	Lauraceae	10	5.59	17.56	20	15.88	53.44
2	Myrtaceae	3	29.71	7.60	6	23.60	37.20
3	Symplocaceae	2	14.17	4.80	4	3.91	26.88
4	Celastraceae	3	26.84	11.40	6	8.56	25.96
5	Rubiaceae	4	23.22	9.68	8	5.20	22.88
6	Ternstroemiaceae	2	19.86	6.48	4	10.58	21.06
7	Myrsinaceae	2	19.94	9.06	4	3.02	16.08

Continued

No.	Families	No.of Species	Total IVI	RD	RDIV	RDO	FIV
8	Clusiaceae	1	11.61	4.13	2	5.98	12.11
9	Oleaceae	2	12.45	4.14	4	3.45	11.59
10	Staphyleaceae	1	6.24	1.56	2	1.55	11.35
11	Berberidaceae	1	12.92	5.26	2	3.61	10.87
12	Euphorbiaceae	2	8.26	3.02	4	2.13	9.15
13	Aquifoliaceae	2	9.13	2.01	4	2.69	8.7
14	Ericaceae	2	7.56	1.67	4	1.76	7.43
15	Elaeocarpaceae	1	7.93	2.01	2	2.34	6.35
16	Sabiaceae	2	5.39	1.56	4	0.48	6.04
17	Araliaceae	1	6.27	2.68	2	1.25	5.93
18	Thymeliaceae	1	4.21	1.23	2	0.72	3.95
19	Pittosporaceae	1	2.97	0.67	2	0.46	3.13
20	Mimosae	1	3.27	0.67	2	0.35	3.02
21	Vacciniaceae	1	3.27	0.67	2	0.35	3.02
22	Sapindaceae	1	1.56	0.55	2	0.08	2.63
23	Urticaceae	1	1.11	0.33	2	0.05	2.38
24	Icacinaceae	1	0.99	0.33	2	0.03	2.36
25	Flacourtiaceae	1	1.68	0.22	2	0.08	2.3
26	Papiloniaceae	1	1.18	0.22	2	0.05	2.27

Table 16. Constancy values of shola forests in different localities

No	Name of Species	NA	AN	UM	TU	ER	RA	PU
1	*Actinodaphne bourdillonii*	1	1	0	2	1	3	4
2	*Allophyllus rhomboidea*	0	0	0	0	0	2	0
3	*Alseodaphne semicarpifolia*	0	0	0	0	0	1	0
4	*Ardisia rhomboidea*	0	3	1	1	2	0	2
5	*Cinnamomum wightii*	3	2	4	0	4	0	1
6	*Cinnamomum perrottetii*	0	0	0	1	0	0	2
7	*Cryptocarya neilgherrensis*	0	0	0	0	0	1	0
8	*Daphniphyllum glaucescens*	0	0	0	1	2	2	2
9	*Debregeasia longifolia*	0	0	0	1	0	1	0
10	*Derris brevipes*	1	1	0	0	0	0	0
11	*Dodonaea viscosa*	0	0	0	2	0	0	1
12	*Elaeocarpus recurvatus*	3	1	2	1	0	0	2
13	*Eugenia spp.*	0	1	1	1	0	0	0
14	*Euonymus angulatus*	2	1	1	2	1	0	2
15	*Eurya nitida*	3	0	1	0	2	0	1
16	*Flaucourtia montana*	0	0	0	0	0	1	0
17	*Garcinia combogia*	2	0	0	2	4	2	0

Continued

No	Name of Species	NA	AN	UM	TU	ER	RA	PU
18	*Gaultheria fragrantissima*	0	1	0	0	0	0	0
19	*Glochidion neilgherrense*	0	1	0	0	0	0	0
20	*Gomphandra coriacea*	0	0	0	0	0	1	0
21	*Ilex denticulata*	0	1	3	0	1	0	2
22	*Ilex wightiana*	0	0	0	0	0	0	1
23	*Ixora notoniana*	1	0	0	3	3	0	0
24	*Lasianthus venulosus*	1	1	1	1	0	2	0
25	*Lasiosiphon eriocephalus*	2	0	0	2	0	0	0
26	*Ligustrum perrottettii*	0	2	2	0	1	0	3
27	*Linocera macrophylla*	0	0	1	0	3	1	0
28	*Litsea glabrata*	0	0	0	2	0	2	0
29	*Litsea ligustrina*	2	3	1	0	1	0	4
30	*Litsea wightiana*	2	3	3	0	2	0	1
31	*Mahonia leschenaultii*	4	2	3	2	3	1	2
32	*Maesa indica*	2	3	1	1	3	4	5
33	*Meliosma wightii*	0	1	1	1	0	0	0
34	*Microtropis microcarpa*	0	0	0	1	0	5	0
35	*Microtropis ramiflora*	0	3	5	1	3	0	1
36	*Neolitsea foliosa*	0	3	0	0	0	0	0
37	*Persia macrantha*	0	0	2	0	0	0	0
38	*Pithecellobium subcoriaceum*	0	0	0	0	0	3	0
39	*Pittosporum neighrrense*	1	0	0	0	0	1	0
40	*Psychotria anamallayana*	1	0	3	3	0	3	0
41	*Rhododendron arboreum*	2	1	1	1	0	0	1
42	*Rhodomyrtus tomentosa*	0	0	0	0	2	0	0
43	*Schefflera recemosa*	1	0	1	1	2	2	1
44	*Symplocos pendula*	2	1	2	0	0	0	0
45	*Symplocos spicata*	0	2	1	0	2	1	2
46	*Syzygium arnottianuum*	3	1	1	4	3	5	4
47	*Tarenna monosperma*	1	0	0	1	0	0	0
48	*Ternstroemia japonica*	0	0	0	3	0	5	0
49	*Turpinia nepalensis*	1	2	2	0	1	0	1
50	*Vaccinium leschenaultii*	0	0	0	0	2	1	1

5.2.1.1.9. Law of homogeneity of vegetation

Percentage frequency was divided into five frequencyclasses (Raunkiaer, 1934) and the values were tested for Law of Frequency for Homogeneity by using the formula, A > B > C <=>D < E. Based on the results (Table 17 and Figs 13-19) it was clear that all localities except Rajamala are heterogeneous.

Table 17. Raunkier's percentage frequency classes

Locality	Percentage Frequency classes				
	A	B	C	D	E
Naikolly Mala	40	36.36	18.18	4.54	-
Anamudi	54.16	20.83	25	-	-
Umayamala	54.16	20.83	16.16	0.04	0.04
Turnursvalley	56	28	12	4	-
Eravikulam	27.27	36.36	27.27	9.09	-
Rajamala	45.83	25	12.5	4.16	12.5
Puvar	39.13	43.47	4.34	8.69	4.34

5.2.1.1.10. Distribution

To study the distribution pattern of species, the abundance/frequency ratio (Whitford, 1948) have been worked out (Table 18). Based on the AB/F ratio, out of 50 species encountered eight (16.32%) species show contagious distribution (AB/F value >0.05), 22 (44.9%) species have random distribution and 20 (38.8%) are having regular distribution.. Important species distributed contiguously are *Maesa indica, Litsea wightiana, Euonymous angulatus, Rododendron arboreum etc.* Species which have random distribution are *Actinadaphne bourdillonii, Mahonia leschenaultii, Cinnamomum wightii, Syzygium arnottianum, Symplocos spicata, Elaeocarpus recurvatus etc.*.

Table 18. Distribution pattern of species in Shola forests and Sub tropical Hill forests

Shola			Sub Tropical Hill Forest	
Distribution	No. of species	Percentage of species	No. of species	Percentage of species
Regular (< 0.025)	20	40	2	5.4
Random (0.025-0.05)	22	44	11	29.72
Contagious (> 0.05)	8	16	24	64.86

