# ECOLOGICAL STUDIES OF THE PARAMBIKULUM TIGER RESERVE IN THE WESTERN GHATS OF INDIA, USING REMOTE SENSING AND GIS

Thesis submitted to the

Cochin University of Science and Technology

For the award of degree of

Doctor of Philosophy

Under the faculty of Environmental Studies

By

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Department of GIS and Remote Sensing

Forest Management and Information System Division

Kerala Forest Research Institute, Peechi

2014

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Under the guidance of

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2014

# DECLARATION

I hereby declare that the work embodied in the thesis entitled '**Ecological Studies of the Parambikulam Tiger Reserve in the Western Ghats of India, using Remote Sensing and GIS**' submitted to the Cochin University of Science and Technology (CUSAT), Cochin, Kerala, India for the award of Degree of Doctor of Philosophy is a record of work carried out by me under the guidance of **Dr. A.R.R. Menon**, Scientist F, Dept. of GIS and Remote Sensing, Kerala Forest Research Institute, Peechi and no part of the thesis has formed the basis for the award of any degree or diploma earlier.

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12/02/2014.

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## CERTIFICATE

This is to certify that the thesis entitled '**Ecological Studies of the Parambikulam Tiger Reserve in the Western Ghats of India, using Remote Sensing and GIS**' is a bonafide record of research work done by the candidate **Mr. Magesh G.** in the Dept. of GIS and Remote Sensing, Kerala Forest Research Institute, Peechi under my supervision and submitted to the Cochin University of Science and Technology for the partial fulfillment of the requirements for the award of Degree of Doctor of Philosophy in Environmental Studies and no part of the thesis has formed the basis for the award of any degree or diploma earlier.

Peechi
03-02-2014.

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**Magesh G.**

*Dedicated to my Grand father …..*

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# Abstract

An attempt has been made to study the tropical forest biodiversity in the Parambikulam Tiger Reserve of Western Ghats using Geospatial technology. The major objectives of the study are Land use land cover mapping (LULC) and Phytodiversity analysis. Satellite data was used to map the land use / land cover using supervised classification techniques in Erdas imagine. The change for a period of 32 years was assessed using the multi-temporal satellite datasets from Landsat MSS (1973), Landsat TM (1990), and IRS P6 LISS III (2005). A geospatial approach was used for the land cover analysis. Digital elevation models, Satellite imageries and SOI topo sheets were the data sets used in the analysis. Vegetation sampling plots distributed over the different forest types were enumerated and studied for Phytodiversity analysis. Various diversity indices were calculated and compared with other forests of the Western Ghats.

The Parambikulam Tiger Reserve has a spectrum of forest types ranging from wet evergreen to dry deciduous within an area of 643.7 $km^2$. Vegetation and land cover type mapping using the IRS P6 LISS III satellite data of the year 2005 showed that the area is predominantly covered with Evergreen forest followed by moist deciduous forest and Semi evergreen forests. Altogether, seven land cover classes have been identified, assessment of change for the last three decades showed a considerable degree of degradation of intact forest cover to degraded forest and non-forest categories. The overall assessment from 1973 to 2005 indicated changes in the landscape.

About 479 species were recorded from all the forest types of the Sanctuary. Out of this 214 are of Tree species, Shrubs 78, Herbs 116 and Climbers 71. Among this, 290 species were recorded from the Evergreen forest, 196 species from Semi evergreen forest, 222 species from Moist deciduous forest, 64 species form Dry deciduous forest and 96 species from Teak plantation forest. Phytodiversity at ground level indicated that species richness is high in the evergreen forest while Shannon Weiner diversity was higher for Semi evergreen forest. The distribution of girth classes shows the classical negative exponential pattern which is a common feature found in the pristine forest (undisturbed) also. Of the total 479 species recorded from the 145 plots, 39 species are endemic to Western Ghats, 61 species are endemic to Southern Western Ghats and 7 species are endemic to Southern Western Ghats of Kerala, which is about 23 per cent of the total species represented from the sample plots.

Geoinformatics, a subject that evolved in the last few decades, has overwhelmed most other old generation techniques due to its tremendous spatial analysis capabilities and inferences. The present study, '*Ecological Studies of the Parambikulam Tiger Reserve in the Western Ghats of India, using Remote Sensing and GIS*' addresses the structural status of vegetation from landscape to species level, and land cover mapping explores the analytical findings of practical conservation.

Key words: *Parambikulam Tiger Reserve,* land cover mapping, Phytodiversity analysis, Remote Sensing, GIS.

Chapter 1

# INTRODUCTION

# CHAPTER – 1

# INTRODUCTION

## 1.1. General

Forest constitutes one of the world's important valuable natural resources and plays key role in global ecological balance. These living treasures of earth, have assumed much importance as they satisfy needs of the living beings and because of their significant role in the environmental harmony. For many years, the problems of deforestation in the tropical forest had raised considerable international interest. Forest ecosystem studies have expanded spatially in recent years to address large-scale environmental issues. Development of Remote Sensing and Geographic Information System (GIS) technologies have led to the betterment of mapping and interpretation techniques as a means of understanding and effectively managing the present resources sustainably.

Ecology had emerged as a branch of biological science in the recent past. Ecological principles have been the basis of conservation activities. An important aspect of the effects of environment on the life of an organism is the interaction of ecological factors. All the ecological factors are interrelated and variation in any one may affect the other. Human activities and the land surface systems are so complex that these are not the same over the large landscapes and from one time to the next. The presence of resources defines the utilization of a particular piece of land and changes in the land use land cover over a period. Ecosystem structures are driven by land use land cover practices in combination with its management practices. Understanding the impact of land use land cover processes on the biodiversity is a crucial issue and critical to study over the areas having high biological richness and economical importance.

At present, it is a fact that biodiversity is essential for ecosystem services and well-being of humanity. For conservation and management of bioresource and biodiversity in totality, identifying the drivers of biodiversity loss and monitoring their impact is an important issue, predominately in the regions, which harbors it. Biodiversity helps directly (through biological products) and indirectly (through ecosystem services) to well being of human and its society. It contributes much more than a material welfare, to security of life, social relations, health and happiness of individual. A sector of society round the globe have significantly benefited from actions causing changes in biodiversity over the last century. However, major part of the society has suffered decreased well-being.

Humans are fundamentally altering the diversity of life on earth, and many of these changes are irreversible. Across a range of taxonomic groups, either the population size or range or both, majority of species are currently declining. At a global scale, the number of species on the planet is declining rapidly. Over the past few hundred years, humans have accelerated the species extinction rate by between fifty and one thousand times background rates typical over the planet's history.

Forest cover is of great importance from the ecological point of view. It protects and stabilizes soils and local climates as well as soil hydrology and efficiency of the nutrient cycle between soil and vegetation. Forests are also the essential habitat of numerous plant and animal species. Virgin forests, especially those in the tropics are an irreplaceable repository of the genetic heritage of the world's flora and fauna.

Since "up-to-date" land cover information is needed and the progressive change in land cover over periods of decades is of interest, remotely sensed data should provide a better source for derivations of land cover due to internal consistency, reproducibility and coverage in locations where ground-based knowledge is sparse (Roy and Joshi, 2002). Thus, remote sensing is one of the potential tools to carry out vegetation mapping.

## 1.2. Research Background

Studies have shown that, there remains only few landscapes on the Earth those are still in their natural state. Due to anthropogenic activities, the Earth surface is being significantly altered in some manner and man's presence on the Earth and his use of land has had a profound effect upon the natural environment thus resulting into an observable pattern in the land use/land cover over time.

The land use/land cover pattern of a region is an outcome of natural and socio –economic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressure. Hence, information on land use / land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing hassle of increasing population.

Land use and land cover change has become a central component in current strategies for managing natural resources and monitoring environmental changes. The advancement in the concept of vegetation mapping has greatly increased research on land use land cover change thus providing an accurate evaluation of the spread and health of the world's forest, grassland, and agricultural resources has become an important priority.

Viewing the Earth from space is now crucial to the understanding of the influence of man's activities on his natural resource base over time. In situations of rapid and often unrecorded land use change, observations of the earth from space provide objective information of human utilization of the landscape. Over the past years, data from Earth sensing satellites has become vital in mapping the Earth's features and infrastructures, managing natural resources and studying environmental change.

Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analyses of Earth - system function, patterning, and change at local, regional and global scales over time; such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and management of biological diversity (Wilkie and Finn, 1996).

**1.3. Tropical Rainforest**

Tropical Rainforests are the greatest celebrations of life on earth (Myers, 1991) deserve special environmental attention, as they constitute the most biologically diverse terrestrial ecosystem. Tropical forests are important in at least two ways: one is the compositional organisation and the other to functional role it plays in maintaining the earth's habitability. The compositional organisation facilitates the tropical forests to contain more than half of all plant and animal species, even though its area is only 7% of the total land mass (Groombridge and Jenkins, 2000). As a result, 18 of the worlds 25 biodiversity hotspots owe their status to tropical forests (Myers *et al*., 2000). Tropical forests cover only seven percent of the earth's surface, but contain up to 60-70 percent of all living species. These are the one of the most complex and fragile ecological systems in the world. Not much has been studied on these ecosystems, mainly due to barriers like extreme climatic and geographic conditions. These forests are characterized by a variety of vegetation types due to climatic, edaphic and biogeographic factors.

Information on the distribution and abundance of tree species is of primary importance in the planning and implementation of biodiversity conservation. The diversity of trees is fundamental to total rainforest biodiversity, because trees provide resources and habitat structure for almost all other rainforest species. The disappearance of tropical forests comes at a time when our knowledge on their structure and dynamics is woefully inadequate. The results of quantitative inventory have enormous significance for the conservation and management of tropical forests.

Forest is a complex biotic community, which has tremendous power of self-maintenance. However, most of our forests have lost these qualities due to increasing biotic interference. For management of forest ecosystem, it is essential to evaluate them, in time, to get information about the structure and function (Rao and Mishra, 1994). The quality of habitat is generally reflected in the status of vegetation cover and its seasonal variation.

In India, as in many tropical regions of the world, forest degradation continues due to various factors such as, extension of cultivation, grazing, extraction of forest products, hydroelectric projects and commercial plantations. Because of these activities, in the Western Ghats, nearly 40 percent of the natural vegetation has disappeared during the last eight decades (Menon and Bawa, 1997). The rich and diverse vegetation wealth of India undoubtedly is due to its immensely varying climatic and geographical conditions with varied ecological habitats. Hence, it is essential to have a reasonably fair assessment of floral and faunal components of the biodiversity for optimum utilization of resources.

In ecological terms, rainforests have been defined as "multi-storied, closed, broad leaved forest vegetation with a continuous tree canopy of variable height and with characteristic diversity of species and life-forms" (Sneadaker, 1970). Tropical rainforests in particular possess an astonishing array of flora and fauna. In fact, at least half of the earth's species are found in rainforests.

Rainforests now cover less than 6 percent of earth's land surface. Tropical rainforests produce 40 percent of earth's oxygen. The tropical regions are endowed with a remarkably high level of biological diversity and habitat heterogeneity; so there are roughly twice as many species in tropical regions in comparison to temperate ones. In India, there are three ecological hotspots where these rainforest occur, *viz*., Western Ghats, North Eastern Himalayas and Andaman and Nicobar Islands. They harbour the largest number of species in the smallest area (Nayar, 1997). The environmental impacts of transforming forests through mining, forestry activities, shifting cultivation, agricultural development, wildlife exploitation and major engineering works are manifold.

Phytodiversity studies in tropical rainforest are important in the context to know the process or mechanism that maintain high diversity, species richness, within these forest at the same time providing a database about the number and status of the species existing in that area.

### 1.4. Geospatial assessment of tropical forest

Geospatial technology, which is the combination of remote sensing, geographical information system (GIS) and Global positioning system (GPS) provides effective tools in understanding the tropical forest complexity. The improvements in spatial, spectral, temporal and radiometric resolutions of remote sensing data over the past few decades have kept pace with the information needs for the assessment of forests. These developments have considerably increased the ability of ecologists to characterize the tropical forest more efficiently. Integration of Remote Sensing and GIS allow the reliable, accurate and updated database on the various resources of the Tiger reserve. This holistic approach not only allows identifying areas of resources exploitation, but also their need for conservation, maintenance and/or improvement of ecological and environmental condition.

### 1.5. Western Ghats

The Western Ghats, with a latitudinal range of more than 10 degrees, lies parallel to the West coast of India. Its forests are one of the best representatives of non-equatorial tropical evergreen forest in the world. The Western Ghats cover only 5% of India's total geographical area, but contain more than 27% of the country's total plant species. The number of total endemic plant species in the Western Ghats is estimated to be 1500 (Nayar, 1997). With a wide array of bioclimatic and topographic conditions, the Western Ghats have a high level of biodiversity and endemism. This has earned it a status as one of the biodiversity "hotspots" of our planet.

The Striking feature of the Western Ghats is the formation of tropical rainforests along its windward region. By virtue of its location, the Kerala State occupies biodiversity rich areas of the Nilgiri Hills, Anamalai High Ranges and

Agasthyamalai Hills of the Western Ghats. The formation of Palakkad gap separated the Nilgiri Hills from the Anamalai-Agasthyamalai Hill ranges. The latter, a remarkable group of hill range situated south of palakkad gap is more complex than others where we have the highest peak of south of the Himalaya *i.e*. Anamudi. The introduction of plantation crops and extension of Teak and Eucalyptus plantations have resulted in the unprecedented destruction of large areas of virgin forests along the Western Ghats. Establishment of large number of hydroelectric and irrigation projects resulting in the submersion of catchment areas rich in vegetation, have further accelerated regressive changes in the forest flora of the region.

**1.6. Biodiversity Assessment**

The biodiversity has remained as one of the central themes of ecology since many years. However, after the Rio's Earth Summit, it has become the main theme for not only ecologists, but also the biological community, environmentalists, planners and administrators. As many countries including India are party to the Convention on Biological Diversity, each nation has the solemn and sincere responsibility to record the species of plants and animals occurring in their respective countries assess the biodiversity properly and evolve suitable management strategies for conserving the biodiversity, which often described as the living heritage of man.

Measures of diversity are frequently seen as indicators of ecological systems. There are mainly three reasons why biodiversity should be studied. First, the need has come as many countries are signatories to the Convention on Biological Diversity. Secondly, despite changing fashions and preoccupations, diversity has remained the central theme of ecology. The well documented patterns of spatial and temporal variation in diversity which intrigued the early investigators of the natural world continue to simulate the minds of ecologists today. Thirdly, considerable debate surrounds the measurement of diversity. It is mainly due to the fact that ecologists have devised a huge range of indices and models for measuring diversity. So for the various environments, habitats and situations the species abundance models and diversity indices should be used and the suitability evaluated.

As rates of habitat and species destruction continue to rise, the need for conserving biodiversity has become increasingly imperative during the last decade (Wilson, 1988). For effective planning and sustainable utilization of forest resources, measurable indicators of its composition, structure and functioning must be identified (Noss, 1990). Conservation strategies that are prepared, based on the data on vegetation such as species composition, distribution pattern and diversity status of any forest region along with Remote sensing data and GIS would be very much reliable and operational. Therefore floristic ground survey must be carried out in any forest region in order to obtain the above said information.

In India with the advent of its new National forest policy during 1988, the objective of forest management has been shifted from timber production to biodiversity conservation. To meet this objective, it is necessary to collect quantitative information on the vegetation.

## 1.7. Land Use Land Cover (LULC)

Land use and land cover are two types for describing land. Land use is a description of the way that humans are utilizing any particular piece of land for one or many purposes. Land cover is the physical material on the surface of any piece of land. Land use/land cover information is essential for a number of planning and management activities. The existing land use patterns, because of their strong influence on how land could be used in future, become a crucial factor in deciding as to how land development, management and planning activities should be undertaken. Most of the natural resources are directly or indirectly related to the surface cover in a given locality. Therefore, to maintain harmony among sustainable resources and socio-economic needs, land cover and land use studies should be dealt with care.

Land cover, the composition and characteristic of land surface elements is key environmental information. It surrogates many scientific resource management and policy purposes and a range of human activities. Although land cover mapping is one of the earliest applications of aerospace technology, routine mapping over large area has recently come under consideration. As international focus on environmental change led to land cover characterization, research and development started in ninetees. With the impending threat to environment, land cover mapping is now being given the highest priority. Information on land cover plays a vital role in environmental research, including studies of habitat characterization, biodiversity assessment, biogeochemical processes, net primary productivity, hydrological processes *etc*. These serve as a scientific basis for planning future land use, especially with regards to forestry, range management and agriculture (Kuchler, 1988).

Information needed in forestry involves characterizing the location, area, and status of the forest resources and the change in spatial and time domains. The scientific community has looked increasingly towards the remotely sensed data as a means of obtaining more accurate land cover information for wide range of applications because of its receptivity and internally consistent measurements. Geospatial technologies, such as remote sensing, Geographical Information System (GIS), and Global Positioning System (GPS) provide vital support to collect, analyze and store all types of geospatial information. Vegetation characteristics derived from remotely sensed data are particularly important for both qualitative and quantitative forest assessment. It helps to assess the structure of the vegetation cover and model the functions involved within this.

### 1.8. Vegetation Mapping

Vegetation is the primary producer of any ecosystem. Therefore, the natural vegetations could be considered as one of the most important components on earth as it governs all forms of life. They provide food, oxygen, fertility and finally the life for all living being on earth. Vegetation cover shows much variability across the globe. They are classified at different levels based on their specific features. However, the vegetation alone does not give rise to these different ecosystems. These terrestrial ecosystems in which the vegetation communities plays the major role are closely coupled with their surrounding environments; any change in their surrounding environments will be reflected by these vegetation communities.

Different studies have been carried out at different spatial and temporal scales for identifying the vegetation dynamics as well as the relationships among different vegetation types and their surrounding environments. Over the past century, significant changes at global and regional level have been observed in climate as well as in vegetation cover. However, it is evident that the vegetation is closely interrelated with their surrounding environments. Changes in different climatic parameters could affect on vegetation cover at varying levels. They can be severe and even detrimental on some forms of vegetations and can be minor on some others. Hence, an equal attention has to be paid on the vegetation dynamics. More importantly the relationships that could exist among these interrelated components have to be identified in order to make accurate and realistic predictions on the changing conditions of the vegetation as well as the climatic parameters.

Vegetation Cover is a spatial description of the land surface that responds to global climate, determining major fluxes in the biogeochemical cycle of the earth system. Even though the land surface occupies only 30% of the globe and the oceans are the primary driving force for the Earth's physical climatology, vegetation cover influences the planet's biogeochemical cycles. Vegetation mapping is an important part of natural resource inventory and management, along with effort to develop baseline data for any area, region or country. It is the processes of displaying the geographic relationship of objects and features. Although maps show objects with respect to attributes, their principal purpose is to depict objects in terms of their relative location (Thakker *et al*., 1999). Vegetation cover mapping has been practiced for centuries and has produced archives of maps and atlases (Mathews, 1983). Since these maps have been produced at different times and by various methods, widely different descriptions of land cover distribution result (DeFries and Townshend, 1994) are available. There is a wide diversity of classification systems in use, and a wide diversity of ecosystems and vegetation that researchers are dealing with.

Effective management of forest ecosystem needs knowledge about their potential, extent and composition. This information is the basis for understanding and analysing the forest cover dynamics and restoring the same. There is necessity to obtain reliable data about vegetation resources at various levels. It will help in planning forest management strategy for sustained yield and benefits for the society. The standard source of such information has been vegetation mapping.

### 1.9. Application of Remote Sensing and Geographical Information System for studying Vegetation cover

Remote Sensing is the science and the art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Lillesand and Kiefer, 1994). Remote sensing due to its capability to provide timely, synoptic and repetitive coverage over large areas across various spatial scales, have made it a very powerful tool for monitoring the forest resources. Remote sensing as well as the related technologies such as digital image processing, Global Positioning System (GPS) and Geographic Information System will continually help to manage and to protect the forest resources.

Remote Sensing is a powerful technique for Surveying, Mapping and Monitoring earth resources. Remote Sensing and Geographic Information Systems (GIS) can be a useful tool inpreparing spatial extent of different vegetation type, forest crown density and monitoring. The synoptic and repetitive coverage and real time data provided by orbiting satellites have opened up immense possibility in terms of resource mapping, resource management, resource targeting, disaster monitoring and assessment and environment monitoring. Remote Sensing and GIS techniques combined together will form effective tools in planning, decision making, and managing entire landscape

Satellite data is capable of satisfying the classification and mapping needs in the country with reasonable accuracy and is cost effective. Recent developments in remote sensing have indicated that, if this information is judiciously combined with ground based studies, it is possible to carry out detailed forest inventories and monitoring of natural vegetation cover (Tucker *et al.*, 1985; Botkin *et al.*, 1984). Remote sensing data based maps showed utility to identify, classify landscapes and to study its structure, function and changes (Troll, 1971). Thus remote sensing data has been accepted as a basic input in studying principles of landscape ecology and management of landscapes.

Geographic Information System (GIS) gives a strong opprotunity to analyse environmental problems by linking remotely sensed data with geographical data. Remotely sensed data are finding acceptability as primary source of information for GIS with the transformation of data to information provided by image interpretation (Trotter, 1991). The integration of RS and GIS known as Geospatial Analysis is a crucial tool for the challenges resources manager face now and into the first twenty first century. It allows us as resource managers to develop, analyse, and display spatially explicit to deal with larger spatial scales such as regional landscapes. At its most fundamental level, Remote Sensing provides a means by which data can be produced and analyzed for an area and then incorporated in decision making or procedures (Colwell, 1983). GIS may be the most important technology resource managers have acquired in recent past.

At present, usage of remote sensing technology for various resource monitoring has not only been tested and demonstrated, but is also being routinely applied in an operational way. Satellite remote sensing has demonstrated a large potential to obtain information especially for high resolution sensors. However, the spatial and spectral bands in which sensors collect the remotely sensed data are two important parameters in mapping and development of forest resource information system.

Over the past decades the satellite based techniques and the use of remotely sensed data have achieved a major progress and is now becoming a promising approach in wider range of disciplines. Earth orbiting satellites are increasingly being used as data sources leading to a better formulation of issues surrounding global changes. The flexibility of these earth-orbiting systems in terms of resolution has been found very compatible with the objectives of monitoring land cover.

Remote sensing techniques have a number of advantages over the conventional techniques that largely demands both time and money. Their ability to produce multi temporal images at frequent intervals and at varying levels of spatial resolutions facilitates temporal monitoring of vegetation over an area. Over the last century, these satellite based technologies have been developed rapidly as a promising approach in a wide range of applications and is being used extensively in vegetation dynamic related studies all over the world.

### 1.10. Need of the study

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. Information about the spatial status and distribution pattern of vegetation types and their changes are necessary for planning, utilisation and management of the wildlife sanctuaries. Vegetation classification and mapping have been considered significant in deriving basic information in the ecosystem conservation and management of Wildlife Sanctuaries (Muller-Dombois and Ellenberg, 1974).

Remote sensing forms a valuable tool in mapping and monitoring of biodiversity and provides valuable information to quantify spatial patterns, biophysical patterns, ecological process that determine species richness and anthropogenic factors causing loss of species richness and for predicating response of species to global changes. Information on existing land use / land cover, its spatial distribution and change are essential requisite for planning (Dhinwa, 1992). This land use planning and land management strategies hold key for development of any region. The conventional methods of detecting land use/ land cover changes are costly and low in accuracy. Remote sensing because of its capabilities of synoptic viewing and repetitive coverage provides useful information on land use / land cover dynamics (Sharma *et al*., 1989).

The rapid depletion of forests made it essential to know the rate and trend of this degradation so that timely measures could be taken to prevent further loss of forest resources. Timely and accurate information for detecting changes over a period of time is required for Forest Ecosystems. This can be done through repetitive and cost effective technique of remote sensing. Accurate forest cover/vegetation map information is essential for formulating various management plans.

Study of protected areas provides ample scope for evolving suitable management policies. As the protected areas are the prime centers of conservation and diversity, scientific information on bioresources needs to be collected and documented for sustainable use and conservation. Detailed biological studies in such hotspot areas provide ample scope for formulating effective management practices. Greater diversity in the climatic, geographic and edaphic factors in this region cumulates with microclimatic fluctuations within the habitats derives the crucial and tangible diversity. In this context, the present study envisages an ecological study with the help of geospatial tools of Parambikulam Tiger Reserve, a protected area with unique phytogeography, rich and diverse flora and fauna, in the lap of Anamalai High Ranges, one of the hotspots areas of great ecological and environmental significance.

Located immediate south of Palakkad gap in the Anamalai High Ranges, Parambikulam Tiger Reserve enjoys diverse phytogeography , and the Western Ghats meets the Deccan Plateau endowed with floristic elements of these regions with the Nelliampathy Ghats in the north and Anamalai in the south prop up the diversity. Substantial teak bearing moist deciduous forests in the beautifulParambikulam valley were clear felled for the extraction of timber. Subsequently, establishment of large extent of teak plantations and construction of three reservoirs caused the incomprehensible devastation of vast areas of natural forests. The plantation activities in the Nelliampathy hills also caused further erosion to the plant diversity of the region. Even after the heavy devastation of the forested areas, the tiger reserve, especially in Parambikulam valley, remains species rich due to the inaccessible pristine forests at the top of hills and valleys of Karimala and Orukomban, which lodge a number of rare and threatened plants. Thus biodiversity documentation of a protected area like Parambikulam Tiger Reserve is of great significance.

No detailed vegetation analysis has so far been carried out for this tiger reserve, excepting perhaps for some passing references in Forest Working Plans based on some randomized sampling of plots. The present study based on advanced geospatial techniques followed by detailed phytosociological analysis reveals the following very interesting information, which is new to science and to this area.

### 1.11. Objectives

The proposed study envisages the following specific objectives:

1. To assess the Land use /Land cover pattern of the study area.
2. Phytosociological analysis of the different forest types of the reserve and assessment of plant diversity.

Chapter 2

# REVIEW OF LITERATURE

# CHAPTER – 2

# REVIEW OF LITERATURE

## 2.1. Forest Ecology

Tropical forest occupy less than seven percentage of the terrestrial surface, yet contain more than half of all plant and animal species (Groombridge and Jenkins, 2000). Moreover, they are the most genetically diverse terrestrial communities on earth (Hubbel and Foster, 1983). They are exceptional because of their species richness (Kraft *et al*., 2008), high standing biomass and carbon storage (Bonan, 2008) and global net primary productivity (Sabine *et al*., 2004). The systematic studies on tropical forest ecology were initiated by Hubbel (1979). Biodiversity surveys and ecological studies have mainly focused on areas with a high concentration of plants and animal diversity, intact biological reserves and protected areas with low level of human intervention (Fazey *et al*., 2005). The absence of baseline data and the lack of monitoring mechanisms have severely hampered the conservation of tropical forests. A number of attempts have been made to understand the compositional organization of tropical forest (Hubbel, 1979; Hubbel *et al*., 1999; Myers *et al*., 2000; Condit *et al*., 2002; Forest *et al*., 2007 and Kraft *et al*., 2008).

Ecological systems do not exist as discrete units but represent a continuum on an environmental gradient consisting of different land cover types in the form of landscapes. Landscapes represent a mosaic of interacting ecosystems in relatively large to very large areas consisting of patches of land use and land covers (Forman and Godron, 1986). High quality information on the extent and distribution of land cover types is an essential prerequisite for management of landscape. It is one of the easily measured indices to assess the effects of changing environmental conditions.

An understanding assumption of many forest ecology and forestry practices is that vegetation communities are largely influenced by the dominant species in an association, and that understanding the distributions of the largest, most abundant woody species will lead to an understanding of vegetation communities and their functional role as a whole (Eyre, 1980).

Assessment of the patterns of biodiversity over space and time, and across environmental gradients is crucial to understand their origin, function and maintenance. Considering the above factors, many studies have carried out randomly or stratified randomly using small sized plots to address the various components of diversity. Study by Davidar *et al*., (2007) at macro scales (entire Western Ghats) points out that seasonality is the primary driver of beta diversity. Similarly, alpha diversity is also highly correlated with seasonality Davidar *et al*., (2005). However alpha diversity is mainly related to the rainfall gradient (Ramesh *et al*., 2010). Study by Joseph *et al*., (2008) in Mudumalai wildlife sanctuary indicated that species richness has the highest correlation with drainage density (a complex interplay of climate and topography).

In addition, floristic composition studies such as Pascal, 1988; Chandrasekhara and Ramakrishnan, 1994; Ganesh *et al*., 1996; Parthasarathy and Karthikeyan, 1997; Parthasarathy, 1999, 2001; Srinivas and Parthasarathy, 2000; Devy and Davidar, 2001; Dutt *et al*., 2002; Giriraj *et al*., 2008; Addo-Fordjour *et al*., 2009; have also yielded a wealth of data on the tree diversity.

The advancement of Geospatial technology opened up a new arena to understand the ecology of tropical forest and to analyze changes in tropical forest conditions (Johnston, 1998; Wardsworth and Treweek, 1999; Kerr and Ostrovsky, 2003; Turner *et al*., 2003; Pettorelli *et al*., 2005; Townsend *et al*., 2008).

## 2.2. Vegetation mapping

Vegetation is the primary producer of any ecosystem and thereby governs all forms of life on earth. Therefore, it is being considered as one of the most important components on earth. Classical reviews of vegetation classification are those given by Champion (1936), Chandrasekharan (1962a, 1962b, 1962c, 1962d) and Champion and Seth (1968). Of these, most widely accepted forest classification system is that of Champion (1936) and Champion and Seth (1968). Even though Champion and Seth's (1968) system of classification is widely used, several drawbacks were pointed out in the classification (Puri *et al*., 1983). In management of natural vegetation special assessment of land cover data along with structural appraisal are essential. The remote sensing derived vegetation map provides perspective horizontal view and helps in delineating different landscape elements and their spatial characteristics (Gordon, 1991). Shirish and Roy (1993) used satellite derived vegetation map for analyzing landscape elements of Madhav National Park, M.P. Vegetation mapping using interpretation of satellite remote sensing data provides qualitative characteristics of vegetation and can be adjusted to the requirements/objectives of the survey (Kuchler, 1988). Vegetation/land cover classification and mapping have been attempted for southern part of the country by French Institute, Pondicherry in collaboration with various State Forest Departments (Legris and Meher-Homji, 1968). Vegetation pattern analysis, monitoring and conservation of natural resources of Rudraprayg were undertaken effectively by Raturi and Bhatt (2004). Land cover mapping of East Champaran district of Bihar State was done using IRS-1D LISS 3 Satellite data by Manju *et al.,* (2005).

Projections of future land cover patterns are needed to evaluate the implication of human action on the future of ecosystems (Turner *et al*., 1995). Models that predict future land cover pattern can support generation of plausible scenarios for accessing land cover conditions under a range of assumption about rates and patterns of change that reflect current and recent trends (Brown *et al*., 2002). Forest vegetation patterns along an altitudinal gradient in sub-alpine zone of west Himalaya, India was studied by (Gariola, 2008). Vegetation Cover Mapping and Landscape Level Disturbance Gradient Analysis in Warangal District, Andhra Pradesh, using Satellite Remote Sensing and GIS were done by Reddy *et al*., 2008. Vegetation pattern analysis of Karuvannur watershed, Kerala using remote sensing and GIS was done by Renjith *et al*., (2010).

### 2.2.1 Relevance of Remote Sensing and GIS in Vegetation mapping

Remote sensing is defined as the science of deriving information about an object from measurements of electro-magnetic radiation reflected or emitted from the object (Lillesand and Kiefer, 1994). The history 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 17th April, 1986. Geographic information system is a set of tools for collecting, storing, retrieving, transforming and displaying spatial data from the real world for a particular set of purposes (Burrough, 1986). Storing, retrieving and analyzing landscape ecological parameters in GIS using spatial data structures form a powerful base for multi-scale studies of landscape ecosystems in Geographical Information System (Menon and Bawa, 1997). Satellite based remote sensing has found a very valuable application in forest management, not only for surveys, but also for studying the role of forest in maintaining ecological balances and elucidating their impact on global climate (Rao, 1990). A considerable amount of work has been carried out in India to the various aspect of forest management using visual and digital analysis of satellite data (Madhavanunni, 1990; Madhavanunni *et al*., 1991; Jadhav *et al*., 1991). Remote sensing surveys have helped to understand the status of our forest and to initiate steps to increase the forest cover (Chandrasekhar *et al*., 1991). Monitoring forest cover using satellite remote sensing techniques with special reference to Wildlife Sanctuaries and National Parks was conducted (Madhavanunni, 1983) to assess the qualitative changes in the forest cover of Wildlife Sanctuaries and National Parks in India. Porwal and Roy (1991) used 1:50,000 Landsat Thematic Mapper False Colour Composite (TM FCC) for delineation and mapping of heterogeneous forests of Western Ghats, Kerala. The forest cover map of India was prepared by visual interpretation of Landsat imagery of the year 1991-1993 by Forest Survey of India (Annon, 1993). Roy *et al.*, (1992) used 1:50,000 Landsat TM FCC for mapping Chandaka Wildlife Sanctuary in Orissa. Roy *et al*. (1993) mapped tropical forests of Andaman Islands using Lands TM FCC of 1:50,000 scale and identified nine landcover classes. Forest cover map of Corbet National Park was prepared by Anjana *et al.,* (1999), using IRS 1B LISS 2 data. Biodiversity characterization of Western Ghats was done by National Remote Sensing Agency

(Anon, 2002) using Satellite remote sensing and GIS. Menon and Sashidharan (1990) evaluated different digital techniques for land cover mapping. Menon (1991) mapped rubber area using IRS 1A data. Menon and Ranganadh (1993) used IRS data for mapping Silent Valley region. Kushwaha (1990) studied the Forest-type mapping and change detection from satellite imagery. Giriraj *et al.,* 2008 studied the spatial forest cover change patterns in the Kalakad-Mundanthurai Tiger Reserve (KMTR), South Western Ghats (India) using time series remote sensing data from 1973, 1990 and 2004.

Daniel (2007) studied the application of RS and GIS in the Land cover mapping and change detection in a part of south West of Nigeria. Several studies demonstrated the ability of remote sensing data to assess terrestrial vascular plant species diversity (Stohlgren *et al*., 1997; Gould, 2000; Griffiths *et al*., 2000; Nagendra, 2001; Murthy *et al*., 2003; Asner *et al*., 2008; Mc Roberts, 2009). Goparaju *et al.,* (2005) used GIS and RS to analyze the effects of fragmentation on plant diversity. Murthy *et al.* (2006) reviewed the scope of a geo informatics based biodiversity programme in India. Varghese and Krishna Murthy (2006) attempted to use geo informatics as a tool for conservation of Rare, Endangered and Threatened (RET) plant species. Magesh *et al.,* (2010) studied the Phytodiversity assessment of Parambikulam Wildlife Sanctuary using geospatial approach.

### 2.3. Phytosociological studies

Understanding of vegetation composition, diversity of species and their habitats, and comparison with similar other habitats, may become a tool to estimate the level of adaptation to the environment and their ecological significance. Vegetation ecology is the study of both the structure of vegetation and vegetation systematic. This includes the investigation of species composition and the interrelationship of species in communities. It further includes the study of community variations in spatial or geographic sense, and the study of community development, change and stability in the time sense (Muller-Dombois and Ellenberg, 1974).

Some phytosociological work done in Kerala are by Singh *et al.,* (1984) for Silent Valley, Basha (1987) for the evergreen forests of Silent Valley and Attappadi, Menon and Balasubramanian (1985) for Trichur forest division and Pascal and Pelissier (1996) for tropical evergreen forests of southwest India. Jayakumar *et al*., (2002) conducted forest type mapping and vegetation analysis of Kolli hills. Jayakumar (2003) conducted a detailed floristic and phytosociological study in New Amarambalam Reserved Forests of the Nilgiri Biosphere Reserve, Western Ghats of India. Tree species diversity of Sitaphar forest reserve was done by Nath*et al.,* (2000). Density, frequency, abundance, IVI *etc*. were worked out by Phillips (1959) and Muller-Dombois and Ellenberg (1974). Shannon and Wiener (1949) equation has been widely applied to quantify anything that came in hand particularly, species diversity. Simpson (1949) proposed another index to study the Floristic diversity and Concentration of dominance. Margalef (1958) and Menhinick (1964) developed indices for quantifying species richness. Singhal and Soni (1989) analysed vegetation of woody species of Masoori. Biodiversity assessment and population density of woody species of tropical wet evergreen forests of Courtallum was carried out by Parthasarathy and Karthikeyan (1997). Kushawa *et al.,* 2012 studied the Species diversity and community structure in sal (Shorea robusta) forests of two different rainfall regimes in West Bengal. Magesh *et al.,* (2011) studied the vegetation status, species diversity and endemism of the forests in southern Western Ghats of Kerala. In addition to these, many studies have been made on phytosociological aspects of forest vegetation in Kerala by Menon, (1978, 1981, 1991, 1999, and 2006). The floristic inventories of the protected areas, forest divisions and administrative districts in Kerala have been compiled by Manilal and Sivarajan, 1982; Mohanan and Henry, 1994; Sasidharan, 1997, 1998, 1999, 2004a, 2004b, 2006, 2007; and Sivarajan and Mathew, 1997. Taxonomic knowledge is crucial to meet the challenges of biodiversity conservation in the 21$^{st}$ century (Bhaskaran *et al*., 2010).

Chapter 3

# STUDY AREA

# CHAPTER -3

# STUDY AREA

## 3.1. Location

Geographically Parambikulam Tiger Reserve (PKTR) lies between the longitudes 76º 30' and 76º 55' East and latitudes 10º 15' and 10º 35' North. The Tiger Reserve is situated in Palakkad and Thrissur district in the state of Kerala and the drainage basin is Chalakkudi River. Parambikulam Tiger Reserve has an area of 643.662 $km^2$, of which 390.89 $km^2$ comprises the core zone and 252.772 $km^2$ the buffer zone (Fig. 3.1 and Fig.3.2). The Tiger Reserve lies in between the Anamalai hills and Nelliampathy hills. Tropical Evergreen Forests, Moist Deciduous Forests and Teak Plantation Forests are the prominent biogeographic Biomes. The differential rainfall coupled with edaphic formation is attributed to the various biome formations. The Tiger Reserve represents one of the country's major centres of biological endemism in its evergreen and semi-evergreen Biomes.

Parambikulam Tiger Reserve lies immediately south of Palghat gap in the Western Ghats. Parambikulam had been well known for rich forests and wildlife. Forest of the Parambikulam valley is one of the most intensively worked forest stretches in the state. The Parambikulam-Aliyar project and associated dams that came up in sixties and extensive teak plantations extending over almost 100 $km^2$ had tremendous impact over the biodiversity of the forest tract. Parambikulam Tiger Reserve is the upper catchment area of the Chalakkudy River. The tribal communities *viz*. Kadars, Malasars and Muduvas live inside the reserve in five settlements.

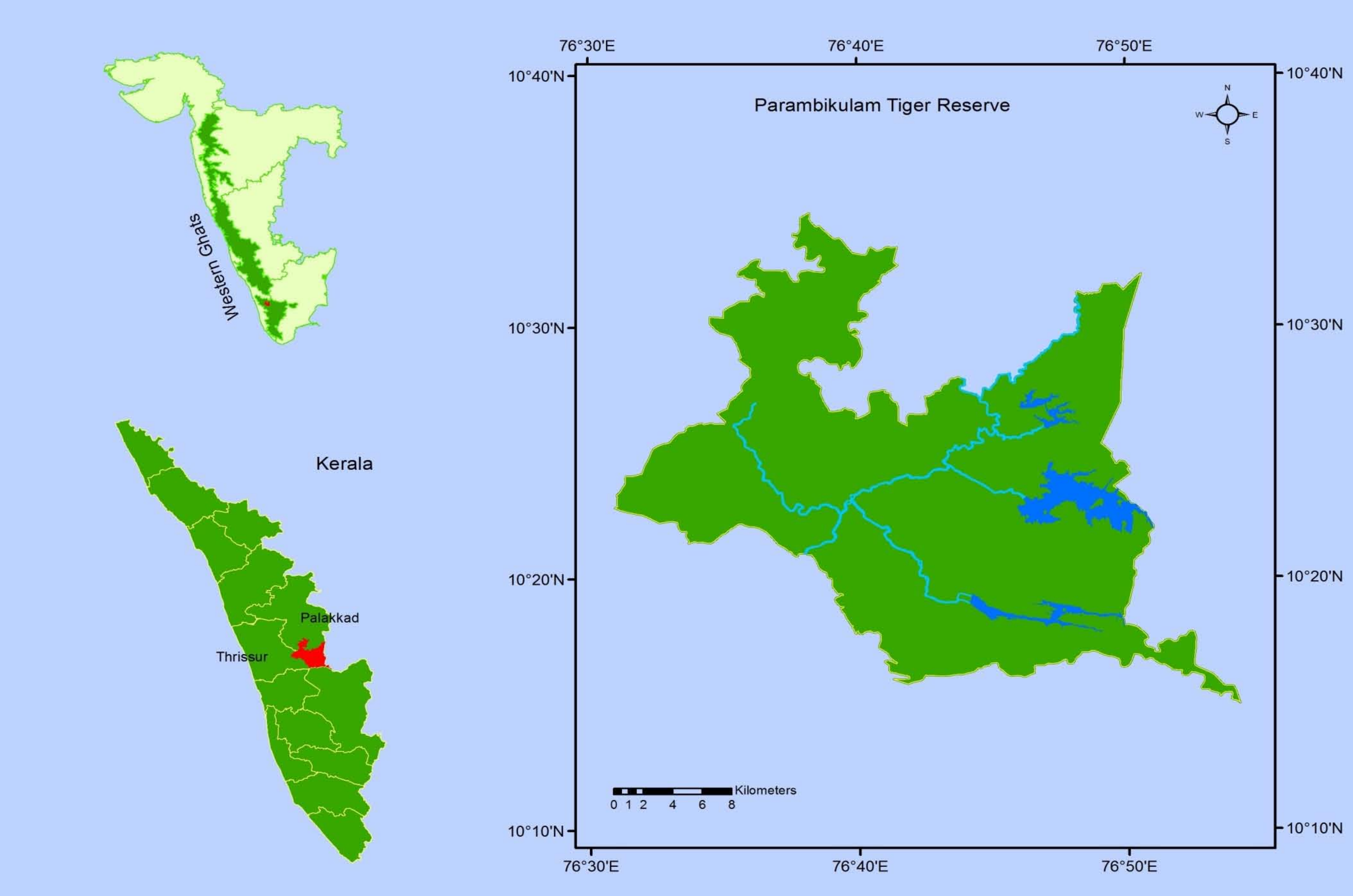



Fig. 3.1 Study area map

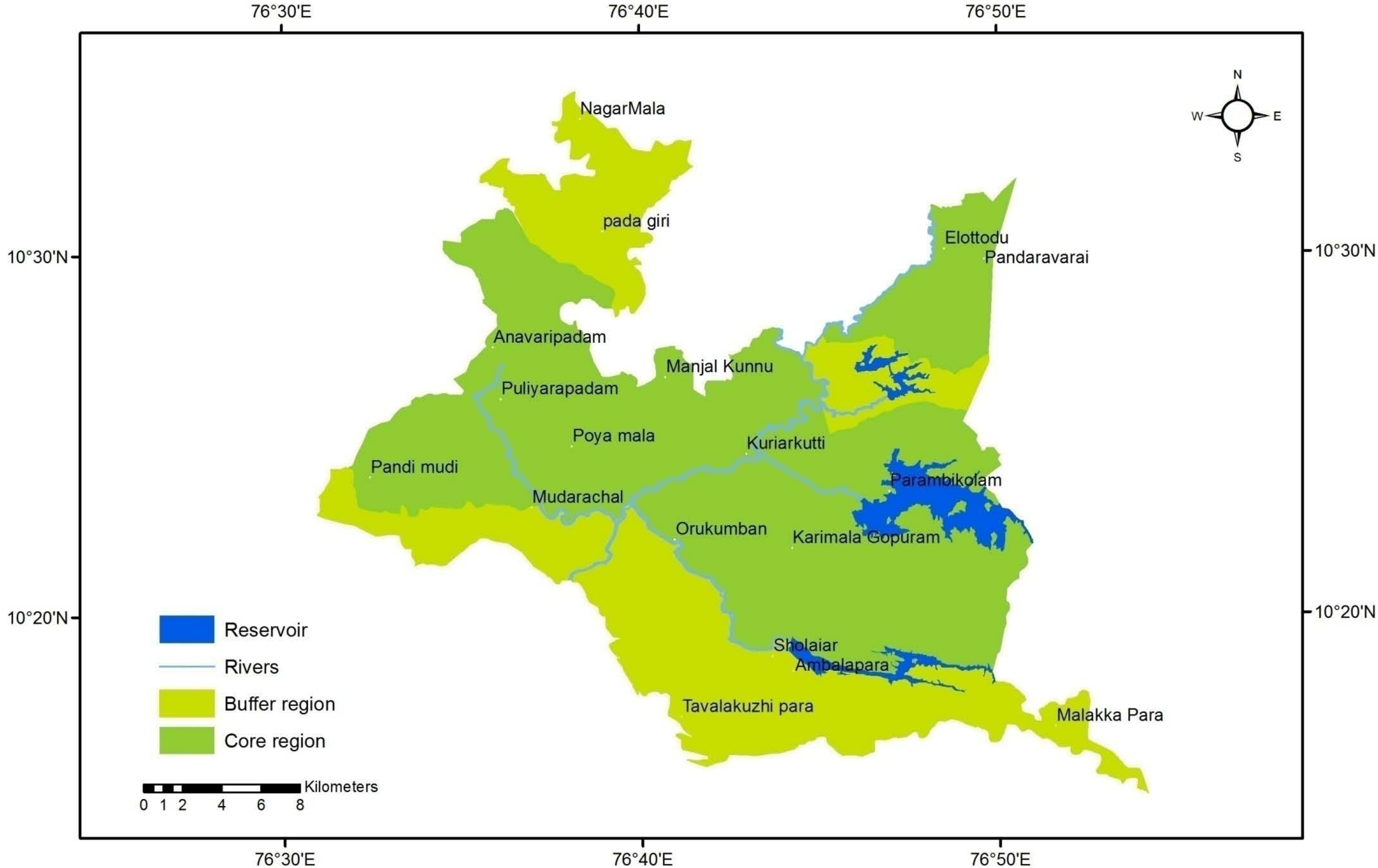



Fig. 3.2 Core and buffer zones of PKTR

In 1962 a small sanctuary was established in Sungam Range of Nemmara Forest Division. The area of this sanctuary was enhanced to 285 $km^2$ in 1973 and the present Parambikulam Tiger Reserve was notified in 2010. Parambikulam Tiger Reserve has an area of 643.662 $km^2$, which is contiguous with the Anamalai Wildlife Sanctuary of Tamil Nadu. Of the 643.662 $km^2$ of the tiger reserve, 390.89 $km^2$ comprises the core zone and 252.77 $km^2$ the buffer zone. The Parambikulam Wildlife Sanctuary spans over an area of 285 $km^2$ and the tiger reserve comprises 235 $km^2$ of the sanctuary and areas from the adjacent forest divisions of Nemmara, Vazhachal and Chalakudy. There are 10 forest ranges coming under the PKTR (Fig. 3.3). The areas of housing the dam and the colonies were excluded from the core area. The buffer zone comprises 11 tribal colonies. Since the year 2010 has been declared as the International Biodiversity Year and 2011 as International year of Forest, the declaration of the tiger reserve is an important step in protecting this biodiversity. Parambikulam Tiger Reserve is the 38$^{th}$ Tiger Reserve in India and is the second tiger reserve of Kerala state after Periyar Tiger Reserve in Thekkady.

Parambikulam is really an all-in-one Tiger Reserve. It is endowed with luxuriant vegetation and all kinds of magnificent wildlife of the State. It is one of the best tiger reserves in the country for viewing the savage beauty of gaur, the awesome majesty of elephant and the 'fearful symmetry' of tiger. Chirping birds and gurgling streams make this reserve lively and lovely. Of all the sanctuaries in Kerala Parambikulam has the largest gaur population. Sambar, spotted deer, jungle cat, and lion tailed macaque; common otter, sloth bear, etc. are also common. There are also a good number of tigers and leopards. Earlier known by the name of Parambikulam Wildlife Sanctuary, the reserve contains around 20 Tigers.

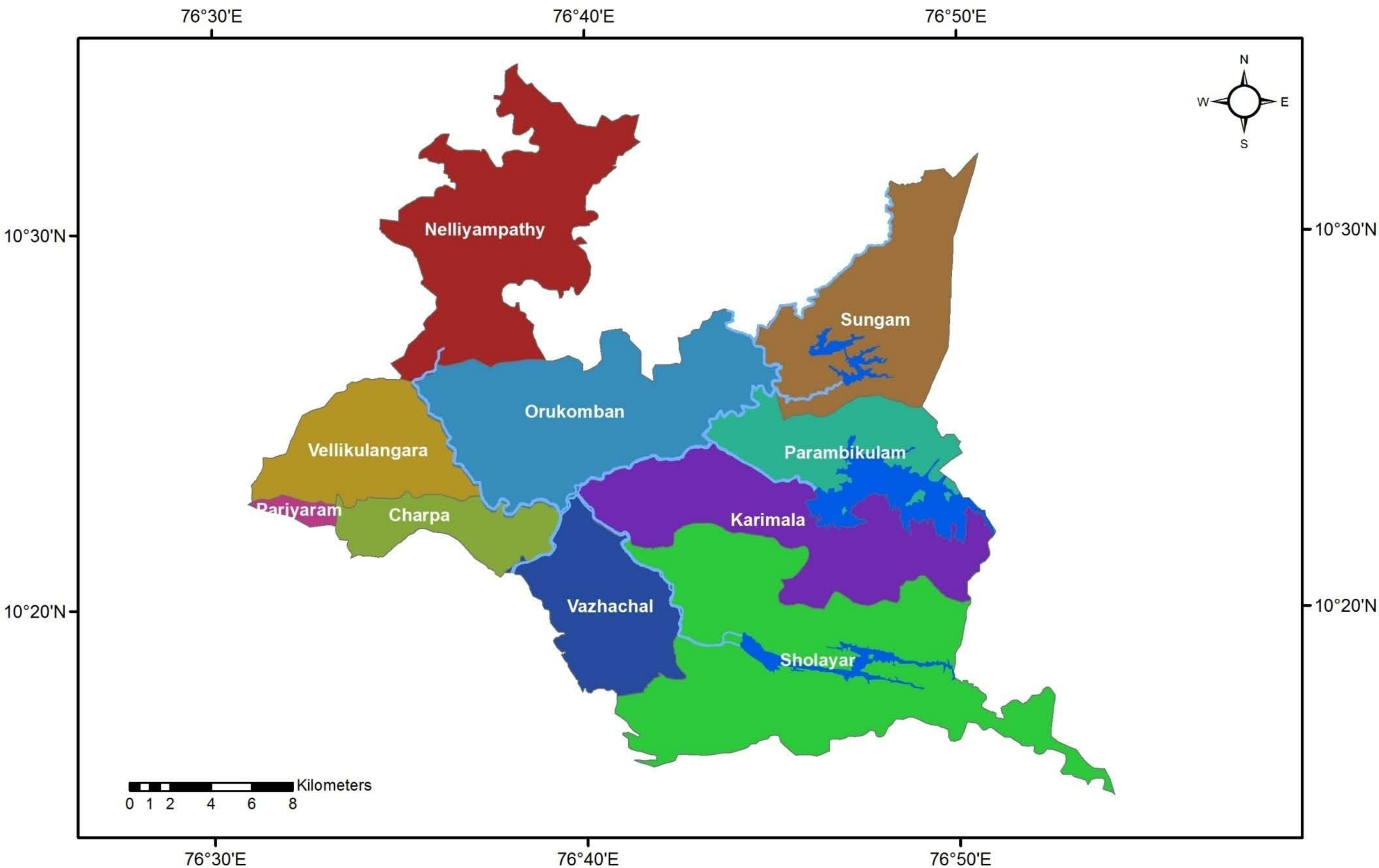



Fig. 3.3 Forest ranges in PKTR

## 3.2. Topography

The tiger reserve exhibits hilly terrain with characteristic distribution of undulating plains interspersed with marshy fields in the valleys. The altitude varies between 84m and 1527m, and the highest peak is Padagiri which has an elevation of 1527m. The mountain slopes are non-symmetrical and non-uniform, spread throughout the area in different directions. The mountain ridges, which have well defined valleys, slope down straightly to streams, which permit denser growth of vegetation in those regions. The ridges of the reserve are of sheet rock and are exposed at the top. Some of the hilltops have a thin crust of soil favoring stretches of grasslands. The terrain is mostly undulating with a valley in the basin. The Pada Giri is the highest peak (1527m). Major peaks in the tiger reserve are Karimala (1439m), Pandaravarai (1290m), Poya Mala (1125m), Kuchimudi (1040m), Vengoli (1120m), Puliyarapadam (1010m), Manjal Kunnu (1225), Pullala Mala (1444m) and Kakani Mala (1163m). From the north eastern corner of the Parambikulam basin close to where the Anamalais terminate is a small gap close to Top slip. The southern tip of the gap rises up abruptly to a sheer height of more than 1000m from the floor of the Plaghat gap. It is higher than the floor of the Parambikulam basin by atleast 400-500m. This range called the Nelliampathies runs due west all along the southern edge of the Palghat gap and after about 50 km. swings south west and south and is then broken up into a series of irregular north west and west running ridges descending to the Palghat and Trichur plains. Lying in the southern part of Western Ghat, immediately south of Palghat gap, Parambikulam Tiger Reserve, exhibits mountainous terrain (Fig.3.4.). The area in general has a slope towards west.