Fig.13. Percentage frequency histogram of shola
Locality: Naikolli Mala

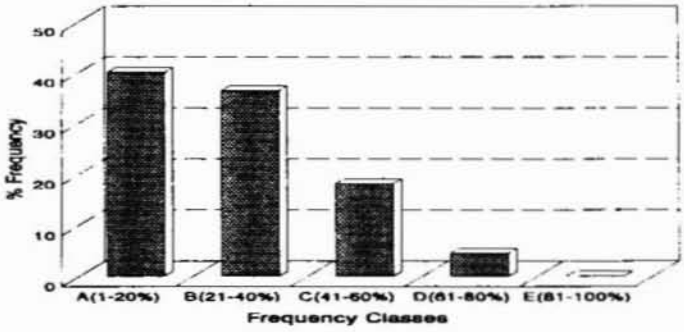


Fig.14. Percentage frequency histogram of shola
Locality: Anamudi

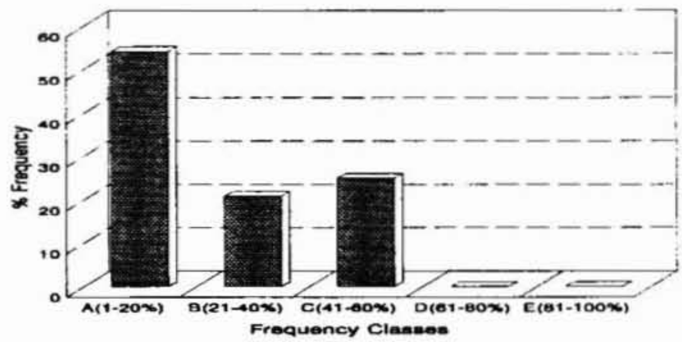


Fig.15. Percentage frequency histogram of shola
Locality: Umaya Mala

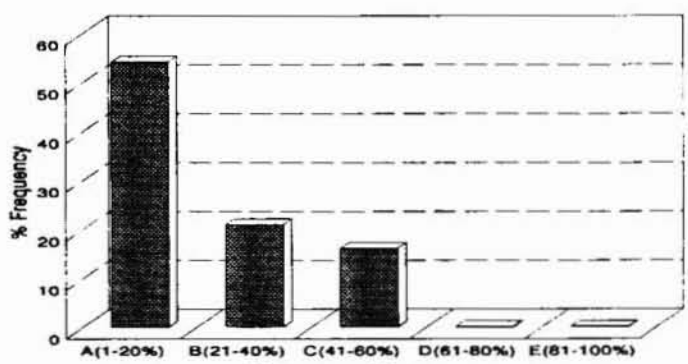


Fig.16. Percentage frequency histogram of shola
Locality: Turners Valley

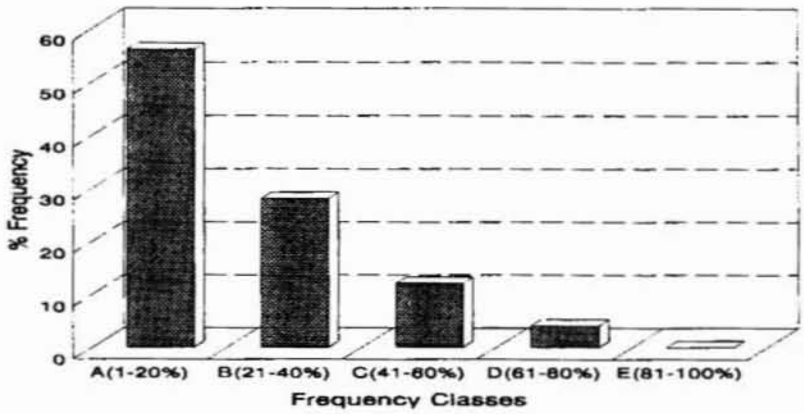


Fig.17. Percentage frequency histogram of shola
Locality: Eravikulam

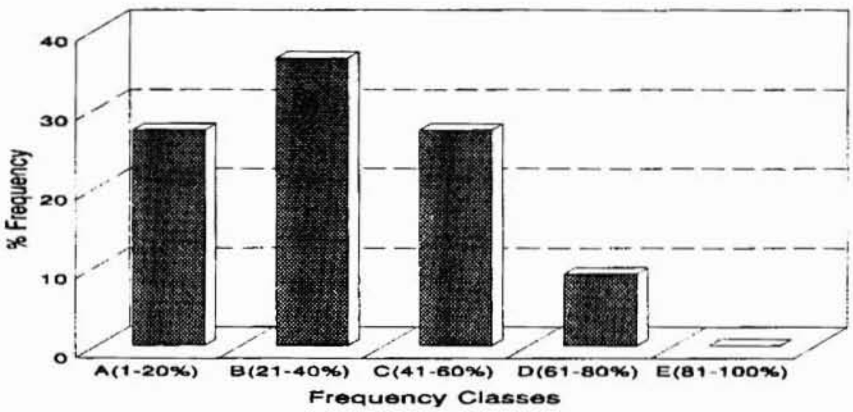


Fig.18. Percentage frequency histogram of shola
Locality: Rajamala

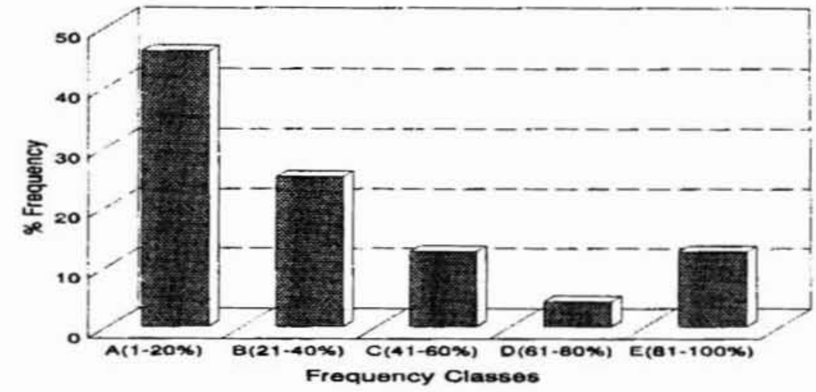
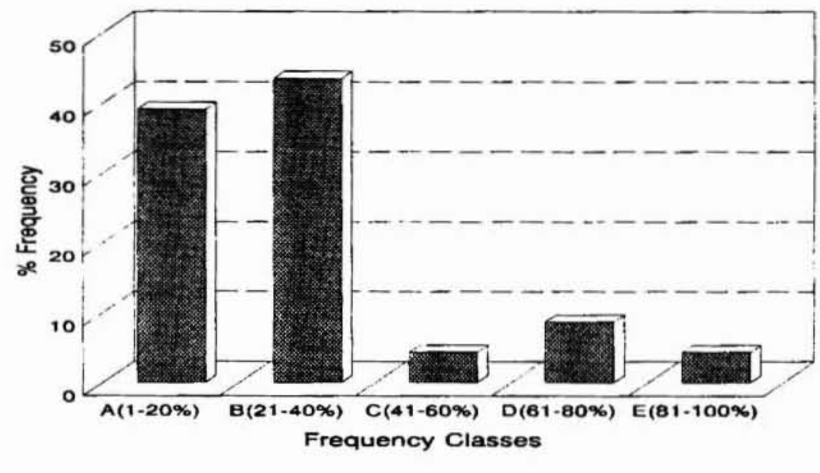


Fig.19. Percentage frequency histogram of shola
Locality: Puvar



5.2.1.1.11. Maturity index

Maturity index values of seven localities are presented in Table 19. It ranges from 37.92 (Rajamala) to 26.40 (Turnersvalley).

Table 19. Maturity index, Diversity index, and Continuum index values of Shola forests

Locality	Altitude (m)	MI value	DI value	CI value
Naikollymala (NA)	2150	30.00	2.85	1550.67
Anamudi (AN)	2350	28.75	2.93	1640.45
Umayamala (UM)	2100	30.42	2.82	1492.41
Turnersvalley (TU)	1950	26.40	2.95	1428.33
Eravikulam (ER)	2100	37.27	2.88	1514.15
Rajamala (RA)	2000	37.92	2.79	1550.23
Puvar (PU)	2150	33.04	2.88	1512.96

5.2.1.1.12. Similarity index

Highest similarity (84.44) was obtained on comparison of the locality Eravikulam with Puvar. Rajamala shows highest (75%) dissimilarity with Anamudi. More than 60% similarity was observed among localities Naikollymala with Anamudi and Umayamala, Anamudi with Umayamala, Eravikulam and Puvar. More than 60 % dissimilarity was observed among localities Rajamala with Anamudi, Umayamala and Puvar (Table 20).

Table 20. Matrix of similarity and dissimilarity

Similarity

	*NA	AN	UM	TU	ER	RA	PU
NA	-	60.86	65.21	59.57	59.09	43.47	57.77
AN	39.14	-	79.16	48.97	60.86	25.00	68.08
UM	34.79	20.84	-	53.06	69.56	33.3	72.34
TU	40.43	51.03	46.94	-	46.80	53.06	54.16
ER	40.91	39.14	30.44	53.20	-	47.82	84.44
RA	56.53	75.00	66.70	46.94	52.18	-	35.29
PU	42.23	31.92	27.66	45.84	15.56	64.71	-

Dissimilarity

*See Table 19 abbreviation of localities

5.2.1.1.13. Continuum index

Continuum index value ranges from 1428.33 to 1640.48. Anamudi records the highest value whereas Turnursvalley has the lowest (Table 19). Considering the whole area there is not much variation in the percentage continuum index value of different localities (13.36-15.34). This indicates more or less uniform environment.

5.2.1.1.14. Diversity indices

Two components of diversity viz.; species richness and evenness values were worked out and are presented in Table 21. Turners valley shows maximum richness whereas least richness is shown by Naikollymala. Evenness index value (E5) maximum is shown by Eravikulam and minimum by Umayamala.

Table 21. Florstic Diversity of Shola forests

	Localities						
	*NA	AN	UM	TU	ER	RA	PU
Richness indices							
N_0	22	24	24	25	22	24	23
R_1	4.49	4.85	4.97	4.91	4.25	4.42	4.68
R_2	2.12	2.23	2.37	2.21	1.78	1.8	2.18
Diversity indices							
D	0.07	0.06	0.08	0.06	0.06	0.08	0.07
H'	2.85	2.92	2.82	2.95	2.88	2.79	2.88
N_1	17.28	18.54	16.77	19.10	17.81	16.28	17.81
N_2	14.28	16.66	12.50	16.66	16.66	12.50	14.28
Evenness indices							
E_1	0.92	0.91	0.88	0.91	0.93	0.87	0.91
E_2	0.78	0.77	0.69	0.76	0.80	0.67	0.77
E_3	0.77	0.76	0.68	0.75	0.80	0.66	0.76
E_4	0.83	0.90	0.74	0.87	0.93	0.76	0.80
E_4	0.81	0.89	0.72	0.86	0.93	0.75	0.79

* See Table 19 for locality abbreviations

Shannon Weiner Index for species diversity ranges from 2.80 to 2.95 and Turners valley records highest value. Simpson index for Concentration of Dominance value ranges from 0.06 to 0.08 and Rajamala and Umayamala records highest values.

5.2.1.2. Sub tropical hill forest

These type of forests are referred as stunted evergreen forests, considered comparatively inferior to tropical wet evergreen forests of lower elevation. They are less luxuriant than tropical wet evergreen forests. The trees are smaller and having less shapely boles and festooned with mosses, lichens and ferns. The low height of trees of this type are mainly due to the high velocity of wind and less favourable condition of soil.

5.2.1.2.1. Floristics

The Important species of upper canopy are *Canarium strictum, Bischofia javanica, Persia macrantha, Prunus zeylanica etc.* Lower storey is comprised of tree species *Syzygium cumini, Aglaia roxburghiana, Cinnamomum malabatrum, Elaeocarpus serratus, Ligustrum perrottetti, Hydrocarpus alpinia, Gomphandra coriatia etc.* Ground flora is sparse. Epiphytes are represented by various species of orchids and ferns.

5.2.1.2.2. Density

A total of 37 species with 237 individuals were encountered in a sample plot of 2500m^2. The quantitative values of species are given in Table 22. Dominant species based on IVI are *Syzygium cumini, Bischofia javanica, Canarium strictum* and *Ardisia romboidea.*

Table 22. Phytosociological data of sub tropical hill forest

Altitude. 1700 m.