## 3.3. Rainfall

Much of the rainfall that is received in the tiger reserve is *orographic* in origin. Though the tiger reserve is blessed with rain during both North West and North East monsoon, the former contributes maximum to the total precipitation recorded in the tiger reserve. In addition, pre monsoon showers are felt during April and May. This intense rainfall availability for nearly 6 months make the tiger reserve more or less wet throughout the year.

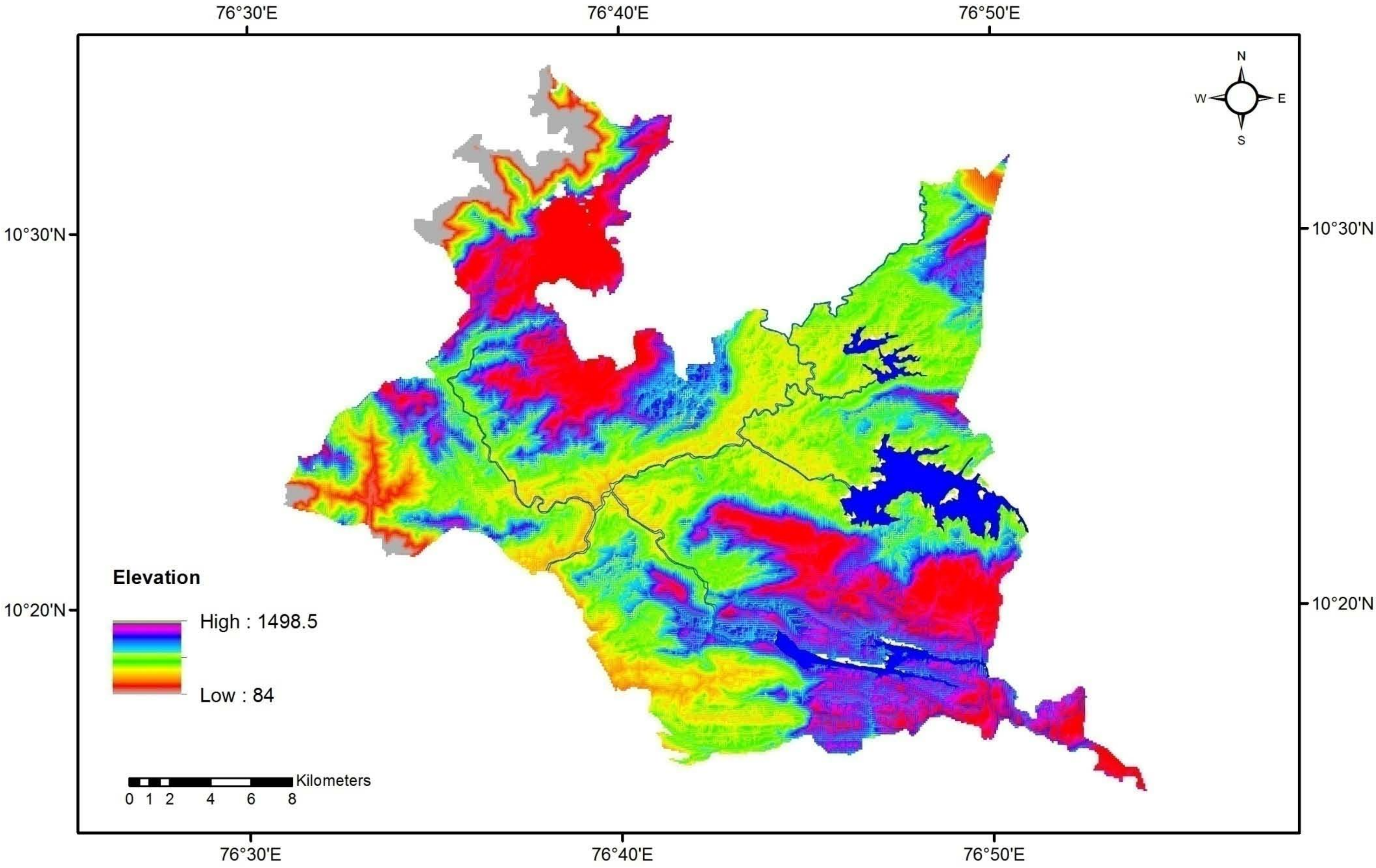



Fig.3.4 Digital Elevation Model of PKTR

### 3.4. Temperature

The mean monthly temperature fluctuates between 25.6 ºC (March) and 20.9 ºC (January). The mean monthly range of temperature indicates that March is the month of extreme temperature variations with 18.8 ºC of difference between mean monthly minimum and maximum temperatures and such flux is the least in August. Mean diurnal range for each month shows that March is the month of maximum diurnal range. Annual extreme range of temperature in the tiger reserve is 15.30 ºC. Absolute extreme range of temperature in the tiger reserve is 40 ºC (Fig.3.5). However, March is the hottest month with mean monthly temperature of 25.74 ºC and January the coolest month with 21.2 ºC.

### 3.5. Climate

The tiger reserve exhibits wet tropical climate. Temperature varies from 15 ºC to 32 ºC. March is the hottest month and January, the coolest month. Total rainfall varies between 1400 mm and 2300 mm. July is the wettest month and January, the driest. Tiger reserve is blessed with rain during both South West and North East monsoons. The tiger reserve experiences pleasant weather conditions excluding those periods of macro regional climatic conditions such as the two monsoons, namely South West and North East of which the former being the period of extreme weather conditions.

### 3.6. Soil

The soil is found neutral in reaction in the dry deciduous forest and very strongly acidic in montane grasslands. Whereas, it is moderate to strongly acidic in other forest types. Organic carbon is high in all forest types except for teak plantations where it is medium. The texture is clay to sandy loam. Soil in all the forest types possesses moderate water holding capacity.

### 3.7. Hydrology

There are 7 major valleys and 8 major river systems (Fig.3.6). Several streams originate from the hill ranges and flow down westward to join the river Chalakudi. The north eastern corner of the Parambikulam basin, *i.e*. the gap area between the Anamalis and the Nelliampathies is drained by Tekkady Ar. The Western slopes of the Anamalais are

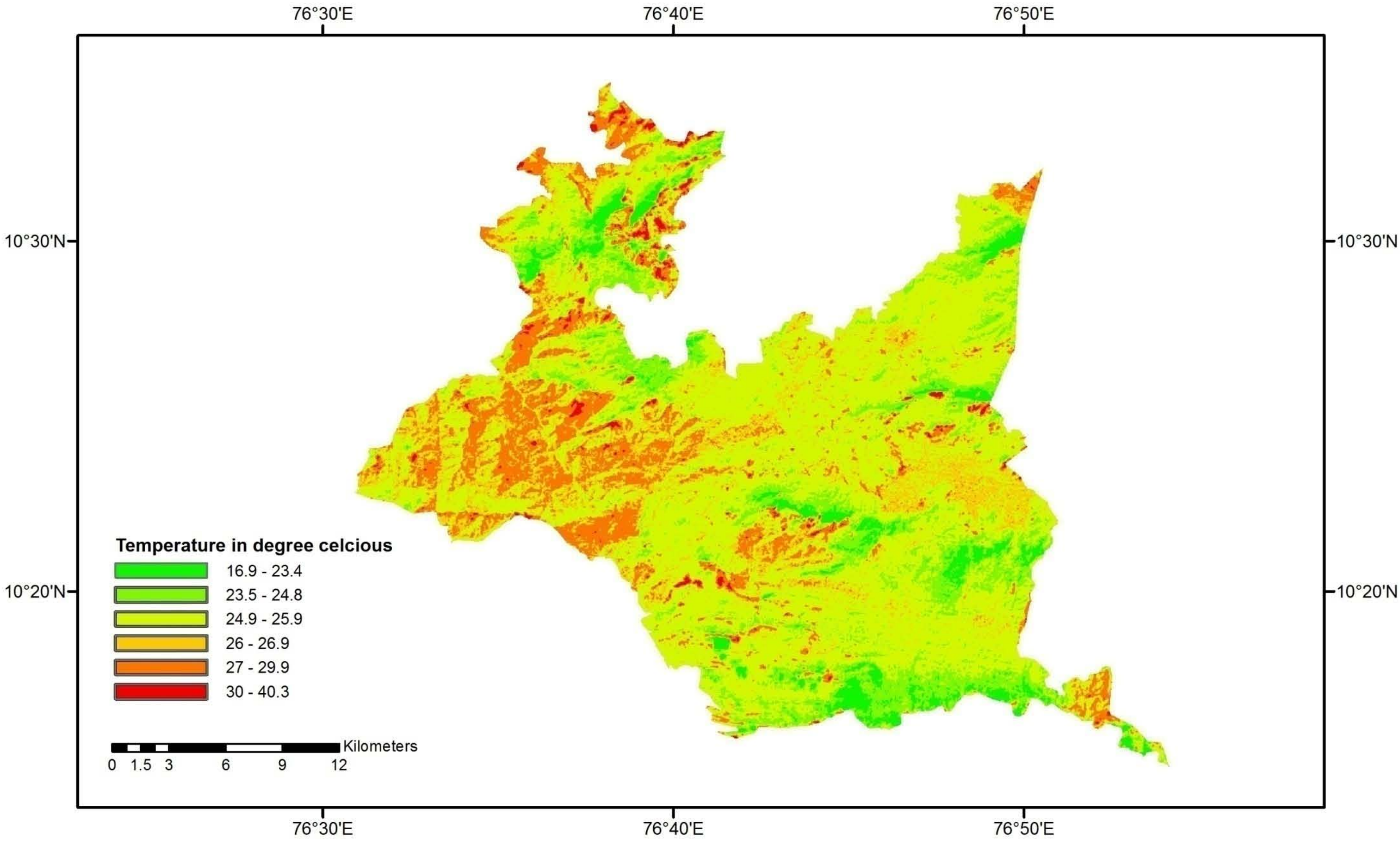



Fig.3.5 Land surface temperature map of PKTR derived from Landsat 7 ETM+ image

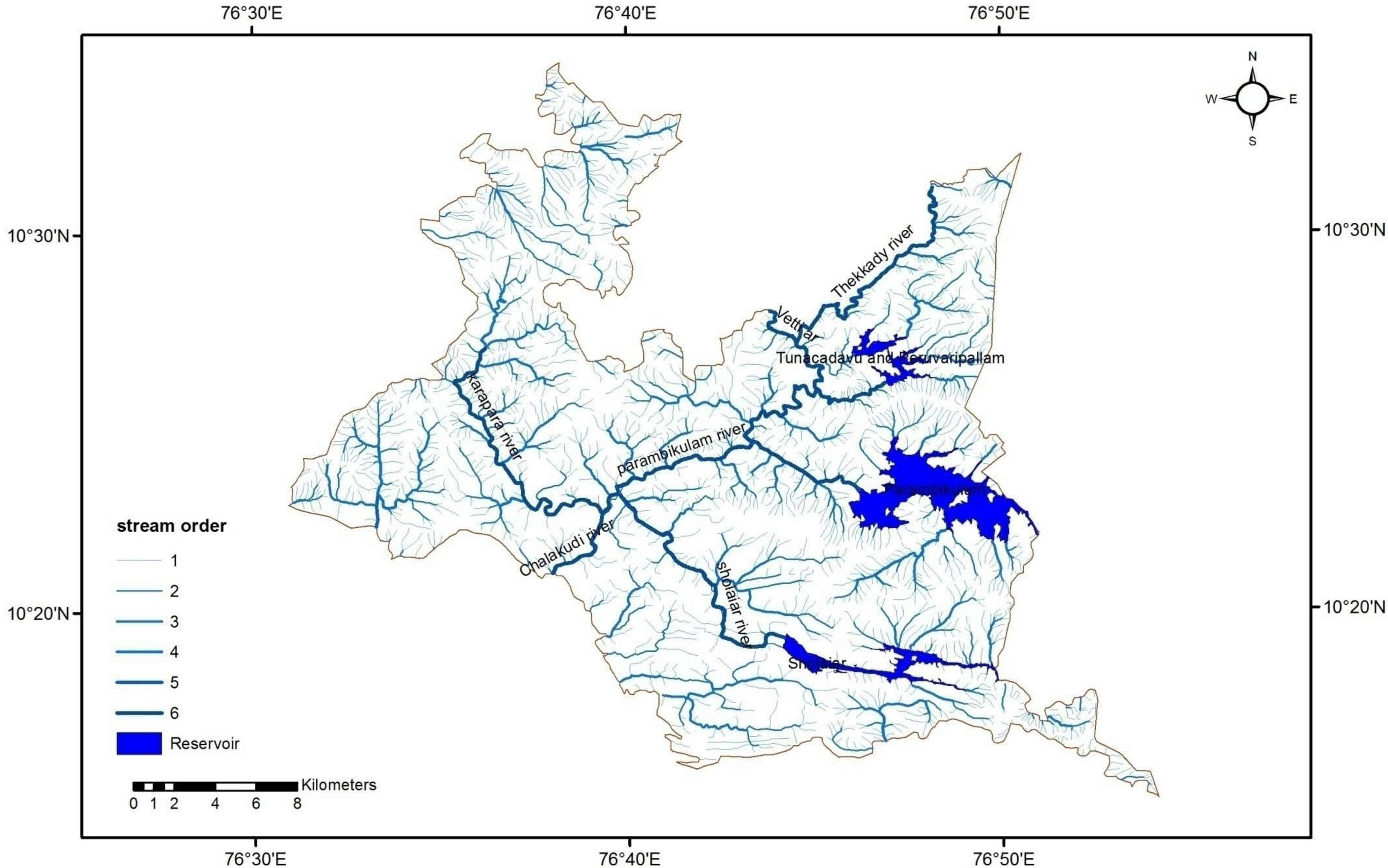



Fig.3.6 Drainage map of PKTR

drained from the north by Thunakkadavu Ar and from the south by the Parambikulam Ar. The Vetti Ar and Tekkady Ar join and the combined stream is then joined by the Thunakkadavu Ar flowing in from the west and the common river called Kuriarkutty Ar flows south west along the floor of the basin . It then receives Pulikkalar from its right bank. At the place called Kuriarkutty, Parambikulam Ar joins Kuriarkutty Ar where after the river is called the Parambikulam Ar. The Parambikulam Ar flows south west till Orukumbankutty, where Sholayar joins it from the left flank and the Karappara River from the right flank. The river then empties out of the Parambikulam basin through a gorge to reach the Chalakkudy valley.

Apart from the natural rivers and streams, the tiger reserve possesses 4 man made reservoirs namely Parambikulam, Thunacadavu Peruvaripallam and Sholayar whose cumulative water spread is 26.127 $km^2$. The reservoir harbors several kinds of aquatic fauna.

**3.8. Geology**

Lying south of the Palghat gap in the Anamalai hills of Western Ghats, the tiger reserve manifests interesting geological formations. The Western Ghats in general is formed of charnockites that had its origin in the Pre Cambrian (4600 to 570 million years ago) era. A survey conducted in 1963-64 by the Geological Survey of India identifies the major formations in the tiger reserve to be that of Hornblende biotite gneiss, garnetiferous biotite gneisses and charnockites, which had been intruded by granitic orthoclasic gneisses and plagioclase porphorite dyke (Fig.3.7). Major geologic formations are metamorphic where as the intruded ones are igneous in origin.

A superfluous observation of the major rock exposures reveals that most of them are banded gneisses, which can be inferred so from its gneissose structure and characteristic foliating nature. Charnockites are seen along the high precipitous slopes. Presence of hypersthane as the major component confirms it as charnockites.

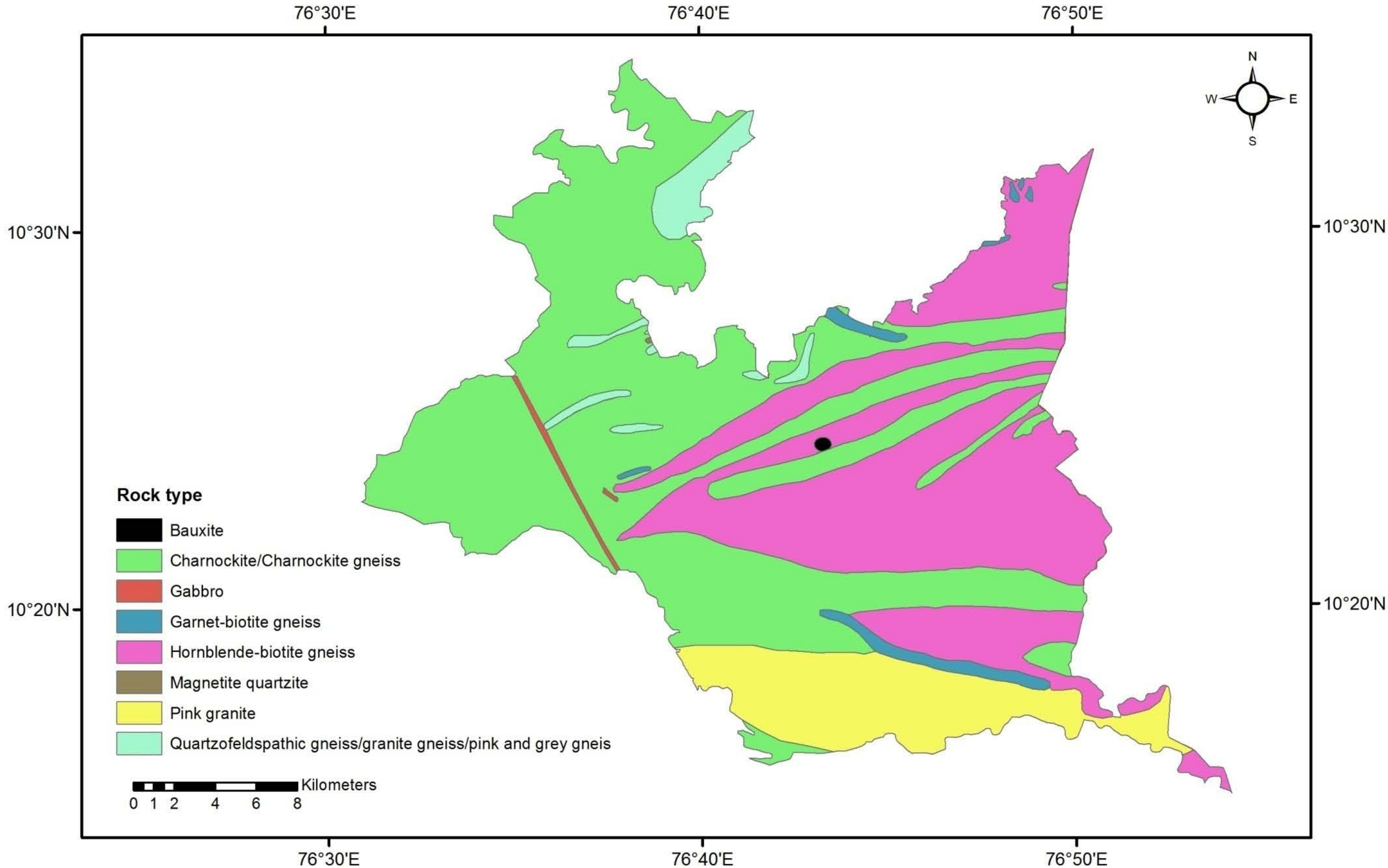



Fig.3.7 Geological type map of PKTR derived from geological quadrangle map

Major minerals found in the rocks of the tiger reserve are quartz ($SiO_2$) and feldspars (Orthoclase) ($KAlSi_3O_2$). Biotite [Mica, $H_2K(Mg, Fe)_8Al(SiO_4)_3$], Hornblende [$Ca(Mg, Fe)_4Al(Si_7Al)O_{22}(OH,F)_2$] and Hypersthenes [$(Mg,Fe)_2SiO_6$] are the other minerals. Mineral deposits of economic importance are not found within the tiger reserve.

### 3.9. Geography

In contrast to other mountainous regions in the Western Ghats the ridges here run west-east. The southern slopes of these ridges are steeper than the northern slopes. Geologically the tiger reserve has Hornblende biotite gnesis and charnockites.

### 3.10. Forest Types

According to the revised classification of forest types of India by Chandrasekharan (1962) and Champion and Seth (1968), the natural vegetation of the sanctuary can be classified into following forest types (Table 3.1).

Table 3.1: Forest Types of PKTR based on Champion and Seth Classification

| Code | Forest Type |
|---|---|
| **IA/C4** | West coast tropical evergreen forests |
| **2A/C2** | West coast semi-evergreen forests |
| **3B/C2** | Southern moist mixed deciduous forest |
| **5A/C3** | Southern dry mixed deciduous forests |
| **2/E3** | Moist bamboo brakes |

**West Coast Tropical Evergreen Forests ( IA/C4 )**

This type of forest is found in areas wherever humidity and soil moisture conditions are favourable, rainfall is 1500-5000mm or more and altitude is 250 to 1200m. The main forests of this type are found in Orukomban range and they fall under the core zone of this sanctuary. These evergreen forests are contiguous with the evergreen forests of adjoining forest divisions, Chalakkudy and Nemmara. Padagiri and Karimala are the regions, where evergreens meet with grasslands. At Pooppara, it is in continuation of the evergreen forests of the Vazhachal forest division. Small patches of evergreen trees are also found within the moist deciduous localities such as Parambikulam, Vengoli, Karianshola and Pulikkal areas.

**West Coast Tropical Semi Evergreen Forests (**2A/C2**)**

There is no clear-cut area of semi evergreen forests. These forests appear to be ecological zones in areas where the moist deciduous forests merge with evergreen. Thus these forests represent a transitional zone between evergreen and moist deciduous forests. Lofty trees with thick and buttressed tree trunks are found growing with cylindrical bole. The ground floor of semi evergreen forests receives more light than the ground floor of evergreen forests, due to comparatively lighter canopy. Due to variation in the mixture of species of evergreen forests and deciduous Forests, it becomes difficult to determine the exact status of these forests.

**Southern Moist Mixed Deciduous Forests (3B/C2)**

These forests are found over the ridges and lower slopes having elevation of 100m to 400m where the soil is generally rich. The chief feature of the moist deciduous forests is a leafless period in the dry season between March and May. Naturally growing moist teak was one of the dominant species present in these forests. Physiognomically, the moist mixed deciduous forests have a closed canopy with tall and cylindrical trees. Trees tend to attain a height of 30.4 m and more. The under storey is well defined and the forest floor is full of vegetal growth. It has been observed in Anappady, Elathode and interstate boundary area that the floral elements of dry deciduous forests consisting of Anogeissus, Bombax, Tamarindus etc., exist within the moist deciduous forests.

In Vengoli, Thellikkal, Pulikkal and Pooppara areas good quality teak, rosewood, terminalias and Schleichera spp. grow in depressions having rich soil. In drier locality such as Anappady, Elathode, Thellikkal east etc., Anogeissus, Albizzia, Sterculia, Grewia and Emblica trees are common. Bamboos are also found in dense thicket formations extensively. In areas such as Orukomban and

Kothala, trees such as Xylia xylocarpa and Grewia tiliifolia come up in localized lateritic patches.

**Southern Dry Mixed Deciduous Forests (5A/C3)**

This type of forest is attributed to relatively low rainfall and lower altitude i.e., 300m-400m above MSL. Many species growing in this forest type are common to the moist deciduous forests. However their percentage of occurrence is low. The leaf-fall starts earlier when compared to moist deciduous forests. Generally, the trees remain leafless between January and May. Physiognomically, the dominant trees attain height of 18 m to 24 m and are not gregarious. The canopy is comparatively open allowing grass and herbs to grow. Bamboos occurring as under growth are heavily browsed and become bushy. New culms of Bamboo grow during November – December. These forests are highly prone to fire. The grass and many herbs dry up by December and January and leaf fall starts. The forest floor is thickly covered with dry twigs and leaves. The north east portion of this sanctuary adjacent to the plains of Tamil Nadu has a small patch of this type of forests covering about an area of 15 sq.km around Thekkady and Keerappady.

**Moist Bamboo Brakes ( 2/E3 )**

The brakes are often dense, even if the bamboos grow in clumps. Bamboo brakes are usually found along streams or on badly drained hollows more or less displacing the trees. More or less continuous cover of one or two species of tall clumped bamboos with occasional stands of Terminalias and other trees are found. The moist bamboo brakes are sufficiently aggressive to be able to hold against tree growth. The latter probably gains ground after good seed years, so that gradually the bamboo ceases to dominate.

*Bambusa arundinacea*, the only bamboo has come up in highly fertile and well drained soil in Muduvarachal, Pulikkal, Kothala, Pooppara, Vengoli and Thellikkal areas of this sanctuary. The Natural bamboo brakes also occur along the stream banks, reservoir banks and in sheltered depressions. Vengoli has the largest area of such bamboo brakes in the Sanctuary. In Elathode, Thellikkal east and Thekkady areas where habitats are comparatively dry *Dendrocalamus strictus* is growing. *D. strictus* (Kal-mungil) is not growing gregariously like *Bambusa arundinacea*, but it is heavily browsed, so it has acquired the shape of thicket. However, its regeneration is satisfactory.

**3.11. Statement of Significance**

(i) Parambikulam Tiger Reserve is a well-protected ecological portion of the Anamalai sub unit of Western Ghats, as it is buffered by ecologically similar forests of other forest divisions and Protected Areas of Kerala and Tamil Nadu.

(ii) The Reserve supports diverse habitat types *viz*., evergreen forests, semi evergreen, moist deciduous, dry deciduous and shola forests. Other unique habitats like montane grasslands and marshy grasslands known locally as 'vayals' are here. Considerable extent of man-made teak plantations and the deep freshwater ecosystem created by the construction of three dams add to the diversity of the place.

(iii) The floral diversity of the tiger reserve is extraordinary. As per the research report of Kerala Forest Research Institute by Sasidharan (2002), the sanctuary supports an estimated 1400 species of Angiosperms. So far 1,320 species of flowering plants belonging to 680 genera and 133 families have been identified. This includes about 70 species of orchids also. The inventory is not completed yet. This magnitude of floral richness is due to the mosaic vegetation pattern in this sanctuary.

(iv) The tiger reserve supports healthy population of several endangered wild animals. The presence of about 20 tigers underscores the healthiness of this ecosystem. Most of the herbivorous species of the Western Ghats *viz*., Asian elephant, spotted deer, sambar and barking deer (Muntjac) are found here. Parambikulam tiger reserve supports one of the highest densities of gaur population in Southern India. The only South Indian wild goat, the Nilgiri Tahr is found on the high altitude rocky hills and grasslands in the tiger reserve. A healthy population of about 250-300 Lion-tailed macaques among the other primates and arboreal animals are found here. Rodents like Malabar giant squirrel, and flying squirrel are among the important arboreal animals. The significant population of resident and migratory avifauna of about 273 species makes the tiger reserve a bird watchers paradise. Among the aquatic fauna, crocodiles, otters, freshwater fish especially Mahseer, an endemic game fish are worth mentioning. The tiger reserve is also home of several rare small animals like Tarantula (large bodied spiders).

(iv) There are several endemic, rare, endangered and threatened species of flora and fauna adding to the diversity of the reserve. To name a few, *Haplothismia exannulata,* a monotypic genus of *Burmanniaceae* rediscovered here after 1951; *Coscinium fenestratum* and *Utleria salicifolia*, the IUCN 'redlisted' medicinal plants endemic to Anamalais; *Tomopterna parambikulamana*, an endemic frog of Parambikulam and *Garra surendranathanii*, an endemic sucker fish can be mentioned among the others like King Cobra, Lion-Tailed Macaque, Nilgiri Tahr, Tiger, *etc*.

(v) The Tiger Reserve being a part of major ecological continuum from Peechi to Eravikulam through Anamalai, aids the survival of large viable populations of wildlife. The Parambikulam valley extends from East to West opening up migratory routes for wild animals from Nelliampathy to Eravikulam National Park. Parambikulam tiger reserve along with Indira Gandhi Wildlife Sanctuary forms the northern most extension of Anamalai portion of the Western Ghats before being blocked by Palakkad Gap. Thus migration of animals like elephants and subsequent genetic exchange between their populations is facilitated. Because of such conservation importance, this sanctuary has declared as a Tiger Reserve in 2010.

(vi) The four man-made reservoirs and natural river systems besides adding to the beauty of the place support several unique life forms. Also, Parambikulam provides the life support system for the human population living in the plains of Kerala and Tamil Nadu by supplying good water and air.

(vii) This tiger reserve is the home of about 1,300 people belonging to several tribal and non-tribal communities whose livelihood is almost fully dependent on the forests of the tiger reserve. This tiger reserve can be treated as a model for peaceful co-existence of tribal people and wildlife.

(viii) About 1/3rd of the tiger reserve area is occupied by Teak monoculture plantations that are in various stages of extraction. The approximate stumpage value of these plantations is an astounding Rs. 2000 crores.

(ix) The intangible benefits accrued from the tiger reserve are enormous and invaluable. Especially this is the carbon sink and an important life-support system for the vast adjacent plains of Kerala and Tamil Nadu.

(x) The aesthetic appeal of the tiger reserve with its lush greenery, magnificent wildlife, inviting peaks, serene valleys, meandering rivers and placid lakes, is beyond compare.

Chapter 4

# MATERIALS AND METHODS

# CHAPTER-4

# MATERIALS AND METHODS

## 4.1. Data and Software used

Spatial and nonspatial data were used in this study. The descriptions of individual data sets were given below.

### 4.1.1. Remote sensing data

Satellite imageries of Indian Remote Sensing satellites (IRS) and Landsat series images of NASA's Earth observation program available through Global Land Cover Facility (GLCF) were used for land cover analysis.

### 4.1.2. IRS imageries

Satellite imageries of IRS P6 LISS-3 with the resolution of 23.5 m for the year 2005 and IRS ID LISS-3 with the resolution of 23.5 m for the year 1999 obtained from NRSC (National Remote Sensing Centre), Hyderabad, Dept. of Space, Govt.of India, were used for analysis.

### 4.1.3. Technical Specification of IRS P6 LISS-3 image

The Linear Imaging Self Scanning Sensor (LISS-III) is a multispectral camera operating in four spectral bands, three in visible and near infrared and one in SWIR region. The sensor is attached to the Indian Remote Sensing satellite, IRS P6. The IRS P6 LISS III image dated 8$^{th}$ February, 2005 was acquired from National Remote Sensing Centre (NRSC), Dept. of Space, Govt.of India, Hyderabad.

Spatial Resolution: 23.5m

Spectral Range: 0.45-1.75μm

Number of Bands: 4

Temporal Resolution: 24 days

### 4.1.4. Technical Specification of IRS ID LISS-3 image

The IRS ID LISS III image dated 24th February, 1999 was acquired from National Remote Sensing Centre (NRSC), Dept. of Space, Govt.of India, Hyderabad.

Spatial Resolution: 23.5m

Spectral Range: 0.45-1.75μm

Number of Bands: 4

Temporal Resolution: 24 days

### 4.1.5. Landsat imageries

Landsat (name indicating Land + Satellite) imagery is available since 1972 from six satellites in the Landsat series. These satellites have been a major component of NASA's Earth observation program, with three primary sensors evolving over thirty years: MSS (Multi-Spectral Scanner), TM (Thematic Mapper), and ETM+ (Enhanced Thematic Mapper Plus). Landsat supplies high resolution visible and infrared imagery, with thermal imagery and a panchromatic image also available from the ETM+ sensor. The collection of Landsat available through GLCF is designed to compliment overall project goals of distributing a global, multi-temporal, multi-spectral and multi-resolution range of imagery appropriate for land cover analysis.The technical specifications of the Sensors are given in Table 4.1.

Table 4.1.Technical Specification of the Sensors of Landsat imageries

| **Technical Specification of Sensor** | | | | | |
|---|---|---|---|---|---|
| **Satellite** | **Sensor** | **Spectral Range** | **Bands** | **Scene Size** | **Pixel Resolution** |
| L 1-4 | MSS multi-spectral | 0.5 - 1.1 μm | 1, 2, 3, 4 | 185x185 km | 60 meter |
| L 4-5 | TM multi-spectral | 0.45 - 2.35 μm | 1, 2, 3, 4, 5,6, 7 | | 30 meter |
| L 7 | ETM+ multi-spectral | 0.450 - 2.35 μm | 1, 2, 3, 4, 5, 7 | | 30 meter |

### 4.1.6. Landsat Multispectral Scanner (MSS)

The Multispectral Scanner system sensors onboard on NASA's Landsat series satellites had 4 bands in the green (band1), red (band2), and near-infrared (band 3 and 4) portions of the electromagnetic spectrum. The data dated 10th February 1973 downloaded form (United States Geological Survey) USGS-EROS Centre (http://glovis.usgs.gov) was used for the present study.

Spatial Resolution: 60m

Spectral Range: 0.5 - 1.1 μm

Number of Bands: 4

Temporal Resolution: 18 days

### 4.1.7. Landsat Thematic Mapper (TM)

The Thematic Mapper is an advanced, multispectral scanner with seven bands. The data dated 24th January 1990 downloaded form USGS-EROS Centre was used for the present study.

Spatial Resolution: 30m

Spectral Range: 0.45 - 2.35 μm

Number of Bands: 7

Temporal Resolution: 16 days

### 4.1.8. Landsat Enhanced Thematic Mapper plus (ETM+)

The Enhanced Thematic Mapper plus instrument is a multispectral scanning radiometer capable of providing high resolution imaging information of the Earth's surface. The data dated 14th January 2001 was downloaded from USGS-EROS Centre.

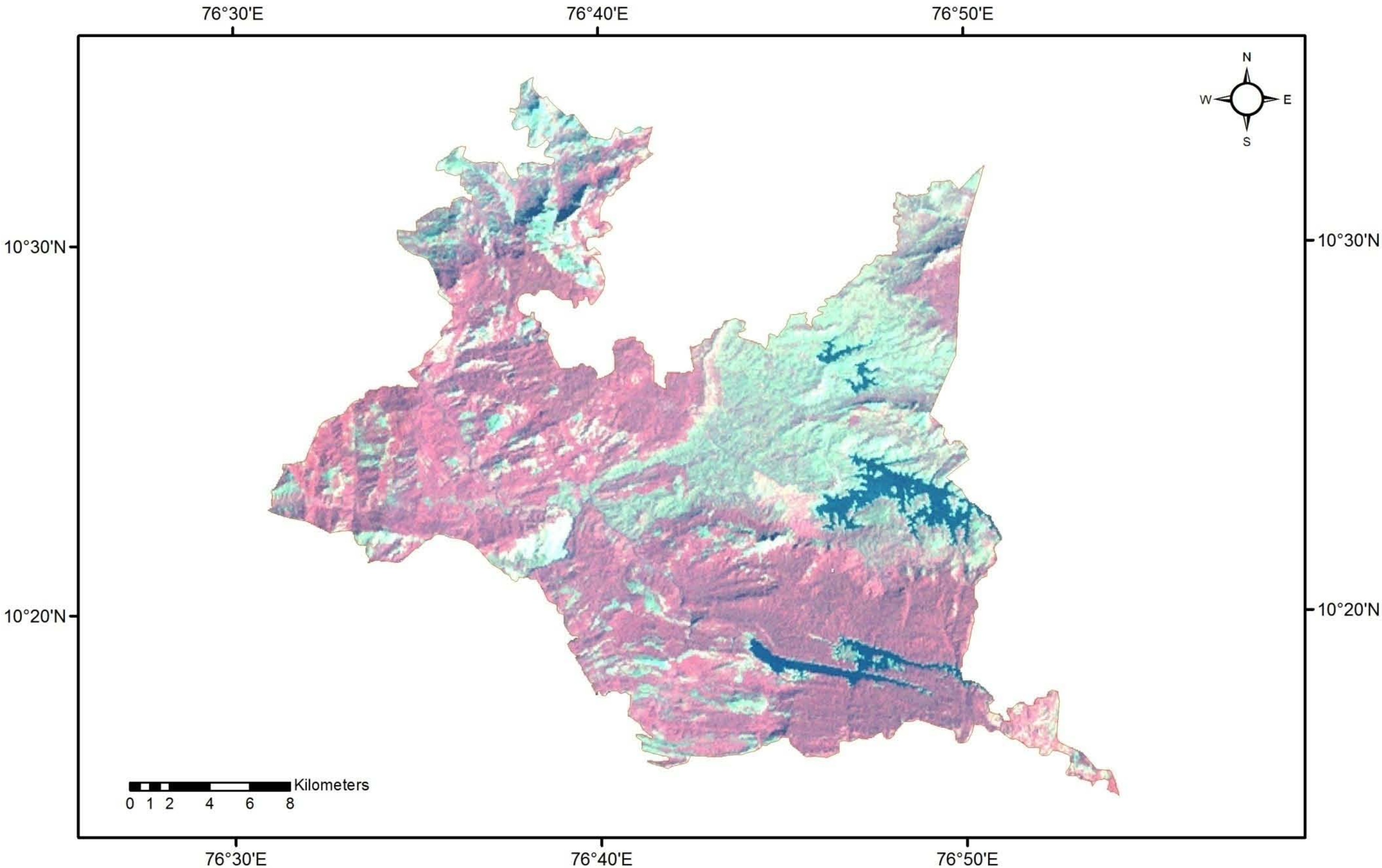
Spatial Resolution: 30m

Spectral Range: 0.450 - 2.35 μm

Number of Bands: 6

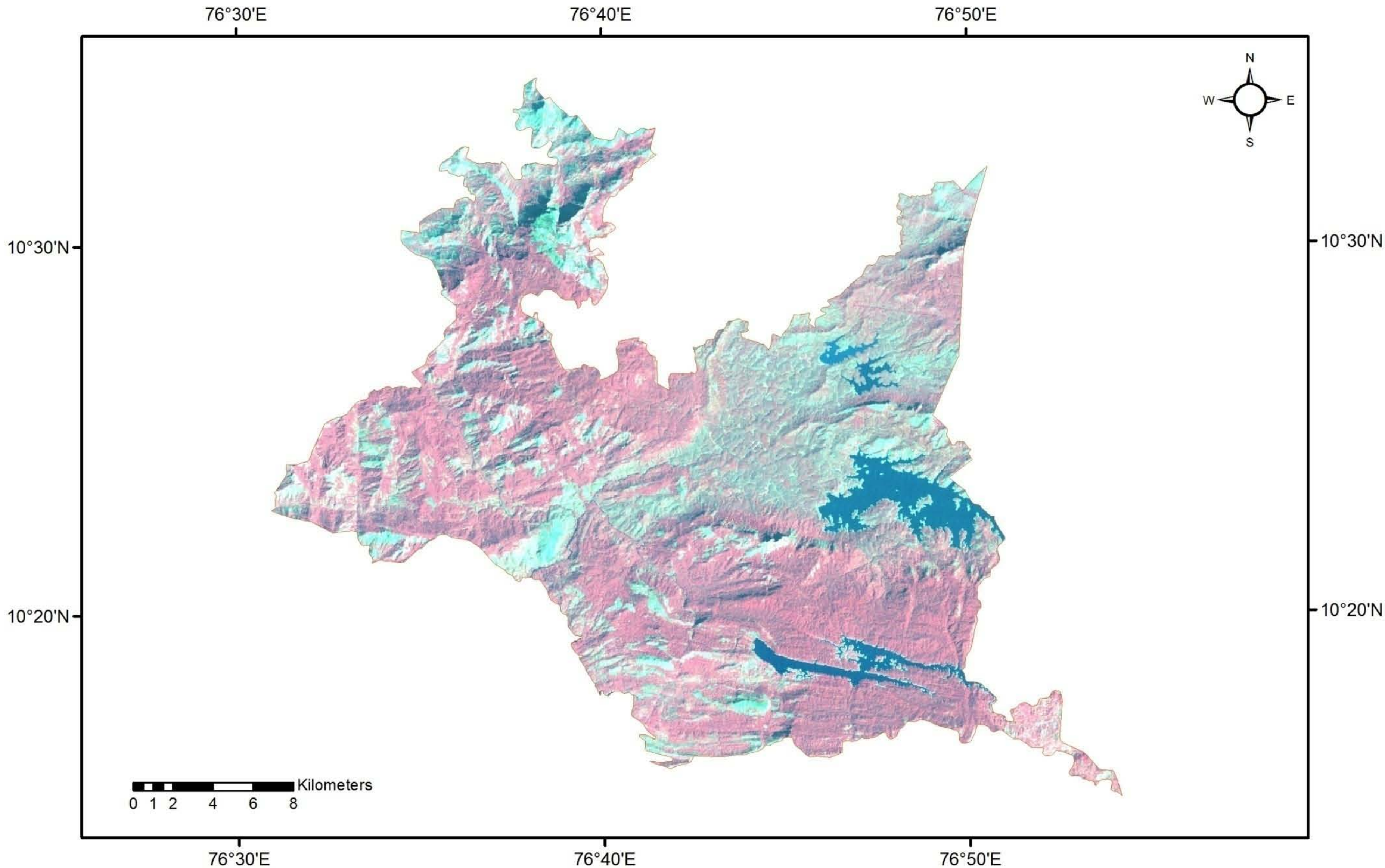
Temporal Resolution: 16 days

False Colour Composite (FCC) images of the study area between 1973 to 2005 showing different vegetation formations are shown in (Fig. 4.1 a, b, c , d&e).

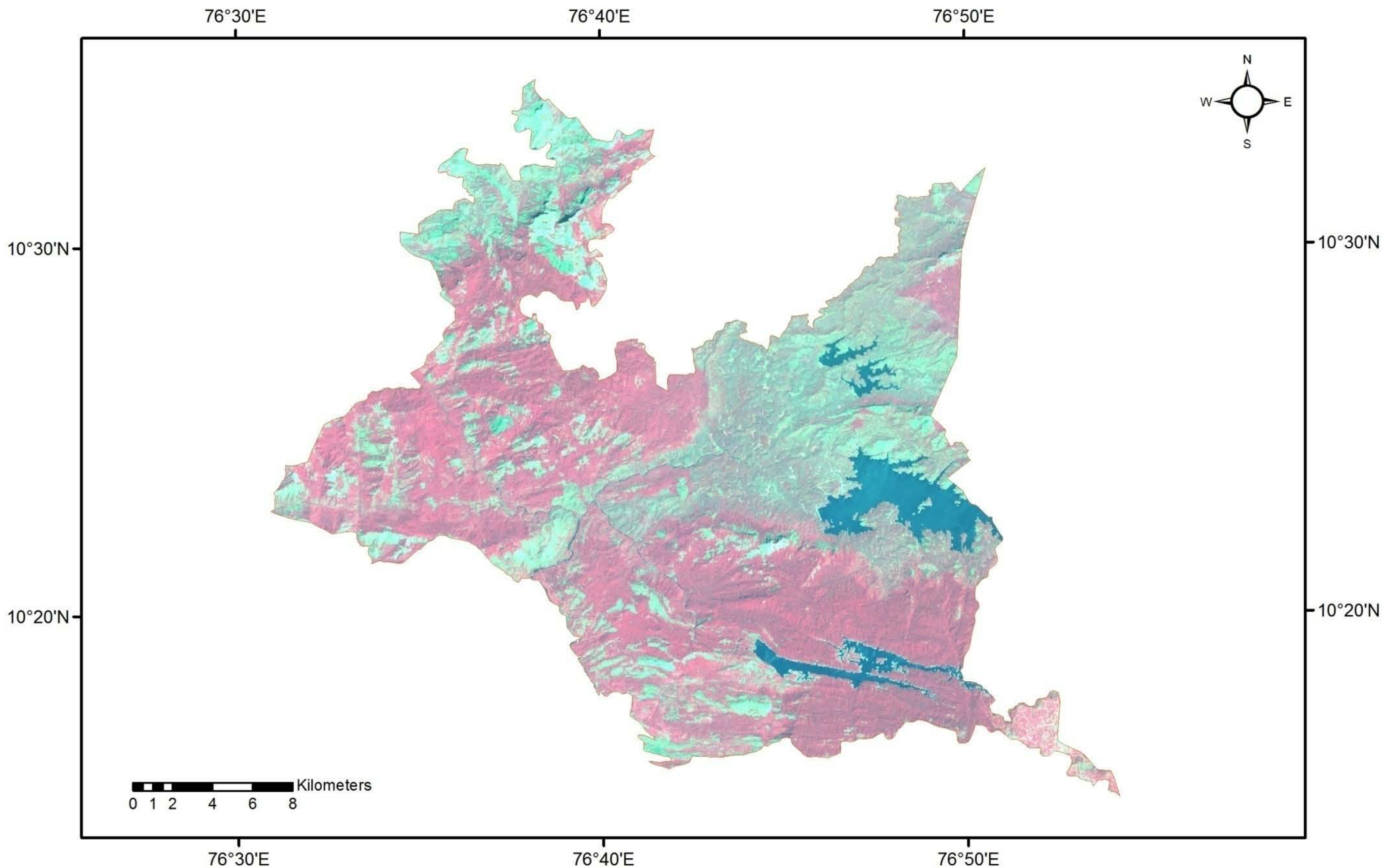



a. Landsat Multispectral Scanner (MSS) for the year1973

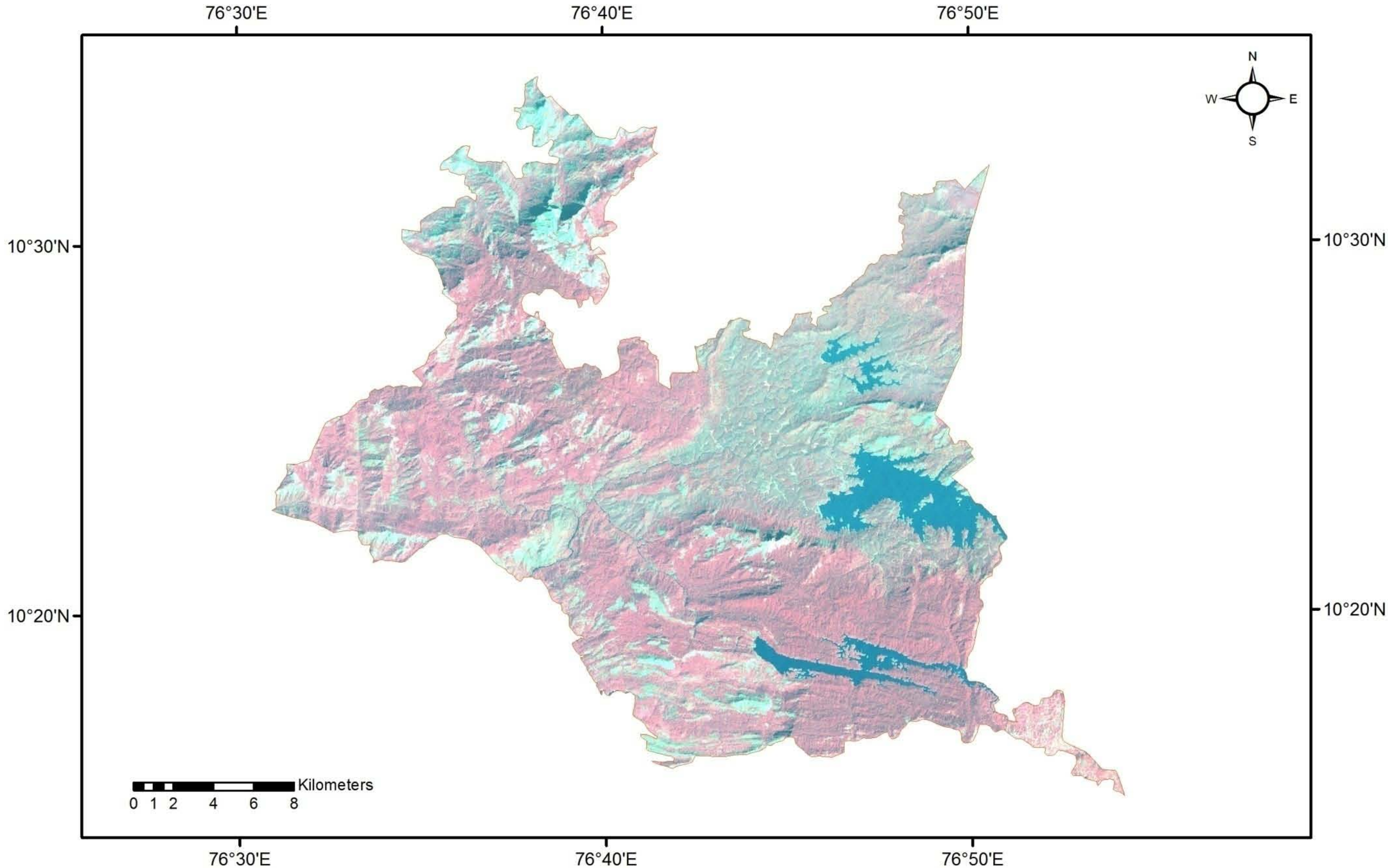
Fig. 4.1. False Colour Composite (FCC) images of PKTR for the year, a.1973, b.1990, c.1999 d. 2001, e. 2005



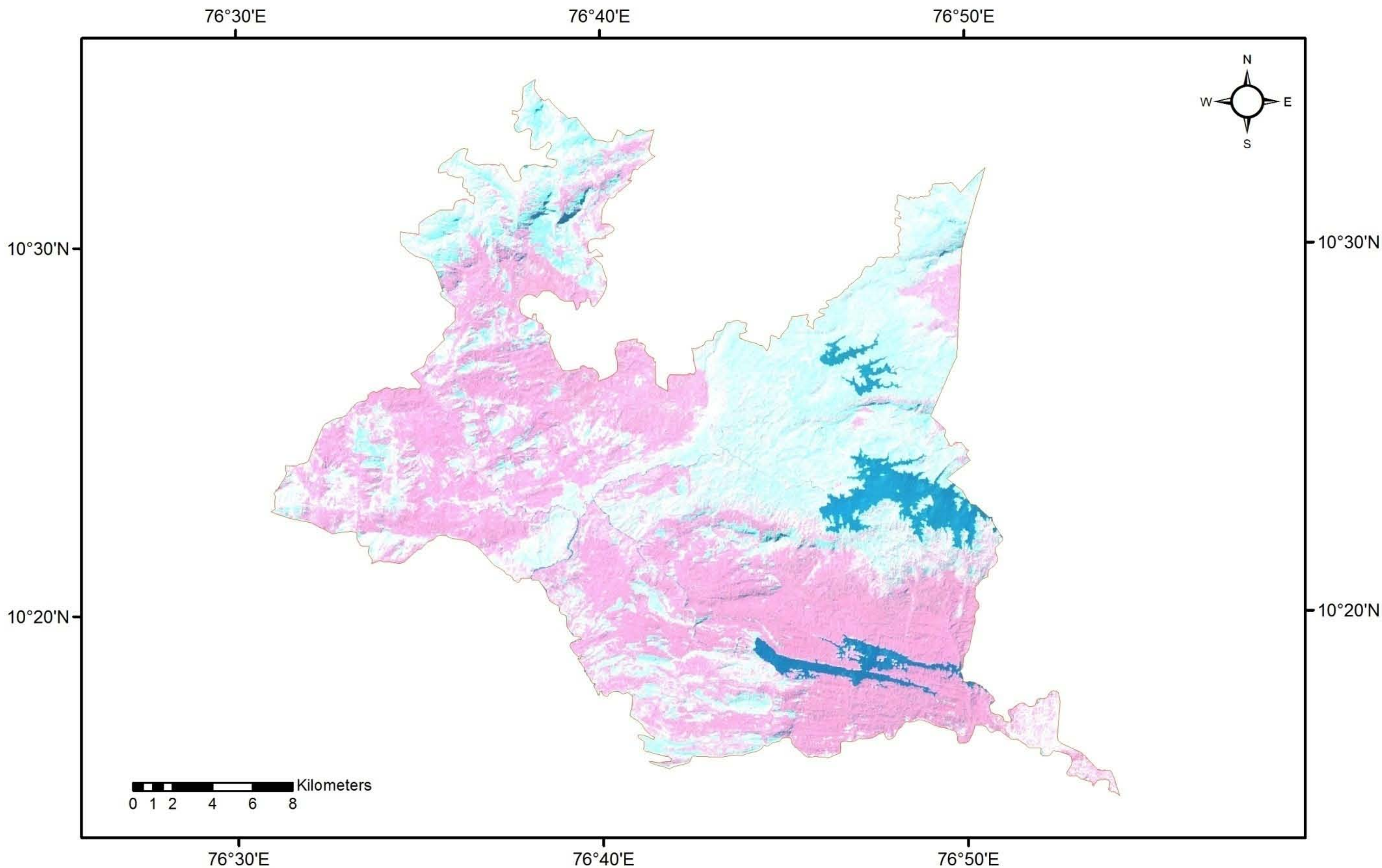

b. Landsat Thematic Mapper (TM) for the year 1990




c. IRS 1D LISS III image for the year 1999




d . Landsat Enhanced Thematic Mapper Plus (ETM+) for the year 2001




e. IRS P6 LISS III image for the year 2005

### 4.1.9. Toposheet

Survey of India (SOI) topographic maps of 58B10, 58B11, 58B14 and 58B15 of 1:50,000 scales pertaining to the study area were referred. These maps have been used for preparing base map, drainage *etc.* for the study area and carrying out field work.