No	Species	D	AB	PF	BA	RD	RF	RBA	IVI	AB\F
1	*Syzygium cumuni*	0.36	1.29	28.00	2577.6	3.80	3.91	11.59	19.30	0.05
2	*Bischofia javanica*	0.20	1.25	16.00	2577.6	2.11	2.23	11.59	15.93	0.08
3	*Canarium strictum*	0.28	1.17	24.00	2036.6	2.95	3.35	9.15	15.45	0.05
4	*Ardisia rhomboidea*	0.80	1.67	48.00	25.78	8.44	6.70	0.12	15.26	0.03
5	*Garcinia combogia*	0.56	1.17	48.00	286.40	5.91	6.70	1.29	13.90	0.02
6	*persia macrantha*	0.56	1.27	44.00	286.40	5.91	6.15	1.29	13.35	0.03
7	*Ficus nervosa*	0.12	1.50	8.00	2436.4	1.27	1.12	10.95	13.34	0.19
8	*Eurya nitida*	0.60	1.50	40.00	198.89	6.33	5.59	0.89	12.81	0.04
9	*Gomphandra coriacea*	0.60	1.67	36.00	198.89	6.33	5.03	0.89	12.25	0.05
10	*Tarenna asiatica*	0.48	1.20	40.00	11.46	5.06	5.59	0.05	10.70	0.03
11	*Aporosa*	0.48	1.50	32.00	161.10	5.06	4.47	0.72	10.25	0.05
12	*Alseodaphne semicarpifolia*	0.08	1.00	8.00	1790.0	0.84	1.12	8.05	10.01	0.12
13	*Cedrella toona*	0.12	1.50	8.00	1559.3	1.27	1.12	7.01	9.40	0.19
14	*Prunus zeylanica*	0.24	1.50	16.00	962.61	2.53	2.23	4.33	9.09	0.09
15	*Cryptocarya neilgherensis*	0.16	1.00	16.00	1089.0	1.69	2.23	4.90	8.82	0.06
16	*Memecylon luschington*	0.44	1.57	28.00	49.72	4.64	3.91	0.22	8.77	0.06
17	*Mastixia arboria*	0.32	1.14	28.00	198.89	3.38	3.91	0.89	8.18	0.04
18	*Ixora spp*	0.32	1.60	20.00	378.76	3.38	2.79	1.70	7.87	0.08
19	*Michelia champaka*	0.20	0.62	32.00	286.40	2.11	4.47	1.29	7.87	0.02
20	*Olia glandulifer*	0.08	1.00	8.00	1145.6	0.84	1.12	5.15	7.11	0.12

No	Species	D	AB	PF	BA	RD	RF	RBA	IVI	AB\F
21	*Lasianthus spp.*	0.24	1.00	24.00	49.72	2.53	3.35	0.22	6.10	0.04
22	*Isosandra perrottettiana*	0.20	1.00	20.00	198.89	2.11	2.79	0.89	5.79	0.05
23	*Elaeocarpus serratus*	0.08	1.00	8.00	795.54	0.84	1.12	3.58	5.54	0.12
24	*Mallotus albus*	0.24	1.50	16.00	121.00	2.53	2.23	0.54	5.30	0.09
25	*Elaeocarpus munronii*	0.16	2.00	8.00	509.15	1.69	1.12	2.29	5.10	0.25
26	*Trema orientalis*	0.16	1.33	12.00	286.40	1.69	1.68	1.29	4.68	0.11
27	*Linoceira*	0.20	1.25	16.00	71.60	2.11	2.23	0.32	4.66	0.08
28	*Maesa indica*	0.16	1.33	12.00	286.40	1.69	1.68	1.29	4.66	0.11
29	*Aglaea roxburghiana*	0.12	1.50	8.00	447.49	1.27	1.12	2.01	4.40	0.19
30	*Hydnocarpus alpinia*	0.12	1.50	8.00	447.49	1.27	1.12	2.01	4.40	0.19
31	*Psychotria elongata*	0.24	2.00	12.00	17.90	2.53	1.68	0.08	4.29	0.17
32	*Ligustrum perrottettii*	0.16	1.33	12.00	86.63	1.69	1.68	0.39	3.76	0.11
33	*Meliosma simplifolia*	0.08	1.00	8.00	336.12	0.84	1.12	1.51	3.47	0.12
34	*Symplocos cochinchinensis*	0.12	1.50	8.00	198.89	1.27	1.12	0.89	3.28	0.19
35	*Vaccinium neilgherensis*	0.08	1.00	8.00	31.82	0.84	1.12	0.14	2.10	0.12
36	*Celtis tetrandra*	0.08	2.00	4.00	31.82	0.84	0.56	0.14	1.54	0.50
37	*Cinnamomum malabatrum*	0.04	1.00	4.00	71.60	0.42	0.56	0.32	1.30	0.25

Total No.of Individual: 237 ; Total basal area: 22245.86; MI: 19.35; CI: 1618.78

Total No. of Qtd.occ: : 179; Diversity: 3.38; Con. of Dominance: 0.04

Ardisia rhomboidea exhibits highest density (0.8) followed by *Eurya nitida* (0.6), *Gomphandra coriacea*, *Persea macrantha* (0.5). The lowest density value is recorded by *Cinnamomum malabatrum* (0.4).

5.2.1.2.3. Abundance

The following species show high abundance values (abundance value in parenthesis): *Celtis tetrandra* (2), *Elaeocarpus munronii*(2) and *Psychotria elongata* (2). Only one species shows abundance value of less than one.

5.2.1.2.4. Frequency

The highest percentage frequency is exhibited by *Ardisia romboidea* and *Garcinia gummi-gutta* (48) followed by *Persea macrantha* (44) and *Eurya nitida* (40). None of the species shows percentage frequency greater than 50.

5.2.1.2.4. Basal area

Basal area of the stand is 44.16 m^2/ha. Among individual species highest basal area is exhibited by *Syzygium cumini* (2577.6), *Bischofia javanica* (2577.6) followed by *Ficus nervosa* (2436.4) and *Canarium strictum* (2036.6)

5.2.1.2.6. Important value index

The highest IVI is recorded by *Syzygium cumini* (19.3) followed by *Bischofia javanica* (15.93) and *Canarium strictum* (15.45). Only 12 species show IVI values of more than 10. The least IVI value was recorded by *Cinnamomum malabatrum* (1.3).

5.2.1.2.7. Family importance value

Family importance value registered maximum in Myrtaceae (120.31) which was followed by Burseraceae (69.73) and Euphorbiaceae (68.8). The detailed Family importance values are presented in Table 23.

Table 23. Family Importance Values (FIV) of Sub tropical hill forests

No	Families	No.of species	Total IVI	RD	RDIV	RDO	FIV
1	Myrtaceae	2	23.96	5.48	5.4	109.4	120.3
2	Euphorbiaceae	3	31.48	9.7	8.10	69	86.8
3	Burseraceae	1	15.45	2.95	2.7	64.08	69.73
4	Rubiaceae	4	28.96	13.5	10.8	17.6	41.91
5	Meliaceae	2	13.8	2.53	5.4	27.06	34.99
6	Lauraceae	4	33.48	8.86	10.8	14.55	34.22
7	Rosaceae	1	9.09	2.53	2.7	25.96	31.19
8	Moraceae	1	13.34	1.26	2.7	32.85	26.81
9	Clusiaceae	1	13.9	5.90	2.7	18.02	26.62
10	Oleaceae	3	15.53	4.64	8.1	13.46	26.2
11	Elaeocarpaceae	2	10.64	2.53	5.4	16.3	24.23
12	Ternstroemiaceae	1	12.81	6.32	2.7	13.41	22.43
13	Myrcinaceae	1	15.26	8.43	2.7	2.58	13.71
14	Coronaceae	1	8.18	3.37	2.7	7.15	13.22
15	Anonaceae	1	7.87	2.10	2.7	6.43	11.23
16	Flacourtiaceae	1	5.54	1.26	2.7	7.15	11.11
17	Melastomataceae	1	8.77	4.64	2.7	2.45	9.97
18	Sapotaceae	1	5.79	2.10	2.7	4.47	9.27
19	Ulmaceae	2	6.2	2.53	5.4	0.5	8.43
20	Sabiaceae	1	3.47	0.84	2.7	3.02	6.56
21	Symplocaceae	1	3.28	1.26	2.7	1.78	5.74
22	Vacciniaceae	1	2.10	0.84	2.7	0.07	3.61

5.2.1.2.8. Distribution

Two species, *Garcinia gummi-gutta* and *Michelia spp.* are distributed regularly. Eleven species distributed randomly and twenty four species distributed contagiously. Dominant species *viz. Syzygium cumini* and *Bischofia javanica* are observed contagiously distributed.

5.2.1.2.9. Maturity index

Maturity index shows very low value (19.5).

5.2.1.2.10. Continuum Index

Continuum index value obtained for Subtropical hill forests is 1618.78 (Table 22).

5.2.1.2.11. Floristic Diversity

Floristic diversity comprising richness, diversity and evenness are given in Table 24. Floristic richness of subtropical hill forests is found to be 37 species with girth >15cm. Shannon weiner index for diversity value records 3.38 and Simpson's index for concentration of dominance is 0.04.

Table 24. Florstic diversity of Southern Sub torpical hill forest

Richness	
N0	37
R	6.59
Diversity	
D	0.04
H	3.38
Evenness	
E	0.94

N0 = Number of species
R = Richness index
D = Concentration of dominance
H = Diversity index
E = Evenness index

5.2.1.3. Grassland

This study is limited to general species composition which were recognised by remote sensing because of spectral differentiability of grasslands. With respect to the percentage frequency of species, dominant grass species were identified as community types. Thus, three major grassland communities obtained are the following:

1. *Dichanthium polyptychum-Eulalia phaeothrix - Chrysopogon zeylanicus Schima nervosum.*
2. *Arundinella mesophylla-Andropogon lividis -Ischaemum indicum - Chrysopogon zeylanicus-Schima nervosum.*
3. *Arundinella - Chrysopogon zeylanicus - Eulalia phaeothrix*

Grassland community type 1 occupies comparatively less area and is mostly seen in the lower elevation of Rajamala side and some parts of the center of the park. Dominant species component of this type are *Arundinella mesophylla*, *Chrysopogon zeylanicus* and *Andropogon lividis* (Table 25).