### 4.1.10. Ground Truth Data

Ground truth data was collected from the study area to recognize and relate vegetation types to their tonal variation on the satellite images. Intensive ground truthingwere carried out to develop interpretation criteria for stratifying forest into different vegetation types.

Ground truthing was done based on stratification of the image data, variation in signatures, *etc*. The information and location were noted with the help of maps, image print outs and Global Positioning System (GPS).

### 4.1.11. Ancillary data used

Forest type map prepared by French Institute of Pondicherry for the year 2002 (Based on remote sensing data from Landsat 5 (TM) and Spot-1(HRV) between 1990 and 1992), Watershed Atlas of Kerala prepared by Kerala State Land use Board on 1:50,000 scale (1996) and Forest working plans were used as ancillary data. Global Positioning System (GPS) used for mapping were 'Trimble Geo Explorer' series with accuracy of 2-6m and 'Garmin - V plus' with accuracy of 11-15m.

### 4.1.12. Software used

The following softwares were used for the present study.

Erdas Imagine

Arc GIS

Mapinfo

Global Mapper

Invent NTFP

Flowering Plants of Kerala

## 4.2. Digitization

The essential part of mapping is the digitization of base layers. Survey of India toposheets 58B10, 58B11, 58B14 and 58B15 of 1:50,000 scale representing the study area were scanned at 600 dpi and edited using Adobe Photoshop. The scanned raster images were then registered by giving the geo coordinate values using GIS softwares (Mapinfo, ArcGIS). Different layers such as watershed, forest boundaries, roads, streams, rivers, reservoirs and geological types were digitized from the available maps prepared by various agencies using GIS softwares.

## 4.3. Digital Image Processing

Steps involved in Digital Image Processing are;

### 4.3.1 Geometric correction (Image rectification) of satellite image

Georeferencing refers to the process of adding map coordinates to image data. The objective of geometric correction is to compensate for the distortions and degradations caused by the errors due to variation in altitude, velocity of the sensor platform, variations in scan speed and in the sweep of the sensors field of view, earth curvature and relief displacement. The first step in analysis was the geometric correction of satellite images. The satellite image of IRS-P6 LISS III for the year 2005 covering the Parambikulam Tiger Reserve were rectified for geometric correction with reference to 1:50,000 scale SOI topographic maps in Polyconic Everest coordinate system using geometrical rectification tools of ERDAS Imagine. Satellite images were registered to the toposheets using the common uniformly distributed Ground Control Points (GCPs) such as road, river, reservoirs, intersections that are clearly visible in the images. Nearest neighbourhood method was used for resampling, which uses the nearest pixels without any interpolation. A total of 20 ground control points were used for registration of image and was then subset and masked for further analysis. The image processing was done using Erdas Imagine. The area of study was extracted by overlaying the boundary. The local enhancement was carried out for taking the GCP's and also in the later stage of mapping.

### 4.3.2. Image enhancement and transformation

The raw digital data were enhanced using contrast stretching and/or ratio based techniques to facilitate better discrimination during ground data collection or locating sample points. Appropriate enhancement techniques were applied for the remotely sensed data. In its basic form the linear contrast stretching involves mapping of pixel values from the observed range to the full range of display device.

### 4.3.3. Land use land cover mapping

Digital interpretation of satellite imageries are implemented to prepare landcover map. Pre-field interpreted map and digitally enhanced satellite data are used on the ground to identify different land use and land cover classes and to generate geodatabase for the land use and land cover. Supervised classification technique was used to prepare the land use land cover map from the satellite images. The locations of the training sites were digitized using AOI (Area of Interest) tools. After the signatures were defined based on the knowledge of the data and ground information, scenes are classified using Maximum Likelihood Algorithm of Supervised Classification into different vegetation types.

### 4.3.4. Ground truthing

Ground truthing refers to the acquisition of knowledge about the study areas from fieldwork, analysis of the data set and personal knowledge. Ground truth data are considered to be the most accurate (true) data available. Data should be collected at the same time as the remotely sensed data, so that the data correspond as much as possible to ground realities. Reconnaissance survey was made in the study area to recognize and relate vegetation types to their tonal variation on the satellite images. Intensive ground truth was carried out to develop interpretation criteria for stratifying forest into different vegetation types. Sample plots of size 0.1 ha were laid randomly at different strata observed on imagery ensuring that these are true representative of respective vegetation types. Ground truthing is essential for performing a good classification.

## 4.4. Forest cover density

For mapping and monitoring the forest cover density, False Colour Composite (FCC) of satellite imageries were prepared using Landsat MSS, Landsat TM, IRS 1D LISS III, Landsat ETM and IRS P6 LISS III digital data pertaining to February 1973, January 1990, February 1999, January 2001 and February 2005 respectively. The Landsat satellite data provided by Global Land Cover Facility (GLCF) was radiometrically and geometrically (orthorectification with UTM/WGS 84 projection) corrected. For the IRS P6 LISS III and IRS 1D datasets same principle was applied for geometric correction. Detailed ground truth was collected with the help of 1:50,000 scale toposheets, base maps, Global Positioning System (GPS) and local investigation. The accuracy of the forest features were tested using GPS in the ground. A similar classification scheme was used for mapping. Local enhancement (data scaling and histogram equalization) was carried out on the temporal scenes for the better interpretation.

The forest cover is classified in to four tree canopy density classes such as; Very Dense Forest (VDF) with canopy density more than 70%, Moderately Dense Forest (MDF) with canopy density between 40-70% and Open Forest (OF) with canopy density between 10-40% and very low density areas have been classified under Degraded Forest (DF) / Scrub with canopy density less than 10%. (SFR, 2011).

## 4.5. Phytosociology

Phytosociology is the study of vegetation characteristics, classification, relationships and distribution of plant communities. It refers to structural attributes of plant community, which can be divided as qualitative characters (physiognomy, stratification, dispersion, sociability, *etc*.) and quantitative characters (density, dominance, frequency, *etc*.). Structural variations in plant communities modulates spectral signatures, thus remote sensing data give basis to describe qualitative characters of community structure (Thomas *et al.,* 1993). It provides homogeneous unit to lay down sample plots for quantitative study of the community structure. The prerequisite for the quantitative study of community structure is to map qualitative characters of vegetation in a landscape. The vegetation is sampled according to a plot method in various strata. Such sampling helps in obtaining maximum information about community with minimum efforts in the least time (Roy *et al.*, 1993). Phytosociological analysis provides the real meaning to any biodiversity analysis by quantifying the structural parameters of communities. The methodology used for vegetation studies of PKTR are as follows:

With a view to study the phytosociology of vegetation in Parambikulam Wildlife Sanctuary, a thorough reconnaissance survey was carried out initially to assess the structural characteristics of the permanent vegetation so as to design the sampling procedure and intensity. Based on the species area curve method, minimum quadrant size of 0.1 ha (31.6m X 31.6m) has been considered as a matter of convenience for phytosociological data collection from all the forest types. In each plot all the species names of trees (height, girth), herbs, shrubs, climbers and epiphyte were recorded. Stratified random sampling was adopted for analyzing vegetation composition of all the forest types. Representative area of each community was selected on vegetation map and it was located on ground with the help of Global Positioning System.

The census quadrat method (Oosting, 1956) was adopted and in each of the plot, trees of 30 cm and above Girth at Breast Height (GBH) of 1.37m above the ground level were enumerated (Roy, 1993). At the centre of the plot 5m x 5m plot is taken for measurement of shrubs and regeneration. In corners of the plot, 1m x 1m subplot will be done to account herbs. Total numbers of seedlings and saplings of various species are counted and average height of each species is recorded. For shrubs, total number of tillers for each species was enumerated. In each of this plot, tree, shrubs and herbs data will be collected for assessment of species richness, diversity and predominant species.

A total of 145 plots of 0.1 ha were laid in the predominant forest types concentrating on arborescent species in the core area of PKTR during the year 2006-2008 for the enumeration of trees, shrubs, herbs and regeneration. Evergreen forests were the maximum attempted (61 plots) followed by moist deciduous forests (51 plots) Semi evergreen forests (15 plots) Teak Plantations forests (15 plots) and Dry deciduous forests (3 plots) (Table 4.2). The spatial location (latitude and longitude) and altitude of each quadrate was recorded using GPS and pocket altimeter with a sensitivity of 20m. The distribution of sample plots in PKTR is depicted in Fig. 4.2.

Identification of plants was done using Flora of Presidency of Madras (Gamble and Fischer, 1915-1936) and by seeking assistance from experts. Distribution and IUCN status was determined by perusal of literature (Sasidharan, 2004a, 2006, 2007, www.iucnredlist.org). The detailed information regarding the sample plots laid in different vegetation types of PKTR in various locations are given in Appendix I.

Table 4.2. Details of sample plots laid in different vegetation types

| **Sl. No** | **Vegetation types** | **Area sampled (ha)** | **No. of Plots** |
|---|---|---|---|
| 1 | West coast tropical evergreen forest | 6.64 | 61 |
| 2 | West coast semi evergreen forest | 1.63 | 15 |
| 3 | Southern moist mixed deciduous forest | 5.55 | 51 |
| 4 | Southern dry mixed deciduous forest | 0.33 | 3 |
| 5 | Moist teak-bearing forest | 1.63 | 15 |
| | **Total** | **15.79** | **145** |

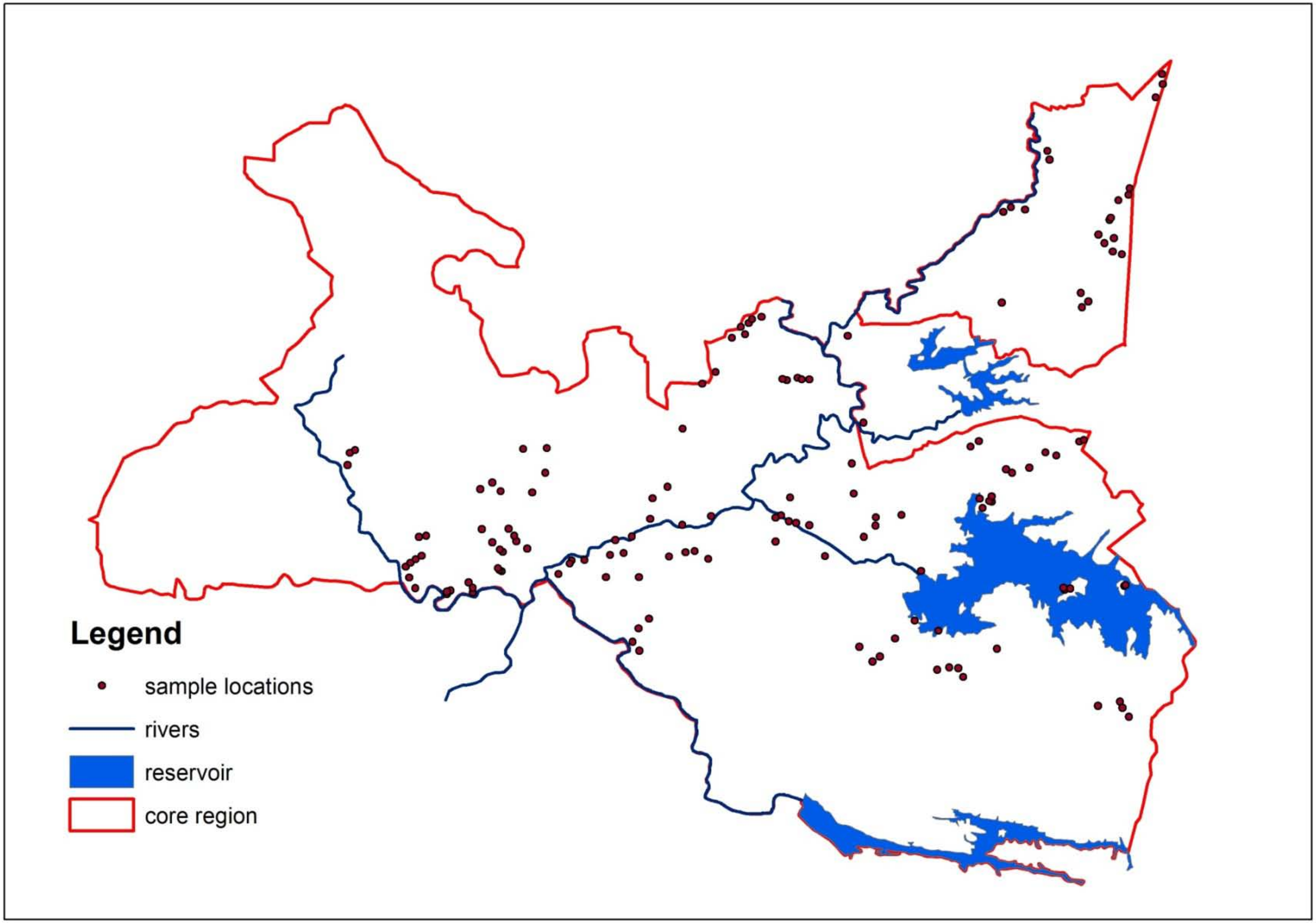



Fig. 4.2. Locations of sample plots in the core area of PKTR

### 4.5.1. Data Analysis

The data gathered from various plots under each vegetation type were analyzed type wise. The phytosociological parameters worked out for each plot using the formulae (Curtis and McIntosh, 1950; Phillips, 1959; Misra, 1968) given against each. Importance Value Index (IVI) of various species was also worked out (Muller-Dombois and Ellenberg, 1974) as the sum of Relative density, Relative frequency and Relative dominance of each of them. The quadrat data were then processed for quantitative and qualitative analysis to evaluate structural composition and organization of the community. From the quadrat data obtained from the field work the following primary and secondary analysis were done.Density, Frequency, Abundance, IVI (Importance Value Index), and biodiversity indices were calculated by using formulae.

**i) Density**

Density is defined as the number of individuals of a species in a unit area and is an expression of numerical strength of a species in a community. From the sampling data the density was calculated as follows:

$$\text{Density (D)} = \frac{\text{Number of individuals encountered}}{\text{Total area sampled in m}^2}$$

**ii) Relative Density (*RDi*)**

Relative density is the study of numerical strength of a species in relation to total number of all species and is calculated as:

$$\text{Relative density } (RDi) = \frac{\text{Number of individuals belonging to species i}}{\text{Total numberof individuals}} \times 100$$

**iii) Abundance**

Abundance is described as the number of individuals per quadrat of occurrence.

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

**iv) Frequency**

It is expressed as the percentage of occurrence of a given species in the sample plots studied. It denotes the homogeneity of distribution of various species in the ecosystem. For comparison of different communities, frequency is expressed in terms of percentage values (frequency %).

$$\text{Frequency (Fi)} = \frac{\text{Number of quadrats in which species i was present}}{\text{Total number of quadrats sampled}} \times 100$$

The species which is well distributed and have a chance of being recorded in any part of the ecosystem will have frequency 100%. While a species which is restricted to a certain areas will be encountered in low frequency values

$$\text{Relative Frequency } (RFi) = \frac{Fi}{\sum Fi}$$

**v) Basal area and Relative Basal Area**

Basal area refers to the ground actually occupied by the stems and is one of the chief characters that determine the dominance and the nature of community. As a general rule, high basal area indicates greater dominance. The average basal area and the relative basal area were calculated out of the average diameter of the stem at breast height using the following formulae:

$$Basal\ Area\ of\ trees = \pi r^2$$

$$r = \frac{gbh}{2\pi}$$

$$\text{Relative Basal Area (RBAi)} = \frac{BAi}{BP} X100$$

Where BAi = Sum of basal area of the trees belonging to a species

BP = Sum of basal areas of all the trees in a plot

**vi) Importance Value Index (IVI)**

It is used to express dominance and ecological success of any species. IVI provides an overall importance of a species in a community. This index was derived from three characteristics of vegetation *viz*., relative frequency, relative density, and relative basal area as:

Importance Value Index (IVI) = Relative Density (*RDi*) + Relative Frequency (*RFi*) + Relative Basal Area (*RBA*i)

**vii) Species richness**

Diversity is frequently seen as indicator of wellbeing of ecological systems, therefore it has occupied central theme in ecological studies (Magurran, 1988). The species richness and diversity measures based on abundances are two important components of diversity. Species richness is the oldest and simplest concept of species diversity. It is the number of species in the community. Diversity of communities can be assessed using species richness indices (measure of number of species in sampling unit), species abundance model (measure of degree of evenness) and indices based on the proportional abundances of species (Shannon & Simpson Index). The Biodiversity indices are mathematical expressions of species importance relationships (Odum, 1983). Based on the phytosociological data analyzed for the above aspects, the following indices are used for the present study to get the species richness, species dominance, diversity and evenness of the permanent vegetation.

**viii) Biodiversity indices**

Diversity lies at the root of some of the most fundamental and exciting questions in theoretical and applied ecology (Magurran, 1988). Therefore mapping and measuring ecological diversity both qualitative and quantitative is instructive Krebs (1989). The inherent aim of the study was to collect and present the most basic data on the forests of Parambikulam Tiger Reserve which can be utilized as a baseline for further academic research and for determining the conservation values for management and protection. Standard sampling methods (Muller-Dombois and Ellenberg, 1974) were adopted, to fulfill the objectives.

1. Simpson's index

Diversity indices incorporate both species richness and evenness in to a single value as it takes in to account the number of species present as well as the relative abundance of each species. It represents the probability that two randomly selected individuals in the habitat belong to the same species. If the probability is high then the diversity of the community sampled is low. Simpson's index was the first diversity index used in ecology. The concentration of dominance was determined by Simpson's (1949) index as given below

$$\lambda = \sum_{i=1}^{s} Pi^{2}$$

Where $pi = \frac{ni}{N}$

Where ni = total number of individual of species 'i', and N = total number of individuals of all species in the area.

This index varies from 0 to 1 and gives the probability that two individuals drawn at random from a population belong to the same species. If the probability is high then the diversity of the community sampled is low.

2. Shannon's index [H']

The Shannon index, H' (also called the Shannon- weaver index or the Shannon -wiener index) is one of several diversity indices used to measure biodiversity. It has probably been the most widely used index in community ecology. The advantage of this index is that it takes into account the number of species and the evenness of the species. The index is increased either by having more unique species or by having greater species evenness.

$$H' = -\sum_{i=1}^{r} (p_i \log p_i)$$

Where, $p_i = \frac{n_i}{n}$

Where ni = total number of individual of species 'i', and N = total number of individuals of all species in the area.

As in Simpson index by applying calculus, it can be shown that for any given number of species, there is a maximum possible *H'*, $H'_{max} = ln(S)$ which occurs when all the species are present in equal numbers.

### 4.14. Richness indices

i) Margalef's index

$$R = \frac{S - 1}{\ln(n)}$$

Where S=Number of species recorded
N=Total number of individuals observed.

ii) Menhinick's index

$$R2 = \frac{S}{\sqrt{n}}$$

Where S = Number of species recorded n= Total number of individuals summed over all the species.

Diversity lies at the root of some of the most fundamental and exciting questions in theoretical and applied ecology (Magurran, 1988). Therefore, mapping and measuring ecological diversity both qualitative and quantitative is instructive Krebs (1989).

The inherent aim of the study was to collect and present the most basic data on the forests of Parambikulam tiger reserve, which can be utilized as a baseline for further academic research and for determining the conservation values for management and protection. Standard sampling methods (Muller-Dombois and Ellenberg, 1974) were adopted, to fulfill the objectives. Remote sensing and GIS analysis was done using standard remote sensing and GIS softwares and statistical analysis followed recognized texts on ecological methodology and analysis (Jayaraman, 2001; Krebs, 1989 and Magurran 1988).

### 4.5.2. Regeneration Studies

Regeneration studies were conducted in all locations by laying out sample plots of 5m X 5m. The regeneration plots were laid within the tree plots of 31.62m X 31.62m size. The following classification was followed for regeneration enumeration, based on height differences *viz*., saplings (Above 130cm height and >15cm and <30cm GBH), seedlings (Below 100cm height and <15cm GBH).

Chapter 5

# RESULTS AND DISCUSSION

Chapter 5.1

# Land cover mapping

# CHAPTER- 5
# RESULTS AND DISCUSSION

## 5.1. LAND COVER MAPPING

Land cover maps of PKTR were prepared using satellite images of Landsat MSS for the year 1973, Landsat TM for the year 1990 and IRS P6 LISS III for the year 2005.

### 5.1.1. Land Cover mapping for the year 1973

Land cover map for the year 1973 is prepared (Fig. 5.1.2) using Landsat MSS data. Altogether, seven land cover classes have been identified viz., West coast tropical evergreen forests, West coast semi evergreen forests, Southern moist mixed deciduous forest, Moist bamboo brakes, Teak plantation forest and Open areas/grasslands.

The area is predominantly covered by Evergreen (34%) and Semi evergreen forests (17%) followed by Moist deciduous forest (16%) and Teak plantations (15%). The land cover classes, area statistics and percentage of area are given in Table 5.1.1 and Fig. 5.1.1.

Table 5.1.1. Area statistics of land cover classes in PKTR for the year 1973.

| Sl No | Land cover classes | Area ($km^2$) |
|---|---|---|
| 1 | West coast tropical evergreen forest | 219 |
| 2 | West coast semi evergreen forest | 110 |
| 3 | Southern moist mixed deciduous forest | 103 |
| 4 | Teak plantation | 96 |
| 5 | Open areas/grasslands | 62 |
| 6 | Moist bamboo brakes | 27 |
| 7 | Reservoir | 26 |
| | **Total** | **643** |


Fig. 5.1.1. Area of land cover classes in percentage derived from Landsat MSS data of the year 1973.

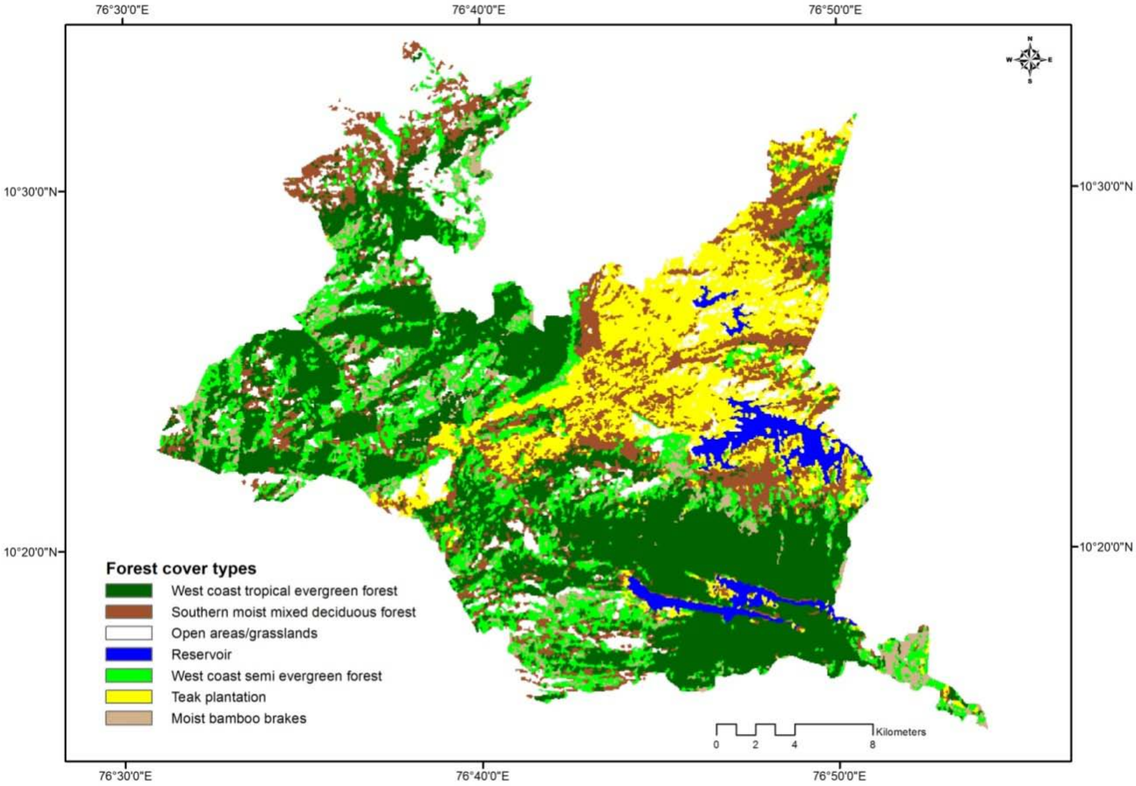



Fig. 5.1.2. Land cover map of PKTR derived from Landsat MSS data of the year 1973

### 5.1.2. Land Cover mapping for the year 1990

Land cover mapping using the Landsat TM data of the year 1990 showed that the area is predominantly covered by Evergreen (32%) and Semi evergreen forests (16%) followed by Moist deciduous forest (19%) and Teak plantations (15%) (Fig. 5.1.4.). The land cover classes and its area statistics are given in Table 5.1.2 and Fig. 5.1.3.

Table 5.1.2. Area statistics of land cover classes in PKTR for the year 1990.

| Sl No | Land cover classes | Area ($km^2$) |
|---|---|---|
| 1 | West coast tropical evergreen forest | 204 |
| 2 | West coast semi evergreen forest | 102 |
| 3 | Southern moist mixed deciduous forest | 121 |
| 4 | Teak plantation | 88 |
| 5 | Open areas/grasslands | 68 |
| 6 | Moist bamboo brakes | 39 |
| 7 | Reservoir | 21 |
| | **Total** | **643** |


Fig. 5.1.3. Area of land cover classes in percentage for the year 1990.

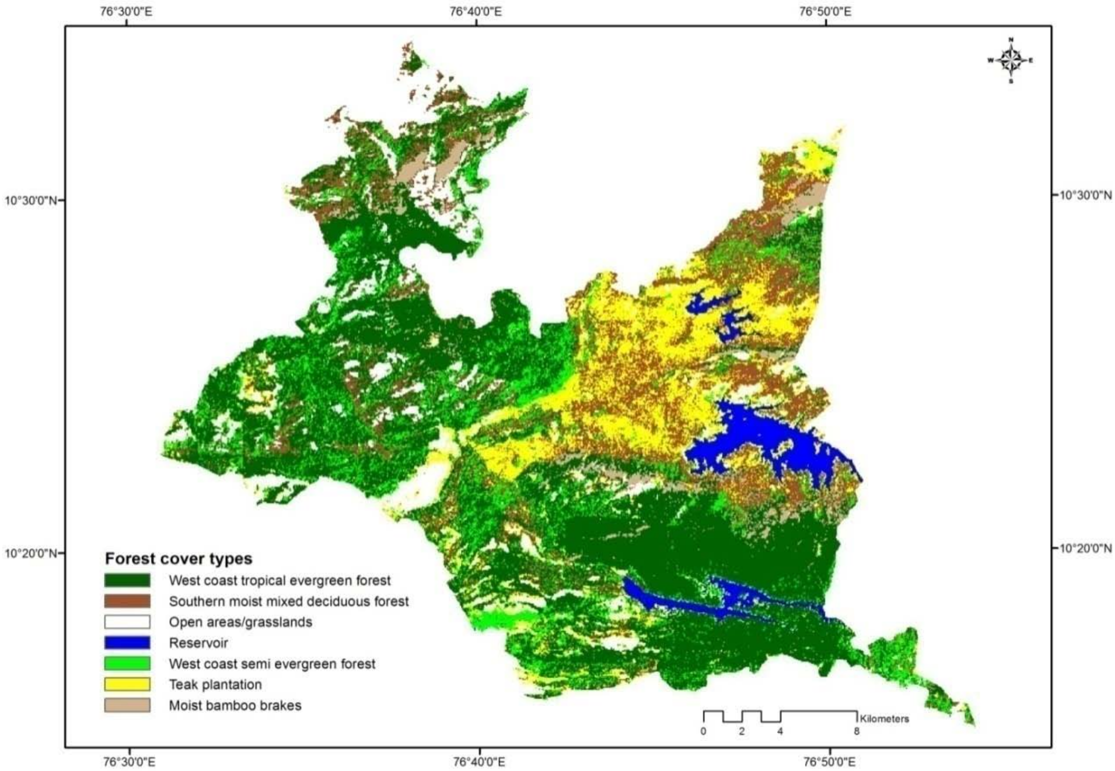



Fig. 5.1.4. Land cover map of PKTR derived from Landsat TM data for the year 1990.

### 5.1.3. Land Cover mapping for the year 2005

Land cover map was prepared from IRS P6 LISS III satellite imagery of the year 2005 (Fig.5.1.6). Among the forest types, Evergreen forest covers 36%, Semi evergreen forest 17%, Moist deciduous forest 20%. The area is predominantly covered by Evergreen forest, which is approximately 229 km$^2$ of the total area. The details of land cover classes are given in Table. 5.1.3. and Fig.5.1.5.

Table 5.1.3. Area statistics of land cover classes in PKTR for the year 2005.

| Sl No | Land cover classes | Area (km$^2$) |
|---|---|---|
| 1 | West coast tropical evergreen forest | 229 |
| 2 | West coast semi evergreen forest | 108 |
| 3 | Southern moist mixed deciduous forest | 127 |
| 4 | Teak plantation | 65 |
| 5 | Open areas/grasslands | 61 |
| 6 | Moist bamboo brakes | 28 |
| 7 | Reservoir | 25 |
| | **Total** | **643** |

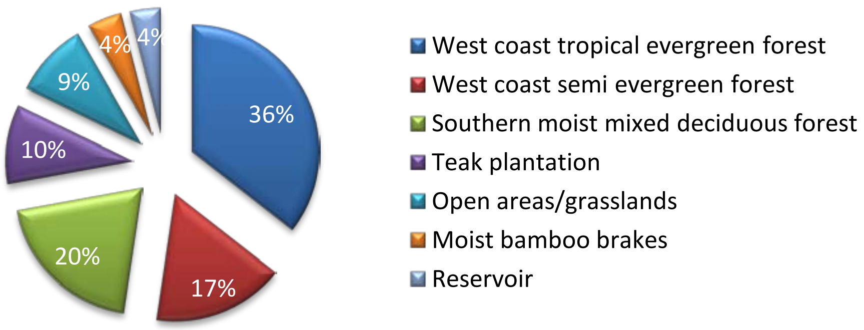



Fig. 5.1.5. Area of land cover classes in percentage for the year 2005.

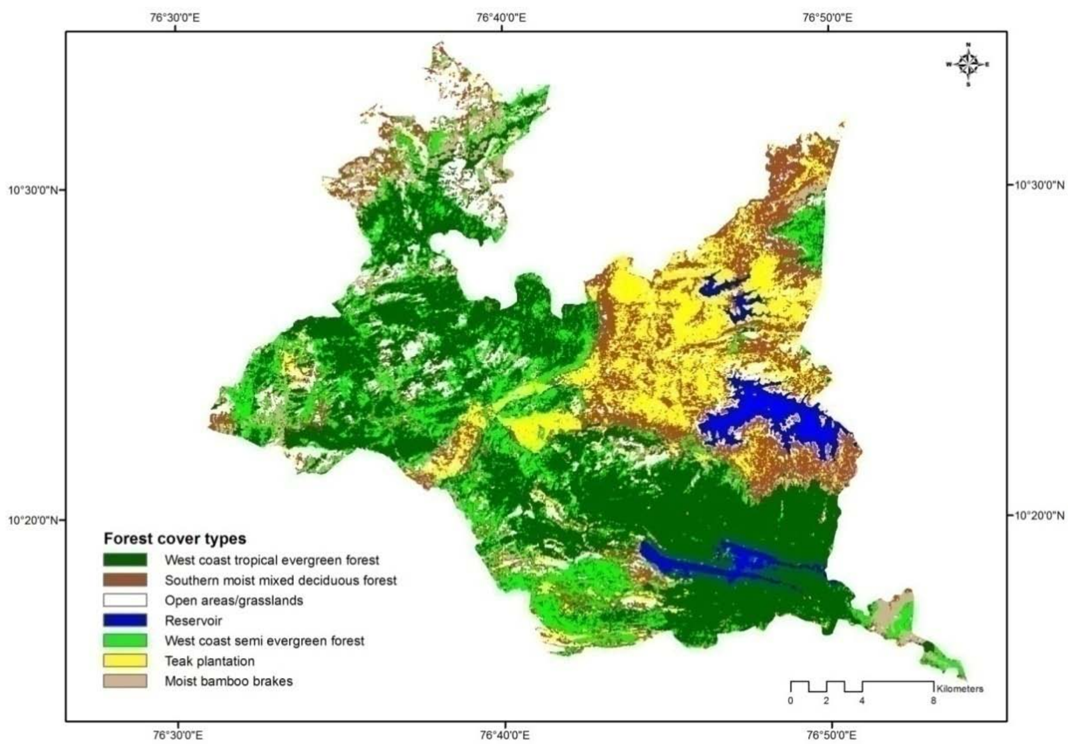



Fig. 5.1.6. Land cover map of PKTR derived from IRS P6 LISS III satellite image of the year 2005.

### 5.1.4. Accuracy assessment

Accuracy assessment was performed to give a reliability level to the results obtained after interpretation of the satellite data. In assessment of forest cover, accuracy assessment illustrates as how accurately the satellite imageries are interpreted to match the exact position on the earth/ground. This was done by ground truth with carefully designed field verification using satellite images. Mapping accuracy assessment was undertaken following Congalton, 1991.

An overall accuracy assessment of the forest types was performed using the reference data taken from field observations. Extensive ground truth survey was conducted for the collection of training sets and reference pixels for accuracy estimation. A total of 138 stratified random points proportionate to the area of the classified forest type were taken as reference data for accuracy estimation. Error Matrix developed for the accuracy assessment is represented in Table 5.1.4.

Table 5.1.4. Error matrix for the land cover map prepared for the year 2005

| | | Reference Data | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Forest types** | EG | SEG | MD | TP | R | O | MBB |
| Classified Data | EG | 37 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SEG | 1 | 14 | 1 | 0 | 0 | 0 | 2 |
| | MD | 0 | 0 | 18 | 4 | 0 | 0 | 1 |
| | TP | 0 | 0 | 0 | 18 | 0 | 0 | 0 |
| | R | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| | O | 0 | 0 | 0 | 2 | 1 | 12 | 0 |
| | MBB | 0 | 2 | 0 | 0 | 0 | 2 | 13 |
| | **Total** | 38 | 16 | 19 | 24 | 11 | 14 | 16 |

EG- West coast tropical evergreen forests, SEG- West coast semi evergreen forests, MD- Southern moist mixed deciduous forest, TP-Teak plantation, R-Reservoir, O-Open areas/grasslands, MBB-Moist bamboo brakes

Here, the diagonals represent sites classified correctly according to reference data and the off diagonals were misclassified. A measure for the overall classification accuracy can be derived from this table by counting how many pixels were classified the same in the satellite image and on the ground and dividing this by the total number of points. The error matrix method reveals that, out of 138 sampling points where observations were made, classification of 122 sampling points of the elements along the main diagonal of the matrix was found accurate.

$$\frac{122}{138} \times 100 = 88.41\%$$

Overall accuracy for the land cover map obtained with seven land cover classes is 88.41%, which is termed as 'high' by the generally accepted norms.

### 5.1.5. Comparison of Land cover change assessment for the year 1973 and 2005

The overall change assessment from 1973 to 2005 indicated changes in the land cover classes. The major changes during 1973-2005 accounts the reduction of 34 $km^2$ teak plantation, which has regained to mixed moist deciduous stands. The positive change accounts the increase in area of Southern moist mixed deciduous forest by 25 $km^2$ and West coast tropical evergreen forest by 11 $km^2$. Here, the unmanaged Teak plantations in remote locations that are having sufficient regeneration capacity has attained the status of mixed moist deciduous stands, which in turn results in the reduction of area of Teak forest and the regain of moist deciduous forest. As it is declared as a protected area followed by wildlife sanctuary and to tiger reserve, the conservation and management activities of this area got improved which resulted in an increase in area of evergreen forest by the transformation of semi evergreen forest to evergreen. (Table 5.1.5., Fig.5.1.7.).

Table 5.1.5. Comparison of Land cover changes in PKTR for the year 1973 and 2005.

| Land cover classes | 1973 | 2005 | Change ($km^2$) | % of change |
|---|---|---|---|---|
| West coast tropical evergreen forest | 218 | 229 | 11 | 2 |
| West coast semi evergreen forest | 109 | 108 | -1 | 0 |
| Southern moist mixed deciduous forest | 103 | 127 | 25 | 4 |
| Teak plantation | 99 | 65 | -34 | -5 |
| Open areas/grasslands | 62 | 61 | -1 | 0 |
| Moist bamboo brakes | 33 | 28 | -5 | -1 |
| Reservoir | 20 | 25 | 5 | 1 |

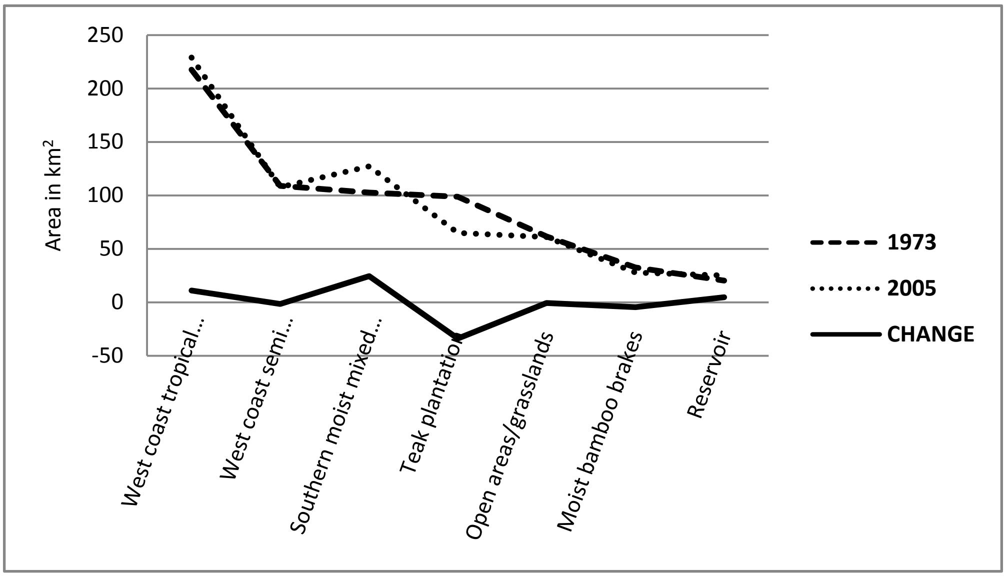



Fig.5.1.7. Land cover change assessment in PKTR for the year 1973 and 2005.

### 5.1.6. Time series analysis of Land cover change during the year 1973 to 1990 and 1990 to 2005

In the present study, an attempt has been made to carry out land cover change detection analysis. Change detection involves the use of multi-temporal datasets to derive land cover changes for different period of satellite image. Change detection analysis is performed between two-time periods such as 1973-1990 and 1990-2005 using the classified land cover maps prepared from satellite images.

#### 5.1.6.1. Change matrix for PKTR during 1973 to 1990

During 1973 to 1990 the change in forest cover was mainly from evergreen to semi-evergreen forest (16 km$^2$), semi evergreen to moist deciduous (13 km$^2$) and to open areas (12 km$^2$), moist deciduous to teak plantation (16 km$^2$), teak plantation to moist deciduous (30 km$^2$), open areas to teak plantation (9 km$^2$) and to moist deciduous forest (9 km$^2$). The change matrix is given in Table 5.1.6. Land cover change map from 1973 to 1990 is shown in Fig. 5.1.8.

Table 5.1.6. Land cover change matrix of PKTR for the year 1973 to 1990.

| Forest types | EG | SEG | MD | TP | O | MBB | R |
|---|---|---|---|---|---|---|---|
| EG | 198 | 16 | 0 | 0 | 2 | 2 | 0 |
| SEG | 6 | 72 | 13 | 5 | 12 | 1 | 0 |
| MD | 0 | 8 | 66 | 16 | 5 | 7 | 1 |
| TP | 0 | 4 | 30 | 57 | 7 | 0 | 0 |
| O | 0 | 2 | 9 | 9 | 40 | 1 | 1 |
| MBB | 0 | 0 | 2 | 1 | 2 | 28 | 0 |
| R | 0 | 0 | 0 | 0 | 0 | 0 | 20 |

EG- West coast tropical evergreen forests, SEG- West coast semi evergreen forests, MD- Southern moist mixed deciduous forest, TP-Teak plantation, R-Reservoir, O-Open areas/grasslands, MBB-Moist bamboo brakes

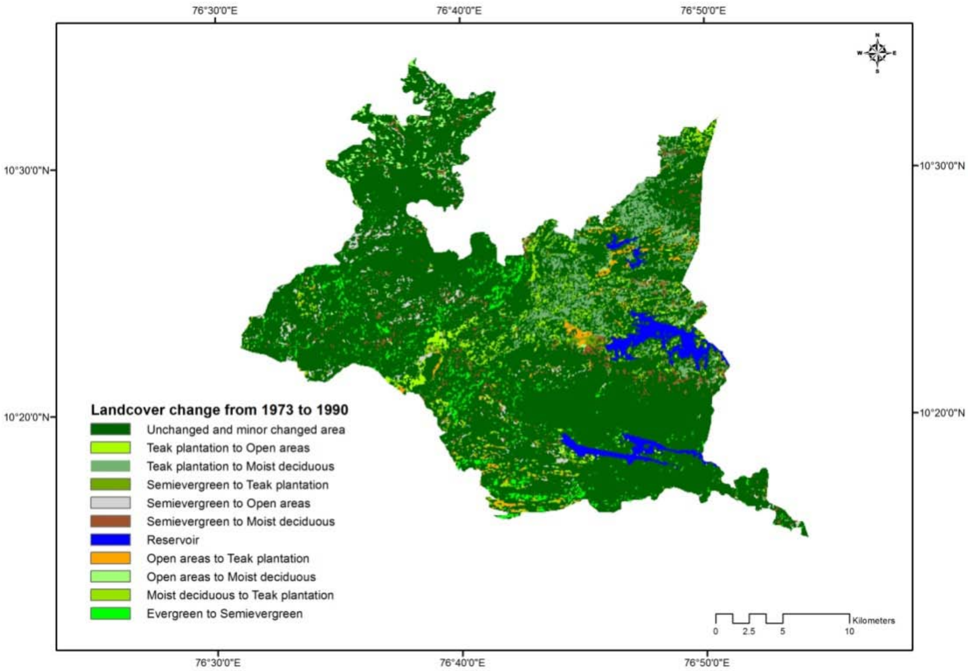



Fig. 5.1.8. Land cover change map from 1973 to 1990.

### 5.1.6.2. Change matrix for PKTR during 1990 to 2005.

During the year 1990 to 2005, the changes observed in forest cover was mainly from evergreen to semi-evergreen forest (13 km$^2$), semi evergreen to evergreen (10 km$^2$) and to moist deciduous (13 km$^2$), moist deciduous to semi evergreen (12 km$^2$), to open areas (9 km$^2$) and to moist bamboo brakes (9 km$^2$). Teak plantation to moist deciduous forest (20 km$^2$) and to open areas (8 km$^2$). Table 5.1.7. and Fig. 5.1.9.

Table 5.1.7. Land cover change matrix of PKTR for the year 1990 to 2005

| Forest types | EG | SEG | MD | TP | O | MBB | R |
|---|---|---|---|---|---|---|---|
| **EG** | 215 | 13 | 0 | 2 | 4 | 0 | 2 |
| **SEG** | 10 | 46 | 13 | 2 | 3 | 0 | 0 |
| **MD** | 0 | 12 | 79 | 2 | 9 | 9 | 1 |
| **TP** | 0 | 0 | 20 | 48 | 8 | 2 | 1 |
| **O** | 2 | 5 | 10 | 7 | 35 | 4 | 1 |
| **MBB** | 0 | 1 | 4 | 2 | 1 | 13 | 0 |
| **R** | 2 | 0 | 1 | 0 | 1 | 0 | 21 |

EG- West coast tropical evergreen forests, SEG- West coast semi evergreen forests, MD- Southern moist mixed deciduous forest, TP-Teak plantation, R-Reservoir, O-Open areas/grasslands, MBB-Moist bamboo brakes

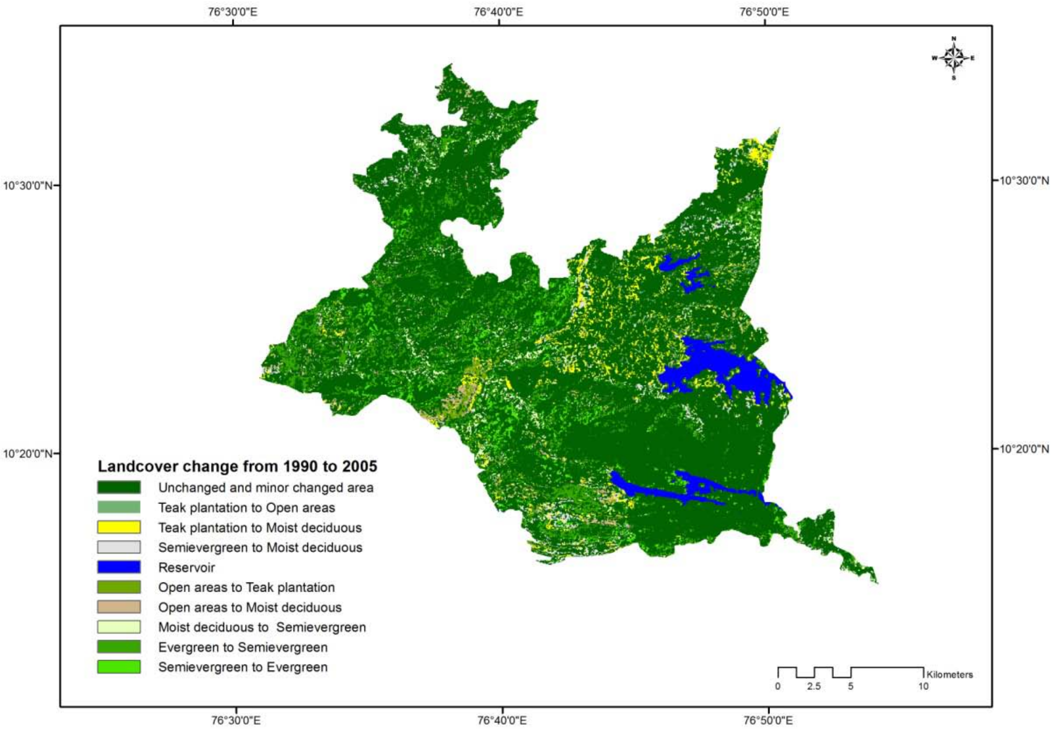



Fig. 5.1.9. Land cover change map from 1990 to 2005.

## 5.1.7. Forest cover density during the year 1973-2005

Forest cover density maps during the year 1973-2005 was prepared using five time series satellite images of Landsat MSS data for the year 1973, Landsat TM data for the year 1990, IRS 1D LISS-III for the year 1999, Landsat ETM+ for the year 2001 and IRS P6 LISS-III for the year 2005.

During 1973 to 2005, Very dense forest has increased gradually by 36 $km^2$ *i.e*. from 162 $km^2$ to 198 $km^2$ and Moderately dense forest has increased by

15 km² in 1990 and 11 km² in 2001 and again increased gradually by 5 km² in 2005. Open forest has decreased by 18 km² in 1990 and 11 km² in 1999. Degraded forest has decreased by 8 km² in 1990 and 19 km² in 2001 and 9 km² in 2005. The density stratification reflected that nearly 31% (200 km²) of the forest area in PKTR falls under moderately dense forest and 30% (198 km²) of the area falls under Very dense forest category. (Table 5.1.8; Fig.5.1.10). The terrain and inaccessibility conditions in the PKTR have kept the area comparatively free from disturbance, and therefore, high density (around 61%) of the area falls under the dense forest category) is maintained in general. The degraded (low density) forest covers an area of 52 km² which occurs near habitations and open areas. Forest cover density maps prepared for the year 1973, 1990, 1999, 2001 and 2005 are shown in Fig. 5.1.11. - Fig. 5.1.15.

Table 5.1.8. Forest cover density of PKTR during the year 1973-2005

| **Forest cover density** | **1973** | **1990** | **1999** | **2001** | **2005** |
|---|---|---|---|---|---|
| Very Dense Forest | 162 | 170 | 175 | 187 | 198 |
| Moderately Dense Forest | 170 | 185 | 184 | 195 | 200 |
| Open Forest | 201 | 183 | 172 | 168 | 163 |
| Degraded Forest/Scrub | 85 | 77 | 80 | 61 | 52 |

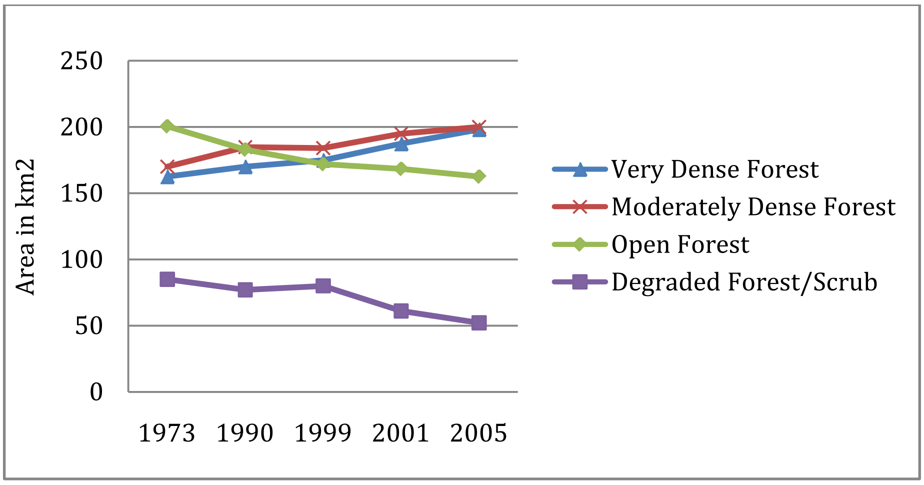



Fig. 5.1.10. Forest cover density of PKTR during the year 1973-2005

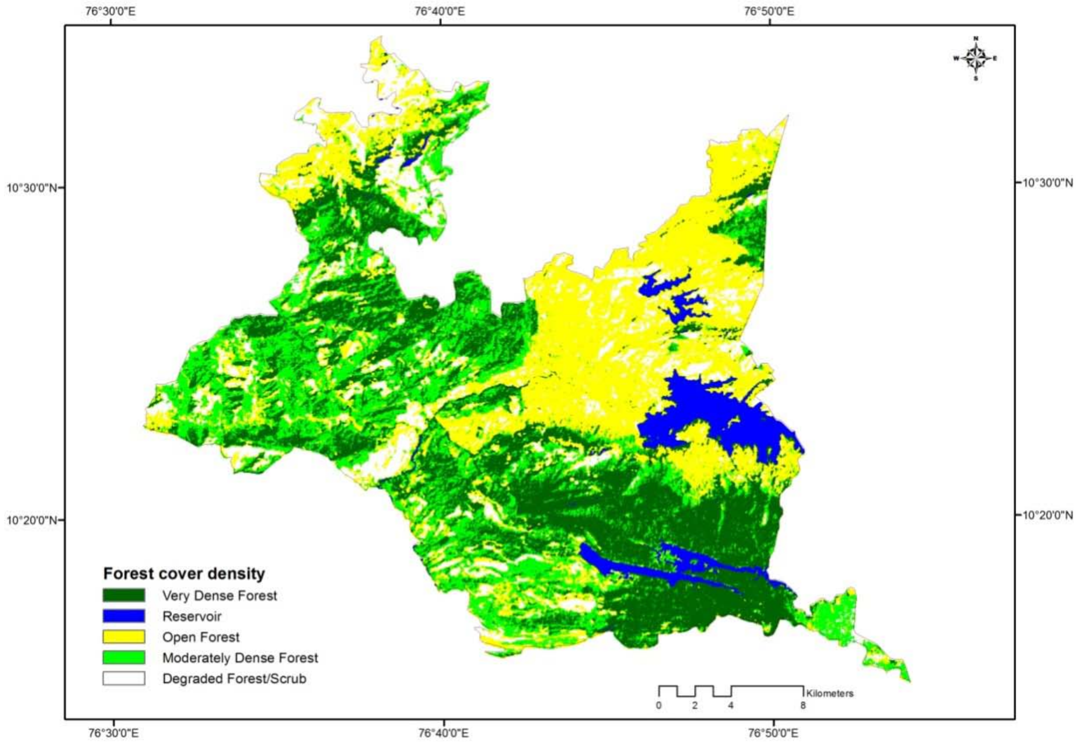



Fig. 5.1.11. Forest cover density map derived from Landsat MSS data for the year 1973.

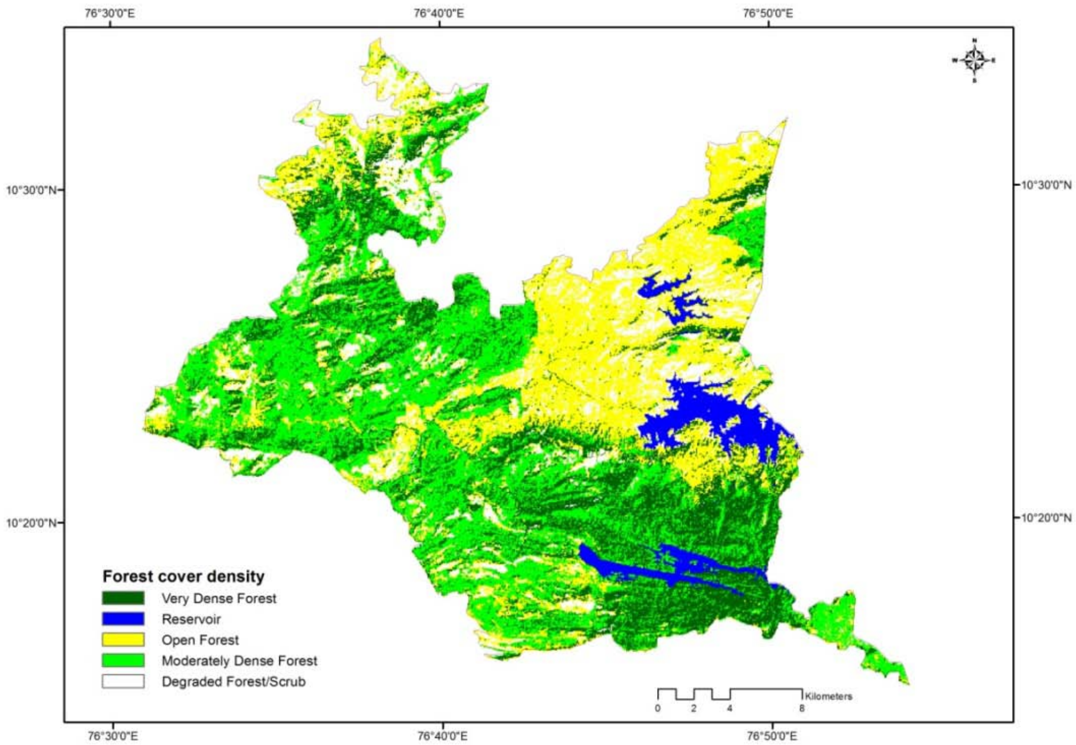



Fig. 5.1.12. Forest cover density map derived from Landsat TM data for the year 1990.

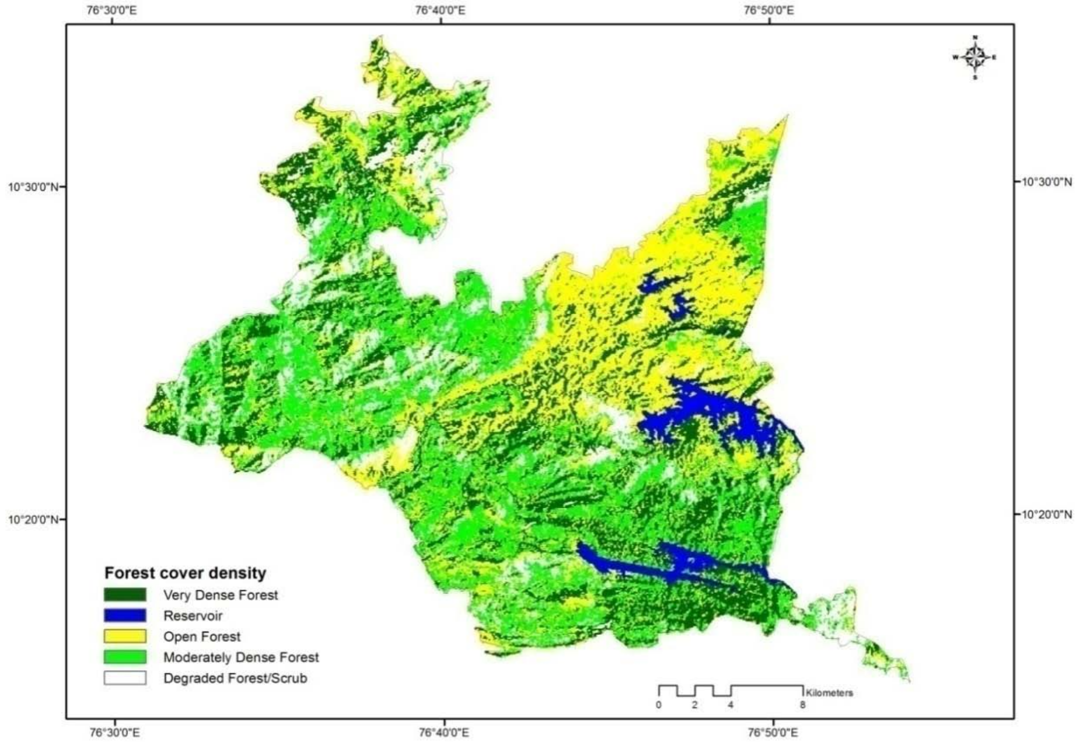



Fig. 5.1.13. Forest cover density map derived from IRS 1D LISS-III data for the year 1999.

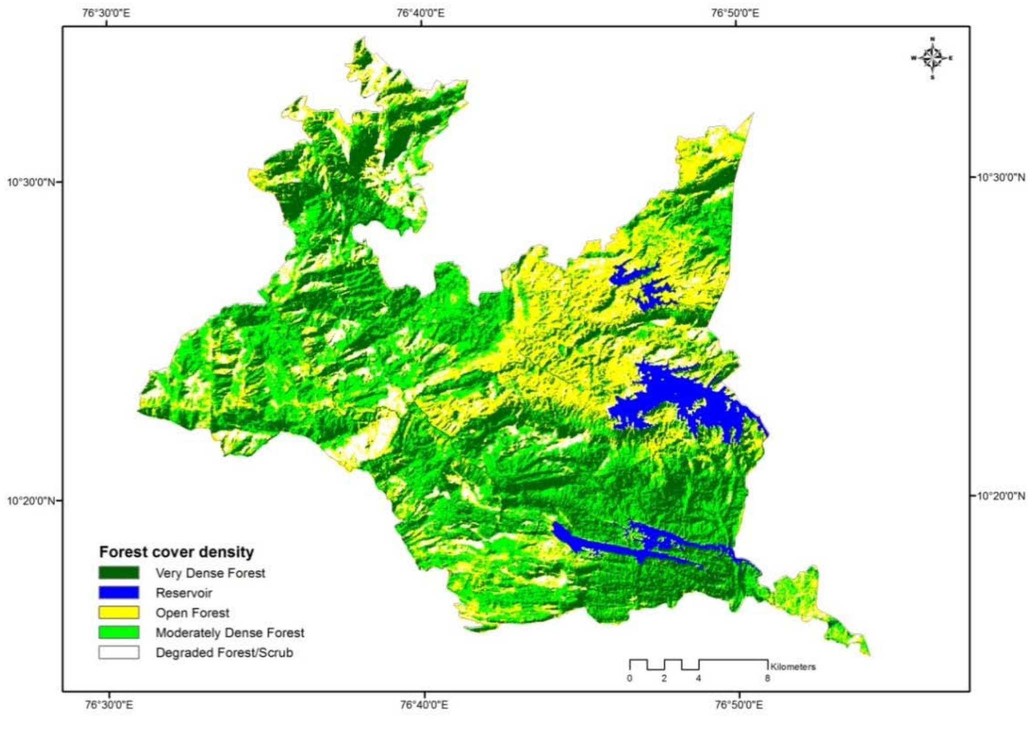



Fig. 5.1.14. Forest cover density map derived from Landsat ETM+ for the year 2001.

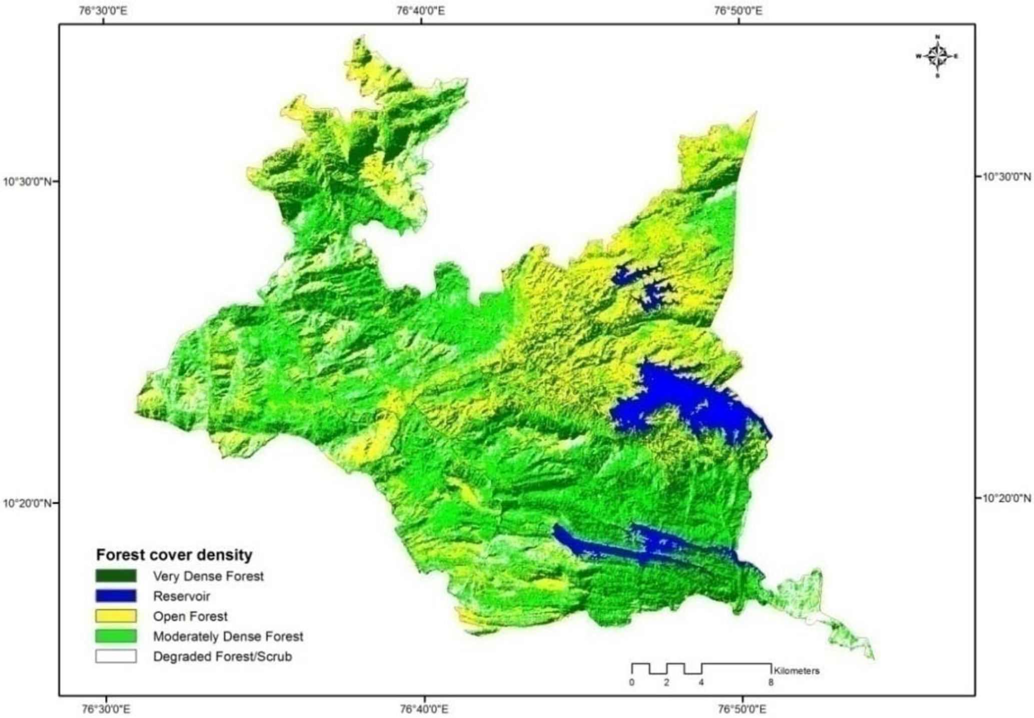



Fig. 5.1.15. Forest cover density map derived from IRS P6 LISS-III for the year 2005.

### 5.1.8. Forest cover density change during the year 1973-2005

During 1973 to 2005, Very dense forest has increased by 36 $km^2$ *i.e.* from 162 $km^2$ to 198 $km^2$ and moderately dense forest has increased by 30 $km^2$ from 170 $km^2$ to 200 $km^2$. Open forest has decreased by 30 $km^2$ and the degraded forest has decreased by 33 $km^2$. Here, open forest and degraded forest has been transformed to very dense forest and moderately dense forest during a period of 32 years. (Table 5.1.9 & Fig. 5.1.16).

Table 5.1.9. Forest cover density changes in PKTR during the year 1973-2005

| Forest cover density | 1973 | 2005 | Change |
|---|---|---|---|
| Very dense forest | 162 | 198 | 36 |
| Moderately dense forest | 170 | 200 | 30 |
| Open forest | 201 | 163 | -38 |
| Degraded forest/Scrub | 85 | 52 | -33 |

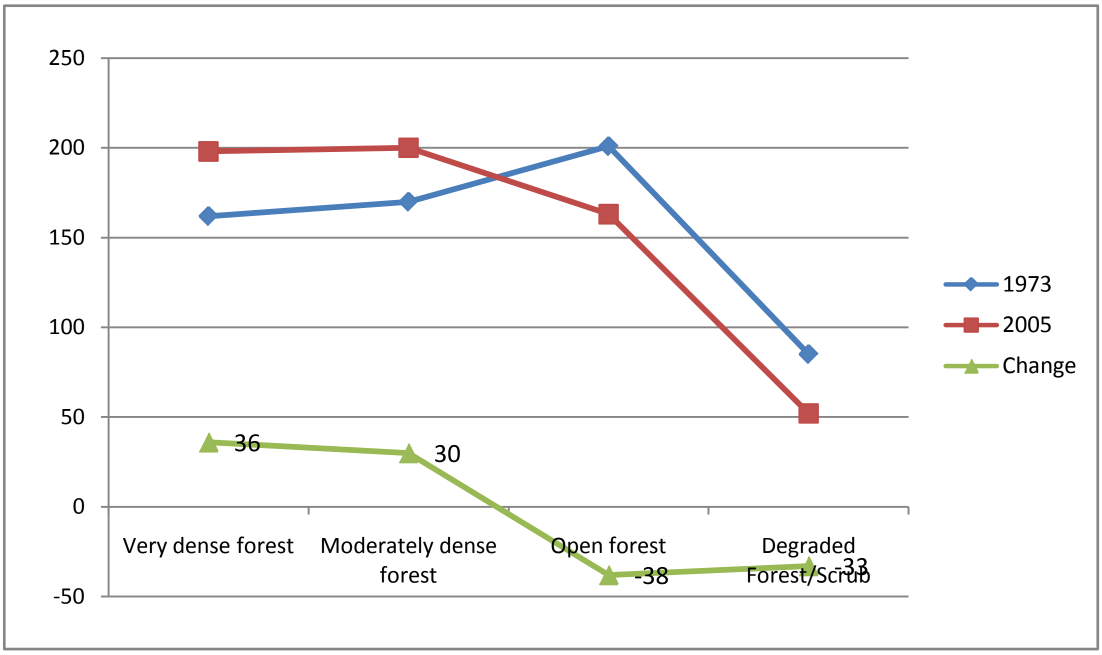



Fig. 5.1.16. Temporal changes of Forest cover density in PKTR during the year 1973-2005

### 5.1.9. Discussion

The Parambikulam basin of Nelliampathies is one of the areas in Kerala with a long history of forestry operations and yet has continued to remain forested even today. Although the dams and the plantations have decimated the area and forest continuity considerably, this remains one of the most extensive contiguous forest tracts in the Kerala part of the Western Ghats.

Vegetation is a vital component of the ecosystem, which indicates the effects of changing environmental conditions in an obvious and easily measurable manner. The PKTR has a wide spectrum of forest types ranging from tropical evergreen to dry deciduous within an area of 643.7 km$^2$. The distribution of land cover was according to the prevailing climatic and topographic gradients in the area. The western and southern parts of the higher elevation zones of the area, where rainfall is higher showed moist types of vegetation, while northern part were predominantly covered with deciduous types of vegetation. Land cover mapping of PKTR using the IRS P6 LISS III data of 2005 depict seven land cover classes, *viz.*, evergreen forest, semi evergreen forest, moist deciduous forest, teak plantation, Moist bamboo brakes and open areas/grassland. The area is predominantly covered with Evergreen forests (36%), Semi evergreen forests (17%), Moist deciduous forests (20%), of the total area. Therefore, this spatial resolution is sufficient for discerning the forest types and provides insightful information about the cover types. The evergreen forests of the study area are comparatively less degraded in nature due to its inaccessibility and subsequent low anthropogenic pressure. The moist deciduous forests are very close to habitations, so also the semi evergreen forests. The results indicate that the approach suggested here is adequate in identifying the features essential for any forest inventory and can provide reliable information on land cover features.

The changes in the vegetation cover over a period of thirty two years based on digital classification of Landsat image and IRS LISS-III data during the period 1973 to 1990 shows that evergreen forest area has been decreased by 14 $km^2$ and semi evergreen forest by 7 $km^2$, which is an indication of the change in land cover type from intact forest to degraded forest or the degradation of forest areas. This may be due to the past timber extraction practices and over exploitation of natural resources. Menon and Bawa, (1997) estimated an annual rate of decline of 0.57% in the whole Western Ghats during 1920-1990 and Jha *et al.*, (2000) estimated a decline of 1.16% per year during the period of 1973-1995 in the southern Western Ghats. Prasad *et al.*, (1998) estimated an amount of 0.9% (during 1961-1988) in the Kerala part of Western Ghats. An increase in area of moist deciduous forest by 24 $km^2$ and the reduction of Teak plantation forest by 34 $km^2$ point out that the natural forests in PKTR are getting improved. Here the increase in area of moist deciduous forest and reduction in area of teak plantation in 1973-2005 might have been due to the improvement of teak plantation to Moist mixed deciiduous forest.

The evergreen forests of the PKTR have undergone extensive degradation primarily in the form of selective logging and clear felling to raise teak plantation, resulting in secondary succession stages such as semi-evergreen among the major phenological types. Ramesh et al., (1997) have pointed out that there is significant loss of biologically rich areas between 1960 and 1990. The present study quantified 6 $km^2$ increase of Bamboo patches during 1973-1990 and diminished by 11 $km^2$ during 1990-2005. It is also observed that the Bamboo growth is more near settlements, open areas and roads. Several forests in Western Ghats and elsewhere in tropics have experienced these kinds of changes, with a concomitant loss of native biodiversity and ecological integrity (Dutt et al., 2002; Muthuramkumar et al., 2006).

The original natural vegetation in the valley and the lower hills of eastern parts of the tiger reserve were almost entirely replaced by teak plantations after clear felling the moist deciduous, evergreen and semi evergreen forests in patches during the period 1921 to 1983. During 1973 to 1990, the forest cover of PKTR has changed considerably from evergreen to semi-evergreen forest type (16 $km^2$), semi evergreen to moist deciduous (13 $km^2$) and open areas (12 $km^2$), moist deciduous to teak plantation (16 $km^2$). A positive change in forest cover was noticed that around 30 $km^2$ of teak plantation was transformed to moist deciduous forest and open areas are changed to teak plantation (9 $km^2$) and to moist deciduous forest (9 $km^2$). Forest cover changes form moist deciduous to teak plantation (16 $km^2$) and open areas to teak plantation (9 $km^2$) because of the activities of Teak plantation raising programs. Though the area is declared as protected area, it is facing continuous disturbances and the causes behind forest cover changes are plantation activities, past clear felling of natural forests for timber extraction, settlements, and construction of reservoirs.

The rate of change was considerably lower after 1990's. This is probably due to the continuous initiatives taken by government administration to declare this area as a protected area in 1962 and this protection was then extended to the teak plantations in 1973, and in 1985, a wildlife sanctuary was created which prevents all the activities which leads to the extraction and exploitation of forest resources. However being a WLS the plantations are left without much weeding or extraction of miscellaneous tree species because of which some areas have developed into mixed stands which resulted the conversion of 20 $km^2$ Teak plantation to moist deciduous forest. While in February 2001, the Supreme Court of India forbade all extraction of forest resources in protected areas, which resulted in the betterment of the forest condition.

A study conducted by Jha et al., 2000 estimated changes in forest cover between 1973 and 1995 in the southern part of the Western Ghats showed a loss of 25.6% in forest cover over 22 years. The dense forest was reduced by 19.5% and open forest decreased by 33.2%. Consequently, degraded forest increased by 26.64% and plantations (6.78%). The Palghat district have experienced the highest annual rates of loss of dense forest by 2.1% and the plantations increased most notably at an annual rate of 6.90%.

The forests of the PKTR have undergone significant changes during the last few decades due to extensive logging, land conversion and forest degradation. The density stratification reflected that nearly 31% (200 $km^2$) of the forest area in PKTR falls under moderately dense forest. The factors *viz.* terrain, accessibility and non proximity to a disturbance source have helped to preserve higher densities as it is revealed that about 30% of PKTR is occupied by very dense forest and occurs in remote and uninhabited areas. The degraded (low-density) forest covers an area of 52 $km^2$ which is occur near habitations or settlements and openings.

Advancement in geospatial technologies provides a medium to evaluate forest cover in the inaccessible and remote areas. This can also enable a multi scalar assessment of the associated ecosystem parameters (forest canopy density, habitat diversity, *etc.*). The satellite remote sensing is best suited for analysis of canopy closures, as elucidated by Roy *et al.*, (1994). The biodiversity of the PKTR is noteworthy and the detailed assessment poses a challenge. Past timber extraction practices, over exploitation of natural resources, construction of dams and population pressure has seriously affected the ecosystem stability and forest density. This study addressed the need to understand the canopy density of forest communities, which is critical for a management planning process, also describes the use of the geospatial tools *viz.*, a combination of earth observation data along with the GIS tools that can pertinently contribute to the process. The derived thematic outputs will provide a synoptic understanding of the extent of forests in the Parambikulam landscape.

Chapter 5.2

# Vegetation

## 5.2. VEGETATION

### 5.2.1. Vegetation analysis of PKTR

The Parambikulam Tiger Reserve exhibits a spectrum of vegetation types ranging from West coast tropical evergreen forests, West coast semi-evergreen forests, and Southern moist mixed deciduous forests to Southern dry mixed deciduous forests. Rather than natural forest, there are Teak plantations raised by forest department.  Subsequently, such plantation in some areas is being converted by natural regenerating indigenous species, where teak is the dominant species and attained the status of Moist mixed deciduous stands. Interspersed with other types; there are low-lying marshy lands and grass lands.

#### 5.2.1.1. Species diversity

During the study about 479 species of flowering plants belonging to 335 genera under 103 families were recorded from all the forest types of the Tiger reserve. Regarding the habit of the plants, out of the 479 species, 214 were tree species, 78 belonged to shrubs, 116 Herbs and 71 Climbers (Fig. 5.2.1). While concerning the habitat of the species, 290 species were recorded from the West coast tropical evergreen forest, 196 species from Semi evergreen forest, 222 species from Moist deciduous forest, 64 species from Dry deciduous forest and 96 species from Teak plantation forest. It is represented in Table 5.2.1.

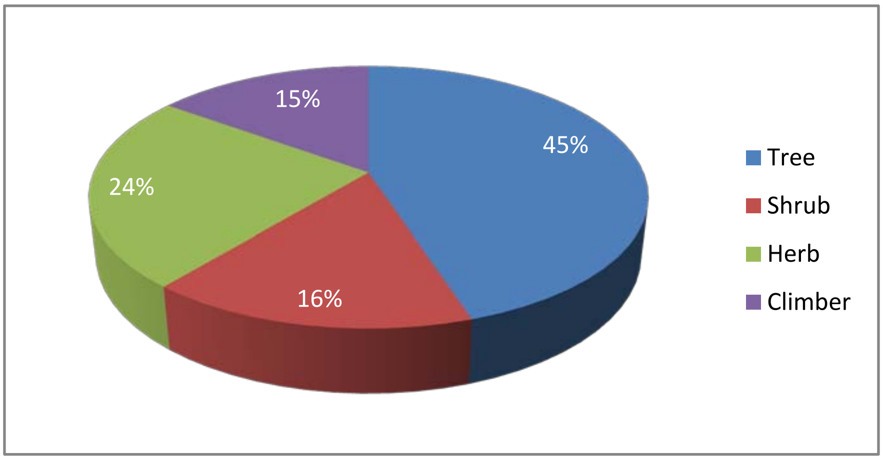



Fig. 5.2.1. Life form representation in the angiosperm flora of PKTR

Table 5.2.1. Habit and Habitat of the vegetation of PKTR

| Vegetation Types | Habit | | | | |
|---|---|---|---|---|---|
| | Trees | Shrubs | Herbs | Climbers | Total |
| Evergreen forest | 161 | 38 | 46 | 45 | 290 |
| Semi evergreen | 116 | 25 | 27 | 28 | 196 |
| Moist Deciduous | 85 | 36 | 62 | 39 | 222 |
| Dry Deciduous | 26 | 15 | 19 | 4 | 64 |
| Teak plantation | 49 | 14 | 14 | 19 | 96 |
| **Total** | **214** | **78** | **116** | **71** | **479** |

### 5.2.1.2. Family composition

Among the families, Euphorbiaceae is the largest one which constitutes 23 species, followed by Lauraceae (18 species), Meliaceae (14 species), Moraceae (11 species) and Ebenaceae (10 species), (Table 5.2.2 and Fig. 5.2.2).

Table 5.2.2. Dominant Families of PKTR

| Family | No. of species in each family | Percentage |
|---|---|---|
| Euphorbiaceae | 23 | 11 |
| Lauraceae | 18 | 8 |
| Meliaceae | 14 | 6 |
| Moraceae | 11 | 5 |
| Ebenaceae | 10 | 5 |
| Anacardiaceae | 8 | 4 |

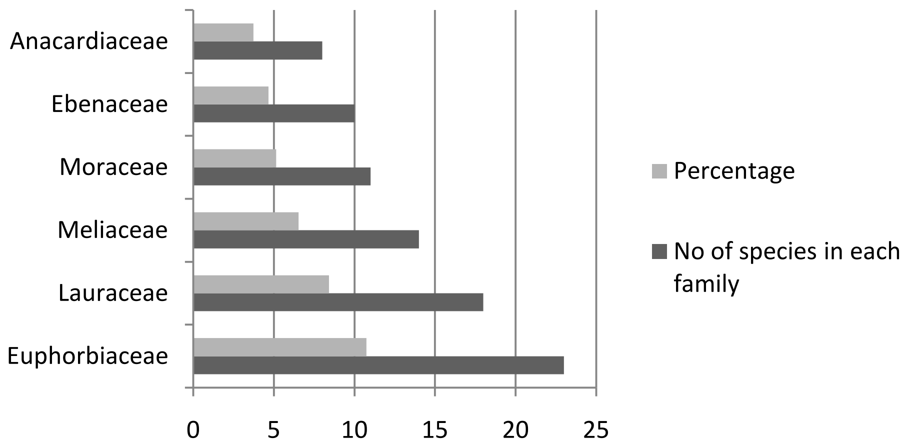



Fig. 5.2.2. Dominant Families of PKTR

### 5.2.1.3. Endemicity and RET (IUCN) status

Identification of endemic species of a region or a country is considered a priority exercise in any programme of conservation of biodiversity, the PKTR shows high degree of endemism. Of the total 479 arborescent species recorded from the 145 plots, 39 species are endemic to Western Ghats, 61 species are endemic to Southern Western Ghats, and 7 species are endemic to Southern Western Ghats of Kerala, which contributes about 23 per cent of the total species represented in the sample plots (Fig. 5.2.3).

Among the conservation category, a number of critically endangered species such as *Syzygium palghatense* Gamble, *Vateria indica* L., *Piper barberi* Gamble and a few threatened species like *Arisaema barnesii* C.E.C. Fisch., *Pothos armatus* C.E.C. Fisch. and a few rare, endangered, and vulnerable species were also recorded from PKTR (Table 5.2.3). A Possibly extinct species, *Ophiorrhiza brunonis* Wight & Arn. was rediscovered during the study. *Pothos thomsonianus* Schott, threatened taxa was reported from the area as an addition to the flora of Parambikulam Wildlife Sanctuary.

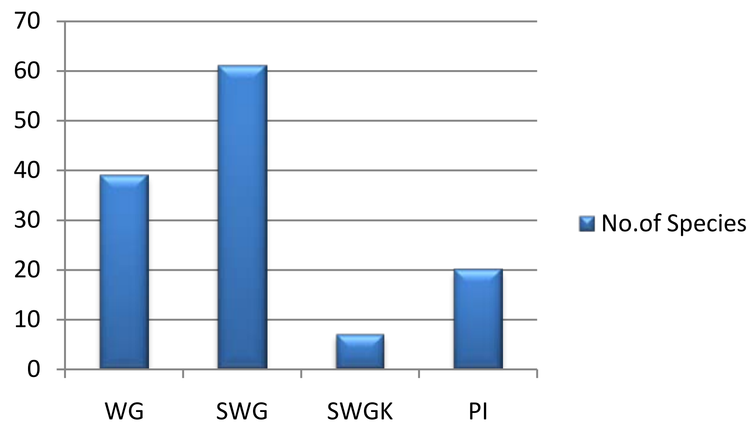



Fig. 5.2.3. Status of endemism in PKTR

WG-Western Ghats, SWG-Southern Western Ghats, SWGK-Southern Western Ghats of Kerala, PI-Penninsular India

Table 5.2.3. Details of Red listed species of PKTR

| Sl.No | Species | RET status | Reference | Endemism | Habit |
|---|---|---|---|---|---|
| 1 | *Actinodaphne malabarica* Balakr. | Rare | Nayar,1997 ;Sasidharan,2004. | SWG | Tree |
| 2 | *Aglaia barberi* Gamble | Rare | Nayar,1997 ;Sasidharan,2004. | WG | Tree |
| 3 | *Aglaia lawii* (Wight) Saldanha | Rare | Nayar,1997 ;Sasidharan,2004. | | Tree |
| 4 | *Aglaia perviridis* Hiern | Vulnerable | IUCN,2000 ;Sasidharan,2004. | | Tree |
| 5 | *Atuna travancorica* (Bedd.) Kosterm | Endangered | IUCN,2000 ;Sasidharan,2004. | SWG (Kerala) | Tree |
| 6 | *Beilschmiedia wightii (*Nees) Benth. *ex* Hook. f. | Rare | Ahmedullah&Nayar,1987; Sasidharan,2004 | SWG | Tree |
| 7 | *Casearia wynadensis* Bedd. | Vulnerable | IUCN,2000; Sasidharan,2004. | WG | Tree |
| 8 | *Cryptocarya beddomei* Gamble | Vulnerable | IUCN,2000; Sasidharan,2004 | SWG | Tree |
| 9 | *Dalbergia latifolia* Roxb. | Vulnerable | IUCN,2000; Sasidharan,2004. | | Tree |
| 10 | *Diospyros ebenum* Koenig | Data deficient | Sasidharan,2004. | | Tree |
| 11 | *Dipterocarpus indicus* Bedd. | Endangered | Sasidharan,2004. | WG | Tree |
| 12 | *Dysoxylum beddomei* Hiern | Endangered | IUCN,2000; Sasidharan,2004. | SWG (Kerala) | Tree |
| 13 | *Holigarna grahamii* (Wight) Kurz | Rare | Nayar,1997; Sasidharan,2004. | WG | Tree |
| 14 | *Hopea parviflora* Bedd. | Endangered | Sasidharan,2004. | SWG | Tree |
| 15 | *Hopea racophloea* Dyer | Endangered | IUCN,2000; Sasidharan,1997,2004. Nayar,1997 . | PI | Tree |
| 16 | *Humboldtia vahliana* Wight | Rare | Sasidharan,2004. | SWG | Tree |
| 17 | *Melicope lunu-ankenda* (Gaertn.) Hartley | Endangered | Sasidharan,2004. | | Tree |
| 18 | *Orophea uniflora* Hook. f. & Thoms. | Vulnerable | IUCN,2000;Sasidharan, 1997,2004.Nayar&Sastry 1988; | SWG | Tree |
| 19 | *Pterospermum reticulatum* Wight & Arn. | Vulnerable | IUCN,2000 ;Sasidharan,2004 | SWG | Tree |
| 20 | *Semecarpus travancorica* Bedd. | Rare | Nayar,1997 ;Sasidharan,2004. | SWG | Tree |
| 21 | *Symplocos macrophylla* Wall. ex A. DC ssp. *rosea* (Bedd.) Nooteb | Endangered | Sasidharan,2004. | SWG | Tree |
| 22 | *Syzygium chavaran* (Bourd.) Gamble | Endangered | IUCN,2000; Sasidharan,2004. | | Tree |
| 23 | *Syzygium palghatense* Gamble | Critically Endangered | IUCN,2000; Sasidharan,2004. Nayar&Sastry,1987; Nayar,1997. | SWG (Kerala) | Tree |
| 24 | *Tabernaemontana alternifolia* L. | Low Risk | IUCN,2000; Sasidharan,2004. | SWG | Tree |
| 25 | *Vateria indica* L. | Critically Endangered | Sasidharan,2004. | WG | Tree |
| 26 | *Vepris bilocularis* (Wight & Arn.) Engl. | Rare | Ahmedullah& Nayar,1987; | SWG | Tree |

| Sl.No | Species | RET status | Reference | Endemism | Habit |
|---|---|---|---|---|---|
| | | | Sasidharan,2004. | | |
| 27 | *Allophylus concanicus* Radlk. | Rare | Nayar&Sastry,1998 ;Sasidharan,2004. | WG | Shrub |
| 28 | *Capparis rheedei* DC. | Rare | Nayar,1997 ;Sasidharan,2004. | WG | Shrub |
| 29 | *Glycosmis macrocarpa* Wight | Rare | Nayar;1997 ;Sasidharan,1997,2004, Ahmedullah& Nayar,1987. | | Shrub |
| 30 | *Tabernaemontana gamblei* Subram. & Henry | Low risk | IUCN,2000 ;Sasidharan,2004. | SWG | Shrub |
| 31 | *Arisaema barnesii* C.E.C. Fisch. | Threatened | Nayar,1997; Sasidharan,2004. | SWG | Herb |
| 32 | Oberonia brachyphylla Blatt. & McCann | Rare | Nayar,1997; Sasidharan,2004. | SWG | Herb |
| 33 | Belosynapsis vivipara (Dalz.) C.E.C. Fisch. | Vulnerable | Nayar,1997 ;Sasidharan,2004. | WG | Herb |
| 34 | *Ophiorrhiza brunonis* Wight & Arn. | Possibly Extinct | Nayar,1997 ;Sasidharan,2004. | SWG | Herb |
| 35 | *Cyclea fissicalyx* Dunn | Rare | Ahmedullah& Nayar,1987 ;Sasidharan,2004. | SWG (Kerala) | Climber |
| 36 | *Kunstleria keralensis* C.N. Mohanan & N.C. Nair | Rare | Nayar,1997; Sasidharan,2004. | SWG (Kerala) | Climber |
| 37 | *Morinda reticulata* Gamble | Endangered | Nayar,1997 Sasidharan,2004. | SWG | Climber |
| 38 | *Piper barberi* Gamble | Critically Endangered | Nayar,1997; Sasidharan,2004. | SWG | Climber |
| 39 | *Pothos armatus* C.E.C. Fisch. | Threatened | Nayar,1997; Sasidharan,2004 . | SWG | Climber |

### 5.2.1.4. Epiphytes and Pteridophytes

There were 24 number of ephiphytic orchid species recorded from different forest types of the study area. The common epiphytic orchid species were *Aerides ringens* (Lindl.) C.E.C. Fisch, *Oberonia sebastiana* Shetty & Vivek., *Acampe praemorsa* (Roxb.) Blatt. & McCann, *Bulbophyllum sterile* (Lam.) Suresh, *Oberonia santapaui* Kapad., *Vanda tessellata* (Roxb.) Hook. ex D. Don, *Kingidium niveum* Sathish etc. Among the ephiphytic orchid species, 10 species were shown the endemism towards the various parts of Western Ghats and Peninsular india (Table 5.2.4.). Rather than the epiphytic orchids, the study area is rich in epiphytic pteridophytes. The common pteridophytes recorded from the PKTR were *Drynaria quercifolia* (L.) J. Sm., *Pteris quadriaurita* Retz., *Pteris longipes* D. Don, *Microsorum punctatum* (L.) Copel., *Asplenium nidus L*.etc.

Table 5.2.4. Status of endemism in epiphytic orchid species of PKTR

| Sl No | Species | SWG | WG | PI |
|---|---|---|---|---|
| 1 | *Oberonia sebastiana* Shetty & Vivek. | * | | |
| 2 | *Eria pauciflora* Wight | * | | |
| 3 | *Oberonia santapaui* Kapad. | * | | |
| 4 | *Oberonia brachyphylla* Blatt. & McCann | * Rare | | |
| 5 | *Kingidium niveum* Sathish | * (Kerala) | | |
| 6 | *Dendrobium ovatum* (L.) Kranz. | | * | |
| 7 | *Luisia evangelinae* Blatt. & McCann | | * | |
| 8 | *Gastrochilus flabelliformis* (Baltt. & McCann) Saldanha | | * | |
| 9 | *Dendrobium heyneanum* Lindl. | | | * |
| 10 | *Bulbophyllum sterile* (Lam.) Suresh | | | * |

SWG-Southern Western Ghats, WG-Western Ghats PI-Penninsular India, *- refers the taxa showing the endemism in corresponding column.

### 5.2.1.5. Tree diversity

A total of 7088 trees of above 30 cm. GBH belonging to 214 species out of 148 genera and 55 families were enumerated from the 15.79 ha. of the sampling area. The overall stand density of the forests of Parambikulam Tiger Reserve is 448 individuals/ha. The distribution of sample points with other compositional attributes in different vegetation types are given in Table 5.2.5.

Table 5.2.5. Details of phytodiversity attributes of different vegetation types.

| Parameters | Types of vegetation | | | | | |
|---|---|---|---|---|---|---|
| | EG | SEG | MD | DD | TP | Total |
| No.of plots (31.62x31.62m (0.1ha)) | 61 | 15 | 51 | 3 | 15 | 145 |
| Area sampled (ha) | 6.64 | 1.63 | 5.55 | 0.33 | 1.63 | 15.79 |
| No.of individuals | 3747 | 877 | 1745 | 68 | 645 | 7088 |
| No.of species | 161 | 116 | 85 | 26 | 49 | 214 |
| Mean Stand density / ha. | 564 | 536 | 314 | 208 | 394 | 448 |
| Shannon's Index (H') | 4.07 | 4.10 | 3.22 | 2.98 | 2.54 | 4.38 |
| Simpson's Index | 0.03 | 0.02 | 0.08 | 0.05 | 0.22 | 0.02 |

EG-West coast tropical evergreen, SEG-West coast semi evergreen, MD-Southern moist mixed deciduous, DD-Southern dry mixed deciduous, TP-Teak plantation.

In the PKTR, West coast tropical evergreen forest type was shown maximum number of species (161) and the stand density were 564 individuals/ha. While analyzing the diversity among different forest types, high Shannon (4.1) indices followed by low Simpson indices (0.02) were observed in Semi evergreen which indicates the diverse community in comparison with other forest types. On the other hand the Teak plantation recorded lowest diversity indices (2.54).

The two moist deciduous forest species such as *Terminalia paniculata* and *Lagerstroemia microcarpa* were the dominant species in the study area which had the Important Value indices 61.89 and 35.37 respectively. Followed by, *Tectona grandis, Aglaia barberi* and *Palaquium ellipticum.*

### 5.2.1.6. Density, Frequency, Basal area and IVI

IVI values are used to express dominance and ecological success of any species according to its density, frequency and dominance in relation to all other species. IVI values indicate that the most successive tree species in the PKTR are *Terminalia paniculata, Lagerstroemia microcarpa, Tectona grandis, Aglaia barberi* and *Palaquium ellipticum.* Density is found maximum for *Terminalia paniculata* (26.98 individuals/ha) followed by *Tectona grandis* (21.03 individuals/ha), *Aglaia lawii* (21.03 individuals/ha) and *Aglaia barberi* (20.58 individuals/ha). The top ten dominant species in the reserve is given in Table. 5.2.6.

Table 5.2.6. Ten dominant species having highest value of IVI in the PKTR

| Species | N | D | RD | RF | RB | IVI |
|---|---|---|---|---|---|---|
| *Terminalia paniculata* | 426 | 26.98 | 6.01 | 2.36 | 10.62 | 18.99 |
| *Lagerstroemia microcarpa* | 253 | 16.02 | 3.57 | 3.22 | 6.29 | 13.08 |
| *Tectona grandis* | 332 | 21.03 | 4.68 | 1.09 | 5.32 | 11.10 |
| *Aglaia barberi* | 325 | 20.58 | 4.59 | 2.72 | 2.84 | 10.14 |
| *Palaquium ellipticum* | 225 | 14.25 | 3.17 | 2.04 | 4.83 | 10.05 |
| *Aglaia lawii* | 332 | 21.03 | 4.68 | 1.95 | 2.31 | 8.94 |
| *Myristica beddomei* | 182 | 11.53 | 2.57 | 2.27 | 2.37 | 7.20 |
| *Drypetes oblongifolia* | 285 | 18.05 | 4.02 | 1.77 | 1.23 | 7.02 |
| *Vateria indica* | 113 | 7.16 | 1.59 | 1.54 | 3.37 | 6.51 |
| *Polyalthia fragrans* | 164 | 10.39 | 2.31 | 2.31 | 1.64 | 6.26 |

(N - No. of individuals, D - Density (No./ha), RD – Relative density, RF -Rel.Frequency, RB - Rel. Basal Area, IVI - Importance value index.)

### 5.2.1.7. Girth Class distribution of trees in PKTR

Girth class distribution when graphically plotted is represented as an inverted 'J' shaped curve. Any distortion in the curve is an indication of disturbance. Population density of tree species across girth class interval showed that around 45% of individuals belonged to 30-60 cm GBH. The highest number of species (175) was also observed in the same category, (Table 5.2.7). The study area represents typical mature stands with good regeneration.

Table 5.2.7. Population structure of tree species along girth class frequencies

| Girth class | No. of individuals. | No. of species | % of individuals |
|---|---|---|---|
| 30-60 | 3176 | 175 | 44.78 |
| 60-90 | 1375 | 156 | 19.39 |
| 90-120 | 832 | 125 | 11.73 |
| 120-150 | 648 | 101 | 9.14 |
| 150-180 | 415 | 89 | 5.85 |
| >180 | 647 | 112 | 9.12 |
| **Total** | **7093** | **758** | **100** |

Percentage of individuals of trees plotted against Girth class for all the forest types in the entire study area together provided a graph which almost represents a negative exponential or 'inverse J' curve (Fig. 5.2.4). The frequency of individuals was maximum in the lower GBH class *i.e.* the higher number of individuals (45%) was represented in 30-60 cm GBH class. The number of species was also higher in the lower size classes. The distribution of girth classes show classical negative exponential pattern which is a common feature found in the pristine forest.

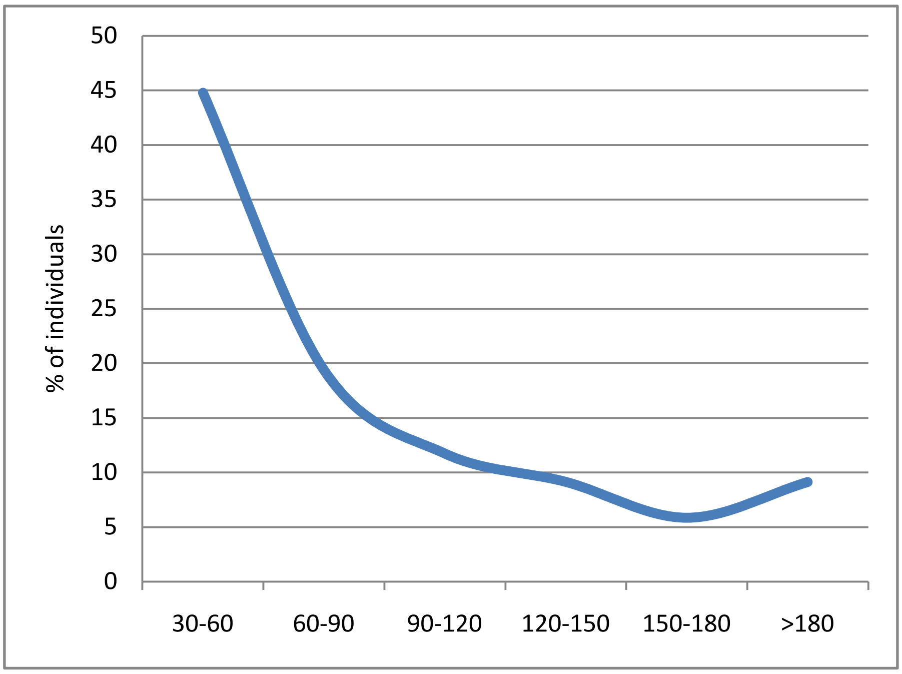



Fig. 5.2.4. Girth class distribution of trees plotted against the percentage of individuals

Number of individuals plotted against the girth class interval of different types of forest showed that the number of individuals is decreasing from lower girth class (30-60 cm) to higher classes (150-180 cm) and for the girth class above 180 cm; number of individuals is more than the preceding girth class. In case of Teak plantation & dry deciduous forest there is a gradual decline in number of individuals (Table 5.2.8).

Table 5.2.8. Girth class distribution of different forest types

| Girth class | EG | SEG | MD | DD | TP |
|---|---|---|---|---|---|
| 30-60 | 1855 | 438 | 612 | 33 | 237 |
| 60-90 | 750 | 164 | 306 | 15 | 140 |
| 90-120 | 391 | 98 | 231 | 4 | 107 |
| 120-150 | 271 | 64 | 206 | 9 | 97 |
| 150-180 | 176 | 50 | 138 | 3 | 47 |
| >180 | 309 | 63 | 252 | 4 | 17 |
| **Total** | **3752** | **877** | **1745** | **68** | **645** |

### 5.2.1.8. Status of Shrub, herb and climber

A total of 4168 individuals of shrubs belonging to 78 species were recorded from 145 plots covering 3625m$^2$ of Parambikulam Tiger Reserve. Based on IVI values *Chromolaena odorata* (20.02), *Strobilanthes ciliates* (18.66), *Glycosmis pentaphylla* (15.07), *Helicteres isora* (14.44) *Ziziphus rugosa* (9.24) *Tabernaemontana gamblei* (8.47), *Strobilanthes anceps* (8.11) etc., were the dominant components of shrubacious layer (Table 5.2.9.).

Table 5.2.9. Relative density, relative frequency and Importance value Index of shrub layer

| Species | Rel. Density | Rel. Frequency | IVI |
|---|---|---|---|
| *Chromolaena odorata* | 10 | 9.9 | 20.0 |
| *Strobilanthes ciliatus* | 11 | 7.1 | 18.6 |
| *Glycosmis pentaphylla* | 6.5 | 8.5 | 15.0 |
| *Helicteres isora* | 7.1 | 7.3 | 14.4 |
| *Ziziphus rugosa* | 4.1 | 5.1 | 9.2 |
| *Tabernaemontana gamblei* | 5.6 | 2.8 | 8.4 |
| *Strobilanthes anceps* | 5.2 | 2.8 | 8.11 |
| *Saprosma glomeratum* | 4.1 | 3.4 | 7.5 |
| *Dendrocride sinuate* | 3.8 | 2.2 | 6.1 |
| *Lantana camara var. camara* | 2.9 | 2.8 | 5.7 |
| *Bambusa bambos* | 1.6 | 3.7 | 5.3 |

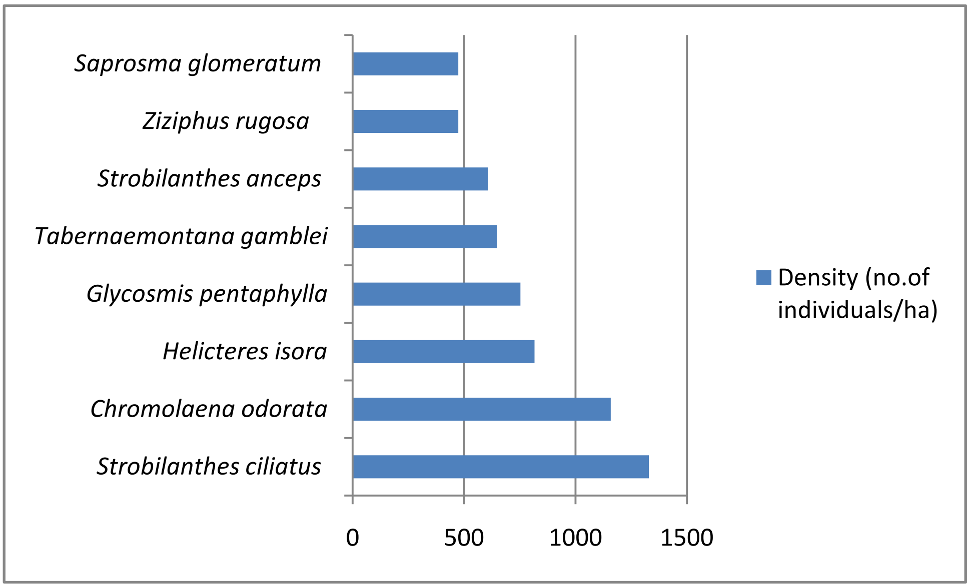



Fig. 5.2.5. Density of shrub layer at PKTR

*Strobilanthes ciliates* (1329 individuals/ha), *Chromolaena odorata* (1158 individuals/ha), and *Helicteres isora* (816 individuals/ha) etc., were the shrub species with large number of individuals/ha (Fig. 5.2.5.).

The Shannon Wiener index (H) diversity of the shrubacious layer of the PKTR was 3.47. The Simpson's dominance value is 0.04. Margalefs Species richness (R1) showed was 9.2.

A total of 97 herb species were recorded from 145 plots covering 145 $m^2$ from the forests of Parambikulam Tiger Reserve.