Table 25. Grass community Type 1

No	Species	QDOC	PF	RPF
1	*Arundinella mesophylla*	9	90	18
2	*Andropogon lividis*	6	60	12
3	*Chrysopogon zylanicus*	5	50	10
4	*Ischaemum indicum*	5	50	10
5	*Dichanthium polyptychum*	4	40	8
6	*Schima nervosa*	4	40	8
7	*Poa annua*	3	30	6
8	*Themeda tremula*	3	30	6
9	*Eragrostis nigra*	2	20	4
10	*Eulalia thwaitisi*	2	20	4
11	*Helictotrichon virescens*	2	20	4
12	*Arundinella vaginata*	1	10	2
13	*Digitaria vallichiana*	1	10	2
14	*Eulalia trispicata*	1	10	2
15	*Melinis minutiflora*	1	10	2

Grassland community type 2 occupies more or less equal area as the grassland type 3. It occupies the northwestern part of the National Park and Anamudi area. *Dichanthium polyptychum*, *Eulalia phaeothrix* and *Chrysopogon zeylanicus* are the most frequent species (Table 26).

Grassland community type 3 is seen mostly on the northeastern side of the National Park. The major components of this category are *Arundinella purpuria*, *Chrysopogon zeylanicus* and *Eulalia phaeothrix* (Table 27).

Table 26. Grass community type 2

No	Species	QDOC	PF	RPF
1	*Dichanthium polyptychum*	8	80	14.8
2	*Eulalia phaeothrix*	7	70	12.9
3	*Chrysopogon zylanicus*	5	50	1.3
4	*Andropogon lividis*	4	40	7.4
5	*Schima nervosa*	4	40	7.4
6	*Agrostis peninsularis*	3	30	5.6
7	*Indochlea oligantha*	3	30	5.6
8	*Ischæmum indicum*	3	30	5.6
9	*Tripogon bromoides*	3	30	5.6
10	*Arundinella vaginata*	2	20	3.7
11	*Bromus ramosus*	2	20	3.7
12	*Cyrtococcum deccanence*	2	20	3.7
13	*Isachne bourneorum*	2	20	3.7
14	*Poa flexosa*	2	20	3.7
14	*Arundinella purpuria*	1	10	1.9
15	*Coclachne perpu silla*	1	10	1.9

Table 27. Grass community type 3

No	Species	QDOC	PF	RPF
1	*Arundinella purpuria*	10	100	23.3
2	*Chrysopogon zylanicus*	9	90	20.9
3	*Eulalia phæothrix*	5	50	11.6
4	*Bothriochloa pertosa*	3	30	6.8
5	*Agrostis peninsularis*	2	20	4.6
6	*Andropogon lividis*	2	20	4.6
7	*Eragrostis uniloides*	2	20	4.6
8	*Isachne bourneana*	2	20	4.6
9	*Ischamum indicum*	2	20	4.6
10	*Zenkaria elegens*	2	20	4.6
11	*Agrostis humilus*	1	10	2.3
12	*Bromus ramosus*	1	10	2.3
13	*Panicum gardneri*	1	10	2.3
14	*Themeda tremula*	1	10	2.3

A total of 23 grass species is recorded from the study site. Of these highest mean percent frequency is shown by *Chrysopogon zeylanicus* (63.3), followed by *Dichanthium polyptychum* (40), *Eulalia pheothrix* (40), *Andropogon lividis* (40), *Arundinella purpuria* (36.6) and *Ischaemum indicum* (33.3). Lowest mean percentage frequency (3.3) is represented by species like *Eulalia trispicata*, *Digitaria wallichiana* and *Panicum gardeneri*.

Non grass species associated with grasslands are *Plebophyllum kunthianus*, *Eupatorium spp*, *Osbekia leschenaultiana*, *Polygala sibirica*, *Smithia spp*, *Drocera peltata*, *Rununculus reniformis*, *Anaphalis spp.*, *Swertia spp.*, *Hypericum spp.* and the fern *Pteridium aquilinum*.

5.2.1.4. Scrubs

Major associations of scrub Savannah are *Phlebophyllum kunthianum* and *Pteridium acquilinum*. *Phlebophyllum kunthianum* usually blooms once in twelve years and it gives the valley an enchanting beauty (Plate 4.A).

5.2.1.5. Spatial distribution pattern of Shola forest

The shola forests are distributed intermixed with the rolling grasslands of varying altitudes The size of shola patches varies from 0.1 ha to 300 ha. In order to study the distribution pattern, the shola forests were categorised into different size classes as well as different altitudinal classes.

Based on the size of shola, it was observed that there is a general trend in increase in the number of shola patches of the lower size classes (Fig. 20) *viz*. 0.1 to 1ha classes consists the maximum number of sholas (45.15%) and 84.28% of the total number of sholas included in the 0.1 to 5 ha classes.

Altitudinal distribution of shola shows that the number of sholas are increasing with the increasing altitude from 1701 to 2100 m.whereas mean area of shola are decreasing with the increasing altitude from 1701 to 2500m (Fig 21).

Number of shola patches are increasing from altitude 1701m to 2100m from 2101m to 2500m there is a gradual decline.

5.2.2. Discussion

5.2.2.1. Shola forests

The forest areas, locally known as 'sholas', are classified as Southern Montane wet temperate forests (Chandrashekharan, 1962 and Champion and Seth, 1968). The high altitude shola forests is one of the botanically interesting regions of peninsular India. However, compared to other forest types, no detailed study on Phytosociology of sholas have been made. Shola forests are less explored vegetation of Western Ghats. Quantitative values of shola forests were compared with the other tropical forests of India (Table. 28).

Table 28. Comparison of Vegetation characteristic of other tropical forests in India

Forest	Locality	Plot size	Girth class	Density M / ha	basal Area m / ha	Authors name
Evergreen	Silent Valley	-	>31.5	620-709	29-103	Singh *et al*, 1984
Evergreen	Karnataka	0.44		466-1386	33-48	Rai & Proctor, 1986
Evergreen	Attapadi	0.2	>10	1520	59.6	Pascal,1988
Semi evergreen	Panamberi	-	>10	2080	42.1	Pascal, 1988
Dry Tropical Forest	Vindhyan	-	>30	294-559	7-23	Jha & Singh,1990
Dry evergreen	Puthupet	0.3	>20	1130	36	Visalakshi, 1995
Dry evergreen	Marakkanam	0.2	>20	280	11	Visalakshi, 1995
Shola	Eravikulam	0.7	>15	1268	25	Present study
Sub trop. Hill forest	Eravikulam	0.25	>15	948	44.16	Present study

Fig.20.Distribution of Shola in different size classes

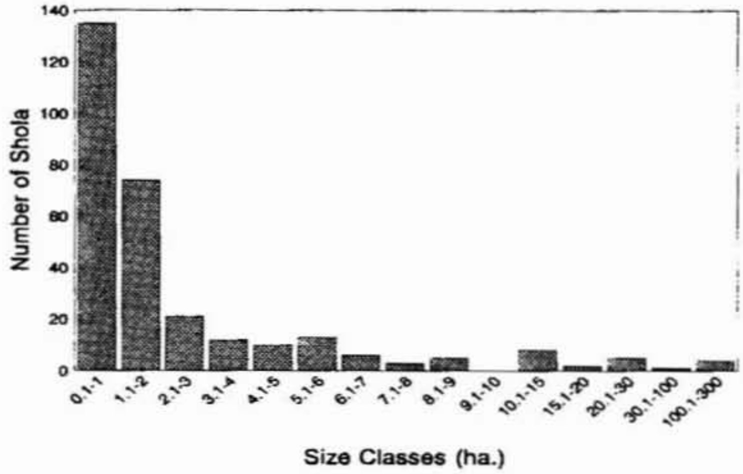
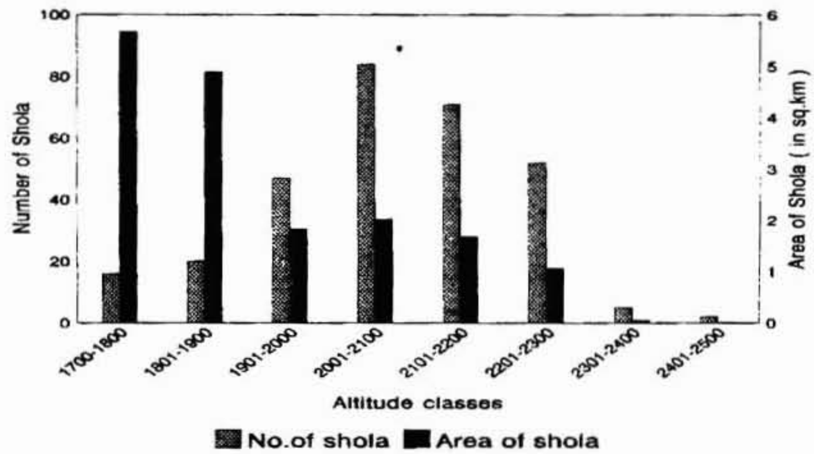


Fig.21. Distribution of Shola in different altitudes



5.2.2.1.1. Density

Density, abundance and frequency are the three important parameters of a vegetation. Density gives the number of individuals per unit area. Based on the analysis of density data vegetation the highest mean density was shown by *Maesa indica* and the lowest mean density was recorded by *Ilex wightiana* .Competition is one of the major reasons which effects the density status of a locality. Competition first becomes operative at higher densities and on better sites. Considering the factors it is clear that the density values among species varies with the locality. This indicates that the locality factors such as, altitude, terrain, topography *etc*. have a major role on supporting certain species which are more adaptable in some localities. I have obtained a total number of 1277 individuals per hectare (>15 cm gbh), which is slightly less than what Shibu Jose *et al.* (1991) got for a part of Shola forests of Eravikulam National Park. Saxena (1979) had reported that the total density for tropical forests except tropical rainforests ranges from 5.5 to 11.7 trees 100 m^2. It is generally believed that communities with higher density are more efficient in capturing energy and converting it into biomass (Odum, 1969). According to Whittaker (1965) high density does not always accompany high biomass.

The highest stand density of shola forest (1277/ha-1) owes to its characteristic compactness and ecological adaptation of prevailing climatic conditions. Highest mean diversity of *Maesa indica, Microtropis ramiflora and Syzigium arnottianum* denotes its ecological tolerance.

5.2.2.1.2. Abundance

Abundance gives an expression of the relative number of individuals of each species in the vegetation of an area (Bharucha and Deleuw, 1957).