Table 5.2.10. Relative density, relative frequency and Importance value Index of herbaceous layer

| Species | Rel. Density | Rel. Frequency | IVI |
|---|---|---|---|
| *Lepidagathis incurva var. incurva* | 10.93 | 6.8 | 17.7 |
| *Pellionia heyneana* | 10.42 | 7.1 | 17.5 |
| *Mimosa pudica* | 6.39 | 5.9 | 12.3 |
| *Cyathula prostrate* | 5.86 | 5.6 | 11.5 |
| *Stachyphrynium spicatum* | 4.51 | 4.4 | 8.9 |
| *Curculigo orchioides* | 3.04 | 4.4 | 7.5 |
| *Rungia repens* | 4.22 | 2.7 | 6.9 |
| *Zingiber nimmonii* | 3.01 | 3.8 | 6.8 |
| *Commelina benghalensis* | 2.17 | 3.8 | 6.0 |
| *Commelina diffusa* | 3.13 | 2.7 | 5.8 |

*Lepidagathis incurva var. incurve* (17.7), *Pellionia heyneana* (17.5), *Mimosa pudica* (12.3) and *Cyathula prostrata* (11.5), *Stachyphrynium spicatum* (8.9), *Curculigo orchioides* (7.5) etc. were the most dominant herbs in the study area based on IVI values.

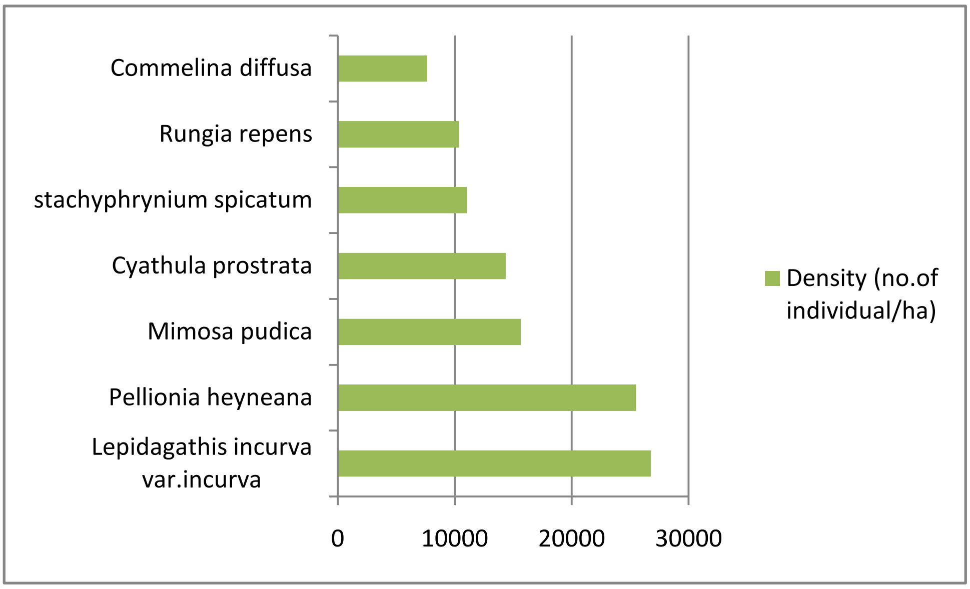



Fig. 5.2.6. Density of herbaceous layer at PKTR

With regard to Density of Herbaceous layer of PKTR the most dominant herb species were *Lepidagathis incurva* var.*incurva* (26758 individuals/ha), *Pellionia heyneana* (25517 individuals/ha), *Mimosa pudica* (15655 individuals/ha), *Cyathula prostrata* (14344 individuals/ha), *Stachyphrynium spicatum* (11034 individuals/ha) etc.

The Shannon Wiener index (H) of diversity of the herbaceous layer of the PKTR was 3.71. The Simpson's dominance value is 0.042. Margalefs Species richness (R1) showed was 11.7.

A total of 71 climber species were recorded from the Parambikulam Tiger Reserve. *Smilax zeylanica* (14.76), *Cyclea peltata* (13), and *Ziziphus oenoplia* (10.77) *Piper argyrophyllum* (8.6) etc. were the most dominant climbers based on IVI values (Table 5.2.11.).

Table 5.2.11. Relative density, relative frequency and Importance value Index of climber layer

| Species | Rel. Density | Rel. Frequency | IVI |
|---|---|---|---|
| *Smilax zeylanica* | 6.7 | 8.0 | 14.8 |
| *Cyclea peltata* | 6.3 | 6.6 | 13.0 |
| *Ziziphus oenoplia* | 5.2 | 5.5 | 10.8 |
| *Piper argyrophyllum* | 5.9 | 2.7 | 8.7 |
| Mikania micrantha | 5.7 | 2.7 | 8.5 |
| *Cryptolepis buchananii* | 4.2 | 4.1 | 8.4 |
| *Desmos lawii* | 4.4 | 3.8 | 8.3 |
| *Hemidesmus indicus var. indicus* | 3.5 | 3.8 | 7.4 |
| *Strychnos colubrine* | 4.4 | 1.6 | 6.1 |
| *Diploclisia glaucescens* | 2.8 | 2.4 | 5.3 |

Based on the density, *Smilax zeylanica* (397 no.of ind. /ha), *Cyclea peltata* (372 no.of ind. /ha), *Ziziphus oenoplia* (308 no.of ind. /ha), *Piper argyrophyllum* (350 no.of ind. /ha) *Mikania micrantha* (336 no.of ind. /ha), *Cryptolepis buchananii* (251 no.of ind. /ha) etc were the dense climber species at the study area (Fig. 5.2.7.).

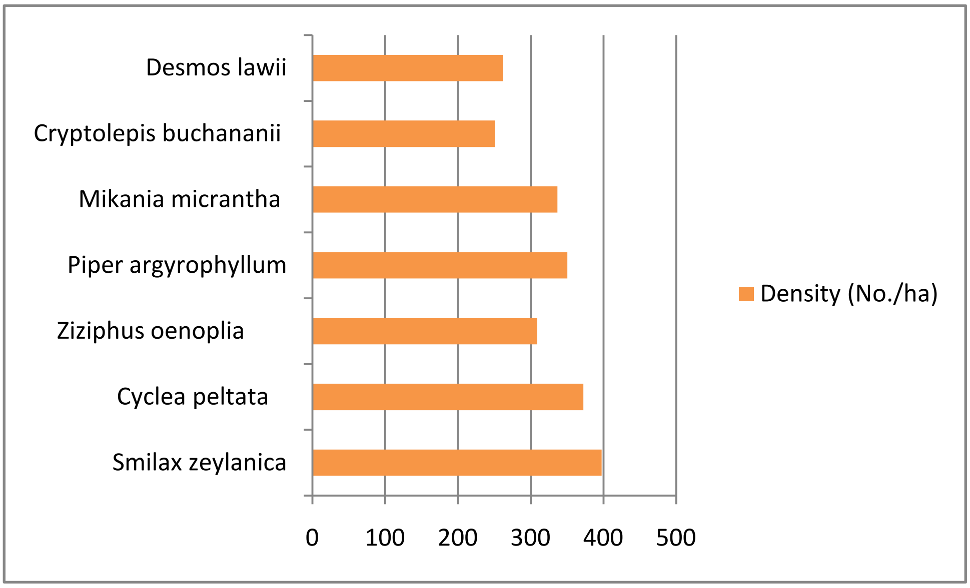



Fig. 5.2.7. Density of climbers at PKTR

The Shannon Wiener index (H) of diversity of the climber species of the PKTR was 3.72. The Simpson's dominance value is 0.032. Margalefs Species richness (R1) showed was 9.12.

The detailed vegetation analysis of shrubs, herbs and climbers is given in Appendix III.A, B & C.

**5.2.2. West coast tropical evergreen forest**.

A total of 3747 individual trees of above 30 cm GBH belonging to 161 species were enumerated from the sampling area. The overall density of this type of forest is 564 individuals/ha. Major successive associations derived, based on Importance Value Index are *Palaquium ellipticum, Aglaia barberi* , *Aglaia lawii* , *Drypetes oblongifolia* and *Vateria indica*

Wide range of variation is seen among species when consider their mean IVI. It ranges from 0.11 to 18.51. The dominant species based on Importance Value Index are *Palaquium ellipticum* (18.51) *Aglaia barberi* (15.49) *Aglaia lawii* (15.42) *Drypetes oblongifolia* (12.15) *Vateria indica* (12.13) and *Myristica beddomei* (11.61).
Fig. 5.2.8. &Table 5.2.12

Table 5.2.12. Importance Value Index (IVI) of the ten most dominant species in West coast tropical evergreen forest.

| Plant Species | Rel. Density | Rel. Frequency | Rel. Basal Area | IVI |
|---|---|---|---|---|
| *Palaquium ellipticum* | 5.66 | 3.32 | 9.530 | 18.51 |
| *Aglaia barberi* | 6.99 | 3.97 | 4.526 | 15.49 |
| *Aglaia lawii* | 7.87 | 3.24 | 4.305 | 15.42 |
| *Drypetes oblongifolia* | 6.99 | 2.92 | 2.239 | 12.15 |
| *Vateria indica* | 2.94 | 2.59 | 6.606 | 12.13 |
| *Myristica beddomei* | 4.03 | 3.40 | 4.177 | 11.61 |
| *Polyalthia fragrans* | 3.15 | 2.92 | 2.575 | 8.64 |
| *Dysoxylum malabaricum* | 1.84 | 2.59 | 3.670 | 8.11 |
| *Paracroton pendulus ssp. zeylanicus* | 2.16 | 2.75 | 2.64 | 7.56 |
| *Dimocarpus longan* | 2.72 | 2.18 | 2.49 | 7.4 |

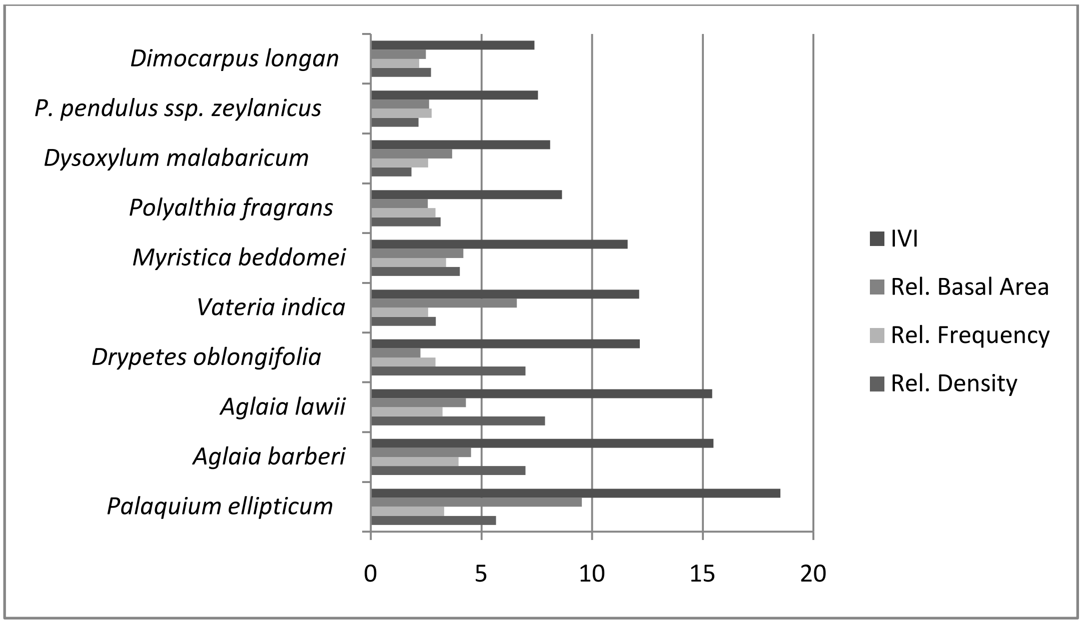



Fig. 5.2.8. Important value index of ten dominant species in West coast tropical evergreen forest.

With respect to density data, the maximum density (number of individuals/ha) was shared by *Aglaia lawii* (44 individuals/ha), followed by *Aglaia barberi* (39 individuals/ha), *Drypetes oblongifolia* (39 individuals/ha) *Palaquium ellipticum* (31 individuals/ha) and *Myristica beddomei* (22.73).

Among 161 species encountered, 7 species recorded mean abundance value greater than 5. These are *Phoebe wightii* (8) *Aglaia lawii* (7.37) *Drypetes oblongifolia* (7.28) *Leea indica* (7.25) *Dimorphocalyx glabellus var. lawianus* (5.6) *Aglaia barberi* (5.35) *Palaquium ellipticum* (5.18).

The species with high frequency percentage values were recorded by *Aglaia barberi* (80.33%), *Myristica beddomei* (68.85%), *Palaquium ellipticum* (67.21%), *Aglaia lawii* (65.27%) and *Baccaurea courtallensis* (60.66%) *etc*.

In west coast tropical Evergreen, girth class distribution of trees showed classical negative exponential pattern which a common feature is found in the undisturbed patch. There was a sudden steep falling in lower girth classes and finally a gradual increase of the upper girth class individuals (i.e. >180) given an inverted 'J' shaped curve.

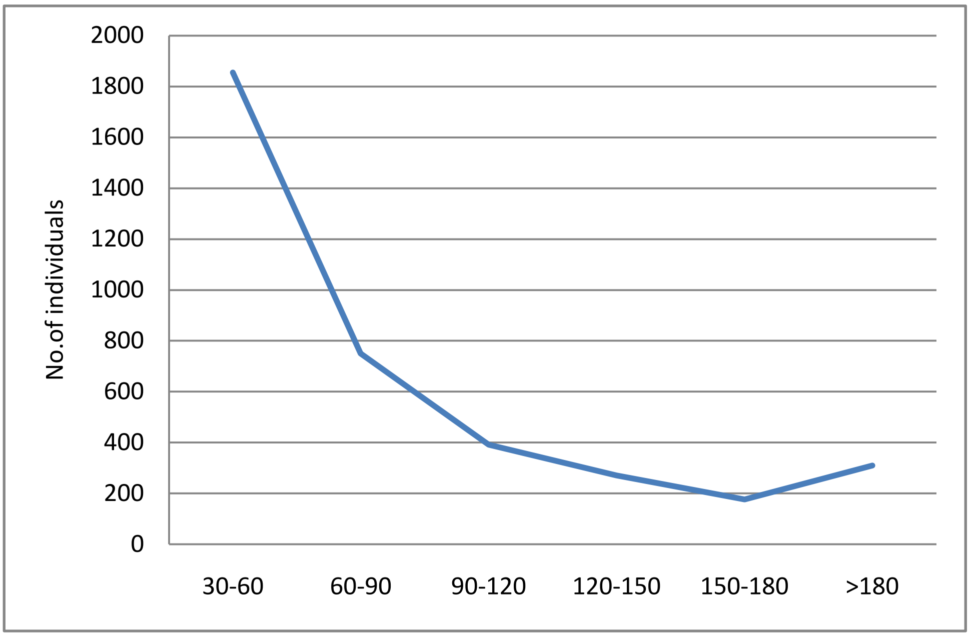



Fig. 5.2.9. Girth class distribution of West coast tropical evergreen forest.

Shannon index diversity of tree component in the forest type is 4.07 followed by 3.4 for climber and 2.8 for shrub and herbs. The Simpson's dominance value (0.02) and Margalefs Species richness (R1) values are high in trees forms (19.44) when compared to other life forms. Diversity and richness Indices of the various life forms in West coast tropical evergreen forests are shown in Table 5.2.13.

Table 5.2.13. Diversity indices of West coast tropical evergreen forest

| | **Richness/Diversity Indices** | | |
|---|---|---|---|
| **Evergreen Life forms** | **Margalef index** | **Shannon index** | **Simpsons index** |
| Tree | 19.44 | 4.07 | 0.02 |
| Shrub | 4.9 | 2.8 | 0.09 |
| Herb | 4.7 | 2.8 | 0.1 |
| Climber | 6.3 | 3.4 | 0.02 |

The detailed structural attributes of West coast tropical evergreen forest is given in Appendix II.A.

### 5.2.3. West Coast Tropical Semi Evergreen forest.

A total of 877 trees of above 30 cm. GBH belonging to 116 species were enumerated from 16335 $m^2$ of the sampling area. The overall density of this type of forest is 536 individuals/ha. Major associations derived; based on Importance Value Index are *Aglaia barberi, Lagerstroemia microcarpa, Polyalthia fragrans, Myristica beddomei* and *Xylia xylocarpa* Table 5.2.14.

Table 5.2.14. Importance Value Index (IVI) of the ten most dominant species in semi evergreen forest.

| Plant Species | Rel. Density | Rel. Frequency | Rel. Basal Area | IVI |
|---|---|---|---|---|
| *Aglaia barberi* | 7.07 | 3.34 | 5.82 | 16.23 |
| *Lagerstroemia microcarpa* | 3.88 | 3.34 | 8.11 | 15.34 |
| *Polyalthia fragrans* | 4.45 | 3.68 | 3.13 | 11.26 |
| *Myristica beddomei* | 3.53 | 2.68 | 3.14 | 9.35 |
| *Xylia xylocarpa* | 4.68 | 0.33 | 3.46 | 8.47 |
| *Hydnocarpus pentandra* | 2.74 | 2.68 | 2.12 | 7.53 |
| *Cinnamomum malabatrum* | 3.08 | 3.34 | 1.03 | 7.46 |
| *Aglaia lawii* | 4.22 | 1.00 | 2.00 | 7.22 |
| *Hopea parviflora* | 1.03 | 1.67 | 4.41 | 7.11 |
| *Persea macrantha* | 1.71 | 2.34 | 2.52 | 6.57 |

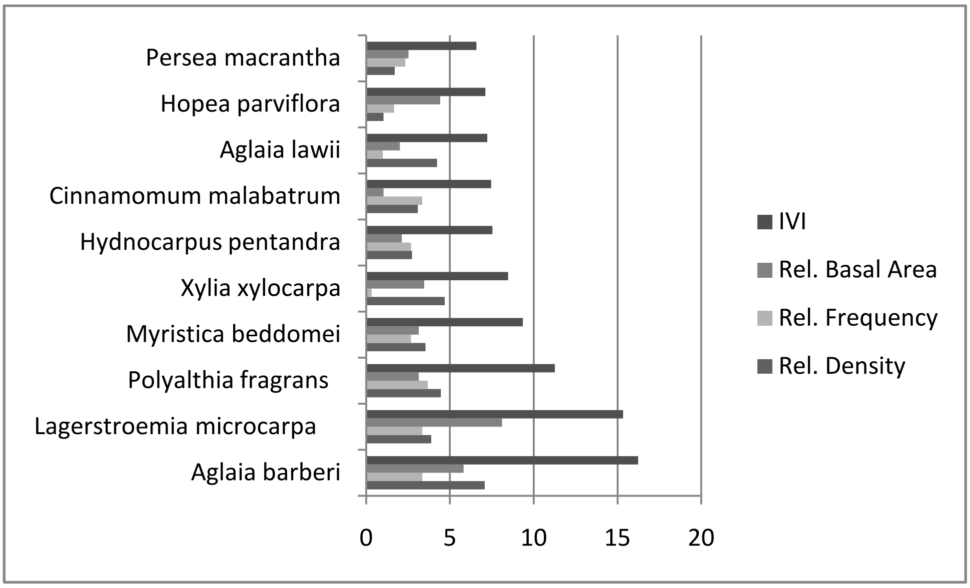



Fig. 5.2.10. Importance Value Index (IVI) of ten dominant species in semi evergreen forest.

With respect to density data, the maximum density (number of individuals/ha) was shared by *Aglaia barberi* (37 individuals/ha) followed by *Xylia xylocarpa* (25 individuals/ha), *Polyalthia fragrans* (23 individuals/ha), *Aglaia lawii* (22 individuals/ha) *Lagerstroemia microcarpa* (20 individuals/ha), *Myristica beddomei* (19 individuals/ha) and *Cinnamomum malabatrum* (17 individuals/ha).

Among 116 species encountered, the maximum abundance value was recorded by *Xylia xylocarpa* (41), *Aglaia lawii* (12), *Tectona grandis* (11), *Orophea erythrocarpa* (9.5) and *Glochidion zeylanicum var. zeylanicum* (8).

Regarding the frequency, the high values were recorded by *Polyalthia fragrans* (73.33%), *Aglaia barberi* (66.67%), *Lagerstroemia microcarpa* (66.67%), *Cinnamomum malabatrum* (66.67%) and *Croton malabaricus* (60%) *etc*.

Wide range of variation is seen among species when consider their mean IVI. It ranges from 0.46 to 16.23. The dominant species based on Importance Value Index are *Aglaia barberi* (16.23), *Lagerstroemia microcarpa* (15.34), *Polyalthia fragrans* (11.26), *Myristica beddomei* (9.35), *Xylia xylocarpa* (8.47) *Hydnocarpus pentandra* (7.5) and *Cinnamomum malabatrum* (7.5).

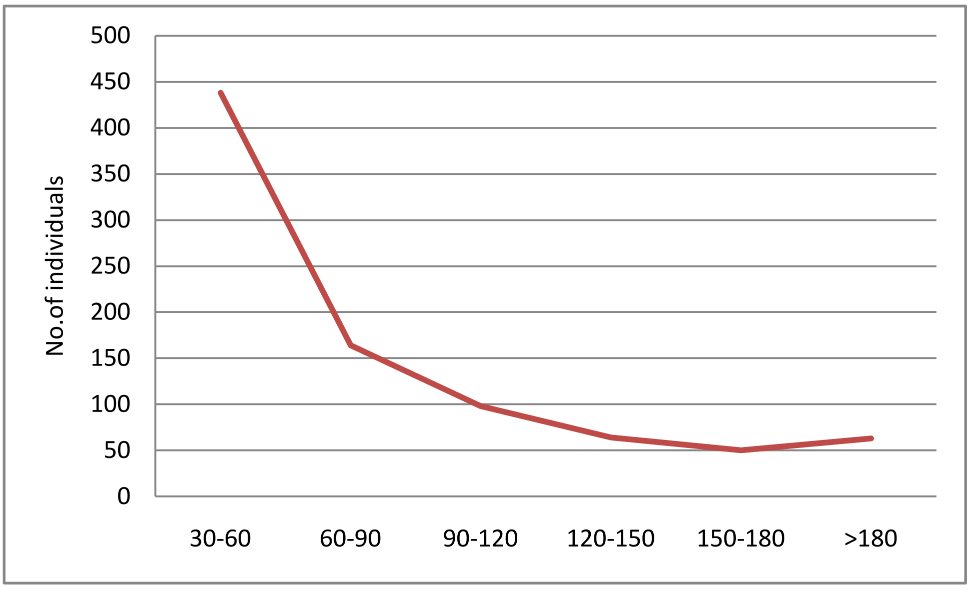



Fig. 5.2.11. Girth class distribution West coast semi evergreen forest

By plotting the girth class of tree components, tropical west coast Semi evergreen type showed almost an inverse "J" shaped curve. After a sudden steep fall from the lower class, then the individuals were shown a gradual decline and finally a slight increase at upper class. The maximum number of tree individuals laid in two lower classes and then an increase of individuals in >180.

Shannon index diversity of tree component in the forest type is 4.10 followed by 4.5 for climber, 3.9 for shrub and 2.9 for herbs. The Simpson's dominance value (0.02) and Margalefs Species richness (R1) values are high in trees forms (16.97) when compared to other life forms. Diversity and richness Indices of the various life forms in West coast tropical semi evergreen forests are shown in Table 5.2.15.

Table 5.2.15. Diversity indices of West coast tropical semi evergreen forest

| **Semi evergreen Life forms** | **Richness/Diversity Indices** | | |
|---|---|---|---|
| | **Margalef index** | **Shannon index** | **Simpsons index** |
| Tree | 16.97 | 4.10 | 0.02 |
| Shrub | 3.9 | 2.65 | 0.08 |
| Herb | 2.9 | 2.65 | 0.09 |
| Climber | 4.5 | 3.02 | 0.05 |

The detailed structural attributes of semi evergreen forest is given in Appendix II.B.

### 5.2.4. Southern moist mixed deciduous forests

A total of 1745 trees of above 30 cm. GBH belonging to 85 species were enumerated from the 55.53 ha sampling area. The overall density of this type of forest is 314 individuals/ha. Major associations derived based on Importance Value Index are *Terminalia paniculata, Lagerstroemia microcarpa, Dillenia pentagyna, Xylia xylocarpa* and *Grewia tiliifolia* (Table 5.3.11).

Table 5.2.16. Importance Value Index (IVI) of the ten most dominant species of Southern moist mixed deciduous forest.

| Plant Species | Rel. Density | Rel. Frequency | Rel. Basal Area | IVI |
|---|---|---|---|---|
| *Terminalia paniculata* | 22.41 | 8.57 | 30.92 | 61.89 |
| *Lagerstroemia microcarpa* | 10.95 | 9.16 | 15.26 | 35.37 |
| *Dillenia pentagyna* | 4.70 | 6.57 | 4.46 | 15.73 |
| *Xylia xylocarpa* | 5.16 | 2.79 | 6.40 | 14.35 |
| *Grewia tiliifolia* | 3.04 | 4.78 | 6.03 | 13.85 |
| *Catunaregam spinosa* | 8.02 | 3.78 | 1.11 | 12.91 |
| *Cassia fistula* | 4.24 | 5.98 | 1.28 | 11.50 |
| *Wrightia tinctoria* | 5.44 | 3.59 | 0.81 | 9.84 |
| *Terminalia elliptica* | 1.32 | 2.19 | 3.57 | 7.08 |
| *Radermachera xylocarpa* | 1.60 | 2.79 | 1.27 | 5.67 |

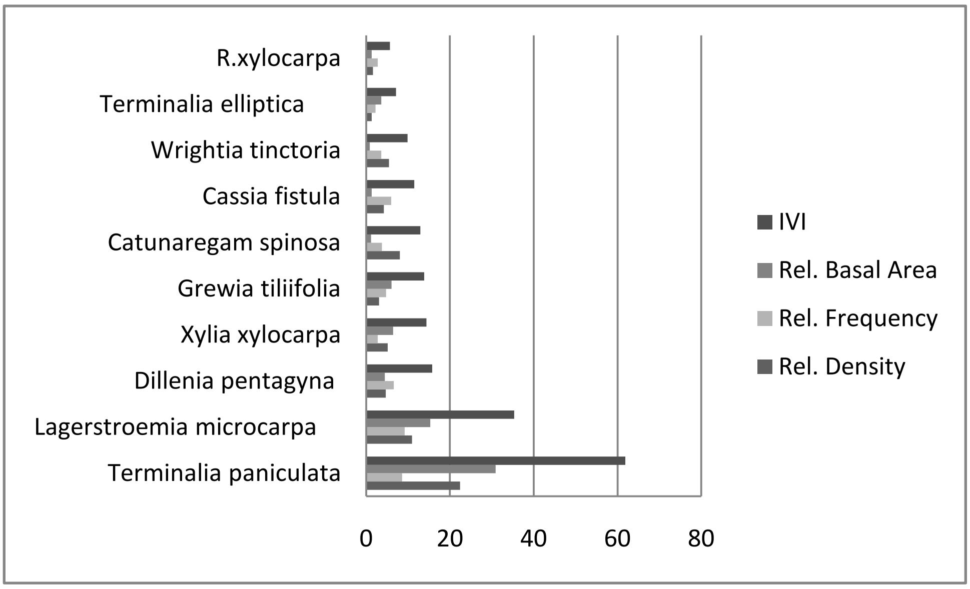



Fig. 5.2.12. Importance Value Index (IVI) of ten dominant species of Southern moist mixed deciduous forest.

With respect to density data, the maximum density (number of individuals/ha) was observed by *Terminalia paniculata* (70.40 individuals/ha), followed by *Lagerstroemia microcarpa* (34.39 individuals/ha), *Catunaregam spinosa* (25.21 individuals/ha), *Wrightia tinctoria* (17.00 individuals/ha) and *Xylia xylocarpa* (16.20 individuals/ha).

Among 85 species encountered, the maximum abundance value was recorded by *Lagerstroemia speciosa* (25), *Terminalia paniculata* (9.09), *Sterculia urens* (8), *Catunaregam spinosa* (7.37) and *Xylia xylocarpa* (6.43).

With regard to frequency, the highest values were recorded by *Lagerstroemia microcarpa* (90.20%), *Terminalia paniculata* (84.31%), *Dillenia pentagyna* (64.71%), *Cassia fistula* (58.82%) and *Grewia tiliifolia* (47.06%).

Wide range of variation is seen among species when consider their mean IVI. It ranges from 0.26 to 61.89. The dominant species based on Importance Value Index are *Terminalia paniculata* (61.89), *Lagerstroemia microcarpa* (35.37), *Dillenia pentagyna* (15.73), *Xylia xylocarpa* (14.35) and *Grewia tiliifolia* (13.85).

The girth class distribution pattern of Southern moist mixed deciduous forest the curve was showed a negative exponential of almost an inverse "J" curve; instead of steep fall, a gradual increase of tree individuals in 90-120,120-150 classes contribute the slight bulged edges on the "j" curve.

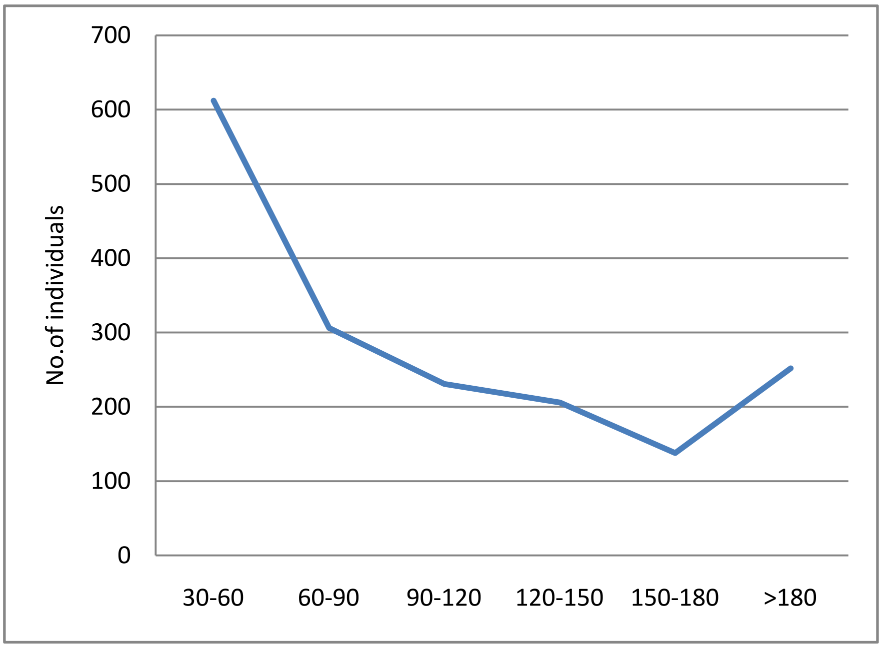



Fig. 5.2.13. Girth class distribution of Southern moist mixed deciduous forest.

Shannon index diversity of tree component in the forest type is 3.21 followed by, 2.7 for shrub, 3.4 for herbs and 3 for climber. The Simpson's dominance value (0.08) and Margalefs Species richness (R1) values are high in trees forms (11.25) when compared to other life forms. Diversity and richness Indices of the various life forms in Southern moist mixed deciduous forests are shown in (Table 5.2.17)

Table 5.2.17. Diversity indices of Southern moist mixed deciduous forest.

| **Moist Deciduous Life forms** | **Richness/Diversity Indices** | | |
|---|---|---|---|
| | **Margalef index** | **Shannon index** | **Simpsons index** |
| Tree | 11.25 | 3.21 | 0.08 |
| Shrub | 4.7 | 2.7 | 0.1 |
| Herb | 7.5 | 3.4 | 0.05 |
| Climber | 6.01 | 3 | 0.06 |

The detailed structural attributes of moist deciduous forest is given in Appendix II.C.

### 5.2.5. Southern dry mixed deciduous forests

A total of 68 trees of above 30 cm. GBH belonging to 26 species were enumerated from the 3267 m$^2$ sampling area. The overall density of this type of forest is 208 individuals/ha. Major associations derived; based on Importance Value Index are *Grewia tiliifolia, Anogeissus latifolia, Lagerstroemia microcarpa, Cleistanthus collinus* and *Diospyros paniculata* (Table 5.2.18).

Table 5.2.18. Importance Value Index (IVI) of the ten most dominant species in Dry deciduous forests

| **Plant Species** | **Rel. Density** | **Rel. Frequency** | **Rel. Basal Area** | **IVI** |
|---|---|---|---|---|
| *Grewia tiliifolia* | 11.76 | 6.45 | 18.94 | 37.15 |
| *Anogeissus latifolia* | 10.29 | 3.23 | 15.46 | 28.98 |
| *Lagerstroemia microcarpa* | 4.41 | 3.23 | 13.58 | 21.22 |
| *Cleistanthus collinus* | 11.76 | 3.23 | 4.39 | 19.38 |
| *Diospyros paniculata* | 8.82 | 6.45 | 2.67 | 17.95 |
| *Radermachera xylocarpa* | 4.41 | 6.45 | 5.87 | 16.73 |
| *Wrightia tinctoria* | 5.88 | 6.45 | 3.38 | 15.72 |
| *Briedelia retusa* | 4.41 | 3.23 | 6.03 | 13.67 |
| *Tamarindus indica* | 1.47 | 3.23 | 6.17 | 10.87 |
| *Terminalia bellirica* | 1.47 | 3.23 | 5.55 | 10.24 |

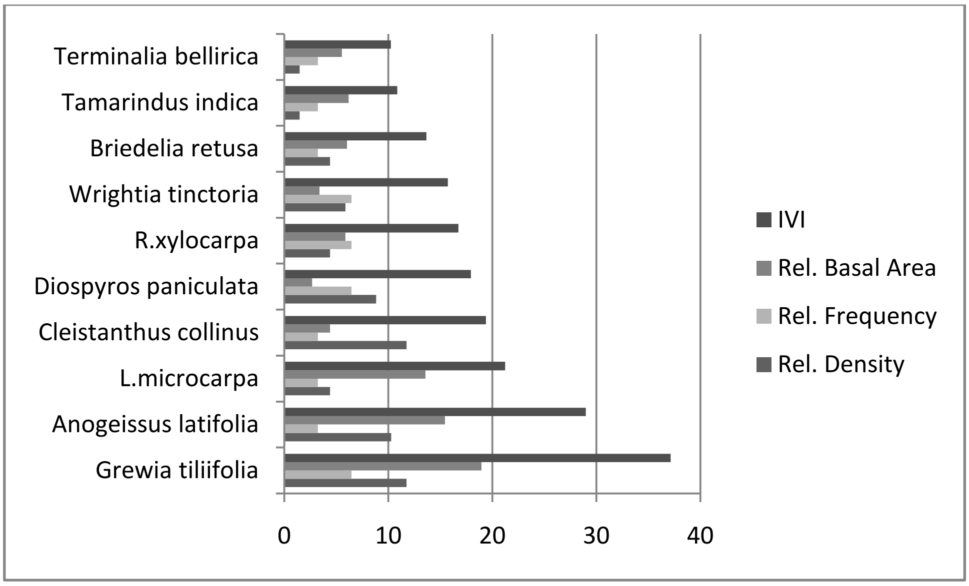



Fig. 5.2.14. Importance Value Index (IVI) of the ten most dominant species in Dry deciduous forests

With respect to density data, the maximum density (number of individuals/ha) was shared by *Grewia tiliifolia* (24.49 individuals/ha), *Cleistanthus collinus* (24.49 individuals/ha), *Anogeissus latifolia* (21.43 individuals/ha), *Diospyros paniculata* (18.37 individuals/ha) and *Wrightia tinctoria* (12.24 individuals/ha).

Among 26 species encountered, the maximum abundance value was recorded by *Cleistanthus collinus* (8), *Anogeissus latifolia* (7) and *Grewia tiliifolia* (4).

With respect to frequency, the highest values were recorded (66.67%) by *Grewia tiliifolia, Diospyros paniculata, Radermachera xylocarpa, Wrightia tinctoria, Premna tomentosa.*

IVI ranges from 4.85 to 37.15. The dominant species based on Importance Value Index are *Grewia tiliifolia* (37.15), Anogeissus latifolia (28.98), *Lagerstroemia microcarpa* (21.22), *Cleistanthus collinus* (19.38) and *Diospyros paniculata* (17.95). Shannon index of the forest type is 2.98.

The Girth class distribution of Dry deciduous forest showed a slight variant of normal inverse 'J' curve. After a steep falling of lower girth classes, a sudden increase of individuals in the girth class range of 120-150 altered the normal curve.

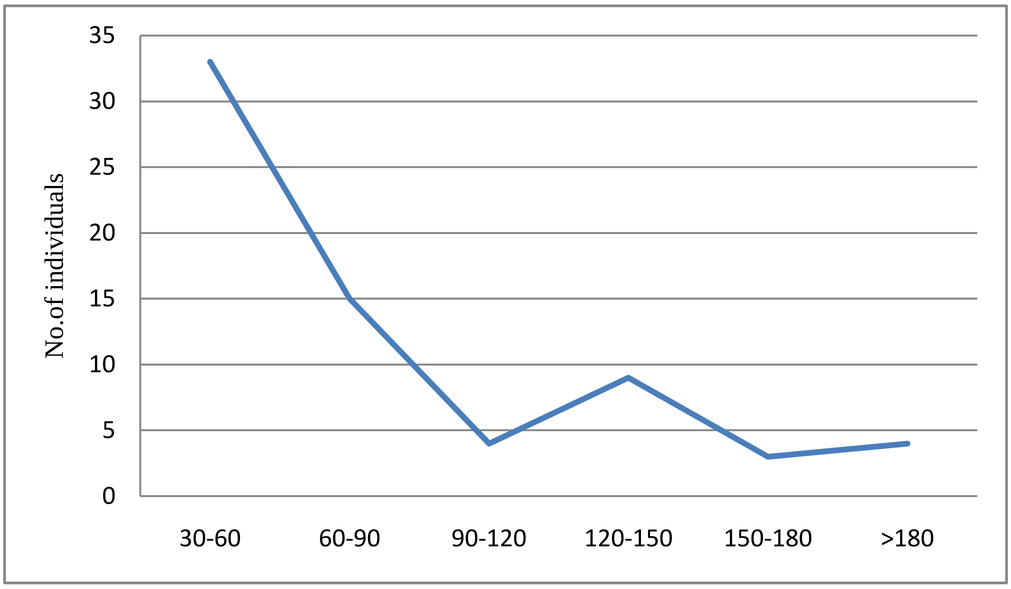



Fig. 5.2.15. Girth class distribution of Southern dry mixed deciduous forests

Shannon index diversity of tree component in the forest type is 2.98 followed by, 2.24 for shrub, 2.8 for herbs and 0.46 for climber. The Simpson's dominance value (0.05) and Margalefs Species richness (R1) values are high in trees forms (5.92) when compared to other lifeforms. Diversity and richness Indices of the various life forms in Southern dry mixed deciduous forests are shown in Table 5.2.19.

Table 5.2.19. Diversity indices of Southern dry mixed deciduous forests

| **Dry Deciduous Life forms** | **Richness/Diversity Indices** | | |
|---|---|---|---|
| | **Margalef index** | **Shannon index** | **Simpsons index** |
| Tree | 5.92 | 2.98 | 0.05 |
| Shrub | 2.7 | 2.24 | 0.12 |
| Herb | 5.3 | 2.8 | 0.02 |
| Climber | 0.78 | 0.46 | 0.78 |

The detailed structural attributes of dry deciduous forest is given in Appendix II.D.

### 5.2.6. Teak plantation

A total of 645 trees of above 30 cm. GBH belonging to 49 species were enumerated from the 16335 $m^2$ sampling area. The overall density of this type of forest is 394 individuals/ha. Major associations derived, based on Importance Value Index are *Tectona grandis, Grewia tiliifolia, Terminalia paniculata, Lagerstroemia microcarpa* and *Xylia xylocarpa* (Table 5.3.13).

Table 5.2.20. Importance Value Index (IVI) of the ten most dominant species in Teak Plantation forest.

| Plant Species | Rel. Density | Rel. Frequency | Rel. Basal Area | IVI |
|---|---|---|---|---|
| *Tectona grandis* | 44.96 | 10.87 | 65.50 | 121.33 |
| *Grewia tiliifolia* | 5.43 | 4.35 | 5.48 | 15.26 |
| *Terminalia paniculata* | 4.50 | 3.62 | 4.58 | 12.70 |
| *Lagerstroemia microcarpa* | 2.79 | 6.52 | 2.22 | 11.54 |
| *Xylia xylocarpa* | 4.03 | 3.62 | 3.15 | 10.80 |
| *Litsea coriacea* | 3.88 | 2.90 | 1.49 | 8.26 |
| *Macaranga peltata* | 2.17 | 4.35 | 1.56 | 8.08 |
| *Antidesma montanum* | 3.57 | 2.17 | 0.79 | 6.53 |
| *Cinnamomum malabatrum* | 2.02 | 3.62 | 0.76 | 6.40 |

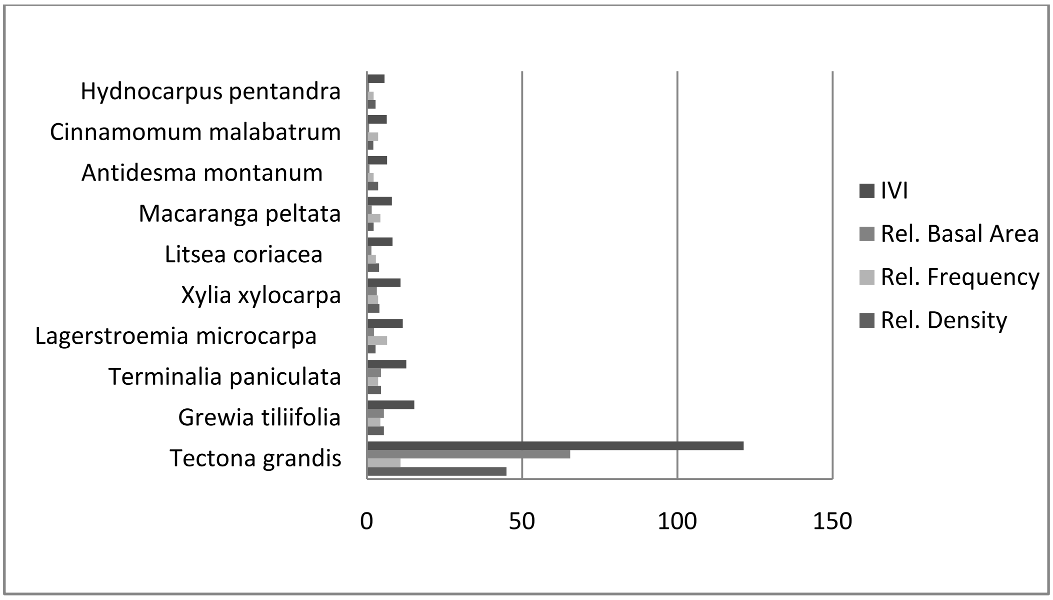



Fig. 5.2.16. Importance Value Index (IVI) of the ten most dominant species in Teak Plantation forest.

With respect to density data, the maximum density was shared by Tectona grandis (177.53 individuals/ha), followed by *Grewia tiliifolia* (21.43 individuals/ha), *Terminalia paniculata* (17.75 individuals/ha), *Xylia xylocarpa* (15.92 individuals/ha) and *Litsea coriacea* (15.30 individuals/ha).

Among 49 species encountered, the maximum abundance value was recorded by *Tectona grandis* (19.33), *Gmelina arborea* (8.00), *Antidesma montanum* (7.67), *Litsea coriacea* (6.25) and *Hydnocarpus pentandra* (6.00).

With respect to frequency, the highest values were recorded by *Tectona grandis* (100%), *Lagerstroemia microcarpa* (60%), *Grewia tiliifolia* (40%), *Macaranga peltata* (40%) and *Terminalia paniculata* (33.33%).

IVI ranges from 0.89 to 121.33. The dominant species based on Importance Value Index are *Tectona grandis* (121.33), *Grewia tiliifolia* (15.26), *Terminalia paniculata* (12.70), *Lagerstroemia microcarpa* (11.54) and *Xylia xylocarpa* (10.80).

The girth class distribution of teak plantation showed a distorted distribution and a gradual decline of individuals in higher classes affected the normal curve. A steep fall of the number of the individuals in the last three classes resulted abnormal pattern which reflects the maturity of the forest type.

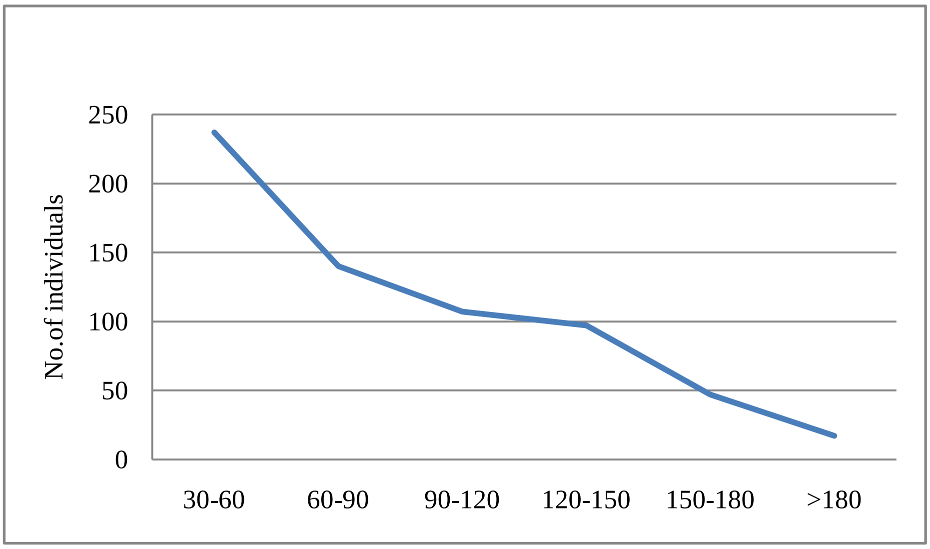



Fig. 5.2.17. Girth class distribution of Teak plantation forest.

Shannon index diversity of tree component in the forest type is 2.53 followed by, 2.19 for shrub, 2.26 for herb and 2.29 for climber. The Simpson's dominance value (0.21) and Margalefs Species richness (R1) values are high in trees forms (7.41) when compared to other life forms. Diversity and richness Indices of the various life forms in Teak plantation are shown in Table 5.2.21.

Table 5.2.21. Diversity indices of Teak plantation forest.

| **Teak Plantation Life forms** | **Richness/Diversity Indices** | | |
|---|---|---|---|
| | **Margalef index** | **Shannon index** | **Simpsons index** |
| Tree | 7.41 | 2.53 | 0.21 |
| Shrub | 2.41 | 2.19 | 0.14 |
| Herb | 1.9 | 2.26 | 0.11 |
| Climber | 3.74 | 2.29 | 0.14 |

The detailed structural attributes of Teak plantation is given in Appendix II.E.

### 5.2.7. Regeneration

A very detailed regeneration study was conducted at PKTR. A total of 161 woody species were recorded from the study area. As far as the regeneration status of seedlings is concerned 105 were found at West coast tropical evergreen forests of the tiger reserve. The regeneration status of saplings observed for West coast tropical semi evergreen forests, Moist deciduous forests, Dry deciduous forest and Teak plantation are 71 species/ha, 78 species/ha 20 species/ha and 47 species/ha respectively.

Table 5.2.22. Dominant trees and their densities in three different growth phases of five vegetation types.

| | | **Density of tree phases** | | |
|---|---|---|---|---|
| **Vegetation types** | **Dominant species** | **Mature** | **sapling** | **Seedling** |
| West coast tropical evergreen | *Aglaia lawii* | 44.40 | 56 | 2072 |
| | *Aglaia barberi* | 39.44 | 39 | 446 |
| | *Drypetes oblongifolia* | 39.44 | 19 | 19.6 |
| | *Palaquium ellipticum* | 31.91 | 39 | 3521 |
| | *Myristica beddomei* | 22.73 | 85 | 354 |

| | | | | |
|---|---|---|---|---|
| West coast tropical semi evergreen | *Aglaia barberi* | 37.9 | 373 | 720 |
| | *Xylia xylocarpa* | 25.0 | … | 27 |
| | *Polyalthia fragrans* | 23.8 | 133 | 160 |
| | *Aglaia lawii* | 22.6 | 533 | 1200 |
| | *Lagerstroemia microcarpa* | 20.8 | … | 53 |
| Southern moist mixed deciduous | *Terminalia paniculata* | 70.4 | … | 15.6 |
| | *Lagerstroemia microcarpa* | 34.3 | 6 | 47 |
| | *Catunaregam spinosa* | 25.20 | 55 | 266 |
| | *Wrightia tinctoria* | 17.10 | 23 | 78 |
| | *Xylia xylocarpa* | 16.20 | 15 | 70 |
| Southern dry mixed deciduous | *Cleistanthus collinus* | 24.4 | 266 | 533 |
| | *Grewia tiliifolia* | 24.4 | 400 | 400 |
| | *Anogeissus latifolia* | 21.4 | 400 | 266 |
| | *Diospyros paniculata* | 18.3 | … | … |
| | *Wrightia tinctoria* | 12.2 | 266 | 533 |
| Teak plantation forest | *Tectona grandis* | 177.5 | 320 | 613 |
| | *Grewia tiliifolia* | 21.4 | 53 | 80 |
| | *Terminalia paniculata* | 17.7 | … | … |
| | *Xylia xylocarpa* | 15.9 | 26 | 53 |
| | *Litsea coriacea* | 15.3 | 26 | 480 |

In west Coast tropical evergreen forest, Aglaia barberi and Myristica beddomei individuals represented in the three stages are in relative proportion and can be seen in the future population in same manner. In the case of *Palaquium ellipticum* and *Aglaia lawii* the no. of individuals in seedlings are high but the establishment in sapling and mature phases are less. But in Semi Evergreen, the establishment of sapling stage of *Aglaia lawii* is better; we can expect density of the species in mature stand more in future. Though *Xylia xylocarpa* and *Lagerstroemia microcarpa* are the most successful species of PKTR, their presence in sapling stage is not been recorded in any of the plots of semi evergreen.

In Moist Deciduous forest, *Catunaregum spinosa*, *Wrightia tinctoria* are showing a healthy regeneration can be expect the mature stands in same proportion in future. In Dry deciduous forest, the seedling and sapling stages not reported in the case of *Diospyros paniculata*. Though the density of *Diospyros paniculata* was 18 individuals/ ha in tree stage, regeneration in the seedling and establishment stages are not seen. In teak plantation the teak remains dominant in all the three phases. In case of Terminalia *paniculata* the absence of individuals is reported in seedling and sapling stages.

Most dominant saplings present in the West coast tropical evergreen forests are *Reinwardtiodendron anamalaiense* (IVI=16), *Polyalthia fragrans* (IVI=9.3), Myristica beddomei (IVI=7.1) and *Baccaurea courtallensis* (IVI=6.1). The dominant saplings of semi evergreen forests, are, *Aglaia lawii* (IVI= 15.6), *Cinnamomum malabatrum* (IVI= 13.1) and *Aglaia barberi* (IVI=11.6). In moist deciduous forests, the dominant saplings are, *Diospyros Montana* (IVI=31.3), *Tabernaemontana alternifolia* (IVI=16.8) and *Caesaria ovata* (IVI=8.54). The dominant saplings in dry deciduous forest are *Anogeissus latifolia* (IVI=8.54), *Cinnamomum malabatrum* (IVI=13.1) and *Aglaia barberi* (IVI=11.6). The dominant saplings in Teak plantation are, *Tectona grandis* (IVI= 21.2), *Cinnamomum malabatrum* (IVI=14.1) and *Polyalthia fragrans* (IVI=11.1).

The dominant seedlings in the West coast tropical evergreen forests include *Palaquium ellipticum* (IVI=22), *Reinwardtiodendron anamalaiense* (IVI=13.7) and *Aglaia lawii* (IVI=13.3). *Aglaia lawii* (IVI=13); *Aglaia barberi* (IVI=8), *Palaquium ellipticum* (IVI=8) are the dominant seedling species in semi evergreen forests. *Olea dioica* (IVI=9.2), *Litsea coriacea* (IVI=7.7) and *Catunaregam spinosa* (IVI=7.5) are dominant in moist deciduous forests. *Ziziphus xylopyrus* (IVI=19.3), *Canthium travancoricum* (IVI=13.6) and *Cleistanthus collinus* (IVI=13) are the most dominant seedling species in Dry deciduous forests. The dominant seedlings in the Teak plantation include *Tectona grandis* (IVI=12), *Litsea coriacea* (IVI=10.5) and *Ixora brachiata* (IVI=8).

Shannon's Diveristy (H') for saplings was highest in tropical evergreen forest (3.5) and least in Dry deciduous forest (2.4) (Fig. 5.2.18.). The seedlings of semi evergreen forest showed highest diversity (3.6) and least for Dry deciduous forest (2.69).

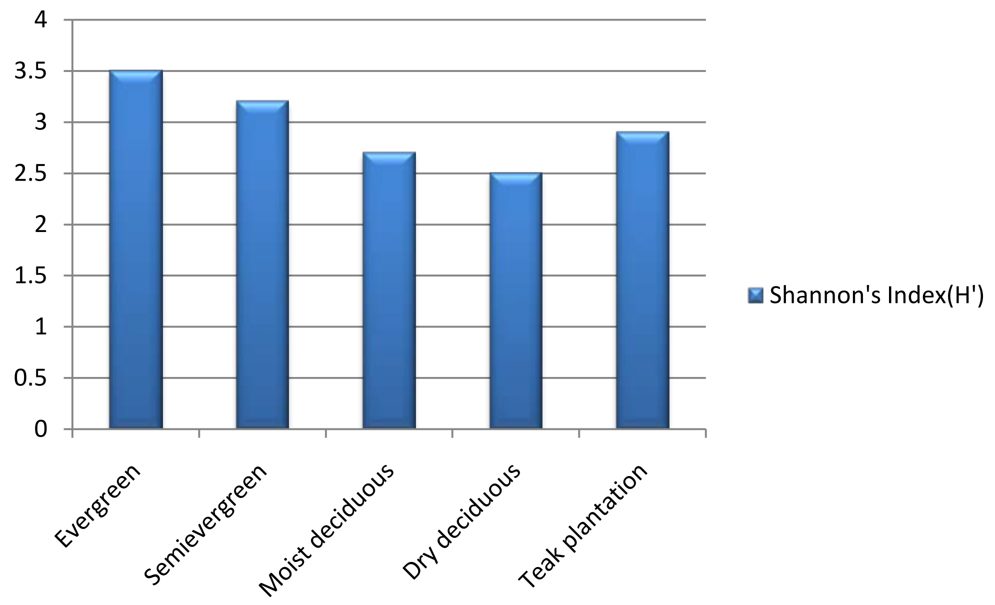



Fig. 5.2.18. Shannon's diversity of saplings of different forest types of PKTR

### 5.2.7.1. Population dynamics of dominant species in PKTR

Population dynamics of selected plant species (Fig. 5.2.19.) were plotted in a graph. Most of the species exhibited good regeneration which could replace the adult population in the coming generation. The population dynamics of *Aglaia lawii* was composed of 332 individuals of mature trees, 89 individuals of saplings and 301 individuals of seedling. However the population dynamics of *Palaquium ellipticum* showed 225 individuals of mature trees and 15 individuals of saplings and 250 individuals of seedlings. All other species such as *Reinwardtiodendron anamalaiense, Cinnamomum malabatrum, Polyalthia fragrans, Aglaia barberi, Litsea coreacea, Myristica beddomei, Dimocarpus longan* and *Diospyros Montana* showed a regenerating layer to replace the standing adult population.

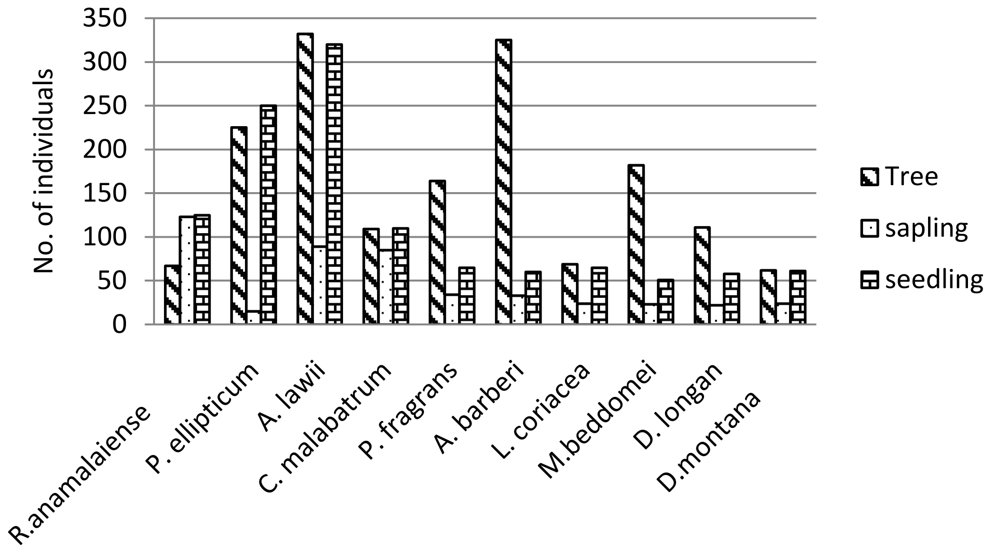



Fig. 5.2.19. Population dynamics of selected species

## 5.2.8. Vegetation status of PKTR other than the Forest types

### 1. Low altitude marshy grass lands – vayals

Low altitude marshy grasslands are termed as '*Vayals*' in Malayalam which are unique features of the Tiger reserve. Grasses and sedges provide high density feeding ground for the wild herbivores during the lean season also. Some of the species growing in vayals are given below:

*Paspalum conjugatum* Berg. *Eragrostis* spp., and *Axonopus compressus* (Sw.) P. Beauv.etc are the major grasses, followed by the sedges such as *Fuirena umbellata* Rottb., *Fimbristylis miliacea* (L.) Vahl, *Fimbristylis narayanii* Fischer, *Cyperus compressus* L., *Cyperus cuspidatus* Kunth, *C. diffuses* Vahl, and *C. tegetum.* The herbs such as *Justicia* spp., *Ludwigia* Spp., *Hygrophile* spp., *Ageratum conyzoides L.*, *Chromolaena odorata* (L.) King & Robins. and *Parthenium hysterophorus* L. are the common components of the marshy lands of PKTR.

## 2. Shola forest

Shola forests are unique montane vegetation occupying temperate habitats in tropical latitude and are the communities restricted to valley and depressions especially along the folds of hills. Karimala hill of this tiger reserve has some resembling characteristics of this type. According to forest type description, the forest restricted to Karimala hills, is not a true shola, but it shows important characters of shola plants *i.e.*, stunted short boled highly branched trees, clothed with mosses and other epiphytes. Woody climbers are few. The species growing in this type of forests are given below.

Major tree species are *Cinnamomum sulphuratum* Nees*, Euonymus indicus* Heyne ex Roxb*., Ligustrum robustum* (Roxb.) Blume*, Maesa indica* (Roxb.) DC*.* *Symplocos cochinchinensis* (Lour.) Moore *etc.* The epiphytic orchids like *Bulbophyllum fuscopurpureum Wight, Bulbophyllum sterile* (Lam.) Suresh*, Oberonia mucronata* (D. Don) Ormerod & Seidenf*., Oberonia santapaui* Kapad*., Dendrobium ovatum* (L.) Kranz*., Dendrobium nutans* Lindl. and the epiphytic pteridophytes such as *Lycopodium phlegmaria* are the common elements of the flora.

## 3.Teak (*Tectona grandis*) Plantations

The original natural vegetation in the valley and the lower hills of eastern parts of the tiger reserve were almost entirely replaced by teak plantations after clear felling the moist deciduous, evergreen and semi evergreen forests in patches during the period 1921 to 1983. At present, the total area under teak is 85 $km^2$ covered by teak plantations of different age classes, the oldest plantation being 1961 RA (Regeneration Area) and the youngest being 1983 RA. It is generally observed that the teak plantations are not an ideal habitat for wildlife owing to lack of diversity in terms of food and cover. During summer, teak sheds its leaves completely building a potential fire hazard. Also, the reflectance of radiation is very high during this season eventually making teak plantations inhospitably hot. This monoculture also faces the threat from epidemic outbreak of insects and disease. Selective impoverishment of soil is also a common phenomenon in monocultures. In the previous management plans, gradual removal of 25% of the growing stock each in the 60$^{th}$, 90$^{th}$ and 120$^{th}$ year is prescribed with the objective of reducing the proportion of teak to 25% and regenerating the remaining 75% area with the native species.

The growth of teak is good in the valley when compared to the elevated locations. Many of these plantations especially, those in the remote corners have not been tended properly. However, many such areas bear a good regeneration of the indigenous species and are preferred by wildlife. At the same time, in several teak plantations, both regularly managed as well as unmanaged ones, poor stock of natural regeneration is observed.  There is thick growth of *Lantana camara* L. in clearings, and of *Eupatorium* sp. in teak plantations, particularly where the plantations have failed.

**4. The teak plantations having sufficient natural regeneration of indigenous species:**

The teak plantations under this category are mostly remote and close to natural forests. These plantations could not establish due to heavy damage caused by wild animals and difficulties of administrating such remote plantations. As such these blocks have practically ceased to be plantations of commercial significance. In these areas, no teak removal operations were prescribed. The objective of management was to promote growth of natural regeneration. In many of these blocks sufficient natural growth was already established. Therefore, these areas were identified and left to nature without any management intervention.

In PKTR teak is the major plantation species and occupies about 90 km$^2$. The number of teak trees per hectare in the natural forests is 15.  In PKTR, teak plantations in the Orukomban and Karimala ranges, several evergreen tree species are regenerating and also established, due to proximitiy of the plantations to semi-evergreen/evergreen forests.  In teak plantations the succession of indigenous trees is taking place through regeneration.  Though quite a large number of indigenous species have established in the plantation, their total basal area is very low when compared with the total basal area of teak trees.

Substantial area belonging to the moist deciduous forests is presently under teak plantations of different age classes, often rich in natural vegetation and plant diversity, mainly depending on the age class. Since teak plantations are intermingled with moist deciduous forests, a number of moist deciduous species are seen in the plantations. It is quite natural that the most dominant species in the plantation forest is *Tectona grandis* (121.33), followed by *Grewia tiliifolia* (15.26), *Terminalia paniculata* (12.70), *Lagerstroemia microcarpa* (11.54) and *Xylia xylocarpa* (10.80). For sampling in teak dominant forests, trees were measured in different areas of plantations. The mean stem density of teak plantation is 177 individuals / hectare.

Raising of teak plantations after clear felling extensive areas of natural forests was the major disturbance at Parambikulam. However, being a tiger reserve, these plantations are left without much weeding or extraction of miscellaneous tree species and this has led to the formation of mixed stands over years. In the absence of any further disturbance, the altered forest biota will slowly return to its normal condition.

### 5.2.9. Discussion

**Sampling scheme**

The primary aim of the study was to understand the floristic and structural status of the permanent vegetation. Small scale plots of size 0.1 ha were laid in different forest types due to its advantage over large plots. Its advantages are; because of their small size, samples can be replicated easily and much of the habitat variation that is typical of these forests is more likely to be represented in many small plots scattered throughout the area than in one large plot equal in area. In addition, several studies conducted in Western Ghats estimated an ideal size of 0.1 ha as sample size. (Suresh and Sukumaran, 1999; Vijayan *et al*., 1999; Rajasekaran, 2000).

The vegetation map of the study area is used as a basic input to study vegetation structure, the distribution of vegetation types with respect to land use, initial stratification and distribution of sample plots. Very few studies have been conducted based on this approach (Roy *et al*, 1993b and Ravan, 1994).

### Floristics and diversity

Species richness observed for trees was 214 out of 55 families which were found to be higher when compared to other forests in Western Ghats. In Peppara wildlife sanctuary a total of 151 tree species in 52 families were recorded (Varghese, 1997). Species estimation of southern moist mixed deciduous forests of Agasthyamalai region of Kerala recorded 49 species (Varghese and Menon, 1998).

The total number of tree species recorded in the West coast tropical evergreen, Semi Evergreen and Moist Deciduous forest were of 161,116 and 78 respectively, these values are higher when compared to the number of species recorded in the forest types of Western Ghats *viz*., 91 in tropical wet evergreen forest in Uppangala, Karnataka, (Pascal and Pelissier, 1996). Pascal (1988) reported 34 species from silent valley and 27 species from Attappady. Ganesh *et al*., (1996) reported 90 tree species under 35 families from KMTR, Western Ghats.

### Family composition

Among the families, Euphorbiaceae is the largest one with 23 species, followed by Lauraceae (18 species), Meliaceae (14 species), Moraceae (11 species) and Ebenaceae (10 species). The highest number of species for Euphorbiaceae is also recorded in Attappady, Naravi, Suthanabi and Bhagavathy forests of Western Ghats (Pascal, 1988). This indicates the wide distribution of Euphorbiaceae in the evergreen forests of Western Ghats. Pascal (1988) reported that the best represented families in terms of the number of species in Uppangala forest of Western Ghats are Euphorbiaceae (20 species) and Anacardiaceae (7 species). In Peppara, highest family registered was Euphorbiaceae, Anacardiaceae and Clusiaceae.

**Endemism and RET status**

Nayar (1997) estimated that, there are about 3800 species of flowering plants in Kerala and 1272 species are Southern Western Ghat endemics. Of the total 479 species recorded from the PKTR, 39 species are endemic to Western Ghats, 61 species are endemic to Southern Western Ghats, and 7 species are endemic to Southern Western Ghats of Kerala, which contributes about 23 per cent of the total species of the study area The Rare and Threatened plants of Kerala is relatively well documented by Ahmedullah &Nayar,1987,Nayar 1997; Nair and Sastry 1998; Sasidharan, 1997,2004. 39 species were recorded in the present study under different conservational categories of IUCN. Among that 26 are tree species. *Ophiorrhiza brunonis* Wight & Arn. a possibly Extinct herb species also rediscovered its survival in the reserve. Despite of past timber extraction and destruction of forest for the sake of Teak plantation, the existing forest of PKTR still support a species rich vegetation with endemic, rare, endangered, threatened and possibly extinct species.

**Girth class distribution**

In the present study of Girth class for all the forest types in the entire area together provides a graph which almost represents a negative exponential or 'inverse J' curve. The size class distribution of the stems were found to exhibit negative exponential or inverse 'J' curve, indicating a good regenerating population (Richards, 1996), a case commonly reported from Western Ghats biodiversity hotspot. For example, Ganesh *et al*., (1996) in Kakachi, Parthasarathy (2001) in Sengaltheri, and Pascal and Pelissier (1996) in Uppangala noted similar trends in their respective study areas.

There was a gradual decrease in species diversity and density with increase in girth class which is in conformity with the studies in the Western Ghats, India (Pascal and Pelisseir 1996; Parthasarathy and Karthikeyan, 1997). While analyzing the girth class distribution it is noted that all forest types were shown almost "J" Curve, except Teak plantation. A steep fall of the number of the individuals in the last three classes resulted abnormal pattern which also reflects the maturity of the forest type. 49 tree species were constituted the lower girth classes and this patch can be established in near future with normal distribution pattern. Though the inverse 'J' curve indicates the regenerating natural forest, it is also noted that in most of the forest types of the PKTR, few individuals and species are represented in more than 180 cm GBH class. It might be due to the selective logging practiced in the study area in the past.

Present study reported Shannon-Weiner diversity index of 4.3 for tree species of the entire sanctuary which is higher compared to various forests of Western Ghats. Shannon-Weiner and Simpson diversity indices indicated high diversity in the area in similar to many other places (Ayyappan and Parthasarathy, 1999, Srinivas and Parthasarathy, 2000). The Climax evergreen forests of the Western Ghats showed Shannon-Weiner indices (H') between 3.6 to 4.3 and Simpson's indices (D) between 0.86 to 0.90 (Rajendraprasad, 1995). Various habitats of Bandipur National park showed Shannon Weiner values in a range of 2.06-2.94 (Prasad *et al*., 1998); Wayanad Wildiife sanctuary showed 2.12 (Rajasekaran, 2000). The evergreen forests of Silent valley, 3.9 (Basha *et al*., 1992).The higher tree species diversity could be attributed to the climatic, topographical and biotic gradients prevailing in the area. The species composition along the gradient is considerably different which might have enhanced the average species diversity.

West coast tropical evergreen forest shows high species richness in Parambikulam tiger reserve (R1-19.44), followed by west coast semi evergreen forest (R1-16.97), Southern Moist deciduous forest (R1-11.25) and Dry deciduous (R1-5.92). In Peppara, species richness of evergreen forest is (R1-7.559) followed by semi evergreen forest (R1-6.0723) and moist deciduous forest (R1-3.5477).

**Density, Frequency, Basal area and IVI**

Tree density (stand density) in evergreen forest was 564 trees/ha which was higher than the mean tree density (419 trees/ha) observed for Western Ghats closed canopy evergreen forest (Ghate *et al*., 1998). Pascal and pelissier (1996) noted 635 trees in the tropical wet evergreen forests of south-west India.

The stand density of other evergreen forest of Western Ghats is as follows; Idukki, 780 trees/ha; Nilambur, 908 trees/ha (Sanalkumar, 1997). Silent Valley, 1082 trees/ha (Basha, 1987); Attappady, 1520 trees/ha (Pascal, 1988); Agasthyavanam Biological Park, 460 trees/ha and Peppara Wildlife Sanctuary 1110 trees/ha (Varghese, 1997). When compared to the forests of Western Ghats these values are similar to the tropical evergreen forest of Courtallum, Western Ghats 482 (Parthasarathy and Karthikeyan, 1997), tropical wet evergreen forest of Uppangala, Karnataka 635 (Pascal and Pelissier, 1996).

Among Semi evergreen forests, PKTR reports 536 trees/ha. A mean stand density of 728 trees/ha for west coast tropical semi evergreen forest has been reported from the central Kerala (Varghese, 1997). For Peppara wildlife sanctuary 755 trees/ha, Agasthyavanam Biologiclal park 500 trees/ha (Varghese, 1997), Kolli hills of Tamilnadu, 592 trees/ha. When compared with hills of Eastern Ghats semi evergreen forests the values reported are in forest of Vellimalai, Kalrayans 397-667/ha and tropical semievergreen forest of Yercaud, Shevarayans 640-986/ha (Kadavul and Parthasarathy, 1999).

The stand density of Southern secondary moist deciduous forest of PKTR were 314 trees/ha. The stand density of Thrissur forest division were 588 trees/ha. In Agasthyavanam Biological Park, 430 trees/ha and Peppara wildlife sanctuary 740-590 trees/ha (Varghese, 1997).

IVI values are used to express dominance and ecological success of any species according to its density, frequency and dominance in relation to all other species. IVI values calculated indicate that the most successive tree species in the PKTR are *Terminalia paniculata, Lagerstroemia microcarpa, Tectona grandis, Aglaia barberi* and *Palaquium ellipticum*.

A total of 78 shrubs species were recorded from 145 plots of Parambikulam Tiger Reserve. Based on IVI values *Chromolaena odorata, Strobilanthes ciliates* and *Glycosmis pentaphylla* It is observed that many areas extracted for timber in the past have been heavily invaded by exotic weeds, viz.

*Chromolaena odorata* (IVI=20.02), which altered the habitat conditions of indigenous flora. The same situation has been reported by Hitendra Padalia (2004) at Andaman Islands.

The absence of annuals is a general characteristic of tropical rainforests (Hall and Swaine 1981) and in the present inventory annuals contributed nearly of 97 herb species were recorded. Out of the total understory diversity and all they were from either open or disturbed sites. Opening of the canopy favoured the invasion of under storied species. (Whittaker and Niering 1965; Devi and Behera 2003).

A total of 71 climber species were recorded from the Parambikulam Tiger Reserve. Based on the density, *Smilax zeylanica, Cyclea peltata, Ziziphus oenoplia* etc were the dense climber species in the study area. Shannon index value for climber diversity maximum recorded from evergreen patch of PKTR and minimum from dry deciduous patch, 3.4 and 0.46 respectivly.

**Regeneration**

The future community structure and composition could be indicated by the regeneration status of the tree species and the life histories of the dominant regenerating populations. While comparing with the present scenario of the evergreen forest, the most successful adult tree species are *Palaquium ellipticum* (18.51), *Aglaia barberi* (15.49), *Aglaia lawii* (15.4). The analysis of future generation showed that *Reinwardtiodendron anamalaiense* (IVI=16), *Polyalthia fragrans* (IVI=9.3), *Myristica beddomei* (IVI=7.1) and *Baccaurea courtallensis* (IVI=6.1). Many localized old species declined over time and might be replaced by new adapted species. Species with a nearly equal distribution of individuals in the three life stages are expected to remain in the near future. The population size of species that lack either seedling or sapling may decline in the coming years.

The species such as *Myristica beddomei, Aglaia beddomei, A.lawii, Polyalthia fragrans, Grewia tiliifolia etc* from the different forest types of PKTR were shown greater number in sapling phase. The greater number of sapling clearly indicates that these species will persist and determine the future vegetation. (Swaine and Hall 1988; Jayasingham and Vivekanatharaja 1994)

The species such as Diospyros paniculata in dry deciduous type, Terminalia paniculata in Teak plantation were represented only by adults without any seedlings and saplings may be due to either their poor seed set, germination or establishment of seedling in the forest. (Ashalatha Devi *et al.,* 2006).

Though the growing stock density of selected species is more in the study area, comparatively poor regeneration was observed in the case of other species. This can be correlated to the disturbance factor, as a result of selective felling in the area. It is true that intermediate disturbance results in the increase of alpha diversity (Connel,1978), it may lead to the shift in the species composition due to the micro environmental changes and thus resulting to the shift of primary species to pioneer species and later to deciduous elements, which ultimately leads to habitat fragmentation due to vegetation type change.

Chapter 6

# SUMMARY AND CONCLUSIONS

# CHAPTER-6

## SUMMARY AND CONCLUSIONS

Forests are complex ecosystems that play a significant role in stabilizing the climate, regulating biogeochemical cycles and containing a major share of the biological diversity. They store 45% of terrestrial carbon, contribute 50% of net primary production, and sequester large amounts of atmospheric carbon annually. Despite their high importance, forests continue to degrade at alarming rates both structurally and functionally. This impairs the habitability of the earth by upsetting the climatic balance, radiation equilibrium and biogeochemical cycles. As protected areas are geospaces established for conservation of biodiversity, information on their bioresources needs to be generate, documented, and analysed for management and effective conservation. Geoinformatics, a subject that evolved in the last few decades, has overwhelmed most other old generation techniques due to its tremendous spatial analysis capabilities and inferences. The present study, 'Ecological *Studies of Parambikulam Tiger Reserve in the Western Ghats of India, using Remote Sensing and GIS'* addresses the structural status of vegetation from landscape to species level, land cover mapping and explores the analytical findings of practical conservation.

The area selected for the study was the PKTR in the Western Ghats biodiversity hotspot where the ecological setting is a representation of the diverse climatic and topographic gradients existing in peninsular India. The PKTR has a spectrum of forest types ranging from evergreen to dry deciduous within an area of 643.7 $km^2$. The vegetation types in the study area include Evergreen, Semi evergreen, Moist deciduous, Dry deciduous and Teak plantation. The results of this study can be summarized into three components – land use / land cover mapping using various data products for different time series, temporal analysis of forest cover density and Phytodiversity analysis of the different forest types of the tiger reserve. The land cover classes delineated using satellite remote sensing data are Evergreen, Semi evergreen, Moist deciduous, Teak plantation, Open areas/grassland, Moist bamboo brakes and Reservoir. Vegetation and land cover type mapping using the IRS P6 LISS III satellite data of the year 2005 showed that the area is predominantly covered with Evergreen forest followed by Moist deciduous forest and Semi evergreen forests. Evergreen forests are generally present on higher hill slopes, whereas mixed moist deciduous forests are present on lower hill slopes and foothills. Altogether, seven land cover classes have been identified, assessment of change for the last three decades showed a considerable degree of degradation of intact forest cover to degraded forest and non-forest categories. All the forest types have undergone change during the 32 years. Around 25 km$^2$ of unmanaged Teak plantations in remote locations that are having sufficient regeneration capacity has attained the status of mixed moist deciduous stands.

The natural vegetation in the valley and the lower hills of eastern parts of the tiger reserve were replaced by teak plantations after clear felling the moist deciduous, evergreen and semi evergreen forests during the period 1921 to 1983. Change detecton study performed for the time period 1973 to 1990, revealed that the forest cover of PKTR has changed considerably from evergreen to semi-evergreen forest, semi evergreen to moist deciduous and open areas, moist deciduous to teak plantation. This may be due to the past timber extraction practices and over exploitation of natural resources. A positive change in forest cover was noticed that teak plantations in some areas were transformed to moist deciduous forest and open areas are changed to teak plantation and to moist deciduous forest. Around 16 km$^2$ of moist deciduous forest and 9 km$^2$ open areas is replaced by teak plantation because of the Teak plantation raising program. Though the area is declared as protected area, it is facing continuous disturbances and the causes behind forest cover changes are plantation activities, past clear felling of natural forests for timber extraction, settlements, and construction of reservoirs.

The rate of change was considerably lower after 1990's. This is probably due to the continuous initiatives taken by government administration to declare this area as a protected area in 1962 and this protection was then extended to the teak plantations in 1973, and in 1985, a wildlife sanctuary was created which prevents all the activities which leads to the extraction and exploitation of forest resources. However being a WLS the plantations are left without much weeding or extraction of miscellaneous tree species because of which some areas have developed into mixed stands which resulted the conversion of 20 $km^2$ Teak plantation to moist deciduous forest. While in February 2001, the Supreme Court of India forbade all extraction of forest resources in protected areas, which resulted in the betterment of the forest condition.

The density stratification reflected that around 60% of the forest area in PKTR falls under dense forest. The factors viz. terrain, accessibility and non proximity to a disturbance source have helped to preserve higher densities in remote areas and uninhabited places. The degraded (low density) forest covers an area of 52 $km^2$ which is occur near habitations or settlements and openings which is an indication of anthropogenic disturbance. Heavy extraction has been the major cause of low density in the forests of PKTR. The intact areas classified as high-density regions (>60% canopy closure) have low disturbance level. As a general trend, the low-density areas are closer to the disturbance source (road, settlements and oen areas), whilst the intact high-density zone is concentrated on hilltops and inaccessible areas. Forest cover density during 1973-2005 showed that open forest and degraded forest has transformed to very dense forest and moderately dense forest during the period of 32 years after the protection became effective. The approach for measuring forest cover density is valuable whilst managing the protected areas like PKTR.

During the study, about 479 species of flowering plants belonging to 335 genera under 103 families were recorded from all the forest types of the Tiger reserve. Out of the 479 species, 214 were tree species, 78 belonged to shrubs, 116 Herbs and 71 Climbers. While concerning the habitat of the species, 290 species were recorded from the West coast tropical evergreen forest, 196 species from Semi evergreen forest, 222 species from Moist deciduous forest, 64 species from Dry deciduous forest and 96 species from Teak plantation forest. Euphorbiaceae is the largest family which constitutes 23 species, followed by

Lauraceae (18 species) and Meliaceae (14 species). Out of 479 arborescent species recorded, 107 species belongs to various Western Ghats endemics, which contribute about 23 per cent of the total species. 39 species are endemic to Western Ghats, 61 species are endemic to Southern Western Ghats, and 7 species are endemic to Southern Western Ghats of Kerala.

39 species of the reserve belongs to various threat categories. The RET species such as Agalaia barberi Gamble and A.lawii (Wight) Saldanha are found to be second and third dominant species of evergreen forest based on IVI values. Vateria indica L. a critically endangered species is found to be the fifth most dominant tree species of evergreen forest. This study indicates that quantitative studies are also essential to have a real status of plants on their distribution, which leads to formulate the conservation policies. *Ophiorrhiza brunonis* Wight & Arn. a possibly Extinct herb species also rediscovered its survival in the reserve. Identification of unique sites, locating the habitats of selected species with Global Positioning System (GPS), mapping of important Rare, Endangered and Threatened plants with their density status, etc., can be used for conservation purpose, especially for species like Ophiorrhiza brunonis, which was considered as possibly extinct and now relocated in the study area.

There were 24 number of epiphytic orchid species recorded, the common epiphytic orchid species were; *Aerides ringens* (Lindl.) C.E.C. Fisch, *Oberonia sebastiana* Shetty & Vivek., *Bulbophyllum sterile* (Lam.) Suresh, *Oberonia santapaui* Kapad., *Vanda tessellata* (Roxb.) Hook. ex D. Don, etc., 10 of epiphytic orchid species were shown the endemism towards the various parts of Western Ghats and Peninsular india. The common epiphytic pteridophytes recorded from the PKTR were *Drynaria quercifolia* (L.) J. Sm., *Pteris quadriaurita* Retz., *Pteris longipes* D. Don, *Microsorum punctatum* (L.) Copel., *Asplenium nidus* L.etc.

Girth class distribution of entire PKTR was shown an inverted 'J' shaped curve. The distortions in the curves were seen in Teak plantation and Moist Deciduous forest types, due to over exploitation and selective logging in the past. Subsequently the forest department neglected Teak plantation and stopped the monoculture at PKTR, which paved the way for the invasion of indigenous flora taken its upper hand. As per the record, these are plantations, which are functionally acting as mixed moist deciduous patches. These patches will be attained the status of Moist teak bearing forest (3B/C1) under Champion and Seth forest type classification in near future.

Phytodiversity analysis indicated that Shannon Weiner diversity for tree species of PKTR was 4.38 and Simpson index is 0.02, high Shannon (4.1) indices followed by low Simpson indices (0.02) were observed in Semi evergreen, which indicates the diverse community in comparison with other forest types. Likewise, Shannon Diversity for shrub layer 3.47, Simpson's 0.04, Margalaef 9.2. Likewise, for herbs layer it was 3.71, 0.042 and 11.7 respectively. For the climbers it was 3.72, 0.032 and 9.12 respectively.

The stand density of PKTR was 564 individuals/ha. The most successive tree species in the reserve are *Terminalia paniculata, Lagerstroemia microcarpa, Tectona grandis, Aglaia barberi* and *Palaquium ellipticum.* Density is found maximum for *Terminalia paniculata* (26.98 individuals/ha) followed by *Tectona grandis* (21.03 individuals/ha)*, Aglaia lawii* (21.03 individuals/ha) and *Aglaia barberi* (20.58 individuals/ha).

As far as the regeneration status of seedlings is concerned, 161 species were recorded from the study area. 105 species from West coast tropical evergreen forests, for West coast tropical semi evergreen forests, Moist deciduous forests, Dry deciduous forest and Teak plantation are 71 species/ha, 78 species/ha 20 species/ha and 47 species/ha respectively. The species such as *Myristica beddomei, Aglaia beddomei, A.lawii, Polyalthia fragrans, Grewia tiliifolia* etc., from the different forest types of PKTR were shown greater number in sapling phase.

Taxonomic knowledge is crucial to meet the challenges of biodiversity conservation in the 21st century (Bhaskaran *et al*., 2010). It is of fundamental importance for understanding bio diversity and ecosystem functioning, as it provides us with the data to explore and describe biodiversity through scientific analysis. The study provides the basic information about the plant species, one of the basic units of biodiversity, which is currently found in the PKTR. Such a list could play an important role for the local and regional authorities interested in future to conserve and sustainably use the phytodiversity for the sustainable development of the area.

PKTR need sustained conservation strategies using detailed spatial data bases generated through tools like RS and GIS, linked with ground based phytosociological studies. It is hoped that these results and maps will be useful in land use zonaton and planning for sustainable use of natural resources. It may be said that only with this level of understanding of biodiversity can a long-term success of conservation policies be assured. Disturbance is one of the major factors for biodiversity loss. Biodiversity of forest patches depends on the existing environmental conditions. The approach of this study is unique due to representation of the results in spatial form that may help in baseline study, planning of plant species inventory, and act as a prime input for species habitat evaluation etc.,

The study has demonstrated the capacity of remote sensing and GIS in detecting the land-cover change with data from different sensors in spite of the absence of past ground data, with appreciable level of accuracy. For design of meaningful conservation strategies, comprehensive information on the distribution of species, as well as information on changes in distribution with time is required. It is nearly impossible to acquire such information purely on the basis of field assessment and monitoring. Remote sensing (RS) provides a systematic, synoptic view of earth cover at regular time intervals, and has been useful for this purpose (Nagendra, 2001). The integration of these tools can increase the accuracy of forest analysis at different spatial scale.

The results quantify the land cover change patterns in PKTR area and demonstrate the potential of multi temporal remote sensing data to provide an accurate, economical means to map and analyze changes in land cover over time that can be used as inputs to land management and policy decisions. The forest cover digital maps based on satellite remote sensing data and GIS techniques can supplement existing conventional ground based sources of information for monitoring changes in the forests cover on a regular basis, which can be helpful for forest resource management and future planning for the development of the areas.

The rarity of woody species and a greater number of singletons in the site underline the need to preserve the vast area of this forest. The establishment of plantations involves alternations of the rainforest habitat. Habitat alteration includes clear felling (for teak plantations) and removal of many large trees, climbers and under storey vegetation. Such a habitat change poses severe threats to wildlife. The PKTR, besides being a biologically important area with unique flora and fauna, is also a habitat for wildlife. It is also a catchment area for 8 river systems. Hence, the protection of this reserve is crucial for the biological conservation of species and human welfare.

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# APPENDICES

# Appendix I

**Details of sample plots laid in different forest types with the altitude, location, range names and coordinate values.**

| Plot No. | Forest Type | Altitude (in meter) | Location | Range | Lattitude | Longitude |
|---|---|---|---|---|---|---|
| 1 | MD | 570 | Near parambikulam dam | Parambikulam | 10.38725 | 76.77027 |
| 2 | EG | 1050 | Karimala gopuram | Karimala | 10.36258 | 76.75843 |
| 3 | EG | 1100 | Karimala gopuram | Karimala | 10.3611 | 76.75631 |
| 4 | SEG | 750 | Karimala gopuram | Karimala | 10.36775 | 76.76283 |
| 5 | EG | 950 | Poopara | Karimala | 10.34838 | 76.82141 |
| 6 | EG | 1000 | Poopara | Karimala | 10.34963 | 76.82783 |
| 7 | EG | 1010 | Poopara | Karimala | 10.3478 | 76.82853 |
| 8 | EG | 1000 | Poopara | Karimala | 10.34516 | 76.83036 |
| 9 | EG | 750 | Vengoli | Parambikulam | 10.42473 | 76.78701 |
| 10 | EG | 750 | Vengoli | Parambikulam | 10.42315 | 76.78470 |
| 11 | MD | 660 | Vengoli | Parambikulam | 10.4166 | 76.79488 |
| 12 | MD | 670 | Vengoli | Parambikulam | 10.41563 | 76.79668 |
| 13 | MD | 550 | Near Duraivayal | Parambikulam | 10.40273 | 76.75733 |
| 14 | MD | 520 | Near Duraivayal | Parambikulam | 10.40036 | 76.75716 |
| 15 | MD | 470 | Duraivayal | Parambikulam | 10.39715 | 76.75380 |
| 16 | SEG | 490 | Mudarachal | Orukomban | 10.3811 | 76.64075 |
| 17 | SEG | 460 | Mudarachal | Orukomban | 10.38241 | 76.64075 |
| 18 | EG | 480 | Mudarachal | Orukomban | 10.384 | 76.63949 |
| 19 | EG | 550 | Mudarachal | Orukomban | 10.38171 | 76.63435 |
| 20 | SEG | 470 | Mudarachal | Orukomban | 10.38065 | 76.63330 |
| 21 | EG | 500 | Kozhimudak | Orukomban | 10.38133 | 76.63330 |
| 22 | EG | 550 | Manjalalipura | Orukomban | 10.38715 | 76.64920 |
| 23 | EG | 550 | Manjalalipura | Orukomban | 10.38753 | 76.64850 |
| 24 | EG | 570 | Manjalalipura | Orukomban | 10.38801 | 76.64800 |
| 25 | EG | 490 | Kottayali | Karimala | 10.39033 | 76.66933 |
| 26 | EG | 490 | Kottayali | Karimala | 10.38938 | 76.66878 |
| 27 | MD | 500 | Kottayali | Karimala | 10.38638 | 76.66556 |

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|---|---|---|---|---|---|---|
| 28 | EG | 500 | Kottayali | Karimala | 10.39038 | 76.67305 |
| 29 | EG | 490 | Puliyala | Orukomban | 10.38231 | 76.62418 |
| 30 | EG | 500 | Puliyala | Orukomban | 10.38538 | 76.62238 |
| 31 | EG | 600 | Nayandanchira | Orukomban | 10.38853 | 76.62133 |
| 32 | EG | 620 | Nayandanchira | Orukomban | 10.38967 | 76.62274 |
| 33 | EG | 650 | Nayandanchira | Orukomban | 10.39062 | 76.62429 |
| 34 | EG | 650 | Nayandanchira | Orukomban | 10.39165 | 76.62596 |
| 35 | EG | 520 | Kariyilathodu | Orukomban | 10.39277 | 76.64938 |
| 36 | EG | 570 | Kariyilathodu | Orukomban | 10.39347 | 76.64858 |
| 37 | EG | 650 | Kariyilathodu | Orukomban | 10.3956 | 76.64632 |
| 38 | EG | 680 | Kariyilathodu | Orukomban | 10.39943 | 76.64332 |
| 39 | SEG | 550 | Puliyala | Orukomban | 10.41785 | 76.60458 |
| 40 | EG | 550 | Puliyala | Orukomban | 10.42136 | 76.60525 |
| 41 | EG | 570 | Puliyala | Orukomban | 10.42213 | 76.60680 |
| 42 | MD | 730 | Manjalalipura | Orukomban | 10.39713 | 76.62521 |
| 43 | MD | 720 | Manjalalipura | Orukomban | 10.39753 | 76.62736 |
| 44 | MD | 600 | Bavappallam | Orukomban | 10.46067 | 76.72415 |
| 45 | SEG | 780 | Thoothanpara | Orukomban | 10.44471 | 76.71101 |
| 46 | SEG | 800 | Thoothanpara | Orukomban | 10.44135 | 76.70702 |
| 47 | EG | 620 | Karinthalappara | Orukomban | 10.40825 | 76.69265 |
| 48 | EG | 690 | Karinthalappara | Orukomban | 10.41161 | 76.69706 |
| 49 | EG | 740 | Madathara | Orukomban | 10.42833 | 76.70143 |
| 50 | EG | 500 | Kariyilathodu | Orukomban | 10.3938 | 76.65651 |
| 51 | EG | 550 | Kurankuzhy | Orukomban | 10.3959 | 76.65333 |
| 52 | EG | 610 | Kurankuzhy | Orukomban | 10.39745 | 76.65271 |
| 53 | EG | 650 | Kurankuzhy top | Orukomban | 10.3995 | 76.65106 |
| 54 | MD | 510 | Thellikkal strip | Orukomban | 10.44306 | 76.73466 |
| 55 | MD | 500 | Thellikkal strip | Orukomban | 10.44258 | 76.73583 |
| 56 | MD | 490 | Thellikkal strip | Orukomban | 10.44261 | 76.73798 |
| 57 | MD | 510 | Thellikkal strip | Orukomban | 10.4423 | 76.73148 |
| 58 | MD | 500 | Thellikkal strip | Orukomban | 10.44268 | 76.73023 |
| 59 | SEG | 800 | Karian Shola | Sungam | 10.47942 | 76.82565 |
| 60 | SEG | 820 | Karian Shola | Sungam | 10.48192 | 76.82333 |

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|---|---|---|---|---|---|---|
| 61 | SEG | 850 | Karian Shola (near vayal) | Sungam | 10.48442 | 76.82158 |
| 62 | EG | 800 | Karian Shola | Sungam | 10.47862 | 76.82835 |
| 63 | EG | 850 | Karian Shola | Sungam | 10.48337 | 76.82598 |
| 64 | EG | 880 | Karian Shola | Sungam | 10.48862 | 76.82483 |
| 65 | MD | 900 | Near Pandaravarai foot hills | Sungam | 10.48927 | 76.82508 |
| 66 | MD | 630 | Karian Shola boundary | Sungam | 10.46342 | 76.81680 |
| 67 | MD | 630 | Near Karian Shola | Sungam | 10.46482 | 76.79362 |
| 68 | MD | 660 | Near Karian Shola | Sungam | 10.46752 | 76.81653 |
| 69 | EG | 650 | Karian Shola | Sungam | 10.46508 | 76.81860 |
| 70 | SEG | 750 | Poopara | Karimala | 10.3567 | 76.78250 |
| 71 | EG | 850 | Poopara | Karimala | 10.3592 | 76.78105 |
| 72 | EG | 900 | Poopara | Karimala | 10.3594 | 76.77847 |
| 73 | EG | 950 | Poopara | Karimala | 10.35878 | 76.77502 |
| 74 | SEG | 500 | Kothala | Karimala | 10.3735 | 76.69172 |
| 75 | EG | 470 | Kothala | Karimala | 10.37072 | 76.68860 |
| 76 | EG | 510 | Orukomban para | Karimala | 10.36681 | 76.68699 |
| 77 | SEG | 490 | Orukomban para | Karimala | 10.36425 | 76.68892 |
| 78 | EG | 910 | Vengoli (near TN boundary) | Parambikulam | 10.42464 | 76.81603 |
| 79 | EG | 890 | Vengoli (near TN boundary) | Parambikulam | 10.42505 | 76.81743 |
| 80 | MD | 900 | Vengoli | Parambikulam | 10.42062 | 76.80948 |
| 81 | MD | 850 | Vengoli | Parambikulam | 10.42147 | 76.80630 |
| 82 | MD | 700 | Vengoli | Parambikulam | 10.4171 | 76.80162 |
| 83 | MD | 510 | Veetikunnu | Parambikulam | 10.38187 | 76.81180 |
| 84 | MD | 510 | Veetikunnu | Parambikulam | 10.3825 | 76.81148 |
| 85 | MD | 520 | Veetikunnu | Parambikulam | 10.38218 | 76.81347 |
| 86 | MD | 540 | Veetikunnu | Parambikulam | 10.38297 | 76.82908 |
| 87 | MD | 540 | Veetikunnu | Parambikulam | 10.38323 | 76.82945 |
| 88 | MD | 500 | Kothala | Karimala | 10.40333 | 76.72995 |
| 89 | MD | 500 | Kothala | Karimala | 10.40167 | 76.73217 |
| 90 | MD | 520 | Kothala | Karimala | 10.40117 | 76.73413 |
| 91 | MD | 530 | Kothala | Karimala | 10.4005 | 76.73800 |
| 92 | SEG | 520 | Karinthalappara(medamchal) | Orukomban | 10.40227 | 76.69197 |
| 93 | MD | 640 | Vetti Ar | Orukomban | 10.45878 | 76.72047 |

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|---|---|---|---|---|---|---|
| 94 | MD | 660 | Vetti Ar | Orukomban | 10.45993 | 76.72147 |
| 95 | MD | 650 | Vetti Ar | Orukomban | 10.45451 | 76.71571 |
| 96 | MD | 640 | Vetti Ar | Orukomban | 10.45556 | 76.71951 |
| 97 | MD | 620 | Vetti Ar | Orukomban | 10.45775 | 76.71831 |
| 98 | MD | 590 | Elathode | Sungam | 10.50845 | 76.80688 |
| 99 | MD | 580 | Elathode | Sungam | 10.50607 | 76.80740 |
| 100 | MD | 570 | Elathode | Sungam | 10.49157 | 76.80038 |
| 101 | MD | 550 | Elathode | Sungam | 10.49222 | 76.79632 |
| 102 | MD | 540 | Elathode | Sungam | 10.49092 | 76.79405 |
| 103 | EG | 540 | Kottayali | Karimala | 10.38551 | 76.67921 |
| 104 | EG | 560 | Kottayali | Karimala | 10.39188 | 76.68048 |
| 105 | EG | 580 | Kottayali | Karimala | 10.39245 | 76.68442 |
| 106 | Teak Plantation | 530 | Kottayali | Karimala | 10.38543 | 76.68873 |
| 107 | EG | 860 | Pezha | Orukomban | 10.41091 | 76.64285 |
| 108 | EG | 890 | Pezha | Orukomban | 10.41022 | 76.64884 |
| 109 | EG | 750 | Pezha | Orukomban | 10.41284 | 76.64638 |
| 110 | EG | 520 | Kalakadannan | Orukomban | 10.40992 | 76.65789 |
| 111 | EG | 580 | Kalakadannan | Orukomban | 10.41561 | 76.66175 |
| 112 | EG | 620 | Kalakadannan | Orukomban | 10.42273 | 76.66217 |
| 113 | SEG | 540 | Kalakadannan | Orukomban | 10.42245 | 76.65533 |
| 114 | EG | 640 | Kilippara kunnu | Karimala | 10.39146 | 76.69747 |
| 115 | MD | 620 | Kilippara kunnu | Karimala | 10.39265 | 76.70219 |
| 116 | MD | 590 | Kilippara kunnu | Karimala | 10.39302 | 76.70490 |
| 117 | Teak Plantation | 600 | Kilippara kunnu | Karimala | 10.39077 | 76.70884 |
| 118 | MD | 570 | Near Tunnel Entry | Parambikulam | 10.40722 | 76.79073 |
| 119 | MD | 600 | Near Tunnel Entry | Parambikulam | 10.4081 | 76.78718 |
| 120 | MD | 640 | Near Tunnel Entry | Parambikulam | 10.4075 | 76.79005 |
| 121 | MD | 630 | Near Tunnel Entry | Parambikulam | 10.40877 | 76.79070 |
| 122 | MD | 570 | Near Tunnel Entry | Parambikulam | 10.40547 | 76.78817 |
| 123 | DD | 500 | Cheerappady | Sungam | 10.524 | 76.83816 |
| 124 | DD | 740 | Uchimudi | Sungam | 10.52783 | 76.84016 |
| 125 | DD | 860 | Uchimudi | Sungam | 10.5307 | 76.83997 |
| 126 | MD | 520 | On the way to Anakkal vayal | Parambikulam | 10.40957 | 76.75087 |

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|---|---|---|---|---|---|---|
| 127 | MD | 530 | Anakkal vayal | Parambikulam | 10.41837 | 76.75038 |
| 128 | MD | 550 | Anakkal vayal | Parambikulam | 10.4301 | 76.75375 |
| 129 | Teak Plantation | 550 | Near Thellikkal | Parambikulam | 10.45515 | 76.74915 |
| 130 | Teak plantation | 560 | Near pklm dam on the way to poopara | Karimala | 10.37286 | 76.76853 |
| 131 | Teak plantation | 580 | Near pklm dam on the way to poopara | Karimala | 10.37003 | 76.77535 |
| 132 | Teak plantation | 700 | On the way to poopara | Karimala | 10.3648 | 76.79232 |
| 133 | Teak Plantation | 540 | Near Kothala vayal | Karimala | 10.39152 | 76.74265 |
| 134 | Teak plantation | 540 | Near Kothala vayal | Karimala | 10.3958 | 76.72827 |
| 135 | Teak Plantation | 540 | Near Kothala vayal | Karimala | 10.40263 | 76.72822 |
| 136 | EG | 1070 | Karimala gopuram | Karimala | 10.3654 | 76.75251 |
| 137 | Teak plantation | 470 | On the way to orukomban | Orukomban | 10.39727 | 76.68673 |
| 138 | Teak plantation | 480 | On the way to orukomban | Orukomban | 10.39625 | 76.68197 |
| 139 | Teak plantation | 470 | Near kuriarkutty | Orukomban | 10.40063 | 76.70135 |
| 140 | Teak plantation | 500 | Near kuriarkutty | Orukomban | 10.40314 | 76.70961 |
| 141 | Teak Plantation | 610 | On the way to kuriarkutty | Parambikulam | 10.40347 | 76.76465 |
| 142 | Teak Plantation | 550 | On the way to kuriarkutty | Parambikulam | 10.40848 | 76.73245 |
| 143 | EG | 1240 | Pandaravarai | Sungam | 10.49773 | 76.83068 |
| 144 | EG | 1150 | Pandaravarai | Sungam | 10.49583 | 76.83025 |
| 145 | EG | 1130 | Pandaravarai | Sungam | 10.49423 | 76.82740 |

EG-Evergreen, SEG-Semi evergreen, MD-Moist deciduous, DD-Dry deciduous.