According to Alok (1953), abundance is considered in terms of distance between the plants. Based on abundance value species are classified in to five groups (Misra and Puri, 1954) as

Abundance value 5: a- abundant or dominant

4: cd- co dominant

3: f- frequent

2: o- occasional

1: r- rare

The identification is influenced by the inclusion of species and parts of species together, the marginal effects of quadrats in counting species and the time factor in the estimation of the number of species especially in the case of herbal flora (Muller-Dombois and Ellenberg, 1974). Numerical abundance and spatial distribution of all species must be taken into account before an understanding of the community organisation can be made (Hainsten, 1959).

Highest mean abundance value recorded by *Maesa indica* indicates highly suitable ecological niche for the species and the uniform number of individuals represented in all localities of the area. species representing all localities are *Mahonia leschenaultii* and *Syzigyum arnottianum*. Eventhough being a dominant species. *Syzygium arnottianum* is seen only in certain localities like Anamudi. Generally a community will consist of a small number of abundant species and much larger number of moderately common and rare species.

5.2.2.1.3. Frequency

It is expressed as the percentage of occurrence of a given species in the sample plots studied. This may be interpreted that it is the chance of drawing the species within the sample area in any one trial and it is the easiest of the quantitatives to determine (Greig-Smith, 1964). It has been widely used for the determination of vegetation analysis where the vegetation is comparatively sparse in cover and species (Phillips, 1959). The percentage frequency of a species indicates its distribution in the area.

Highest mean frequency shown by *Syzygium arnottianum* (54.28) is nearly of similar value (74) which was obtained by Shibu Jose *et al.* (1994) at Rajamala. In general, species composition of sholas among different localities are more or less similar but when we analyse the quantitative characters there would be slight variations.

The vegetation composition in each stand will differ irrespective of the degree of similarity. No two stands are exactly alike, some stands resemble each other than they resemble other stands (Billings, 1964). Out of seven localities studied, in five localities *Syzygium arnottianum* represented by percentage frequency greater than fifty indicating the most frequent species in the shola forest of Eravikulam National Park.

The high percentage frequency exhibited by the species denote their wide range of niche specialisation and capability to establish over a large area.

5.2.2.1.4. Basal area

Cover is a measure of plant distribution and has been emphasized being a greater ecological significance than density is on the observation that cover gives a better measure of plant biom than does the number of individuals and the tree dominance is usually defined as stem cover and the stem cover is the same as basal area (Muller-Dombois and Ellenberg, 1974).

Total basal area of the locality varies from 14.17 m^2/ha to 32.75 m^2/ha and an average basal area of 25 m2/ha. According to Shibujose *et al.* (1994) an average basal area of 48 m^2/ha was obtained mainly because of the selection of enumerated stem size of 10 gbh. In this study, plants which have atleast 15cm gbh is considered as trees. Still, low basal area was obtained indicating the predominance of lower diameter classes. More than 50% of all stems in the area were in the 0-10cm diameter class .

Syzygium arnottianum constitute 20.74% of the total basal area, followed by *Ternstoemia japonica* (8.39%), *Microtropis ramiflora* (8.02), and *Cinnamomum wightii* (7.91%). Out of 49 species, all other species except *Syzigium arnottianum* constitute less than 10 % of the total basal area in the locality. This clearly indicates the highly dominant nature of *Syzigium arnottianum* in the area. Total basal cover ranges from 1073 to 3062 cm^2 . Saxena (1979) reported $100m^2$ for tropical forests except tropical rain forests. Risser and Rice (1971) demonstrated a significant positive correlation between basal area and diversity in Oklahama upland forest. Pascal (1988) reported an area of $59.6m^2$/hectar in the evergreen forests of Attapadi. The basal area values are slightly less than to the other forest types. This may be due to the lower girth classes due to human interference. The comparatively low basal area of the shola forests must be due to the high environmental constraints.

5.2.2.1.5. Important Value Index

Only seven species registered mean IVI of more than 10 and only *Syzigium arnottianum* exceeds mean IVI more than 20 Families which register the highest IVI are Myrtaceae, Rubiaceae, Lauraceae, Berberidaceae, Myrsinae and Celastraceae. Nine families have registered an IVI of more than 15 in the study of Shibu Jose *et al.* (1994) which includes Mimosaceae, Myrtaceae, Rubiaceae, Lauraceae, Celastraceae, Ternstroemiaceae, Myrsinaceae, Vacciniaceae and Cluciaceae with the first six having an IVI of more than 20. In the study samples taken from Rajamala locality four families *viz.* Myrtaceae, Ternstroemiaceae, Rubiaceae and Celastraceae have an IVI of more than 20. In the study of Shibu Jose *et al,* (1994) *Pithecellobium subcoriacium* is having the highest IVI value. *Pithecellobium subcoriacium*, a member of Mimosaeae, is of a rare occurrence in the sholas of interior part of Eravikulam National Park. The most dominant family is Myrtaceae followed by Lauraceae and Styraceae in the shola of Nilgiri (Laxmanan, 1968). Agarwal *et al.* (1961) states that in shola most of the species belong to the family Myrtaceae, Lauraceae, Styraceae and Ericaceae *etc.* The high IVI values of *Syzygiun arnottianum* denotes its ecological success in high altitude shola forests.

5.2.2.1.6. Family importance value

Family importance value indicates that Lauraceae is the most dominant family in shola forests followed by Myrtaceae. As generally seen in montane forests of Western Ghats the shola forests of Eravikulam National Park is also dominated by Lauraceae and Myrtaceae.

5.2.2.1.7. Constancy

Constancy, coined by Du Rietz (1930) is the degree of presence in a unit area (quadrat) instead of the entire stand. He defined constancy as species which have a percentage frequency greater than 90% and he prefers to use the term segment frequency instead of constancy. According to him there is no fundamental difference between frequency of a species in a sample taken from one stand (segment) and constancy of a species in general stands.

The absence of low percentage of high constancy classes (class 4 and 5) suggests that such characteristic species of an area are absent or fewer in number (Menon and Shah, 1981). Constant species may have wide ecological tolerance and occur in several associations (Kershew, 1973). The constancy of a species indicates its distribution in an area. Generally, the percentage of high constancy classes indicate regular but at times it may not be as a definite conclusion, because sometimes the rare species or accidentals also show much high constancy value. Here, it is felt undesirable from the highest and classes for vegetation grouping in each locality. Therefore the average constancy value classes will give us a better idea of vegetation of each locality.

Based the constancy class *Syzygium arnottianum* is species which has a wide distribution in three localities with a 4 or 5 indicating its wide to the area. It is interesting to note that relationship between homogeneity (Homogeneity of set of releves) and constancy of species. The homogeneity of a set of releves depends closely on the constancy of species in the given set and can be concisely formulated the higher the proportions of species of high constancy (i.e.,common to all or to the majority of releves) the higher in the homogeneity in the given set of releves (Morva, 1971) .

5.2.2.1.8. Low of Homogeneity of vegetation

Heterogeneous population generally show dominance of one or two frequency classes and does not follow Raunkaeir's (1934) Law of Frequency classes. The physiochemical nature of environment as biological peculiarities of organism themselves affect the pattern of distribution.

5.2.2.1.9. Distribution

The ratio of abundance and frequency as a measure of contagiousness among plant population, formulated by Whitford (1948) was widely accepted. He suggested the abundance/frequency ratio as a measure of contagiousness. As a general rule, the high frequency and low abundance indicates regular distribution whereas the converse indicates contagious. Dominant species such as *Syzygium arnottianum*, *Cinnamomum wightii* and *Mahonia leschenaultii etc.* are distributed randomly. In general, plants of Eravikulam National Park show 44% of random distribution, 39% of regular distribution and 16 % of contagious distribution ,indicating uniform nature of environment all over the area. Saxena and Singh (1982) have reported the general preponderance of random distribution in the forest communities of Kumaon Himalaya. It has been claimed that in pioneer communities plants tend to be aggregated, but as the community progress towards climax, there distribution become more random or even regular. In general, contagious distribution is common in nature; random distribution is found in very uniform environment and regular distribution occurs where severe competition exists between the individuals (Odum, 1971). The more likely situation which will produce regular distribution is one where there is high density of individuals with an uniform area (Kershew, 1973).

Only eight species show contagious distribution and nineteen species show regular distribution. The vegetation dynamics are closely associated with competition and pattern development, with the exception of absolute limits of species boundaries. Distribution of plants individually depends on phytochemical and environmental factors. These factors mostly influence the competition ability of plants. The very existence of a community itself has behind the principle of differential groupings of species or else the communities may change to the character the single dominant nature. Cent percent contagious distribution indicates heavy population and then over dispersion (Bargali, *et al.*, 1987). Regular distribution occurs where competition between individuals is high(Odum, 1971). The presence of *Syzygium arnottianum, Mahonia leschenaultii* and *Maesa indica* in all seven localities indicates that they are well adapted to the montane climate and moreover they are the important dominant member of shola forests of Eravikulam national park.

5.2.2.1.10. Maturity Index

As a general rule when succession has entered into a final stage or nearing the final stage, the total number of species will reduce, and those which are adapted to the changing environment will only survive, and multiplying to form the dominant community. The principle implied is that the higher the frequency percentage of the locality and smaller the number of sporadic species, the more mature is the community.

Maturity index values of the present study ranges between 26.4 to 37.92. This is well within the range of MI values obtained by Varghese (1996) for Peppara Wildlife Sanctuary and Suraj (1996) for Chimmony Wildlife Sanctuary.

Low maturity index of the forest indicates high species diversity. Nearly similar value (38.6) was obtained for Andaman evergreen forest by Roy, *et al* (1993). The MI values of disturbed areas of Attapadi is 16.33 and undisturbed area is 34 (KFRI, 1980).

Tansley (1920) has defined succession as the gradual change which occures in vegetation of a given area of the earth's surface on which one population succeeds the other". According to Clements (1916) the maturity of vegetation is based on 6 components *viz.*, nudation (exposure of new substrate), b, migration (the arrival of dissmination), c. ecesis (germination, establishment, growth and reproduction),d, competition which may result in species replacement, e, reaction which involves habitat change through the species and finaly stabilization as the climax.

5.2.2.1.11. Similarity index

Based on similarity index it is very clear that all samples taken from localities are similar among each other with a similarity index of more than 60%, whereas it is noticed that Rajamala showed more than 60% dissimilarity with Puvar and 75% with Anamudi. It is assumed because these two localities (Anamudi and Rajamala) may be having more variations in their composition of species and number of common species.