# Appendix II

### A. Summary of the tree vegetation analysis of Evergreen forests

| Species | N | D | A | R D | F | RF | RB | IVI |
|---|---|---|---|---|---|---|---|---|
| *Palaquium ellipticum* | 212 | 31.91 | 5.17 | 5.66 | 67.21 | 3.32 | 9.530 | 18.51 |
| *Aglaia barberi* | 262 | 39.44 | 5.35 | 6.99 | 80.33 | 3.97 | 4.526 | 15.49 |
| *Aglaia lawii* | 295 | 44.41 | 7.38 | 7.87 | 65.57 | 3.24 | 4.305 | 15.42 |
| *Drypetes oblongifolia* | 262 | 39.44 | 7.28 | 6.99 | 59.02 | 2.92 | 2.239 | 12.15 |
| *Vateria indica* | 110 | 16.56 | 3.44 | 2.94 | 52.46 | 2.59 | 6.606 | 12.13 |
| *Myristica beddomei* | 151 | 22.73 | 3.60 | 4.03 | 68.85 | 3.40 | 4.177 | 11.61 |
| *Polyalthia fragrans* | 118 | 17.76 | 3.28 | 3.15 | 59.02 | 2.92 | 2.575 | 8.64 |
| *Dysoxylum malabaricum* | 69 | 10.39 | 2.16 | 1.84 | 52.46 | 2.59 | 3.670 | 8.11 |
| *Paracroton pendulus ssp. zeylanicus* | 81 | 12.19 | 2.38 | 2.16 | 55.74 | 2.76 | 2.643 | 7.56 |
| *Dimocarpus longan* | 102 | 15.35 | 3.78 | 2.72 | 44.26 | 2.19 | 2.490 | 7.40 |
| *Otonephelium stipulaceum* | 108 | 16.26 | 3.27 | 2.88 | 54.10 | 2.67 | 1.617 | 7.17 |
| *Baccaurea courtallensis* | 118 | 17.76 | 3.19 | 3.15 | 60.66 | 3.00 | 0.654 | 6.80 |
| *Cullenia exarillata* | 45 | 6.77 | 3.75 | 1.20 | 19.67 | 0.97 | 4.117 | 6.29 |
| *Hopea parviflora* | 36 | 5.42 | 2.12 | 0.96 | 27.87 | 1.38 | 3.423 | 5.76 |
| *Syzygium gardneri* | 33 | 4.97 | 1.74 | 0.88 | 31.15 | 1.54 | 3.237 | 5.66 |
| *Bischofia javanica* | 30 | 4.52 | 2.14 | 0.80 | 22.95 | 1.13 | 3.158 | 5.09 |
| *Diospyros ebenum* | 53 | 7.98 | 2.30 | 1.41 | 37.70 | 1.86 | 1.237 | 4.52 |
| *Mesua ferrea var. ferrea* | 29 | 4.37 | 1.61 | 0.77 | 29.51 | 1.46 | 2.205 | 4.44 |
| *Croton malabaricus* | 54 | 8.13 | 2.25 | 1.44 | 39.34 | 1.94 | 0.745 | 4.13 |
| *Reinwardtiodendron anamalaiense* | 64 | 9.63 | 4.00 | 1.71 | 26.23 | 1.30 | 0.963 | 3.97 |
| *Orophea erythrocarpa* | 66 | 9.94 | 3.30 | 1.76 | 32.79 | 1.62 | 0.448 | 3.83 |
| *Syzygium lanceolatum* | 40 | 6.02 | 3.64 | 1.07 | 18.03 | 0.89 | 1.803 | 3.76 |
| *Cinnamomum malabatrum* | 52 | 7.83 | 2.36 | 1.39 | 36.07 | 1.78 | 0.591 | 3.76 |
| *Vepris bilocularis* | 46 | 6.92 | 2.19 | 1.23 | 34.43 | 1.70 | 0.790 | 3.72 |
| *Macaranga peltata* | 34 | 5.12 | 1.89 | 0.91 | 29.51 | 1.46 | 1.045 | 3.41 |
| *Atuna travancorica* | 44 | 6.62 | 2.93 | 1.17 | 24.59 | 1.22 | 0.772 | 3.16 |
| *Xanthophyllum arnottianum* | 58 | 8.73 | 3.63 | 1.55 | 26.23 | 1.30 | 0.317 | 3.16 |
| *Dipterocarpus indicus* | 24 | 3.61 | 2.00 | 0.64 | 19.67 | 0.97 | 1.532 | 3.15 |
| *Actinodaphne malabarica* | 39 | 5.87 | 2.17 | 1.04 | 29.51 | 1.46 | 0.594 | 3.09 |
| *Acronychia pedunculata* | 46 | 6.92 | 3.54 | 1.23 | 21.31 | 1.05 | 0.793 | 3.07 |
| *Knema attenuata* | 33 | 4.97 | 2.36 | 0.88 | 22.95 | 1.13 | 0.857 | 2.87 |
| *Mesua thwaitesii* | 14 | 2.11 | 2.80 | 0.37 | 8.20 | 0.41 | 2.088 | 2.87 |
| *Diospyros sylvatica* | 36 | 5.42 | 3.00 | 0.96 | 19.67 | 0.97 | 0.851 | 2.78 |
| *Dimorphocalyx glabellus var. lawianus* | 56 | 8.43 | 5.60 | 1.49 | 16.39 | 0.81 | 0.409 | 2.71 |
| *Hopea racophloea* | 12 | 1.81 | 1.33 | 0.32 | 14.75 | 0.73 | 1.527 | 2.58 |
| *Leea indica* | 58 | 8.73 | 7.25 | 1.55 | 13.11 | 0.65 | 0.294 | 2.49 |

| Species | N | D | A | R D | F | RF | RB | IVI |
|---|---|---|---|---|---|---|---|---|
| *Hydnocarpus pentandra* | 28 | 4.22 | 2.00 | 0.75 | 22.95 | 1.13 | 0.361 | 2.24 |
| *Drypetes venusta* | 35 | 5.27 | 3.89 | 0.93 | 14.75 | 0.73 | 0.508 | 2.17 |
| *Harpullia arborea* | 35 | 5.27 | 3.89 | 0.93 | 14.75 | 0.73 | 0.359 | 2.02 |
| *Vitex altissima* | 14 | 2.11 | 2.00 | 0.37 | 11.48 | 0.57 | 1.046 | 1.99 |
| *Polyalthia coffeoides* | 28 | 4.22 | 4.00 | 0.75 | 11.48 | 0.57 | 0.510 | 1.83 |
| *Garcinia spicata* | 20 | 3.01 | 1.54 | 0.53 | 21.31 | 1.05 | 0.236 | 1.82 |
| *Ixora brachiata* | 28 | 4.22 | 3.11 | 0.75 | 14.75 | 0.73 | 0.272 | 1.75 |
| *Persea macrantha* | 16 | 2.41 | 1.60 | 0.43 | 16.39 | 0.81 | 0.430 | 1.67 |
| *Syzygium cumini var. cumini* | 15 | 2.26 | 3.00 | 0.40 | 8.20 | 0.41 | 0.838 | 1.64 |
| *Diospyros bourdillonii* | 23 | 3.46 | 3.29 | 0.61 | 11.48 | 0.57 | 0.447 | 1.63 |
| *Aglaia elaeagnoidea* | 24 | 3.61 | 3.43 | 0.64 | 11.48 | 0.57 | 0.346 | 1.55 |
| *Holigarna grahamii* | 13 | 1.96 | 2.60 | 0.35 | 8.20 | 0.41 | 0.779 | 1.53 |
| *diospyros montana* | 18 | 2.71 | 2.00 | 0.48 | 14.75 | 0.73 | 0.255 | 1.46 |
| *Alstonia scholaris* | 7 | 1.05 | 1.00 | 0.19 | 11.48 | 0.57 | 0.587 | 1.34 |
| *Symplocos macrophylla ssp. rosea* | 20 | 3.01 | 2.22 | 0.53 | 14.75 | 0.73 | 0.077 | 1.34 |
| *Diospyros paniculata* | 16 | 2.41 | 2.67 | 0.43 | 9.84 | 0.49 | 0.414 | 1.33 |
| *Syzygium sps.* | 16 | 2.41 | 3.20 | 0.43 | 8.20 | 0.41 | 0.397 | 1.23 |
| *Antidesma montanum* | 17 | 2.56 | 2.43 | 0.45 | 11.48 | 0.57 | 0.206 | 1.23 |
| *Chionanthus mala-elengi ssp. mala-elengi* | 15 | 2.26 | 1.67 | 0.40 | 14.75 | 0.73 | 0.077 | 1.21 |
| *Memecylon umbellatum* | 15 | 2.26 | 1.67 | 0.40 | 14.75 | 0.73 | 0.068 | 1.20 |
| *Casearia ovata* | 16 | 2.41 | 2.29 | 0.43 | 11.48 | 0.57 | 0.160 | 1.15 |
| *Litsea coriacea* | 12 | 1.81 | 1.33 | 0.32 | 14.75 | 0.73 | 0.104 | 1.15 |
| *Orophea uniflora* | 16 | 2.41 | 2.00 | 0.43 | 13.11 | 0.65 | 0.047 | 1.12 |
| *Aphanamixis polystachya* | 9 | 1.35 | 1.00 | 0.24 | 14.75 | 0.73 | 0.097 | 1.07 |
| *Lagerstroemia microcarpa* | 7 | 1.05 | 1.40 | 0.19 | 8.20 | 0.41 | 0.406 | 1.00 |
| *Pterospermum reticulatum* | 13 | 1.96 | 2.60 | 0.35 | 8.20 | 0.41 | 0.229 | 0.98 |
| *Trewia nudiflora* | 9 | 1.35 | 1.50 | 0.24 | 9.84 | 0.49 | 0.243 | 0.97 |
| *Ficus sps.* | 3 | 0.45 | 1.00 | 0.08 | 4.92 | 0.24 | 0.644 | 0.97 |
| *Ficus beddomei* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.829 | 0.94 |
| *Actinodaphne tadulingamii* | 8 | 1.20 | 1.33 | 0.21 | 9.84 | 0.49 | 0.235 | 0.93 |
| *Syzygium laetum* | 6 | 0.90 | 1.20 | 0.16 | 8.20 | 0.41 | 0.366 | 0.93 |
| *Flacourtia montana* | 8 | 1.20 | 1.33 | 0.21 | 9.84 | 0.49 | 0.223 | 0.92 |
| *Terminalia bellirica* | 2 | 0.30 | 1.00 | 0.05 | 3.28 | 0.16 | 0.702 | 0.92 |
| *Neolitsea scrobiculata* | 10 | 1.51 | 1.67 | 0.27 | 9.84 | 0.49 | 0.150 | 0.90 |
| *Mangifera indica* | 6 | 0.90 | 1.00 | 0.16 | 9.84 | 0.49 | 0.253 | 0.90 |
| *Aglaia tomentosa* | 12 | 1.81 | 2.40 | 0.32 | 8.20 | 0.41 | 0.137 | 0.86 |
| *Litsea floribunda* | 6 | 0.90 | 2.00 | 0.16 | 4.92 | 0.24 | 0.447 | 0.85 |
| *Artocarpus heterophyllus* | 4 | 0.60 | 1.33 | 0.11 | 4.92 | 0.24 | 0.498 | 0.85 |
| *Garcinia gummi-gutta* | 10 | 1.51 | 1.67 | 0.27 | 9.84 | 0.49 | 0.090 | 0.84 |

| Species | N | D | A | R D | F | RF | RB | IVI |
|---|---|---|---|---|---|---|---|---|
| *Alseodaphne semecarpifolia var. parvifolia* | 12 | 1.81 | 4.00 | 0.32 | 4.92 | 0.24 | 0.248 | 0.81 |
| *Mallotus philippensis var. philippensis* | 8 | 1.20 | 1.33 | 0.21 | 9.84 | 0.49 | 0.110 | 0.81 |
| *Ficus nervosa* | 3 | 0.45 | 1.00 | 0.08 | 4.92 | 0.24 | 0.480 | 0.80 |
| *Glochidion ellipticum* | 11 | 1.66 | 2.75 | 0.29 | 6.56 | 0.32 | 0.158 | 0.78 |
| *Meiogyne ramarowii* | 11 | 1.66 | 2.75 | 0.29 | 6.56 | 0.32 | 0.040 | 0.66 |
| *Diospyros assimilis* | 7 | 1.05 | 1.75 | 0.19 | 6.56 | 0.32 | 0.139 | 0.65 |
| *Cinnamomum wightii* | 5 | 0.75 | 1.67 | 0.13 | 4.92 | 0.24 | 0.273 | 0.65 |
| *Beilschmiedia wightii* | 10 | 1.51 | 3.33 | 0.27 | 4.92 | 0.24 | 0.136 | 0.65 |
| *Callicarpa tomentosa* | 12 | 1.81 | 4.00 | 0.32 | 4.92 | 0.24 | 0.077 | 0.64 |
| *Phoebe lanceolata* | 9 | 1.35 | 3.00 | 0.24 | 4.92 | 0.24 | 0.137 | 0.62 |
| *Diospyros buxifolia* | 5 | 0.75 | 1.25 | 0.13 | 6.56 | 0.32 | 0.142 | 0.60 |
| *Agrostistachys borneensis* | 8 | 1.20 | 2.00 | 0.21 | 6.56 | 0.32 | 0.043 | 0.58 |
| *Ficus drupacea var. pubescens* | 5 | 0.75 | 5.00 | 0.13 | 1.64 | 0.08 | 0.311 | 0.53 |
| *Celtis philippensis var. wightii* | 5 | 0.75 | 2.50 | 0.13 | 3.28 | 0.16 | 0.227 | 0.52 |
| *Flacourtea jungomas* | 5 | 0.75 | 1.67 | 0.13 | 4.92 | 0.24 | 0.134 | 0.51 |
| *Toona ciliata* | 5 | 0.75 | 1.25 | 0.13 | 6.56 | 0.32 | 0.044 | 0.50 |
| *Diospyros candolleana* | 4 | 0.60 | 1.33 | 0.11 | 4.92 | 0.24 | 0.151 | 0.50 |
| *Excoecaria oppositifolia var. crenulata* | 8 | 1.20 | 2.67 | 0.21 | 4.92 | 0.24 | 0.044 | 0.50 |
| *Canarium strictum* | 4 | 0.60 | 1.33 | 0.11 | 4.92 | 0.24 | 0.148 | 0.50 |
| *Glochidion zeylanicum var. zeylanicum* | 4 | 0.60 | 1.33 | 0.11 | 4.92 | 0.24 | 0.120 | 0.47 |
| *Artocarpus hirsuts* | 3 | 0.45 | 1.00 | 0.08 | 4.92 | 0.24 | 0.144 | 0.47 |
| *Melicope lunu-ankenda* | 5 | 0.75 | 2.50 | 0.13 | 3.28 | 0.16 | 0.171 | 0.47 |
| *Olea dioica* | 4 | 0.60 | 1.00 | 0.11 | 6.56 | 0.32 | 0.029 | 0.46 |
| *Mitragyna tubulosa* | 4 | 0.60 | 1.33 | 0.11 | 4.92 | 0.24 | 0.089 | 0.44 |
| *Aglaia perviridis* | 7 | 1.05 | 3.50 | 0.19 | 3.28 | 0.16 | 0.090 | 0.44 |
| *Scolopia crenata* | 5 | 0.75 | 2.50 | 0.13 | 3.28 | 0.16 | 0.138 | 0.43 |
| *Vernonea arborea* | 5 | 0.75 | 2.50 | 0.13 | 3.28 | 0.16 | 0.136 | 0.43 |
| *Antiaris toxicaria* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.312 | 0.42 |
| *Dysoxylum beddomei* | 2 | 0.30 | 1.00 | 0.05 | 3.28 | 0.16 | 0.201 | 0.42 |
| *Aporosa cardiosperma* | 5 | 0.75 | 1.67 | 0.13 | 4.92 | 0.24 | 0.026 | 0.40 |
| *Elaeocarpus serratus var. serratus* | 3 | 0.45 | 1.50 | 0.08 | 3.28 | 0.16 | 0.157 | 0.40 |
| *Terminalia travancorensis* | 2 | 0.30 | 1.00 | 0.05 | 3.28 | 0.16 | 0.183 | 0.40 |
| *Nothopegia colebrookeana* | 3 | 0.45 | 1.00 | 0.08 | 4.92 | 0.24 | 0.064 | 0.39 |
| *Garcinia morella* | 4 | 0.60 | 1.33 | 0.11 | 4.92 | 0.24 | 0.028 | 0.38 |
| *Schefflera wallichiana* | 6 | 0.90 | 3.00 | 0.16 | 3.28 | 0.16 | 0.050 | 0.37 |
| *Archidendron bigeminum* | 3 | 0.45 | 1.50 | 0.08 | 3.28 | 0.16 | 0.124 | 0.37 |
| *Phoebe wightii* | 8 | 1.20 | 8.00 | 0.21 | 1.64 | 0.08 | 0.046 | 0.34 |
| *Lepisanthes tetraphylla* | 4 | 0.60 | 2.00 | 0.11 | 3.28 | 0.16 | 0.071 | 0.34 |
| *Filicium decipiens* | 3 | 0.45 | 1.00 | 0.08 | 4.92 | 0.24 | 0.011 | 0.33 |

| Species | N | D | A | R D | F | RF | RB | IVI |
|---|---|---|---|---|---|---|---|---|
| *Litsea glabrata* | 4 | 0.60 | 4.00 | 0.11 | 1.64 | 0.08 | 0.135 | 0.32 |
| *Dillenia pentagyna* | 3 | 0.45 | 1.50 | 0.08 | 3.28 | 0.16 | 0.052 | 0.29 |
| *Semecarpus travancorica* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.174 | 0.28 |
| *Strombosia ceylanica* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.174 | 0.28 |
| *Sterculia guttata* | 2 | 0.30 | 1.00 | 0.05 | 3.28 | 0.16 | 0.047 | 0.26 |
| *Elaeocarpus variabilis* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.151 | 0.26 |
| *Mitragyna parvifolia* | 2 | 0.30 | 2.00 | 0.05 | 1.64 | 0.08 | 0.123 | 0.26 |
| *Microtropis wallichiana* | 2 | 0.30 | 2.00 | 0.05 | 1.64 | 0.08 | 0.120 | 0.25 |
| *Trichilia connaroides* | 2 | 0.30 | 1.00 | 0.05 | 3.28 | 0.16 | 0.037 | 0.25 |
| *Sapindus trifoliatus* | 2 | 0.30 | 1.00 | 0.05 | 3.28 | 0.16 | 0.030 | 0.25 |
| *Syzygium mundagam* | 2 | 0.30 | 1.00 | 0.05 | 3.28 | 0.16 | 0.021 | 0.24 |
| *Terminalia elliptica* | 4 | 0.60 | 4.00 | 0.11 | 1.64 | 0.08 | 0.041 | 0.23 |
| *Walsura trifolia var.trifolia* | 2 | 0.30 | 1.00 | 0.05 | 3.28 | 0.16 | 0.008 | 0.22 |
| *Clausena indica* | 2 | 0.30 | 1.00 | 0.05 | 3.28 | 0.16 | 0.005 | 0.22 |
| *Syzygium palghatense* | 3 | 0.45 | 3.00 | 0.08 | 1.64 | 0.08 | 0.034 | 0.20 |
| *Litsea wightiana var. wightiana* | 2 | 0.30 | 2.00 | 0.05 | 1.64 | 0.08 | 0.058 | 0.19 |
| *Schleichera oleosa* | 2 | 0.30 | 2.00 | 0.05 | 1.64 | 0.08 | 0.056 | 0.19 |
| *Cryptocarya beddomei* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.075 | 0.18 |
| *Nothapodytes nimmoniana* | 3 | 0.45 | 3.00 | 0.08 | 1.64 | 0.08 | 0.017 | 0.18 |
| *Litsea oleoides* | 3 | 0.45 | 3.00 | 0.08 | 1.64 | 0.08 | 0.015 | 0.18 |
| *Zanthoxylum rhetsa* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.067 | 0.17 |
| *Diospyros peregrina* | 3 | 0.45 | 3.00 | 0.08 | 1.64 | 0.08 | 0.011 | 0.17 |
| *Crataeva magna* | 3 | 0.45 | 3.00 | 0.08 | 1.64 | 0.08 | 0.007 | 0.17 |
| *Mallotus tetracoccus* | 2 | 0.30 | 2.00 | 0.05 | 1.64 | 0.08 | 0.030 | 0.16 |
| *Calophyllum polyanthum* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.053 | 0.16 |
| *Mastixia arborea ssp. meziana* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.052 | 0.16 |
| *Pterygota alata* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.038 | 0.15 |
| *Murraya paniculata* | 2 | 0.30 | 2.00 | 0.05 | 1.64 | 0.08 | 0.010 | 0.14 |
| *Oroxylum indicum* | 2 | 0.30 | 2.00 | 0.05 | 1.64 | 0.08 | 0.008 | 0.14 |
| *paracroton integrifolius* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.034 | 0.14 |
| *Radermachera xylocarpa* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.024 | 0.13 |
| *Aporosa acuminata* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.023 | 0.13 |
| *Polyalthia longifolia* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.022 | 0.13 |
| *Alangium salvifolium ssp. salvifolium* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.018 | 0.13 |
| *Ailanthus triphysa* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.017 | 0.12 |
| *Carallia brachiata* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.015 | 0.12 |
| *Cryptocarya wightiana* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.013 | 0.12 |
| *Terminalia paniculata* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.012 | 0.12 |
| *Elaeocarpus tuberculatus* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.010 | 0.12 |

| Species | N | D | A | R D | F | RF | RB | IVI |
|---|---|---|---|---|---|---|---|---|
| *Drypetus venusta* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.009 | 0.12 |
| *Spondias pinnata* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.008 | 0.12 |
| *Holigarna arnottiana* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.007 | 0.11 |
| *Calophyllum austroindicum* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.004 | 0.11 |
| *Tabernaemontana alternifolia* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.003 | 0.11 |
| *Clerodendrum infortunatum* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.002 | 0.11 |
| *Cassia fistula* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.002 | 0.11 |
| *Pajanalia longifolia* | 1 | 0.15 | 1.00 | 0.03 | 1.64 | 0.08 | 0.002 | 0.11 |

**B. Summary of the tree vegetation analysis of Semi Evergreen forests**

| Species | N | D | A | R D | F | RF | RB | IVI |
|---|---|---|---|---|---|---|---|---|
| *Aglaia barberi* | 62 | 37.96 | 6.20 | 7.07 | 66.67 | 3.34 | 5.82 | 16.23 |
| *Lagerstroemia microcarpa* | 34 | 20.81 | 3.40 | 3.88 | 66.67 | 3.34 | 8.11 | 15.34 |
| *Polyalthia fragrans* | 39 | 23.88 | 3.55 | 4.45 | 73.33 | 3.68 | 3.13 | 11.26 |
| *Myristica beddomei* | 31 | 18.98 | 3.88 | 3.53 | 53.33 | 2.68 | 3.14 | 9.35 |
| *Xylia xylocarpa* | 41 | 25.10 | 41.00 | 4.68 | 6.67 | 0.33 | 3.46 | 8.47 |
| *Hydnocarpus pentandra* | 24 | 14.69 | 3.00 | 2.74 | 53.33 | 2.68 | 2.12 | 7.53 |
| *Cinnamomum malabatrum* | 27 | 16.53 | 2.70 | 3.08 | 66.67 | 3.34 | 1.03 | 7.46 |
| *Aglaia lawii* | 37 | 22.65 | 12.33 | 4.22 | 20.00 | 1.00 | 2.00 | 7.22 |
| *Hopea parviflora* | 9 | 5.51 | 1.80 | 1.03 | 33.33 | 1.67 | 4.41 | 7.11 |
| *Persea macrantha* | 15 | 9.18 | 2.14 | 1.71 | 46.67 | 2.34 | 2.52 | 6.57 |
| *Bischofia javanica* | 13 | 7.96 | 3.25 | 1.48 | 26.67 | 1.34 | 3.72 | 6.54 |
| *Glochidion zeylanicum var. zeylanicum* | 25 | 15.30 | 8.33 | 2.85 | 20.00 | 1.00 | 2.23 | 6.08 |
| *Syzygium gardneri* | 10 | 6.12 | 2.00 | 1.14 | 33.33 | 1.67 | 2.88 | 5.70 |
| *Croton malabaricus* | 15 | 9.18 | 1.67 | 1.71 | 60.00 | 3.01 | 0.77 | 5.49 |
| *Acronychia pedunculata* | 18 | 11.02 | 3.00 | 2.05 | 40.00 | 2.01 | 1.35 | 5.41 |
| *Grewia tiliifolia* | 13 | 7.96 | 6.50 | 1.48 | 13.33 | 0.67 | 2.96 | 5.11 |
| *Dimorphocalyx glabellus var. lawianus* | 19 | 11.63 | 6.33 | 2.17 | 20.00 | 1.00 | 1.88 | 5.05 |
| *Actinodaphne malabarica* | 20 | 12.24 | 4.00 | 2.28 | 33.33 | 1.67 | 1.08 | 5.03 |
| *Macaranga peltata* | 13 | 7.96 | 2.17 | 1.48 | 40.00 | 2.01 | 1.46 | 4.95 |
| *Drypetes oblongifolia* | 23 | 14.08 | 7.67 | 2.62 | 20.00 | 1.00 | 1.30 | 4.92 |
| *Vitex altissima* | 12 | 7.35 | 2.40 | 1.37 | 33.33 | 1.67 | 1.83 | 4.87 |
| *Litsea coriacea* | 22 | 13.47 | 5.50 | 2.51 | 26.67 | 1.34 | 0.99 | 4.84 |
| *Palaquium ellipticum* | 13 | 7.96 | 3.25 | 1.48 | 26.67 | 1.34 | 1.76 | 4.58 |
| *Otonephelium stipulaceum* | 14 | 8.57 | 2.33 | 1.60 | 40.00 | 2.01 | 0.74 | 4.34 |
| *Leea indica* | 19 | 11.63 | 3.80 | 2.17 | 33.33 | 1.67 | 0.35 | 4.19 |
| *Casearia ovata* | 12 | 7.35 | 2.40 | 1.37 | 33.33 | 1.67 | 0.96 | 4.00 |
| *Glochidion ellipticum* | 15 | 9.18 | 3.00 | 1.71 | 33.33 | 1.67 | 0.56 | 3.94 |

| Species | N | D | A | R D | F | RF | RB | IVI |
|---|---|---|---|---|---|---|---|---|
| *Ficus sps.* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 3.21 | 3.66 |
| *Tectona grandis* | 11 | 6.73 | 11.00 | 1.25 | 6.67 | 0.33 | 1.99 | 3.58 |
| *Atuna travancorica* | 9 | 5.51 | 3.00 | 1.03 | 20.00 | 1.00 | 1.45 | 3.48 |
| *Paracroton pendulus ssp. zeylanicus* | 8 | 4.90 | 2.67 | 0.91 | 20.00 | 1.00 | 1.44 | 3.35 |
| *Terminalia paniculata* | 5 | 3.06 | 1.67 | 0.57 | 20.00 | 1.00 | 1.76 | 3.33 |
| *Orophea erythrocarpa* | 19 | 11.63 | 9.50 | 2.17 | 13.33 | 0.67 | 0.45 | 3.29 |
| *Pterospermum reticulatum* | 8 | 4.90 | 2.67 | 0.91 | 20.00 | 1.00 | 1.07 | 2.98 |
| *Dimocarpus longan* | 8 | 4.90 | 2.00 | 0.91 | 26.67 | 1.34 | 0.70 | 2.95 |
| *Flacourtia montana* | 6 | 3.67 | 1.20 | 0.68 | 33.33 | 1.67 | 0.54 | 2.90 |
| *Callicarpa tomentosa* | 14 | 8.57 | 4.67 | 1.60 | 20.00 | 1.00 | 0.27 | 2.87 |
| *Syzygium cumini var. cumini* | 5 | 3.06 | 1.67 | 0.57 | 20.00 | 1.00 | 1.22 | 2.79 |
| *Ficus nervosa* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 2.15 | 2.60 |
| *Vateria indica* | 3 | 1.84 | 1.50 | 0.34 | 13.33 | 0.67 | 1.45 | 2.46 |
| *Harpullia arborea* | 6 | 3.67 | 2.00 | 0.68 | 20.00 | 1.00 | 0.76 | 2.44 |
| *Diospyros paniculata* | 4 | 2.45 | 2.00 | 0.46 | 13.33 | 0.67 | 1.26 | 2.39 |
| *Syzygium laetum* | 6 | 3.67 | 2.00 | 0.68 | 20.00 | 1.00 | 0.62 | 2.31 |
| *Xanthophyllum arnottianum* | 9 | 5.51 | 3.00 | 1.03 | 20.00 | 1.00 | 0.24 | 2.27 |
| *Baccaurea courtallensis* | 6 | 3.67 | 1.50 | 0.68 | 26.67 | 1.34 | 0.22 | 2.24 |
| *Diospyros ebenum* | 6 | 3.67 | 2.00 | 0.68 | 20.00 | 1.00 | 0.42 | 2.11 |
| *Excoecaria oppositifolia var. crenulata* | 8 | 4.90 | 2.67 | 0.91 | 20.00 | 1.00 | 0.15 | 2.07 |
| *Alseodaphne semecarpifolia var. parvifolia* | 6 | 3.67 | 2.00 | 0.68 | 20.00 | 1.00 | 0.31 | 1.99 |
| *Trewia nudiflora* | 4 | 2.45 | 2.00 | 0.46 | 13.33 | 0.67 | 0.80 | 1.92 |
| *Knema attenuata* | 3 | 1.84 | 1.00 | 0.34 | 20.00 | 1.00 | 0.53 | 1.87 |
| *Dysoxylum malabaricum* | 4 | 2.45 | 1.33 | 0.46 | 20.00 | 1.00 | 0.41 | 1.87 |
| *Alstonia scholaris* | 3 | 1.84 | 1.00 | 0.34 | 20.00 | 1.00 | 0.47 | 1.82 |
| *Ficus drupacea var. pubescens* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 1.30 | 1.75 |
| *Mallotus philippensis var. philippensis* | 5 | 3.06 | 1.67 | 0.57 | 20.00 | 1.00 | 0.17 | 1.74 |
| *Cordia wallichii* | 3 | 1.84 | 3.00 | 0.34 | 6.67 | 0.33 | 1.06 | 1.74 |
| *Vepris bilocularis* | 6 | 3.67 | 3.00 | 0.68 | 13.33 | 0.67 | 0.24 | 1.59 |
| *Toona ciliata* | 4 | 2.45 | 2.00 | 0.46 | 13.33 | 0.67 | 0.41 | 1.53 |
| *Ficus rigida* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 1.07 | 1.52 |
| *Mesua ferrea var. ferrea* | 2 | 1.22 | 1.00 | 0.23 | 13.33 | 0.67 | 0.49 | 1.38 |
| *Artocarpus gomezianus ssp. zeylanicus* | 3 | 1.84 | 3.00 | 0.34 | 6.67 | 0.33 | 0.67 | 1.35 |
| *Artocarpus hirsuts* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.84 | 1.29 |
| *Dillenia pentagyna* | 4 | 2.45 | 2.00 | 0.46 | 13.33 | 0.67 | 0.14 | 1.26 |
| *Chionanthus mala-elengi ssp. mala-elengi* | 7 | 4.29 | 7.00 | 0.80 | 6.67 | 0.33 | 0.08 | 1.21 |
| *Schleichera oleosa* | 4 | 2.45 | 2.00 | 0.46 | 13.33 | 0.67 | 0.08 | 1.21 |
| *Elaeocarpus serratus var. serratus* | 3 | 1.84 | 1.50 | 0.34 | 13.33 | 0.67 | 0.18 | 1.19 |
| *Elaeocarpus tuberculatus* | 2 | 1.22 | 1.00 | 0.23 | 13.33 | 0.67 | 0.23 | 1.12 |

| Species | N | D | A | R D | F | RF | RB | IVI |
|---|---|---|---|---|---|---|---|---|
| *Mangifera indica* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.66 | 1.11 |
| *Calophyllum calaba* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.63 | 1.08 |
| *Symplocos macrophylla ssp. rosea* | 3 | 1.84 | 1.50 | 0.34 | 13.33 | 0.67 | 0.06 | 1.07 |
| *Prunus ceylanica* | 2 | 1.22 | 2.00 | 0.23 | 6.67 | 0.33 | 0.49 | 1.05 |
| *Tetrameles nudiflora* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.58 | 1.02 |
| *Orophea uniflora* | 5 | 3.06 | 5.00 | 0.57 | 6.67 | 0.33 | 0.10 | 1.01 |
| *Mitragyna tubulosa* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.55 | 1.00 |
| *Reinwardtiodendron anamalaiense* | 3 | 1.84 | 3.00 | 0.34 | 6.67 | 0.33 | 0.32 | 0.99 |
| *Cassia fistula* | 2 | 1.22 | 1.00 | 0.23 | 13.33 | 0.67 | 0.08 | 0.98 |
| *Ixora brachiata* | 2 | 1.22 | 1.00 | 0.23 | 13.33 | 0.67 | 0.07 | 0.97 |
| *Sapindus trifoliatus* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.50 | 0.95 |
| *Antidesma montanum* | 2 | 1.22 | 1.00 | 0.23 | 13.33 | 0.67 | 0.03 | 0.93 |
| *Syzygium chavaran* | 3 | 1.84 | 3.00 | 0.34 | 6.67 | 0.33 | 0.12 | 0.79 |
| *Antiaris toxicaria* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.33 | 0.78 |
| *Stereospermum colais var. colais* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.31 | 0.76 |
| *Spondias pinnata* | 2 | 1.22 | 2.00 | 0.23 | 6.67 | 0.33 | 0.18 | 0.75 |
| *Tabernaemontana alternifolia* | 3 | 1.84 | 3.00 | 0.34 | 6.67 | 0.33 | 0.05 | 0.73 |
| *Garcinia gummi-gutta* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.24 | 0.69 |
| *Syzygium mundagam* | 2 | 1.22 | 2.00 | 0.23 | 6.67 | 0.33 | 0.12 | 0.68 |
| *Aporosa acuminata* | 2 | 1.22 | 2.00 | 0.23 | 6.67 | 0.33 | 0.08 | 0.64 |
| *Clausena indica* | 2 | 1.22 | 2.00 | 0.23 | 6.67 | 0.33 | 0.05 | 0.61 |
| *Dipterocarpus indicus* | 2 | 1.22 | 2.00 | 0.23 | 6.67 | 0.33 | 0.04 | 0.60 |
| *Litsea wightiana var. wightiana* | 2 | 1.22 | 2.00 | 0.23 | 6.67 | 0.33 | 0.04 | 0.60 |
| *Radermachera xylocarpa* | 2 | 1.22 | 2.00 | 0.23 | 6.67 | 0.33 | 0.03 | 0.60 |
| *Aglaia tomentosa* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.14 | 0.59 |
| *Pterygota alata* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.12 | 0.57 |
| *Hopea racophloea* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.12 | 0.57 |
| *Garcinia morella* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.09 | 0.54 |
| *Actinodaphne tadulingamii* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.07 | 0.52 |
| *Erythrina variegata* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.05 | 0.49 |
| *Nothopegia colebrookeana* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.05 | 0.49 |
| *Litsea deccanensis* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.03 | 0.48 |
| *Canarium strictum* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.03 | 0.47 |
| *Syzygium lanceolatum* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.03 | 0.47 |
| *Olea dioica* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.02 | 0.47 |
| *Magnolia nilagirica* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.02 | 0.47 |
| *Terminalia bellirica* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.02 | 0.47 |
| *Celtis philippensis var. wightii* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.02 | 0.46 |
| *Diospyros montana* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.02 | 0.46 |

| Species | N | D | A | R D | F | RF | RB | IVI |
|---|---|---|---|---|---|---|---|---|
| *Walsura trifolia var.trifolia* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.02 | 0.46 |
| *Briedelia retusa* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.01 | 0.46 |
| *Aglaia elaeagnoidea* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.01 | 0.46 |
| *Mastixia arborea ssp. meziana* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.01 | 0.46 |
| *Cocculus laurifolius* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.01 | 0.46 |
| *Diospyros sylvatica* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.01 | 0.46 |
| *Aphanamixis polystachya* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.01 | 0.46 |
| *Memecylon deccanense* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.01 | 0.46 |
| *Zanthoxylum rhetsa* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.01 | 0.46 |
| *Artocarpus heterophyllus* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.01 | 0.46 |
| *Memecylon umbellatum* | 1 | 0.61 | 1.00 | 0.11 | 6.67 | 0.33 | 0.01 | 0.46 |

### C. Summary of the tree vegetation analysis of Moist deciduous forests

| Species | N | D | A | R D | F | RF | RB | IVI |
|---|---|---|---|---|---|---|---|---|
| *Terminalia paniculata* | 391 | 70.40 | 9.09 | 22.41 | 84.31 | 8.57 | 30.92 | 61.89 |
| *Lagerstroemia microcarpa* | 191 | 34.39 | 4.15 | 10.95 | 90.20 | 9.16 | 15.26 | 35.37 |
| *Dillenia pentagyna* | 82 | 14.76 | 2.48 | 4.70 | 64.71 | 6.57 | 4.46 | 15.73 |
| *Xylia xylocarpa* | 90 | 16.20 | 6.43 | 5.16 | 27.45 | 2.79 | 6.40 | 14.35 |
| *Grewia tiliifolia* | 53 | 9.54 | 2.21 | 3.04 | 47.06 | 4.78 | 6.03 | 13.85 |
| *Catunaregam spinosa* | 140 | 25.21 | 7.37 | 8.02 | 37.25 | 3.78 | 1.11 | 12.91 |
| *Cassia fistula* | 74 | 13.32 | 2.47 | 4.24 | 58.82 | 5.98 | 1.28 | 11.50 |
| *Wrightia tinctoria* | 95 | 17.11 | 5.28 | 5.44 | 35.29 | 3.59 | 0.81 | 9.84 |
| *Terminalia elliptica* | 23 | 4.14 | 2.09 | 1.32 | 21.57 | 2.19 | 3.57 | 7.08 |
| *Radermachera xylocarpa* | 28 | 5.04 | 2.00 | 1.60 | 27.45 | 2.79 | 1.27 | 5.67 |
| *Diospyros montana* | 42 | 7.56 | 3.50 | 2.41 | 23.53 | 2.39 | 0.48 | 5.28 |
| *Dalbergia sissoides* | 17 | 3.06 | 1.42 | 0.97 | 23.53 | 2.39 | 1.79 | 5.15 |
| *Haldina cordifolia* | 16 | 2.88 | 4.00 | 0.92 | 7.84 | 0.80 | 3.22 | 4.93 |
| *Tectona grandis* | 29 | 5.22 | 4.14 | 1.66 | 13.73 | 1.39 | 1.68 | 4.73 |
| *Lagerstroemia speciosa* | 50 | 9.00 | 25.00 | 2.87 | 3.92 | 0.40 | 1.12 | 4.38 |
| *Persea macrantha* | 19 | 3.42 | 3.17 | 1.09 | 11.76 | 1.20 | 1.93 | 4.21 |
| *Olea dioica* | 30 | 5.40 | 3.75 | 1.72 | 15.69 | 1.59 | 0.72 | 4.03 |
| *Stereospermum colais var. colais* | 15 | 2.70 | 2.14 | 0.86 | 13.73 | 1.39 | 1.22 | 3.48 |
| *Tabernaemontana alternifolia* | 19 | 3.42 | 1.90 | 1.09 | 19.61 | 1.99 | 0.20 | 3.28 |
| *Schleichera oleosa* | 10 | 1.80 | 1.43 | 0.57 | 13.73 | 1.39 | 1.28 | 3.25 |
| *Terminalia bellirica* | 9 | 1.62 | 1.29 | 0.52 | 13.73 | 1.39 | 1.29 | 3.20 |
| *Anogeissus latifolia* | 16 | 2.88 | 2.67 | 0.92 | 11.76 | 1.20 | 1.01 | 3.13 |
| *Dalbergia latifolia* | 10 | 1.80 | 1.25 | 0.57 | 15.69 | 1.59 | 0.96 | 3.12 |
| *Trewia nudiflora* | 21 | 3.78 | 2.63 | 1.20 | 15.69 | 1.59 | 0.18 | 2.98 |

| Species | N | D | A | R D | F | RF | RB | IVI |
|---|---|---|---|---|---|---|---|---|
| *Cordia wallichii* | 14 | 2.52 | 2.00 | 0.80 | 13.73 | 1.39 | 0.39 | 2.58 |
| *Careya arborea* | 16 | 2.88 | 2.67 | 0.92 | 11.76 | 1.20 | 0.39 | 2.50 |
| *Litsea coriacea* | 10 | 1.80 | 1.43 | 0.57 | 13.73 | 1.39 | 0.19 | 2.16 |
| *Macaranga peltata* | 9 | 1.62 | 1.80 | 0.52 | 9.80 | 1.00 | 0.63 | 2.15 |
| *Mallotus philippensis var. philippensis* | 11 | 1.98 | 1.83 | 0.63 | 11.76 | 1.20 | 0.29 | 2.11 |
| *Cinnamomum malabatrum* | 17 | 3.06 | 4.25 | 0.97 | 7.84 | 0.80 | 0.33 | 2.10 |
| *Casearia ovata* | 13 | 2.34 | 2.17 | 0.75 | 11.76 | 1.20 | 0.12 | 2.06 |
| *Tetrameles nudiflora* | 2 | 0.36 | 1.00 | 0.11 | 3.92 | 0.40 | 1.43 | 1.95 |
| *Strychnos nux-vomica* | 10 | 1.80 | 2.00 | 0.57 | 9.80 | 1.00 | 0.36 | 1.93 |
| *Aporosa cardiosperma* | 11 | 1.98 | 1.83 | 0.63 | 11.76 | 1.20 | 0.11 | 1.93 |
| *Mitragyna parvifolia* | 7 | 1.26 | 1.40 | 0.40 | 9.80 | 1.00 | 0.46 | 1.85 |
| *Phyllanthus emblica* | 9 | 1.62 | 1.50 | 0.52 | 11.76 | 1.20 | 0.14 | 1.85 |
| *Holarrhena pubescens* | 10 | 1.80 | 5.00 | 0.57 | 3.92 | 0.40 | 0.56 | 1.53 |
| *Actinodaphne malabarica* | 9 | 1.62 | 2.25 | 0.52 | 7.84 | 0.80 | 0.21 | 1.52 |
| *Bauhinia malabarica* | 6 | 1.08 | 2.00 | 0.34 | 5.88 | 0.60 | 0.38 | 1.32 |
| *Chionanthus mala-elengi ssp. mala-elengi* | 6 | 1.08 | 1.50 | 0.34 | 7.84 | 0.80 | 0.10 | 1.25 |
| *Vitex altissima* | 7 | 1.26 | 2.33 | 0.40 | 5.88 | 0.60 | 0.23 | 1.23 |
| *Pterospermum reticulatum* | 9 | 1.62 | 3.00 | 0.52 | 5.88 | 0.60 | 0.07 | 1.18 |
| *Callicarpa tomentosa* | 5 | 0.90 | 1.25 | 0.29 | 7.84 | 0.80 | 0.04 | 1.12 |
| *Glochidion ellipticum* | 7 | 1.26 | 3.50 | 0.40 | 3.92 | 0.40 | 0.22 | 1.02 |
| *Hydnocarpus pentandra* | 3 | 0.54 | 1.00 | 0.17 | 5.88 | 0.60 | 0.19 | 0.96 |
| *Syzygium cumini var. cumini* | 2 | 0.36 | 1.00 | 0.11 | 3.92 | 0.40 | 0.38 | 0.89 |
| *Pterocarpus marsupium* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.60 | 0.86 |
| *Alstonia scholaris* | 2 | 0.36 | 1.00 | 0.11 | 3.92 | 0.40 | 0.34 | 0.85 |
| *Sapindus trifoliatus* | 4 | 0.72 | 2.00 | 0.23 | 3.92 | 0.40 | 0.16 | 0.79 |
| *Briedelia retusa* | 2 | 0.36 | 1.00 | 0.11 | 3.92 | 0.40 | 0.24 | 0.76 |
| *Melia dubia* | 3 | 0.54 | 3.00 | 0.17 | 1.96 | 0.20 | 0.36 | 0.73 |
| *Sterculia urens* | 8 | 1.44 | 8.00 | 0.46 | 1.96 | 0.20 | 0.06 | 0.72 |
| *Polyalthia fragrans* | 3 | 0.54 | 1.50 | 0.17 | 3.92 | 0.40 | 0.14 | 0.71 |
| *Gmelina arborea* | 2 | 0.36 | 1.00 | 0.11 | 3.92 | 0.40 | 0.18 | 0.69 |
| *Glochidion zeylanicum var. zeylanicum* | 3 | 0.54 | 1.50 | 0.17 | 3.92 | 0.40 | 0.11 | 0.69 |
| *Acronychia pedunculata* | 3 | 0.54 | 1.50 | 0.17 | 3.92 | 0.40 | 0.08 | 0.65 |
| *Dalbergia lanceolaria var. lanceolaria* | 3 | 0.54 | 1.50 | 0.17 | 3.92 | 0.40 | 0.07 | 0.64 |
| *Canthium travancoricum* | 3 | 0.54 | 1.50 | 0.17 | 3.92 | 0.40 | 0.05 | 0.62 |
| *Erythrina variegata* | 3 | 0.54 | 1.50 | 0.17 | 3.92 | 0.40 | 0.05 | 0.62 |
| *Elaeocarpus serratus var. serratus* | 5 | 0.90 | 5.00 | 0.29 | 1.96 | 0.20 | 0.13 | 0.62 |
| *Leea indica* | 6 | 1.08 | 6.00 | 0.34 | 1.96 | 0.20 | 0.02 | 0.57 |
| *Ficus sps.* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.31 | 0.57 |
| *Paracroton pendulus ssp. zeylanicus* | 2 | 0.36 | 1.00 | 0.11 | 3.92 | 0.40 | 0.04 | 0.56 |

| Species | N | D | A | R D | F | RF | RB | IVI |
|---|---|---|---|---|---|---|---|---|
| *Ficus beddomei* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.29 | 0.55 |
| *Clausena indica* | 2 | 0.36 | 1.00 | 0.11 | 3.92 | 0.40 | 0.02 | 0.53 |
| *Bombax ceiba* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.26 | 0.52 |
| *Bombax insigne* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.26 | 0.51 |
| *Ficus drupaceae* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.20 | 0.46 |
| *Mitragyna tubulosa* | 2 | 0.36 | 2.00 | 0.11 | 1.96 | 0.20 | 0.14 | 0.46 |
| *Melicope lunu-ankenda* | 3 | 0.54 | 3.00 | 0.17 | 1.96 | 0.20 | 0.03 | 0.41 |
| *Xanthophyllum arnottianum* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.11 | 0.36 |
| *Albizzia odoratissima* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.10 | 0.36 |
| *Canarium strictum* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.07 | 0.33 |
| *Diospyros cordifolia* | 2 | 0.36 | 2.00 | 0.11 | 1.96 | 0.20 | 0.01 | 0.32 |
| *Casearia wynadensis* | 2 | 0.36 | 2.00 | 0.11 | 1.96 | 0.20 | 0.01 | 0.32 |
| *Aglaia barberi* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.05 | 0.31 |
| *Streblus asper* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.02 | 0.28 |
| *Miliusa tomentosa* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.02 | 0.28 |
| *Aporosa acuminata* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.01 | 0.27 |
| *Antidesma montanum* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.01 | 0.27 |
| *Aphanamixis polystachya* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.01 | 0.26 |
| *Humboldtia vahliana* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.01 | 0.26 |
| *Tamarindus indica* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.01 | 0.26 |
| *Spondias pinnata* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.01 | 0.26 |
| *Cipadessa baccifera* | 1 | 0.18 | 1.00 | 0.06 | 1.96 | 0.20 | 0.00 | 0.26 |

### D. Summary of the tree vegetation analysis of Dry deciduous forests

| Species | N | D | A | R D | F | RF | RB | IVI |
|---|---|---|---|---|---|---|---|---|
| *Grewia tiliifolia* | 8 | 24.49 | 4 | 11.76 | 66.67 | 6.45 | 18.94 | 37.15 |
| *Anogeissus latifolia* | 7 | 21.43 | 7 | 10.29 | 33.33 | 3.23 | 15.46 | 28.98 |
| *Lagerstroemia microcarpa* | 3 | 9.18 | 3 | 4.41 | 33.33 | 3.23 | 13.58 | 21.22 |
| *Cleistanthus collinus* | 8 | 24.49 | 8 | 11.76 | 33.33 | 3.23 | 4.39 | 19.38 |
| *Diospyros paniculata* | 6 | 18.37 | 3 | 8.82 | 66.67 | 6.45 | 2.67 | 17.95 |
| *Radermachera xylocarpa* | 3 | 9.18 | 1.5 | 4.41 | 66.67 | 6.45 | 5.87 | 16.73 |
| *Wrightia tinctoria* | 4 | 12.24 | 2 | 5.88 | 66.67 | 6.45 | 3.38 | 15.72 |
| *Briedelia retusa* | 3 | 9.18 | 3 | 4.41 | 33.33 | 3.23 | 6.03 | 13.67 |
| *Tamarindus indica* | 1 | 3.06 | 1 | 1.47 | 33.33 | 3.23 | 6.17 | 10.87 |
| *Terminalia bellirica* | 1 | 3.06 | 1 | 1.47 | 33.33 | 3.23 | 5.55 | 10.24 |
| *Premna tomentosa* | 2 | 6.12 | 1 | 2.94 | 66.67 | 6.45 | 0.45 | 9.84 |
| *Pterocarpus marsupium* | 2 | 6.12 | 2 | 2.94 | 33.33 | 3.23 | 2.73 | 8.89 |
| *Cassia fistula* | 2 | 6.12 | 2 | 2.94 | 33.33 | 3.23 | 2.41 | 8.58 |

| Species | N | D | A | R D | F | RF | RB | IVI |
|---|---|---|---|---|---|---|---|---|
| *Gardenia resinifera* | 1 | 3.06 | 1 | 1.47 | 33.33 | 3.23 | 3.38 | 8.07 |
| *Crataeva magna* | 2 | 6.12 | 2 | 2.94 | 33.33 | 3.23 | 1.90 | 8.07 |
| *Givotia moluccana* | 2 | 6.12 | 2 | 2.94 | 33.33 | 3.23 | 1.58 | 7.75 |
| *Ziziphus xylocarpus* | 2 | 6.12 | 2 | 2.94 | 33.33 | 3.23 | 1.12 | 7.28 |
| *Cordia wallichii* | 2 | 6.12 | 2 | 2.94 | 33.33 | 3.23 | 0.73 | 6.90 |
| *Tectona grandis* | 2 | 6.12 | 2 | 2.94 | 33.33 | 3.23 | 0.50 | 6.66 |
| *Sterculia urens* | 1 | 3.06 | 1 | 1.47 | 33.33 | 3.23 | 1.30 | 5.99 |
| *Ficus nervosa* | 1 | 3.06 | 1 | 1.47 | 33.33 | 3.23 | 0.56 | 5.26 |
| *Diospyros montana* | 1 | 3.06 | 1 | 1.47 | 33.33 | 3.23 | 0.45 | 5.15 |
| *Cordia gharaf* | 1 | 3.06 | 1 | 1.47 | 33.33 | 3.23 | 0.30 | 4.99 |
| *Polyalthia coffeoides* | 1 | 3.06 | 1 | 1.47 | 33.33 | 3.23 | 0.24 | 4.94 |
| *Firmania colarata* | 1 | 3.06 | 1 | 1.47 | 33.33 | 3.23 | 0.17 | 4.87 |
| *Canthium travancoricum* | 1 | 3.06 | 1 | 1.47 | 33.33 | 3.23 | 0.15 | 4.85 |

### E. Summary of the tree vegetation analysis of Teak plantation forests

| Species | N | D | A | R D | F | RF | RB | IVI |
|---|---|---|---|---|---|---|---|---|
| *Tectona grandis* | 290 | 177.53 | 19.33 | 44.96 | 100.00 | 10.87 | 65.50 | 121.33 |
| *Grewia tiliifolia* | 35 | 21.43 | 5.83 | 5.43 | 40.00 | 4.35 | 5.48 | 15.26 |
| *Terminalia paniculata* | 29 | 17.75 | 5.80 | 4.50 | 33.33 | 3.62 | 4.58 | 12.70 |
| *Lagerstroemia microcarpa* | 18 | 11.02 | 2.00 | 2.79 | 60.00 | 6.52 | 2.22 | 11.54 |
| *Xylia xylocarpa* | 26 | 15.92 | 5.20 | 4.03 | 33.33 | 3.62 | 3.15 | 10.80 |
| *Litsea coriacea* | 25 | 15.30 | 6.25 | 3.88 | 26.67 | 2.90 | 1.49 | 8.26 |
| *Macaranga peltata* | 14 | 8.57 | 2.33 | 2.17 | 40.00 | 4.35 | 1.56 | 8.08 |
| *Antidesma montanum* | 23 | 14.08 | 7.67 | 3.57 | 20.00 | 2.17 | 0.79 | 6.53 |
| *Cinnamomum malabatrum* | 13 | 7.96 | 2.60 | 2.02 | 33.33 | 3.62 | 0.76 | 6.40 |
| *Hydnocarpus pentandra* | 18 | 11.02 | 6.00 | 2.79 | 20.00 | 2.17 | 0.72 | 5.69 |
| *Mitragyna parvifolia* | 8 | 4.90 | 1.60 | 1.24 | 33.33 | 3.62 | 0.80 | 5.66 |
| *Dalbergia sissoides* | 6 | 3.67 | 1.50 | 0.93 | 26.67 | 2.90 | 1.74 | 5.56 |
| *Tabernaemontana alternifolia* | 12 | 7.35 | 3.00 | 1.86 | 26.67 | 2.90 | 0.41 | 5.17 |
| *Terminalia bellirica* | 2 | 1.22 | 1.00 | 0.31 | 13.33 | 1.45 | 3.31 | 5.07 |
| *Schleichera oleosa* | 10 | 6.12 | 2.50 | 1.55 | 26.67 | 2.90 | 0.49 | 4.94 |
| *Dillenia pentagyna* | 8 | 4.90 | 2.67 | 1.24 | 20.00 | 2.17 | 0.93 | 4.34 |
| *Dalbergia latifolia* | 6 | 3.67 | 2.00 | 0.93 | 20.00 | 2.17 | 1.16 | 4.27 |
| *Olea dioica* | 4 | 2.45 | 1.00 | 0.62 | 26.67 | 2.90 | 0.39 | 3.91 |
| *Leea indica* | 9 | 5.51 | 3.00 | 1.40 | 20.00 | 2.17 | 0.18 | 3.75 |
| *Cassia fistula* | 6 | 3.67 | 2.00 | 0.93 | 20.00 | 2.17 | 0.49 | 3.60 |
| *Trewia nudiflora* | 9 | 5.51 | 4.50 | 1.40 | 13.33 | 1.45 | 0.38 | 3.23 |
| *Strychnos nux-vomica* | 9 | 5.51 | 4.50 | 1.40 | 13.33 | 1.45 | 0.38 | 3.22 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Persea macrantha* | 3 | 1.84 | 1.00 | 0.47 | 20.00 | 2.17 | 0.50 | 3.14 |
| *Pterospermum reticulatum* | 5 | 3.06 | 1.67 | 0.78 | 20.00 | 2.17 | 0.16 | 3.11 |
| *Aporosa cardiosperma* | 5 | 3.06 | 1.67 | 0.78 | 20.00 | 2.17 | 0.11 | 3.06 |
| *Chionanthus mala-elengi ssp. mala-elengi* | 3 | 1.84 | 1.00 | 0.47 | 20.00 | 2.17 | 0.07 | 2.71 |
| *Actinodaphne malabarica* | 5 | 3.06 | 2.50 | 0.78 | 13.33 | 1.45 | 0.40 | 2.63 |
| *Phyllanthus emblica* | 4 | 2.45 | 2.00 | 0.62 | 13.33 | 1.45 | 0.44 | 2.51 |
| *Gmelina arborea* | 8 | 4.90 | 8.00 | 1.24 | 6.67 | 0.72 | 0.22 | 2.19 |
| *Polyalthia fragrans* | 4 | 2.45 | 2.00 | 0.62 | 13.33 | 1.45 | 0.08 | 2.15 |
| *Catunaregam spinosa* | 4 | 2.45 | 4.00 | 0.62 | 6.67 | 0.72 | 0.10 | 1.44 |
| *Mallotus philippensis var. philippensis* | 3 | 1.84 | 3.00 | 0.47 | 6.67 | 0.72 | 0.16 | 1.35 |
| *Syzygium sps.* | 3 | 1.84 | 3.00 | 0.47 | 6.67 | 0.72 | 0.08 | 1.27 |
| *Litsea floribunda* | 2 | 1.22 | 2.00 | 0.31 | 6.67 | 0.72 | 0.10 | 1.14 |
| *Baccaurea courtallensis* | 2 | 1.22 | 2.00 | 0.31 | 6.67 | 0.72 | 0.05 | 1.09 |
| *Alstonia scholaris* | 1 | 0.61 | 1.00 | 0.16 | 6.67 | 0.72 | 0.11 | 0.99 |
| *Lannea coromandelica* | 1 | 0.61 | 1.00 | 0.16 | 6.67 | 0.72 | 0.11 | 0.99 |
| *Trichilia connaroides* | 1 | 0.61 | 1.00 | 0.16 | 6.67 | 0.72 | 0.09 | 0.97 |
| *Caryota urens* | 1 | 0.61 | 1.00 | 0.16 | 6.67 | 0.72 | 0.05 | 0.93 |
| *Sapindus trifoliatus* | 1 | 0.61 | 1.00 | 0.16 | 6.67 | 0.72 | 0.05 | 0.93 |
| *Radermachera xylocarpa* | 1 | 0.61 | 1.00 | 0.16 | 6.67 | 0.72 | 0.04 | 0.92 |
| *Casearia wynadensis* | 1 | 0.61 | 1.00 | 0.16 | 6.67 | 0.72 | 0.03 | 0.91 |
| *Dimocarpus longan* | 1 | 0.61 | 1.00 | 0.16 | 6.67 | 0.72 | 0.02 | 0.90 |
| *Flacourtia montana* | 1 | 0.61 | 1.00 | 0.16 | 6.67 | 0.72 | 0.02 | 0.90 |
| *Glochidion ellipticum* | 1 | 0.61 | 1.00 | 0.16 | 6.67 | 0.72 | 0.02 | 0.90 |
| *Wrightia tinctoria* | 1 | 0.61 | 1.00 | 0.16 | 6.67 | 0.72 | 0.02 | 0.90 |
| *Elaeocarpus serratus var. serratus* | 1 | 0.61 | 1.00 | 0.16 | 6.67 | 0.72 | 0.02 | 0.90 |
| *Otonephelium stipulaceum* | 1 | 0.61 | 1.00 | 0.16 | 6.67 | 0.72 | 0.02 | 0.90 |
| *casearia ovata* | 1 | 0.61 | 1.00 | 0.16 | 6.67 | 0.72 | 0.01 | 0.89 |

N - No. of individuals, D - Density (No./ha), A - Abundance, RD – Relative density, F -Frequency, RF - Rel.Frequency, RB - Rel. Basal Area, IVI - Importance value index.