Similarly relations among vegetation communities can be expressed mathematically and these expressions are known as community co-efficient or indices of similarity (Jaccard, 1912; Whittaker and Niering, 1965). Endemism plays an important role in the dissimilarity feature of the flora studied, as well as the dissimilarity in species presence is also due to such locational abundance in species of selected families (Menon, 1985).

5.2.2.1.12 . Continuum index

Gleason (1936 and 1939) pointed out the absence of absolute boundaries between the adjacent plant communities and therefore he proposed the continuum concept in phytosociological researches. Curtis and McIntosh (1951) modified Gleason's individual concept and developed the idea of continuum of vegetation involving gradual variation from stand to stand.

Continuum index value (ranging between 1428-1640) indicates the uniform environment in the study area. According to Curtis and McIntosh (1951), no two stands are sufficiently similar in association when correlated with environmental factors. It then implies, a continuum variation of vegetation and can not be classified into discrete entities (Kershew, 1973). Misra (1968) states the plant communities merge in to each other showing a definite gradient which is correlated with environmental gradient.

The continuum index utilizes information from all species present in determining the position of a stand, the species contributing to the continuum value is in accordance to the 'important value' (Greg-Smith, 1964). The term vegetational continuum index used by Muller-Dombois and Ellenberg (1974), is based on the important values which themselves express quantitative data of vegetation.Modification of continuum concept by McIntosh (1967) admits the vegetational discontinuities in nature. He re-emphasises that a vegetation continuity is always found only in comparison of similar vegetational stands. But Longford and Buell (1969) did not accept the validity of continuum concept. According to them the vegetation mostly exists as pluridimentional continuum and the concept failed to resolve the problems of the individual concept of plant associations and the concept of sharply delimited communities. They are of the opinion that the problem of continuity can not be resolved by comprising communities that have not reached the climax stage. Menon (1979) points out the difficulty arises in checking out the dominant species on the basis of IVI. According to him species with high IVI range may naturally be the dominant species. However, in some rare cases though the relative basal area is more and the relative density and relative frequency are less, species show high IVI.. Such species are false dominants and therefore can not be selected as dominant species in a stand, even though they posses a high IVI value.

5.2.2.1.13 . Diversity

Community diversity is the most direct measure of ecosystem fitness. The study of diversity is the study of variation in the number of different ecological circumstances. Diversity can be used as a measure of environmental constraints at play. It has therefore been suggested that the 'index of diversity' can be an indication of the relative importance of the factors that are affecting the population balance as a whole.

The components of diversity can be expressed in different ways, namely the dominant diversity curve (Whittaker, 1965) or species importance curve (Pianka, 1978) or diversity indices (Shannon Weiner, 1949; Margalef, 1958; Pielou 1966; and 1975). For the present study two important richness indices and a series of five evnness indices were worked out. In addition to these, Shannon weiner index and Simpson's index were also used because they give greater weight to rare species in the diversity calculations.

5.2.2.1.13.1. Species richness

In the study area a total of 50 species belonging to 27 families within 7000 $m.^2$ sample plot were obtained. The number of species reported from the tropical forests of different parts of the world are as follows.

Cousens (1951) reported 183 species in 60 acres from Malayan peninsula (a total of 379 species of dbh of above 10 cm). Ashton (1964) reported 760 species (among 3000 trees above 10 cm gbh level) from a 45 ha.

plot in Brunei, MurcaPires *etal.* (1953) reported 60 species (320 trees of gbh of and above 10cm) in one ha plot in Sumatra and 244 species representing 136 genera and 56 families among 2607 trees of and above 30 cm gbh for a 5 ha forest in Amazonia. Basha (1987) reported 383 individuals of 33 species in a quarter ha area from Silent valley.

Pascal and Pellisier (1996) reported a floristic richness of 91 species belonging to 31 families in 3.12 ha for the Uppangala forest of the Western Ghats (of and above 30 cm gbh). Pascal reported 34 species in $800m^2$.(of and above 10 cm gbh) from Silent Valley and 27 species in $1000m^2$. for Attappadi. Ganesh *et al.* (1996) got 90 tree species in 35 families from Kalakad Mundanthurai tiger reserve, Western Ghats. Varghese (1997) obtained 150 tree species in 52 families in 2.1 ha (of and above 15 cm gbh) for Peppara wild life sanctuary.

Richness index R_1 is highest in Umayamala (4.97) and is lowest in Eravikulam (4.25), Similarly R_2 is maximum in Umayamala (2.37) and low at Rajamala (1.8). Very negligible variation in richness indices was observed among localities. The richness index values obtained in our study are comparable with those value obtained by Lakshmi (1995) for Kolli hills, Tamil Nadu.

5.2.2.1.13.2. Floristic diversity

The Shannon Wiener index and Simpson's index are inversely correlated in a curvilinear fashion (Srivastava, 1986). Diversity index represented by Shannon wiener function was higher in upland forest (4.8), in less mesic upland (4.6) and in reparian forest (3.5) (Whittaker, 1977). Monk (1967) reported diversity index for temperate forest between 2-3 and for temperate Himalayan forest (Ralhan *et al.*, 1982) ranging between 0-1.92. The value obtained by Laxmi Pangtey *et al.*, (1987) is 0-2.25. Dani *et al.*, (1991) observed a diversity value of 1.865 to 1.913 in their study in Kantamal region, Orissa, where as concentration of dominance value obtained in their study ranges from 0.188 to 0.238. Lakshmi (1995) got a value of 3.415 for moist deciduous forests of Kolli hills. Diversity index value of Mala region is between 2.09-3.34 (Sanalkumar, 1997). Varghese (1997)got a diversity value ranging between 2.3 to 3.2 for the vegetation in Peppara Wildlife sanctuary. According to Shibu Jose *et al* (1994), Shannon Weiner index value is 4.86 for shola forests of Eravikulam National Park and he states that the value is considerably higher than that of 4.0 for the mid elevation forest of Attapadi by Pascal (1988). The diversity value obtained in this study is comparatively low, and is due to the fact that the lower gbh limit fixed for enumerating the species was 15 cm.

The diversity value recorded for temperate forests is between 1.16 to 3.4 (Braun, 1950, Monk, 1967; Rissar and Rice, 1971). Diversity values (2.79 to 2.94) obtained for shola forests of Eravikulam National park are well in tune with these values indicating that ecologically shola forests are more akin to temperate forests than tropical forests.

Basha (1992) reported diversity value as 3.39 for evergreen forests in Silent Valley. Similar values (3-3.7) were obtained by Chandrasekhara (1992) for Nelliampathy and Sanal (1996) for Nilambur (3-3.5).

Shannon Wiener index is a measure of the average degree of uncertainty in predicting to what species or individual chosen at random from a collection of species and N individuals will belong. This average uncertainty increases as the number of species increases and as the distribution of individuals among the species became even. Thus, 'H' has two properties that have made it a popular measure of species diversity. (1) H =0 if and only if there is one species in the sample , and (2) H is maximum only when all 'S' species are represented by the same number of individuals, that is , a perfectly even distribution of abundance.

Simpson's index which varies from 0 to 1 , gives the probability that two individuals drawn at random from a population belong to the same species, if the probability is high that both individuals belong to the same species, then the diversity of the community sample is low. Concentration of dominance ranges from 0.05 to 0.19 for total vascular plants of Silent Valley (Singh *et al*, 1984). Temperate forests record a high value (0.99) compared to tropical forests (Whittaker, 1965; Risser and Rice 1971). For temperate Himalayan forests (Ralhan *et al* 1982) Concentration of dominance ranges between 0.31 to 1. Similar value was obtained by Laxmi Pangtey *et al.*, 1987). I have obtained a concentration of dominance value between 0.06 to 0.08. This is a little higher than what Shibhu Jose *et al* (1994) reported (0..5) and is assumed to the above mentioned reason.

5.2.2.1.13.3. Species Evenness

Evenness indices values also show a similar trend among each locality indicating the equitability of the whole area, *i.e.*, the individuals are distributed among each species uniformly among all locality. Of these E_4 and E_5 are more significant, since Shannon Wiener index and Simpson's index were used to calculate E_4 and E_5. E_4 is the ratio of the numbers of very abundant to abundant species. When the diversity of the community decreases, that is, as one species tend to dominate, both N_1 and N_2 will tend towards one. Under such conditions , E_4 converges towards the value of one (Peet, 1974). E_5 is known as the Hills ratio. Alatalo (1981) showed that E_5 approaches zero as a single species becomes more and more dominant in a community. This is clearly a desirable property of the evenness index that and is why E_5 is preferred to E_4 (Alatalo, 1981).

Regarding the Shola forests of Eravikulam National Park the value of E_4 and E_5 among localities vary from 0.74 to 0.93 and 0.72 to 0.93 respectively. This indicates the high diversity and the species abundance distribution is uniform in the area.

A high diversity suggests extreme biological competition in otherwise favourable condition. It is usually sufficient just to consider the number of species as the index of diversity. Typically diversity increased, (1) towards tropics, (2) through geological time (Simpson 1969,) (3) away from toxic pollution (Goulden, 1969) and (4) towards the more stable environment (Sanders, 1968). The concept of diversity is particularly important because it is commonly considered as an attribute of a natural or organised community (Hainsten, 1964) or is related to ecological process. Maximum diversity results if individuals are distributed equally among species (Robert and McIntosh, 1966). Certain species of rainforests produces hundreds of species mostly represented by one or a few individuals and having more than 5% of the total (Poore, 1964), a situation approaching the theoretical maximum diversity.

5.2.2.2. Subtropical hill forest

Data of the sub tropical hill forest is comparable with those values obtained by Lakshmi (1995) and Varghese (1997).

5.2.2.2.1. Density

The stand density obtained is 948 trees/ha, and is well comparable with the range reported for other tropical forests. Basal area is found to be 44.16 m^2 and is comparable to tropical forests. The density values are in tune with what is reported by Lakshmi (1995) and Varghese (1997) for subtropical hill forests and comparable with evergreen forests of Silent Valley reported by Singh *et al* (1984) and evergreen forests of Karnataka by Rai and Proctor (1986).

5.2.2.2.2. Frequency

Moderately high percentage frequency of *Garcinia cambogia* and *Ardisia rhomboidea* indicates that these species have wide ecological amplitude in Subtropical hill forests.

5.2.2.2.3. Abundance

Very low abundance value of Subtropical hill forests may be mainly due to lack of niche differentiation or due to reproductive changes of the species.

5.2.2.2.4. Basal area

Basal area obtained is similar to the values from tropical forests (Singh *et. al.*, 1984).

5.2.2.2.5. Important value index

Based on the highest IVI recorded by *Syzygium cumini*, it is considered as most dominant species in subtropical hill forest of Eravikulam National Park.

5.2.2.2.6. Family Important value

Family important value indicatesthat Myrtaceae is most dominant in subtropical hill forest followed by Euphorbiaceae and Burseraceae. This is comparable with the values obtained by Varghese (1997) for subtropical hill forest of Peppara Wildlife Sanctuary.

5.2.2.2.7. Distribution

Unlike shola forests most of the species are distributed contiguously and only two species are distributed regularly. Preponderance of contagious distribution clearly indicates the transition nature of Subtropical hill forests.

5.2.2.2.8. Maturity Index

Compared to shola forests Subtropical forest show low maturity index value. Varghese (1997) reported MI value between 22-25 for Subtropical hill forests of Peppara Wildlife Sanctuary and this is comparable with this study.

When compared with evergreen forests (Roy, 1993) of Andaman, low maturity value of this type of forests may be due to transition nature.

5.2.2.2.9. Continuum Index

Continuum Index value is nearly similar to what is obtained for shola forests, indicating the environmental gradient is not much abrupt. Continuum index value is well in tune with the value reported by Varghese (1997).

5.2.2.2.10. Floristic Diversity

Diversity Index Values and Concentration of Dominance Values are well in with the range obtained by Lakshmi (1995) and Varghese (1997). Simpson's index is found to be ≤ 0.04 indicating that 96% chance in all the cases, for not getting two same species together, which means higher dispersion. Higher Shannon Weiner index means higher diversity. Hills number N_1 measure the number of abundant species in the sample and N_2 the measure of very abundant species. Evenness indices clearly exhibits the high diversity and dispersion.

Comparison of vegetation characteristics between Montane wet temperate and Sub tropical hill forest showed that they differ in their species richness, diversity, stand density, basal area, maturity index, continuum index etc. Similarity in species composition between these two forest types is found to be 20% (Table 29). This is due to the presence of more number of evergreen species in the Subtropical hill forests of this region. Comparing the vegetation characteristics of Subtropical hill forests to Montane wet temperate forests indicates that Sub tropical hill forests shall be treated separately rather than combining together broadly as 'shola forests'.

Table 29. Comparison of vegetation characteristics between Montane wet temperate forest and Sub tropical Hill forest

No	Characteristics	Montane wet Temperate forest	Sub tropical Hill forest
1	Species richness	50	37
2	Stand density (>15 cm.GBH)	1268/ha	948/ha
3	Basal area	$25m^2$./ha	$44m^2$./ha
4	Maturity index	32	19
5	Continuum index	1527	1618
6	Diversity index (Shannon's)	2.87	3.38
7	Concentration of dominance	0.07	0.04
8	Similarity index	20.68 %	20.68%

5.2.2.3. West coast tropical evergreen forest

As this type of forest occupies an area of less than 1 km^2 it is negligibly small for a phytosociological study. Hence, detailed phytosociological observations were not conducted.

5.2.2.4. Grassland

Grasslands are mainly classified into low level grasslands upto 1000m elevation intermixed with forests and high level grasslands above 1000m elevation. High altitude grasslands in South India are observed in Nilgiri hills, Palni hills and Anamalai hills of Western Ghats. In Kerala such type of grasslands are seen in Eravikulam, Munnar, Devikulam and Ponnambalamedu of Idukki district, Pokkunnamala of Calicut, Silent Valley in Palakkad and Western slopes of Agasthyamala in Trivandrum.

Grasslands have a very important role in wildlife management as they provide excellent forage for herbivores (Plate 4b). The grassland enclave within the forests are the main food source of the depleting wild life.

Plate 4a. Neelakurinji gives an enchanting beauty to the valley

Plate 4b. Grasslands provide excellent forage to Nilgiri Tahr

The frequency index has proved very valuable in comparing different vegetation types (Braun Blanquet, 1932). Frequency is much more readily established quantitative measure than either the counting of individuals or the measurements of cover. For comparing different communities frequency is best expressed as a percentage of the total placements *i.e.*, the so called frequency percentage (Gleason, 1920). There are certain limitations in the case of frequency as a measure of vegetation (Ashby, 1961). (1) Since it is deduced from samples over a comparatively wider area; it can not be determined locally and used to examine the effects of habitat factors varying in small areas.(2). The frequency of a species, which is obviously related to its density in the area, can be considerably influenced by clumping of species and the pattern of their distribution.

Blasco (1970) considered the high altitude grassland of Western Ghats as *Chrysopogon zeylanicus-Arundinella* type (Nilgiri) and *Heteropogon contortus- Arundinella mesophylla* and *Arundinella fuscata-Eulalia pheothrix* for Palni hills.

Shibujose *et al.*, (1994) recorded that *Arundinella vaginata* showed a relatively high degree of dominance with a mean biomass yield of 292 gm/m^2 followed by *Andropogon lividis*. In the present study grassland 1 having a dominance by *Andropogon lividis*. According to Srivastava (1994) in areas with somewhat high temperature and less severity to frost, when degraded support a stand of *Chrysopogon montanus*, but as the intensity of frost increases the area is dominated by *Chrysopogon zeylanicus*. *Chrysopogon zeylanicus* grasslands are associated with species of *Themeda, Arundinella, Ischaemum, Eragrostis* and *Tripogon*.

Sreekumar and Nair (1991) described grasslands of Eravikulam National Park as *Eulalia pheothrix-Chrysopogon zeylanicus* dominant type especially in the Anamudi Umayamala slopes. This description is comparable with the present study.

Gupta and Regi (1965) have shown the existence of two major types of grasslands in the Nilgiri plateau, one dominated by *Chrysopogon zeylanicus* and the other by *Dichanthium polyptychus*. The Nilgiri high altitude type is characterised with *Dichanthium polyptychum* and *Chrysopogon* type which has been recorded as the montane phase of *Schima- Dichanthium* type of grasslands of Peninsular India (Puri, *et al*, 1983). From the ecological studies carried out around Ootacamund, Gupta *et al* (1967) showed that the *Dichanthium polyptychum* var. *deccurens* represents the optimum expression of grassland vegetation forming a distinct subtype under the *Schima-Dichanthium* type. *Eulalia phaeothrix, Themada triandra, Bothriochloa insculpta, Ischaemum indicum,* and *Andropogon lividis* and other important associates. As grasslands are subjected to burning and other biotic influences *Dichanthiunm polyptychum* is completely replaced by *Chrysopogon zeylanicus* which apparently is the stable type. Further biotic influences result in invasion of these grasslands by *Eragrostis* species, *Arundinella setosa* and *Tripogon bromoides*. (Agarwal *et al.*, 1961).

Grasslands of Eravikulam National Park are subjected to biotic interference to a lesser degree compared to Nilgiri and Palni hills (Shetty and Vivekananthan, 1971). *Dichanthium polyptychum* growing in the Niligiris may be accepted as of *Schima-Dichanthium* type and not of the *Arundinella* type as considered earlier (Agarwal *et al.*, 1961). According to him *Arundnella spp.* form a higher stage in succession . While the grassland type of Palni is *Themeda- Arudinella* type and the *Chrysopogon zeylanicus* being only a succession stage. The observations and ecological studies made in the high altitude grasslands of Eravikulam National Park (Rice, 1984) indicates that *Dichanthium polyptychum* represents the highest stage in these grasslands.

So, it can be safely stated that *Dichanthium polyptychum* represents the higher stage in grassland development in the areas where it occurs.

5.2.2.5. Distribution pattern of shola forests

The characteristic spatial distribution of shola forests in the Eravikulam National Park may be either due to the fragmentation/degradation of large shola into small sholas or formation/expansion of new sholas. In both the cases the process is increasing with the increasing altitude.

Fragmentation of shola occures either due to anthropogenic or natural factors like fire, frost, wind *etc.*. Small sized and more number of sholas may be due to anthropogenic cause whereas as the number of shola patches are increasing with increasing altitude can be explainable to the effect of frost and wind which is high with increasing altitude. The destruction of shola leads to scrub savanna which, on further degradation, gives rises to grasslands and ultimately to barren rocks (Meher-Homji, 1969).

If it is formation of new shola, the further expansion is prevented or controlled by frost, fire/grazing (Champion, 1936, Ranganathan, 1938, Bor, 1938 and Moher- homji, 1965), and ultimately due to the adverse natural conditions, the shola forests get shrinked towards sheltered pockets. If biotic influences ceased for several years, it is likely that sholas would spread on to area now covered by grasses (Noble, 1967). Srivastava (1994) states that the shola seedlings are expanding slowly in the grasslands by taking shelter of *Rhododendron* and *Hypericum*.

The regeneration of shola species (*Syzygium arnotianum*) in the edges conformed the role of ecotone vegetation is advancing the shola vegetation towards open areas. This indicates a positive trend towards succession (Karunakaran *et al.*, 1997) This trend analysis requires more detailed examination.

Number of shola patches are increasing from altitude 1701 to 2100 and from 2101 to 2500 there is a gradual decline. This may indicate that favorable altitude for shola is 2001 to 2100. 51.83% of total number of shola are in the altitudinal range of 2001-2200. Beyond 2200m elevation wind may be playing a major role in arresting the formation of shola.

Surface configurations plays a vital role in the eventual highly uneven distribution of grassland and shola (Noble, 1967). Under favorable conditions and within limits the shola is able to produce by itself the edaphic conditions necessary for extension (Ranganathan, 1938).

5.2.2.6. Encroachments

Plantations like Black Wattle and Eucalypts were raised in certain areas of southwest region of Pettimudi and southeast region of Vaguvarai. Plantations such as, *Eucalyptus globulus, E. terticornis, Acacia mearnsii, A. dealbata etc.* were raised commonly in all grasslands of Nilgiri and Palani hills but were not common in earlier days at Eravikulam National Park but is now becoming common due to the demand of timber and tannin.

According to Chandrasekharan (1962) the grasslands in the high ranges had been reclaimed by planting Wattle and Eucalypts on a large scale. Kerala Forest Department, Kerala Forest Development Corporations *etc.* made an attempt to afforest the grasslands of the Silent Valley plateau with exotic plant species.

The establishment of monoculture plantations in the high ranges gradually reduced forest cover about 50% to that the beginning of this century. Of this 82% were contributed by monoculture of teak, eucalyptus and wattle (Basha, 1990). An important feature of Black Wattle is that it spreads very quickly in burnt areas (Karunakaran *et al*, 1997).

One of the most disturbing environmental scenes in India is the accelerating deterioration and depletion of vegetation cover. The area under vegetal cover is fast deteriorating mainly due to demand on forest land. These demands arise due to (1) increase in density of population and rising expectations, (2) the very process of development and rehabilitation work (3) faulty land use practices and (4) low priority to forestry sector (Chaudhari *et al*, 1984). Unless something is done against this encroachment by National Park management authority, this highly fragile shola-grassland ecosystem may vanish soon.

CHAPTER VI

SUMMARY AND CONCLUSION

1. Vegetation Mapping

The study envisages ; phytosociological analysis of shola forests and the use of remote sensing for the mapping of shola and grassland vegetation of Eravikulam National Park. Three different scales of vegetation maps were prepared viz.:

a. Large scale detailed vegetation map of 1:25000 scale prepared from aerial photographs of 1:15000 scale.

b. Medium scale vegetation map of 1:50000 scale prepared from Geocoded false colour composite of 1:50000 scale of Indian Remote Sensing Satellite data.

c. Small scale vegetation map of 1:00000 scale prepared from false colour composites of 1:1,25000 scale of Indian Remote Sensing satellite data.

d. A general vegetation map of the area prepared by digital image processing of Indian Remote Sensing Satellite data.

In the map prepared from aerial photographs nine land cover classes were identified. They are Shola, Grassland, Subtropical hill forest, West coast tropical evergreen forest, Scrub, Tea plantation, Wattle plantation, Habitation and Rocks. Subtropical hill forests and West coast tropical evergreen forests were distinguishable from shola forests on aerial photographs. Shola forests were classified into three density classes viz.:

a. Low (1-25%)
b. Medium (26-50%) and
c. High (>50%)

In the map prepared from Geocoded False Colour Composite only seven land cover classes were obtained. West coast evergreen forests couldn't delineated on Geocoded False Colour Composite. Delineation of Subtropical hill forest, West Coast tropical evergreen forest from shola forests was not possible on standard False Colour Composite because they show similar tonal contrast. Habitation, as it is a very small unit, was not distinguishable on both types of imageries. It might have mixed with the units of grassland or rock. In the map prepared from Standard FCC the units of Subtropical hill forest, Evergreen forest and some rocky patches were merged with the units of shola forests. At the same time grassland could be delineated with almost maximum accuracy and comparable with the map prepared from aerial photographs. This emphasises that, for mapping of high altitude shola-grassland vegetation, small scale satellite imagery is not sufficient to extract maximum information.

By using digital image processing, three grassland communities were identified based on their spectral reflectance value. This could enable the quadrat study of grassland types. Digital maps, even though it is not so detailed as in the other maps are very useful to have an overall idea about the National Park and its surroundings. Digital maps are generated through computer processing of computer compatible tapes and it takes very little time compared to other maps prepared through visual interpretation.

The area estimation carried out using digital planimeter and the total area of the National Park is found to be 112 km^2 with the following broader groups viz. Shola forests comprises 19.95 km^2.(17.81%), Grassland 65.44 km^2. (58.42%). Southern subtropical hill forest 9.47 km^2.(8.45%), West coast tropical evergreen 0.2 km^2.(0.18%), Scrub 8.45 km^2. (7.58%), Tea plantation 0.74 km^2. (0.66%), Wattle plantation 0.99 km^2. (0.88%), Habitation 0.11 km^2. (0.09%), and Rock 6.57 km^2. (5.86%). Total area under degraded shola based on density is 0.36 km^2.

Comparative evaluation of different remote sensed data products indicate that the aerial photographs gives better resolution for stratifying vegetation types based on photoelements because of the higher scale factor and three dimensional features. In visual interpretation of satellite data it is rather difficult to delineate smaller units of shola forests from adjacent grasslands. In highly undulating terrain of rolling grasslands which is interspersed with shola forests, cover classification based on aerial photographs are preferred. But for general reconnaissance of larger areas the IRS imagery can be used conveniently.

Because of minute size of shola forests, which often appeared as small reddish dark spots in the satellite imagery, much effort is required to delineate very small units, which got often merged with the adjacent units, affecting the mapping accuracy.

There are many advantages of Geocoded False Colour Composites over standard False Colour Composites. Transfer of interpreted data on to base map is easy since it was subjected to the geometric correction with the orientation to the real north and Geocoded data available in the format same as the size of survey of India toposheets. Hence, the ground control points could be identified easily The study concluded that large scale photographs are preferred for mapping of shola and grassland vegetation.

2. Vegetation analysis

2.1. Shola

The study reveals the presence of 888 individuals under 50 species above 15cm. GBH belonging to 24 families in 0.7 ha. plot of shola forests. The dominant species of shola forests are *Syzygium arnottianum*, *Ixora notoniana*, *Mahonia leschenaulti* and *Maesa indica*. The most dominant family (family with maximum number of species) are Lauraceae (10), Rubiaceae (4), Myrtaceae (3), and Celastraceae (3). The family with maximum number of individuals are Myrsinaceae, Celastraceae, Myrtaceae and Rubiaceae.

The mean basal area of the shola forests in Eravikulam National Park is 25 m^2./ha. and basal area of different localities vary from 14.17m^2/ha to 32.75 m^2/ha. When basal area of individual species is considered *Syzygium arnottianum* represents maximum basal area (677.89 m^2). Distribution studies indicate that the trend is random followed by regular and contagious.

The mean maturity index value is 32 indicating the versatile nature of vegetation in the area. Continuum index value of the localities were between 1492.41 to 1640.45 indicating uniform environmental impact over the vegetation with respect to vegetation change.

The mean diversity index value of 2.87 suggests that the shola vegetation is relatively more diverse. The mean concentration of dominance value of 0.06 indicates that the possibility of having two individuals of the same species at random from a population of 100 pairs is 6 which means that the dominance is not concentrated within a small number of species. Similarity index value indicates that about 35.29% to 84.44% species are similar in a population of 100 individuals. Certain species were confined to all localities viz.: *Syzygium arnottianum, Mahonia leschenaultii* and *Maesa indica.*

2. 2. Sub tropical hill forest

Total area covered by sub tropical hill forest in is 9.47 km^2. 37 species were identified in a sample of 2500 m^2. plot studied. The stand density obtained was 948 individual/ha. Basal area of the stand is 44.16 m^2/ha. Maximum basal area was contributed by *Syzygium cumini* and *Bischofia javanica.* Diversity value is 3.37 and Concentration of dominance value is 0.04 indicating comparatively more diverse nature of vegetation. Dominant species identified are *Syzygium cumini, Bischofia javanica, Ardisia rhomboidea, Ficus nervosa, Canarium strictum, etc.* Maturity index is 19.35 indicating the vegetation is less mature than shola.

2.3. Grassland

Three grassland communities were identified. They are:

1, *Dichanthium polyptychum-Eulalia pheothrix-Chrysopogon zeylanicus-Schima nervosum.*

2. *Arundinella mesophylla-Andropogon lividis-Ischamum indicum-Chrysopogon zeylanicus-Schima nervosum.*

3. *Arundinella purpuria-Chrysopogon zeylanicus-Eulalia pheothrix.*

3. Spatial distribution of shola forests

Spatial distribution of shola forests indicate the following points:

1. The range of altitude in which shola forests exists are from 1700-2500m
2. The relationship between the number of sholas and the area of shola shows that 45.15% of the total number of sholas are distributed in the area classes 1-10 m^2 and 84.28% of sholas distributed in the area classes of 1-50 m^2.
3. The altitudinal distribution of sholas indicate that the number of sholas are increasing with the increasing altitude from 1701 m. to 2100 m. whereas mean area of sholas are decreasing with the increasing altitude.
4. The optimum altitude that favours shola forests is 2001 m. to 2200 m.

The characteristic distribution of shola forests in the Eravikulam National Park may be either due to the fragmentation/degradation of large sholas into small sholas or formation/expansion of new sholas. In both the cases the process is increasing with the increasing altitude. To establish which one of the process determines the present distribution pattern of shola forests require more detailed study on the succession of shola-grassland ecosystem.

4. Encroachments.

The invasion of the exotic flora into the Eravikulam National Park is very less compared to other high altitude regions. However, it was observed the encroachments of tea and wattle plantations taken place into the park. The boundary of the national park is not clearly demarcated in certain areas. In some areas the distinction between national park, reserved forest and estates are vague. Proper demarcation and strengthening of the boundary, as well as constant vigil over national park is necessary for the effective protection and conservation. Total area invaded by both tea and wattle plantations constitute about 1.7 km^2. The high tannin content in the bark of black wattle may change the physical and chemical properties of the soil virtually burning out any thing other than wattle.

5. Conservation and Management

Conservation of natural resources by means of *in situ* and ex-situ methods were largely appreciated and effective to large extent. Of these, in situ conservation of biodiversity and ecological uniqueness in their pristine forms require a viable through well documented area maps.

The present study results the quantitative and qualitative information of unique shola-grassland vegetation including the spatial distribution pattern of shola forests in relation with size and altitude.

In early days the management of national parks consists of protection of park area and its resources. But now park management involves manipulation of plant and animal communities, modification of external influence of man and nature, development and maintenance of aesthetic and recreational values of natural environment, health of animals and forests and other vegetation. Some or all these components require the same information in the form of vegetation map and structural aspects of vegetation for the better management programme.

Protected area managers must be able to asses and monitor vegetation as basis for manipulating it in tune with management objectives. This involves qualitative process such as floristic inventory, community description and photographic recording as well as quantification of factors such as vegetation cover. Information form qualitative and quantitative recording can be portrayed as vegetation map. In this regard, regular monitoring and periodical documentation of the shola-grassland vegetation of Eravikulam National Park is essential. For this purpose, remote sensing data of natural resources will act as a valuable aid.

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