# Appendix III

## A. Vegetation analysis of the Shrubs in PKTR

| Species | N | D | A | R D | F | RF | IVI |
|---|---|---|---|---|---|---|---|
| *Chromolaena odorata* | 420 | 1159 | 12.00 | 10.08 | 0.241 | 9.94 | 20.02 |
| *Strobilanthes ciliatus* | 482 | 1330 | 19.28 | 11.56 | 0.172 | 7.10 | 18.67 |
| *Glycosmis pentaphylla* | 273 | 753 | 9.10 | 6.55 | 0.207 | 8.52 | 15.07 |
| *Helicteres isora* | 296 | 817 | 11.38 | 7.10 | 0.179 | 7.39 | 14.49 |
| *Ziziphus rugosa* | 172 | 474 | 9.56 | 4.13 | 0.124 | 5.11 | 9.24 |
| *Tabernaemontana gamblei* | 235 | 648 | 23.50 | 5.64 | 0.069 | 2.84 | 8.48 |
| *Strobilanthes anceps* | 220 | 607 | 22.00 | 5.28 | 0.069 | 2.84 | 8.12 |
| *Saprosma glomeratum* | 172 | 474 | 14.33 | 4.13 | 0.083 | 3.41 | 7.54 |
| *Dendrocride sinuata* | 160 | 441 | 20.00 | 3.84 | 0.055 | 2.27 | 6.11 |
| *Lantana camara var. camara* | 122 | 337 | 12.20 | 2.93 | 0.069 | 2.84 | 5.77 |
| *Bambusa bambos* | 69 | 190 | 5.31 | 1.66 | 0.090 | 3.69 | 5.35 |
| *Thottea siliquosa* | 163 | 450 | 32.60 | 3.91 | 0.034 | 1.42 | 5.33 |
| *Baliospermum montanum* | 111 | 306 | 13.88 | 2.66 | 0.055 | 2.27 | 4.94 |
| *Triumfetta rhomboidea* | 66 | 182 | 6.60 | 1.58 | 0.069 | 2.84 | 4.42 |
| *Flemingia macrophylla* | 30 | 83 | 3.75 | 0.72 | 0.055 | 2.27 | 2.99 |
| *Ochlandra travancorica* | 80 | 221 | 26.67 | 1.92 | 0.021 | 0.85 | 2.77 |
| *Chassalia curviflora var. ophioxyloides* | 65 | 179 | 16.25 | 1.56 | 0.028 | 1.14 | 2.70 |
| *Ecbolium ligustrinum var. ligustrinum* | 38 | 105 | 6.33 | 0.91 | 0.041 | 1.70 | 2.62 |
| *Psychotria nilgiriensis var. nilgiriensis* | 59 | 163 | 14.75 | 1.42 | 0.028 | 1.14 | 2.55 |
| *Cycas circinalis* | 11 | 30 | 1.57 | 0.26 | 0.048 | 1.99 | 2.25 |
| *Strobilanthes sps.* | 43 | 119 | 10.75 | 1.03 | 0.028 | 1.14 | 2.17 |
| *Stachytarpheta jamaicensis* | 30 | 83 | 6.00 | 0.72 | 0.034 | 1.42 | 2.14 |
| *Dendrocalamus strictus* | 52 | 143 | 17.33 | 1.25 | 0.021 | 0.85 | 2.10 |
| *Urena lobata ssp. lobata* | 32 | 88 | 8.00 | 0.77 | 0.028 | 1.14 | 1.90 |
| *Glycosmis macrocarpa* | 30 | 83 | 7.50 | 0.72 | 0.028 | 1.14 | 1.86 |
| *Briedelia stipularis* | 35 | 97 | 11.67 | 0.84 | 0.021 | 0.85 | 1.69 |
| *Clausena indica* | 35 | 97 | 11.67 | 0.84 | 0.021 | 0.85 | 1.69 |
| *Saprosma foetens* | 23 | 63 | 7.67 | 0.55 | 0.021 | 0.85 | 1.40 |
| *Strobilanthes gamblei* | 33 | 91 | 16.50 | 0.79 | 0.014 | 0.57 | 1.36 |
| *Grewia hirsuta* | 30 | 83 | 15.00 | 0.72 | 0.014 | 0.57 | 1.29 |
| *Justicia santapaui* | 30 | 83 | 15.00 | 0.72 | 0.014 | 0.57 | 1.29 |
| *Abutilon persicum* | 29 | 80 | 14.50 | 0.70 | 0.014 | 0.57 | 1.26 |
| *Dracaena terniflora* | 12 | 33 | 4.00 | 0.29 | 0.021 | 0.85 | 1.14 |
| *Pellionia heyneana* | 11 | 30 | 3.67 | 0.26 | 0.021 | 0.85 | 1.12 |
| *Cipadessa baccifera* | 22 | 61 | 11.00 | 0.53 | 0.014 | 0.57 | 1.10 |

| Species | N | D | A | R D | F | RF | IVI |
|---|---|---|---|---|---|---|---|
| *Rungia wightiana* | 20 | 55 | 10.00 | 0.48 | 0.014 | 0.57 | 1.05 |
| *Sarcandra chloranthoides* | 20 | 55 | 10.00 | 0.48 | 0.014 | 0.57 | 1.05 |
| *Allophylus concanicus* | 7 | 19 | 2.33 | 0.17 | 0.021 | 0.85 | 1.02 |
| *Barleria involucrata var.elata* | 30 | 83 | 30.00 | 0.72 | 0.007 | 0.28 | 1.00 |
| *Lepianthes umbellata* | 17 | 47 | 8.50 | 0.41 | 0.014 | 0.57 | 0.98 |
| *Crotalaria obtecta var. obtecta* | 28 | 77 | 28.00 | 0.67 | 0.007 | 0.28 | 0.96 |
| *Capparis rheedii* | 16 | 44 | 8.00 | 0.38 | 0.014 | 0.57 | 0.95 |
| *Ixora elongata* | 15 | 41 | 7.50 | 0.36 | 0.014 | 0.57 | 0.93 |
| *Maesa indica* | 13 | 36 | 6.50 | 0.31 | 0.014 | 0.57 | 0.88 |
| *Pandanus thawaitesii* | 25 | 69 | 25.00 | 0.60 | 0.007 | 0.28 | 0.88 |
| *Strobilanthes tristis* | 25 | 69 | 25.00 | 0.60 | 0.007 | 0.28 | 0.88 |
| *Breynia disticha* | 22 | 61 | 22.00 | 0.53 | 0.007 | 0.28 | 0.81 |
| *Sida rhombifolia* | 10 | 28 | 5.00 | 0.24 | 0.014 | 0.57 | 0.81 |
| *Grewia obtusa* | 20 | 55 | 20.00 | 0.48 | 0.007 | 0.28 | 0.76 |
| *Solanum xanthocarpus* | 20 | 55 | 20.00 | 0.48 | 0.007 | 0.28 | 0.76 |
| *Strobilanthes asperrimus* | 20 | 55 | 20.00 | 0.48 | 0.007 | 0.28 | 0.76 |
| *Strobilanthes neoasper* | 20 | 55 | 20.00 | 0.48 | 0.007 | 0.28 | 0.76 |
| *Asystasia gangetica var. gangetica* | 7 | 19 | 3.50 | 0.17 | 0.014 | 0.57 | 0.74 |
| *Phoenix loureiroi var. loureiroi* | 5 | 14 | 2.50 | 0.12 | 0.014 | 0.57 | 0.69 |
| *Peristrophe montana* | 15 | 41 | 15.00 | 0.36 | 0.007 | 0.28 | 0.64 |
| *Pogostemon benghalensis* | 15 | 41 | 15.00 | 0.36 | 0.007 | 0.28 | 0.64 |
| *Tarenna asiatica* | 15 | 41 | 15.00 | 0.36 | 0.007 | 0.28 | 0.64 |
| *Barleria acuminata* | 2 | 6 | 1.00 | 0.05 | 0.014 | 0.57 | 0.62 |
| *Solanum torvum* | 12 | 33 | 12.00 | 0.29 | 0.007 | 0.28 | 0.57 |
| *Grewia villosa* | 10 | 28 | 10.00 | 0.24 | 0.007 | 0.28 | 0.52 |
| *Leptonychia candata* | 10 | 28 | 10.00 | 0.24 | 0.007 | 0.28 | 0.52 |
| *Senna tora* | 10 | 28 | 10.00 | 0.24 | 0.007 | 0.28 | 0.52 |
| *Strobilanthes lupulinus* | 10 | 28 | 10.00 | 0.24 | 0.007 | 0.28 | 0.52 |
| *Barleria mysorensis* | 5 | 14 | 5.00 | 0.12 | 0.007 | 0.28 | 0.40 |
| *Persicaria chinensis* | 5 | 14 | 5.00 | 0.12 | 0.007 | 0.28 | 0.40 |
| *Pseudarthria viscida* | 5 | 14 | 5.00 | 0.12 | 0.007 | 0.28 | 0.40 |
| *Senna hirsuta* | 5 | 14 | 5.00 | 0.12 | 0.007 | 0.28 | 0.40 |
| *Allophylus cobbe* | 3 | 8 | 3.00 | 0.07 | 0.007 | 0.28 | 0.36 |
| *Allophylus serrulatus* | 2 | 6 | 2.00 | 0.05 | 0.007 | 0.28 | 0.33 |
| *Colebrookea oppositifolia* | 2 | 6 | 2.00 | 0.05 | 0.007 | 0.28 | 0.33 |
| *Schefflera wallichiana* | 2 | 6 | 2.00 | 0.05 | 0.007 | 0.28 | 0.33 |
| *Thunbergia erecta* | 2 | 6 | 2.00 | 0.05 | 0.007 | 0.28 | 0.33 |
| *Turraea villosa* | 2 | 6 | 2.00 | 0.05 | 0.007 | 0.28 | 0.33 |
| *Barleria prionitis* | 1 | 3 | 1.00 | 0.02 | 0.007 | 0.28 | 0.31 |

| Species | N | D | A | R D | F | RF | IVI |
|---|---|---|---|---|---|---|---|
| *Dimorphocalyx glabellus var. lawianus* | 1 | 3 | 1.00 | 0.02 | 0.007 | 0.28 | 0.31 |
| *Pavonia odorata* | 1 | 3 | 1.00 | 0.02 | 0.007 | 0.28 | 0.31 |
| *Solanum virginianum* | 1 | 3 | 1.00 | 0.02 | 0.007 | 0.28 | 0.31 |
| *Tephrosia pulcherima* | 1 | 3 | 1.00 | 0.02 | 0.007 | 0.28 | 0.31 |

## B. Vegetation analysis of the Herbs in PKTR

| Species | N | D | A | R D | F | RF | IVI |
|---|---|---|---|---|---|---|---|
| *Lepidagathis incurva var. incurva* | 388 | 26759 | 16.87 | 10.93 | 0.159 | 6.78 | 17.71 |
| *Pellionia heyneana* | 370 | 25517 | 15.42 | 10.42 | 0.166 | 7.08 | 17.50 |
| *Mimosa pudica* | 227 | 15655 | 11.35 | 6.39 | 0.138 | 5.90 | 12.29 |
| *Cyathula prostrata* | 208 | 14345 | 10.95 | 5.86 | 0.131 | 5.60 | 11.46 |
| *Stachyphrynium spicatum* | 160 | 11034 | 10.67 | 4.51 | 0.103 | 4.42 | 8.93 |
| *Curculigo orchioides* | 108 | 7448 | 7.20 | 3.04 | 0.103 | 4.42 | 7.47 |
| *Rungia repens* | 150 | 10345 | 16.67 | 4.22 | 0.062 | 2.65 | 6.88 |
| *Zingiber nimmonii* | 107 | 7379 | 8.23 | 3.01 | 0.090 | 3.83 | 6.85 |
| *Commelina benghalensis* | 77 | 5310 | 5.92 | 2.17 | 0.090 | 3.83 | 6.00 |
| *Commelina diffusa* | 111 | 7655 | 12.33 | 3.13 | 0.062 | 2.65 | 5.78 |
| *Zingiber zerumbet* | 80 | 5517 | 8.00 | 2.25 | 0.069 | 2.95 | 5.20 |
| *Sida cordata* | 106 | 7310 | 15.14 | 2.99 | 0.048 | 2.06 | 5.05 |
| *Curcuma aromatica* | 70 | 4828 | 7.00 | 1.97 | 0.069 | 2.95 | 4.92 |
| *Amomum muricatum* | 80 | 5517 | 10.00 | 2.25 | 0.055 | 2.36 | 4.61 |
| *Costus speciosus* | 45 | 3103 | 6.43 | 1.27 | 0.048 | 2.06 | 3.33 |
| *Elephantopus scaber* | 36 | 2483 | 5.14 | 1.01 | 0.048 | 2.06 | 3.08 |
| *Amorphophallus paeoniifolius* | 55 | 3793 | 13.75 | 1.55 | 0.028 | 1.18 | 2.73 |
| *Arisaema barnesii* | 65 | 4483 | 21.67 | 1.83 | 0.021 | 0.89 | 2.72 |
| *Rungia pectinata* | 41 | 2828 | 8.20 | 1.15 | 0.034 | 1.47 | 2.63 |
| *Oplismenus compositus* | 46 | 3172 | 11.50 | 1.30 | 0.028 | 1.18 | 2.48 |
| *Impatiens parasitica* | 50 | 3448 | 16.67 | 1.41 | 0.021 | 0.89 | 2.29 |
| *Amomum cannicarpum* | 42 | 2897 | 14.00 | 1.18 | 0.021 | 0.89 | 2.07 |
| *Dicliptera foetida* | 26 | 1793 | 6.50 | 0.73 | 0.028 | 1.18 | 1.91 |
| *Pouzolzia zeylanica* | 26 | 1793 | 6.50 | 0.73 | 0.028 | 1.18 | 1.91 |
| *Phyllanthus urinaria* | 32 | 2207 | 10.67 | 0.90 | 0.021 | 0.89 | 1.79 |
| *Sida cordifolia* | 25 | 1724 | 8.33 | 0.70 | 0.021 | 0.89 | 1.59 |
| *chloris dolichostachya* | 35 | 2414 | 17.50 | 0.99 | 0.014 | 0.59 | 1.58 |
| *Eragrostis unioloides* | 35 | 2414 | 17.50 | 0.99 | 0.014 | 0.59 | 1.58 |
| *Apluda mutica* | 34 | 2345 | 17.00 | 0.96 | 0.014 | 0.59 | 1.55 |
| *Vernonia cinera* | 23 | 1586 | 7.67 | 0.65 | 0.021 | 0.89 | 1.53 |
| *Kyllinga nemoralis* | 33 | 2276 | 16.50 | 0.93 | 0.014 | 0.59 | 1.52 |

| Species | N | D | A | R D | F | RF | IVI |
|---|---|---|---|---|---|---|---|
| *Globba sessiliflora* | 7 | 483 | 1.75 | 0.20 | 0.028 | 1.18 | 1.38 |
| *Justicia diffusa* | 28 | 1931 | 14.00 | 0.79 | 0.014 | 0.59 | 1.38 |
| *Hydrocotyle javanica* | 20 | 1379 | 10.00 | 0.56 | 0.014 | 0.59 | 1.15 |
| *Amorphophallus bulbifer* | 15 | 1034 | 7.50 | 0.42 | 0.014 | 0.59 | 1.01 |
| *Asclepias curassavica* | 15 | 1034 | 7.50 | 0.42 | 0.014 | 0.59 | 1.01 |
| *Eranthemum capense var. capense* | 15 | 1034 | 7.50 | 0.42 | 0.014 | 0.59 | 1.01 |
| *Haplanthodes neilgherryensis* | 15 | 1034 | 7.50 | 0.42 | 0.014 | 0.59 | 1.01 |
| *Ocimum americanum* | 3 | 207 | 1.00 | 0.08 | 0.021 | 0.89 | 0.97 |
| *Ophiorrhiza brunonis* | 12 | 828 | 6.00 | 0.34 | 0.014 | 0.59 | 0.93 |
| *Alloteropsis cimicina* | 22 | 1517 | 22.00 | 0.62 | 0.007 | 0.30 | 0.91 |
| *Biophytum reinwardtii var. reinwardtii* | 10 | 690 | 5.00 | 0.28 | 0.014 | 0.59 | 0.87 |
| *Bothriochloa pertusa* | 20 | 1379 | 20.00 | 0.56 | 0.007 | 0.30 | 0.86 |
| *Croton bonplandianus* | 20 | 1379 | 20.00 | 0.56 | 0.007 | 0.30 | 0.86 |
| *Isachne globosa* | 20 | 1379 | 20.00 | 0.56 | 0.007 | 0.30 | 0.86 |
| *Sida mysorensis* | 20 | 1379 | 20.00 | 0.56 | 0.007 | 0.30 | 0.86 |
| *Zingiber neesanum* | 20 | 1379 | 20.00 | 0.56 | 0.007 | 0.30 | 0.86 |
| *Ageratum conyzoides* | 9 | 621 | 4.50 | 0.25 | 0.014 | 0.59 | 0.84 |
| *Peperomia pellucida* | 19 | 1310 | 19.00 | 0.54 | 0.007 | 0.30 | 0.83 |
| *Digitaria bicornis* | 18 | 1241 | 18.00 | 0.51 | 0.007 | 0.30 | 0.80 |
| *Peliosanthes teta ssp.humilis* | 18 | 1241 | 18.00 | 0.51 | 0.007 | 0.30 | 0.80 |
| *Chrysopogon nodulibarbis* | 15 | 1034 | 15.00 | 0.42 | 0.007 | 0.30 | 0.72 |
| *Commelina errecta* | 15 | 1034 | 15.00 | 0.42 | 0.007 | 0.30 | 0.72 |
| *Cyanotis villosa* | 15 | 1034 | 15.00 | 0.42 | 0.007 | 0.30 | 0.72 |
| *Emilia scabra* | 15 | 1034 | 15.00 | 0.42 | 0.007 | 0.30 | 0.72 |
| *Setaria intermedia* | 15 | 1034 | 15.00 | 0.42 | 0.007 | 0.30 | 0.72 |
| *Acalypha ciliata* | 2 | 138 | 1.00 | 0.06 | 0.014 | 0.59 | 0.65 |
| *Biophytum sensitivum* | 2 | 138 | 1.00 | 0.06 | 0.014 | 0.59 | 0.65 |
| *Themeda triandra* | 2 | 138 | 1.00 | 0.06 | 0.014 | 0.59 | 0.65 |
| *Acalypha indica* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *Amaranthus spinosus* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *Begonia fallax* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *canscora pauciflora* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *Capillipedium assimile* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *Cyanotis axillaris* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *Cyperus sps.* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *Dimeria ornithopoda* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *Dipteracanthus prostratus* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *Hypericum japonicum* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *Isodon wightii* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |

| Species | N | D | A | R D | F | RF | IVI |
|---|---|---|---|---|---|---|---|
| *Leucas chinensis* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *Micrococca beddomei* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *Ophiorhiza rugosa var.prostrata* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *Parathenium hysterophorous* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *Polygala rosmarintolia* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *Rauvolfia serpentina* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *Sida acuta* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *Zingiber officinale* | 10 | 690 | 10.00 | 0.28 | 0.007 | 0.30 | 0.58 |
| *Phyllanthus amarus* | 8 | 552 | 8.00 | 0.23 | 0.007 | 0.30 | 0.52 |
| *Curcuma neilgherensis* | 6 | 414 | 6.00 | 0.17 | 0.007 | 0.30 | 0.46 |
| *Ophiorrhiza mungosa* | 6 | 414 | 6.00 | 0.17 | 0.007 | 0.30 | 0.46 |
| *Centella asiatica* | 5 | 345 | 5.00 | 0.14 | 0.007 | 0.30 | 0.44 |
| *Naregamia alata* | 5 | 345 | 5.00 | 0.14 | 0.007 | 0.30 | 0.44 |
| *Senna tora* | 5 | 345 | 5.00 | 0.14 | 0.007 | 0.30 | 0.44 |
| *Setaria palmifolia* | 5 | 345 | 5.00 | 0.14 | 0.007 | 0.30 | 0.44 |
| *Solanum americanum* | 5 | 345 | 5.00 | 0.14 | 0.007 | 0.30 | 0.44 |
| *Zeuxine longilabris* | 5 | 345 | 5.00 | 0.14 | 0.007 | 0.30 | 0.44 |
| *Laportea interrupta* | 2 | 138 | 2.00 | 0.06 | 0.007 | 0.30 | 0.35 |
| *Ophiopogon intermedius* | 2 | 138 | 2.00 | 0.06 | 0.007 | 0.30 | 0.35 |
| *Ophiorrhiza rugosa var. prostrata* | 2 | 138 | 2.00 | 0.06 | 0.007 | 0.30 | 0.35 |
| *Achyranthus aspera* | 1 | 69 | 1.00 | 0.03 | 0.007 | 0.30 | 0.32 |
| *Blepharis maderaspatensis* | 1 | 69 | 1.00 | 0.03 | 0.007 | 0.30 | 0.32 |
| *Boerhavia diffusa* | 1 | 69 | 1.00 | 0.03 | 0.007 | 0.30 | 0.32 |
| *Gomphostemma heyneanum* | 1 | 69 | 1.00 | 0.03 | 0.007 | 0.30 | 0.32 |
| *Herissantia crispa* | 1 | 69 | 1.00 | 0.03 | 0.007 | 0.30 | 0.32 |
| *Justicia japonica* | 1 | 69 | 1.00 | 0.03 | 0.007 | 0.30 | 0.32 |
| *Synedrella nudiflora* | 1 | 69 | 1.00 | 0.03 | 0.007 | 0.30 | 0.32 |

### C. Vegetation analysis of the Climbers in PKTR

| Species | N | D | A | R D | F | RF | IVI |
|---|---|---|---|---|---|---|---|
| *Smilax zeylanica* | 144 | 397 | 4.97 | 6.72 | 0.200 | 8.03 | 14.76 |
| *Cyclea peltata* | 135 | 372 | 5.63 | 6.30 | 0.166 | 6.65 | 12.95 |
| *Ziziphus oenoplia* | 112 | 309 | 5.60 | 5.23 | 0.138 | 5.54 | 10.77 |
| *Piper argyrophyllum* | 127 | 350 | 12.70 | 5.93 | 0.069 | 2.77 | 8.70 |
| *Mikania micrantha* | 122 | 337 | 12.20 | 5.70 | 0.069 | 2.77 | 8.47 |
| *Cryptolepis buchananii* | 91 | 251 | 6.07 | 4.25 | 0.103 | 4.16 | 8.40 |
| *Desmos lawii* | 95 | 262 | 6.79 | 4.44 | 0.097 | 3.88 | 8.31 |
| *Hemidesmus indicus var. indicus* | 76 | 210 | 5.43 | 3.55 | 0.097 | 3.88 | 7.43 |

| Species | N | D | A | R D | F | RF | IVI |
|---|---|---|---|---|---|---|---|
| *Strychnos colubrina* | 95 | 262 | 15.83 | 4.44 | 0.041 | 1.66 | 6.10 |
| *Diploclisia glaucescens* | 60 | 166 | 6.67 | 2.80 | 0.062 | 2.49 | 5.29 |
| *Connarus wighti* | 62 | 171 | 7.75 | 2.89 | 0.055 | 2.22 | 5.11 |
| *Ancistrocladus heyneanus* | 47 | 130 | 4.70 | 2.19 | 0.069 | 2.77 | 4.96 |
| *Coscinium fenestratum* | 60 | 166 | 8.57 | 2.80 | 0.048 | 1.94 | 4.74 |
| *Argyreia hirsuta* | 47 | 130 | 5.22 | 2.19 | 0.062 | 2.49 | 4.69 |
| *Toddalia asiatica* | 53 | 146 | 6.63 | 2.47 | 0.055 | 2.22 | 4.69 |
| *Naravelia zeylanica* | 43 | 119 | 5.38 | 2.01 | 0.055 | 2.22 | 4.22 |
| *Anamirta cocculus* | 25 | 69 | 2.50 | 1.17 | 0.069 | 2.77 | 3.94 |
| *Adenia hondala* | 40 | 110 | 5.71 | 1.87 | 0.048 | 1.94 | 3.81 |
| *Cayratia pedata var. pedata* | 40 | 110 | 6.67 | 1.87 | 0.041 | 1.66 | 3.53 |
| *Acacia caesia* | 15 | 41 | 1.50 | 0.70 | 0.069 | 2.77 | 3.47 |
| *Pothos scandens* | 47 | 130 | 11.75 | 2.19 | 0.028 | 1.11 | 3.30 |
| *Gnetum edule* | 26 | 72 | 3.71 | 1.21 | 0.048 | 1.94 | 3.15 |
| *Jasminum multiflorum* | 26 | 72 | 4.33 | 1.21 | 0.041 | 1.66 | 2.88 |
| *Calycopteris floribunda* | 35 | 97 | 8.75 | 1.63 | 0.028 | 1.11 | 2.74 |
| *Jasminum flexile var. flexile* | 45 | 124 | 22.50 | 2.10 | 0.014 | 0.55 | 2.65 |
| *Calamus rotang* | 20 | 55 | 3.33 | 0.93 | 0.041 | 1.66 | 2.60 |
| *Calamus travancoricus* | 28 | 77 | 7.00 | 1.31 | 0.028 | 1.11 | 2.42 |
| *Piper sps.* | 9 | 25 | 1.29 | 0.42 | 0.048 | 1.94 | 2.36 |
| *Thunbergia fragrans* | 18 | 50 | 3.60 | 0.84 | 0.034 | 1.39 | 2.23 |
| *Argyreia elliptica* | 9 | 25 | 1.50 | 0.42 | 0.041 | 1.66 | 2.08 |
| *Dioscorea hispida* | 14 | 39 | 2.80 | 0.65 | 0.034 | 1.39 | 2.04 |
| *Piper nigrum var. nigrum* | 25 | 69 | 8.33 | 1.17 | 0.021 | 0.83 | 2.00 |
| *Cissus discolor* | 9 | 25 | 1.80 | 0.42 | 0.034 | 1.39 | 1.81 |
| *Caesalpinia cucullata* | 8 | 22 | 1.60 | 0.37 | 0.034 | 1.39 | 1.76 |
| *Jasminum coarctatum* | 13 | 36 | 3.25 | 0.61 | 0.028 | 1.11 | 1.71 |
| *croton caudatus* | 22 | 61 | 11.00 | 1.03 | 0.014 | 0.55 | 1.58 |
| *Ichnocarpus frutescens* | 9 | 25 | 2.25 | 0.42 | 0.028 | 1.11 | 1.53 |
| *Hiptage benghalensis* | 13 | 36 | 4.33 | 0.61 | 0.021 | 0.83 | 1.44 |
| *Pueraria tuberosa* | 6 | 17 | 1.50 | 0.28 | 0.028 | 1.11 | 1.39 |
| *Abrus pulchellus* | 20 | 55 | 20.00 | 0.93 | 0.007 | 0.28 | 1.21 |
| *Cissampelos pareira var.hirsuta* | 20 | 55 | 20.00 | 0.93 | 0.007 | 0.28 | 1.21 |
| *Piper barberi* | 14 | 39 | 7.00 | 0.65 | 0.014 | 0.55 | 1.21 |
| *Piper galeatum* | 20 | 55 | 20.00 | 0.93 | 0.007 | 0.28 | 1.21 |
| *Jasminum sps.* | 5 | 14 | 1.67 | 0.23 | 0.021 | 0.83 | 1.06 |
| *Hippocratea bourdilloni* | 10 | 28 | 5.00 | 0.47 | 0.014 | 0.55 | 1.02 |
| *Morinda reticulata* | 10 | 28 | 5.00 | 0.47 | 0.014 | 0.55 | 1.02 |
| *Diplocyclos palmatus* | 15 | 41 | 15.00 | 0.70 | 0.007 | 0.28 | 0.98 |

| Species | N | D | A | R D | F | RF | IVI |
|---|---|---|---|---|---|---|---|
| *Discoria bulbifera* | 15 | 41 | 15.00 | 0.70 | 0.007 | 0.28 | 0.98 |
| *Pothos armatus* | 8 | 22 | 4.00 | 0.37 | 0.014 | 0.55 | 0.93 |
| *Dioscorea bulbifera* | 12 | 33 | 12.00 | 0.56 | 0.007 | 0.28 | 0.84 |
| *Stephania japonica* | 12 | 33 | 12.00 | 0.56 | 0.007 | 0.28 | 0.84 |
| *Asparagus racemosus* | 6 | 17 | 3.00 | 0.28 | 0.014 | 0.55 | 0.83 |
| *Erycibe paniculata* | 6 | 17 | 3.00 | 0.28 | 0.014 | 0.55 | 0.83 |
| *Centrosema molle* | 10 | 28 | 10.00 | 0.47 | 0.007 | 0.28 | 0.74 |
| *Combretum albidum* | 10 | 28 | 10.00 | 0.47 | 0.007 | 0.28 | 0.74 |
| *Cyclea fissicalyx* | 10 | 28 | 10.00 | 0.47 | 0.007 | 0.28 | 0.74 |
| *Kuntsleria keralensis* | 10 | 28 | 10.00 | 0.47 | 0.007 | 0.28 | 0.74 |
| *Lepistemon verdcourtii* | 10 | 28 | 10.00 | 0.47 | 0.007 | 0.28 | 0.74 |
| *Cardiospermum canescens* | 2 | 6 | 1.00 | 0.09 | 0.014 | 0.55 | 0.65 |
| *Hippocratea obtusifolia* | 8 | 22 | 8.00 | 0.37 | 0.007 | 0.28 | 0.65 |
| *Ipomoea cairica* | 7 | 19 | 7.00 | 0.33 | 0.007 | 0.28 | 0.60 |
| *Connarus monocarpus* | 5 | 14 | 5.00 | 0.23 | 0.007 | 0.28 | 0.51 |
| *Hippocratea obtusitolia* | 5 | 14 | 5.00 | 0.23 | 0.007 | 0.28 | 0.51 |
| *Hoya pauciflora* | 5 | 14 | 5.00 | 0.23 | 0.007 | 0.28 | 0.51 |
| *Celastrus paniculatus* | 4 | 11 | 4.00 | 0.19 | 0.007 | 0.28 | 0.46 |
| *Dalbergia horrida* | 3 | 8 | 3.00 | 0.14 | 0.007 | 0.28 | 0.42 |
| *Elaeagnus indica* | 3 | 8 | 3.00 | 0.14 | 0.007 | 0.28 | 0.42 |
| *Entada rheedei* | 2 | 6 | 2.00 | 0.09 | 0.007 | 0.28 | 0.37 |
| *Wattakaka volubilis* | 2 | 6 | 2.00 | 0.09 | 0.007 | 0.28 | 0.37 |
| *Clitoria ternatea* | 1 | 3 | 1.00 | 0.05 | 0.007 | 0.28 | 0.32 |
| *Solanum seaforthianum* | 1 | 3 | 1.00 | 0.05 | 0.007 | 0.28 | 0.32 |

N - No. of individuals, D - Density (No./ha), A - Abundance, RD - Relative density, F - Frequency, RF - Rel.Frequency, RB - Rel. Basal Area, IVI - Importance value index.

# Appendix IV

**List of plant species recorded from the PKTR**

| Species | Family | Habit |
|---|---|---|
| Acronychia pedunculata (L.) Miq. | Rutaceae | Tree |
| Actinodaphne malabarica Balakr. | Lauraceae | Tree |
| Actinodaphne tadulingamii Gamble | Lauraceae | Tree |
| Aglaia barberi Gamble, | Meliaceae | Tree |
| Aglaia elaeagnoidea (A. Juss.) Benth. | Meliaceae | Tree |
| Aglaia lawii (Wight) Saldanha in Saldanha & Nicolson | Meliaceae | Tree |
| Aglaia perviridis Hiern in Hook. | Meliaceae | Tree |
| Aglaia tomentosa Teijsm. & Binn. | Meliaceae | Tree |
| Agrostistachys borneensis Becc. | Euphorbiaceae | Tree |
| Ailanthus triphysa (Dennst.) Alston in Trimen | Simaroubaceae | Tree |
| Alangium salvifolium (L. f.) Wang. in Engl. | Alangiaceae | Tree |
| Albizia odoratissima (L. f.) Benth. | Mimosaceae | Tree |
| Alseodaphne semecarpifolia Nees var. parvifolia Hook. f. | Lauraceae | Tree |
| Alstonia scholaris (L.) R. Br. | Apocynaceae | Tree |
| Anogeissus latifolia (Roxb. ex DC.) Wall. ex Guill. & Perr. | Combretaceae | Tree |
| Antiaris toxicaria Lesch. | Moraceae | Tree |
| Antidesma montanum Blume | Euphorbiaceae | Tree |
| Aphanamixis polystachya (Wall.) Parker | Meliaceae | Tree |
| Aporosa acuminata Thw. | Euphorbiaceae | Tree |
| Aporosa cardiosperma (Gaertn.) Merr. | Euphorbiaceae | Tree |
| Archidendron bigeminum (L.) Neilson | Mimosaceae | Tree |
| Artocarpus gomezianus Wall. ex Trecul ssp. zeylanicus Jarrett, | Moraceae | Tree |
| Artocarpus heterophyllus Lam. | Moraceae | Tree |
| Artocarpus hirsutus Lam. | Moraceae | Tree |
| Atuna travancorica (Bedd.) Kosterm | Chrysobalanaceae | Tree |
| Baccaurea courtallensis (Wight) Muell.-Arg. | Euphorbiaceae | Tree |
| Bauhinia malabarica Roxb., | Caesalpiniaceae | Tree |
| Beilschmiedia wightii (Nees) Benth. ex Hook. f. | Lauraceae | Tree |
| Bischofia javanica Blume | Euphorbiaceae | Tree |
| Bombax ceiba L. | Bombacaceae | Tree |
| Bombax insigne Wall. | Bombacaceae | Tree |
| Briedelia retusa (L.) A. Juss. | Euphorbiaceae | Tree |
| Callicarpa tomentosa (L.) L. | Verbenaceae | Tree |
| Calophyllum austroindicum Kosterm. ex Stevens | Clusiaceae | Tree |
| Calophyllum calaba L. | Clusiaceae | Tree |
| Calophyllum polyanthum Wall. ex Choisy, | Clusiaceae | Tree |
| Canarium strictum Roxb | Burseraceae | Tree |

| | | |
|---|---|---|
| Canthium travancoricum (Bedd.) Hook. f. | Rubiaceae | Tree |
| Carallia brachiata (Lour.) Merr. | Rhizophoraceae | Tree |
| Careya arborea Roxb. | Lecythidaceae | Tree |
| Caryota urens L. | Arecaceae | Tree |
| Casearia ovata (Lam.) Willd. | Flacourtiaceae | Tree |
| Casearia wynadensis Bedd. | Flacourtiaceae | Tree |
| Cassia fistula L. | Caesalpiniaceae | Tree |
| Catunaregam spinosa (Thunb.) Tirveng. | Rubiaceae | Tree |
| Celtis philippensis Blanco var. wightii (Planch.) Soep. | Ulmaceae | Tree |
| Chionanthus mala-elengi (Dennst.) P. S. Green ssp. mala-elengi | Oleaceae | Tree |
| Cinnamomum malabatrum (Burm. f.) Blume | Lauraceae | Tree |
| Cinnamomum wightii Meisner | Lauraceae | Tree |
| Cipadessa baccifera (Roth) Miq | Meliaceae | Tree |
| Clausena indica (Dalz.) Oliver | Rutaceae | Tree |
| Cleistanthus collinus (Roxb.) Benth. ex Hook.f. | Euphorbiaceae | Tree |
| Clerodendrum infortunatum L. | Verbenaceae | Tree |
| Cocculus laurifolius DC. | Menispermaceae | Tree |
| Cordia gharaf (Forssk.) Ehrenb. ex Asch. | Boraginaceae | Tree |
| Crataeva magna (Lour.) DC., Prodr. | Boraginaceae | Tree |
| Croton malabaricus Bedd. | Caparaceae | Tree |
| Cryptocarya beddomei Gamble | Euphorbiaceae | Tree |
| Cryptocarya wightiana Thw. | Lauraceae | Tree |
| Cullenia exarillata Robyns | Lauraceae | Tree |
| Dalbergia lanceolaria L. f. | Moraceae | Tree |
| Dalbergia latifolia Roxb. | Fabaceae | Tree |
| Dalbergia sissoides Graham ex Wight & Arn. | Fabaceae | Tree |
| Dillenia pentagyna Roxb. | Fabaceae | Tree |
| Dimocarpus longan Lour. | Dilleniaceae | Tree |
| Dimorphocalyx glabellus Thw. | Sapindaceae | Tree |
| Diospyros assimilis Bedd., | Euphorbiaceae | Tree |
| Diospyros bourdillonii Brandis | Ebenaceae | Tree |
| Diospyros buxifolia (Blume) Hiern | Ebenaceae | Tree |
| Diospyros candolleana Wight | Ebenaceae | Tree |
| Diospyros cordifolia Roxb. | Ebenaceae | Tree |
| Diospyros ebenum Koenig | Ebenaceae | Tree |
| Diospyros montana Roxb. | Ebenaceae | Tree |
| Diospyros paniculata Dalz. | Ebenaceae | Tree |
| Diospyros peregrina (Gaertn.) Gurke | Ebenaceae | Tree |
| Diospyros sylvatica Roxb. | Ebenaceae | Tree |
| Dipterocarpus indicus Bedd. | Dipterocarpaceae | Tree |
| Drypetes oblongifolia (Bedd.) Airy Shaw | Euphorbiaceae | Tree |
| Drypetes venusta (Wight) Pax & Hoffm. | Euphorbiaceae | Tree |

| | | |
|---|---|---|
| Dysoxylum beddomei Hiern in Hook. f. | Meliaceae | Tree |
| Dysoxylum malabaricum Bedd. ex Hiern | Meliaceae | Tree |
| Elaeocarpus serratus L. | Elaeocarpaceae | Tree |
| Elaeocarpus tuberculatus Roxb. | Elaeocarpaceae | Tree |
| Elaeocarpus variabilis Zmarzty | Elaeocarpaceae | Tree |
| Erythrina variegata L. | Fabaceae | Tree |
| Excoecaria oppositifolia Griff. var. crenulata (Wight) Chakrab. & Gangop. | Euphorbiaceae | Tree |
| Ficus beddomei King | Moraceae | Tree |
| Ficus drupacea Thunb. var. pubescens (Roth) Corner | Moraceae | Tree |
| Ficus nervosa Heyne ex Roth in Roem. & Schult. | Moraceae | Tree |
| Ficus rigida Jack var. bracteata (Corner) Bennet | Moraceae | Tree |
| Filicium decipiens (Wight & Arn.) Thw. | Sapindaceae | Tree |
| Firmiana colorata (Roxb.) R. Br. | Sterculiaceae | Tree |
| Flacourtia jangomas (Lour.) Raeusch. | Flacourtiaceae | Tree |
| Flacourtia montana Graham | Flacourtiaceae | Tree |
| Garcinia gummi-gutta (L.) Robs., | Clusiaceae | Tree |
| Garcinia morella (Gaertn.) Desv. | Clusiaceae | Tree |
| Garcinia spicata (Wight & Arn.) Hook. f. | Clusiaceae | Tree |
| Gardenia resinifera Roth | Rubiaceae | Tree |
| Givotia moluccana (L.) Sreem. | Euphorbiaceae | Tree |
| Glochidion ellipticum Wight | Euphorbiaceae | Tree |
| Glochidion zeylanicum (Gaertn.) A. Juss.var. zeylanicum; Hook. f. | Euphorbiaceae | Tree |
| Gmelina arborea Roxb. | Verbenaceae | Tree |
| Grewia tiliifolia Vahl | Tiliaceae | Tree |
| Haldina cordifolia (Roxb.) Ridsd. | Rubiaceae | Tree |
| Harpullia arborea (Blanco) Radlk. | Sapindaceae | Tree |
| Holarrhena pubescens (Buch.-Ham.) Wall. ex G. Don | Apocynaceae | Tree |
| Holigarna arnottiana Hook. f. | Anacardiaceae | Tree |
| Holigarna grahamii (Wight) Kurz | Anacardiaceae | Tree |
| Hopea parviflora Bedd. | Dipterocarpaceae | Tree |
| Hopea racophloea Dyer | Dipterocarpaceae | Tree |
| Humboldtia vahliana Wight | Caesalpiniaceae | Tree |
| Hydnocarpus pentandra (Buch.-Ham.) Oken | Flacourtiaceae | Tree |
| Ixora brachiata Roxb. ex DC. | Rubiaceae | Tree |
| Knema attenuata (Hook. f. & Thoms.) Warb. | Myristicaceae | Tree |
| Lagerstroemia microcarpa Wight | Lythraceae | Tree |
| Lagerstroemia speciosa (L.) Pers. | Lythraceae | Tree |
| Lannea coromandelica (Houtt.) Merr. | Anacardiaceae | Tree |
| Leea indica (Burm. f.) Merr. | Leeaceae | Tree |
| Lepisanthes tetraphylla (Vahl) Radlk | Sapindaceae | Tree |
| Litsea coriacea (Heyne ex Meisner) Hook. f. | Lauraceae | Tree |
| Litsea deccanensis Gamble | Lauraceae | Tree |

| | | |
|---|---|---|
| Litsea floribunda (Blume) Gamble | Lauraceae | Tree |
| Litsea glabrata (Wall. ex Nees) Hook. f. | Lauraceae | Tree |
| Litsea oleoides (Meisner) Hook. f. | Lauraceae | Tree |
| Litsea wightiana (Nees) Hook. f. | Lauraceae | Tree |
| Macaranga peltata (Roxb.) Muell.-Arg. | Euphorbiaceae | Tree |
| Magnolia nilagirica (Zenk.) Figlar | Magnoliaceae | Tree |
| Mallotus philippensis (Lam.) Muell.-Arg. | Euphorbiaceae | Tree |
| Mallotus tetracoccus (Roxb.) Kurz, | Euphorbiaceae | Tree |
| Mangifera indica L. | Anacardiaceae | Tree |
| Mastixia arborea (Wight) Bedd.ssp. arborea; Hook. f. | Cornaceae | Tree |
| Meiogyne ramarowii (Dunn) Gandhi | Annonaceae | Tree |
| Melia dubia Cav. | Meliaceae | Tree |
| Melicope lunu-ankenda (Gaertn.) Hartley | Rutaceae | Tree |
| Memecylon deccanense Clarke in Hook.f. | Melastomaceae | Tree |
| Memecylon umbellatum Burm.f. | Melastomaceae | Tree |
| Mesua ferrea L. | Clusiaceae | Tree |
| Microtropis wallichiana Wight ex Thw. | Celastraceae | Tree |
| Miliusa tomentosa (Roxb.) Finet & Gagnep. | Annonaceae | Tree |
| Mitragyna parvifolia (Roxb.) Korth. | Rubiaceae | Tree |
| Mitragyna tubulosa (Arn.) Hav. | Rubiaceae | Tree |
| Murraya paniculata (L.) Jack. | Rutaceae | Tree |
| Myristica beddomei King | Myristicaceae | Tree |
| Neolitsea scrobiculata (Meisner) Gamble | Lauraceae | Tree |
| Nothapodytes nimmoniana (Graham) Mabb. | Icacinaceae | Tree |
| Nothopegia colebrookeana (Wight) Blume | Anacardiaceae | Tree |
| Olea dioica Roxb. | Oleaceae | Tree |
| Orophea erythrocarpa Bedd. | Annonaceae | Tree |
| Orophea uniflora Hook. f. & Thoms. | Annonaceae | Tree |
| Oroxylum indicum (L.) Benth. | Bignoniaceae | Tree |
| Otonephelium stipulaceum (Bedd.) Radlk. | Sapindaceae | Tree |
| Pajanelia longifolia (Willd.) K. Schum. | Bignoniaceae | Tree |
| Palaquium ellipticum (Dalz.) Baill. | Sapotaceae | Tree |
| Paracroton integrifolius (Airy Shaw.) Balakr. & Chakrab. | Euphorbiaceae | Tree |
| Paracroton pendulus (Hassk.) Miq. ssp. zeylanicus (Thw.) Balakr. & Chakrab. | Euphorbiaceae | Tree |
| Persea macrantha (Nees) Kosterm. | Lauraceae | Tree |
| Phoebe lanceolata Nees | Lauraceae | Tree |
| Phoebe wightii Meisner in DC. | Lauraceae | Tree |
| Phyllanthus emblica L. | Euphorbiaceae | Tree |
| Polyalthia coffeoides (Thw. ex Hook. f. & Thoms.) Hook. f. & Thoms. | Annonaceae | Tree |
| Polyalthia fragrans (Dalz.) Bedd. | Annonaceae | Tree |
| Polyalthia longifolia (Sonner.) Thw. | Annonaceae | Tree |
| Premna tomentosa Willd. | Verbenaceae | Tree |

| | | |
|---|---|---|
| Prunus ceylanica (Wight) Miq. | Rosaceae | Tree |
| Pterocarpus marsupium Roxb. | Fabaceae | Tree |
| Pterospermum reticulatum Wight & Arn. | Sterculiaceae | Tree |
| Pterygota alata (Roxb.) R. Br. | Sterculiaceae | Tree |
| Radermachera xylocarpa (Roxb.) K. Schum. | Bignoniaceae | Tree |
| Reinwardtiodendron anamalaiense (Bedd.) Mabb. | Meliaceae | Tree |
| Sapindus trifoliatus L. | Sapindaceae | Tree |
| Schefflera wallichiana (Wight & Arn.) Harms | Araliaceae | Tree |
| Schleichera oleosa (Lour.) Oken, | Sapindaceae | Tree |
| Scolopia crenata (Wight & Arn.) Clos | Flacourtiaceae | Tree |
| Semecarpus travancorica Bedd. | Anacardiaceae | Tree |
| Spondias pinnata (L. f.) Kurz | Anacardiaceae | Tree |
| Sterculia guttata Roxb. ex DC., | Sterculiaceae | Tree |
| Sterculia urens Roxb. | Sterculiaceae | Tree |
| Stereospermum colais (Buch.-Ham. ex Dillw.) Mabb. | Bignoniaceae | Tree |
| Streblus asper Lour., | Moraceae | Tree |
| Strombosia ceylanica Gard. | Olacaceae | Tree |
| Strychnos nux-vomica L. | Loganiaceae | Tree |
| Symplocos macrophylla Wall. ex A. DC ssp. rosea (Bedd.) Nooteb. | Symplocaceae | Tree |
| Syzygium chavaran (Bourd.) Gamble | Myrtaceae | Tree |
| Syzygium chavaran (Bourd.) Gamble | Myrtaceae | Tree |
| Syzygium cumini (L.) Skeels var. cumini; | Myrtaceae | Tree |
| Syzygium gardneri Thw. | Myrtaceae | Tree |
| Syzygium laetum (Buch.-Ham.) Gandhi | Myrtaceae | Tree |
| Syzygium lanceolatum (Lam.) Wight & Arn. | Myrtaceae | Tree |
| Syzygium mundagam (Bourd.) Chithra | Myrtaceae | Tree |
| Syzygium palghatense Gamble, | Myrtaceae | Tree |
| Tabernaemontana alternifolia L. | Apocynaceae | Tree |
| Tamarindus indica L. | Caesalpiniaceae | Tree |
| Tectona grandis L. f. | Verbenaceae | Tree |
| Terminalia bellirica (Gaertn.) Roxb. | Combretaceae | Tree |
| Terminalia elliptica Willd. | Combretaceae | Tree |
| Terminalia paniculata Roth | Combretaceae | Tree |
| Terminalia travancorensis Wight & Arn. | Combretaceae | Tree |
| Tetrameles nudiflora R. Br. | Datiscaceae | Tree |
| Toona ciliata Roem., | Meliaceae | Tree |
| Trewia nudiflora L. | Euphorbiaceae | Tree |
| Trichilia connaroides (Wight & Arn.) Bentv. | Meliaceae | Tree |
| Vateria indica L. | Dipterocarpaceae | Tree |
| Vepris bilocularis (Wight & Arn.) Engl. | Rutaceae | Tree |
| Vernonia arborea Buch.-Ham. | Asteraceae | Tree |
| Vitex altissima L. f. | Verbenaceae | Tree |

| | | |
|---|---|---|
| Walsura trifolia (A. Juss.) Harms | Meliaceae | Tree |
| Wrightia tinctoria (Roxb.) R. Br. | Apocynaceae | Tree |
| Xanthophyllum arnottianum Wight | Polygalaceae | Tree |
| Xylia xylocarpa (Roxb.) Taub. | Mimosaceae | Tree |
| Zanthoxylum rhetsa (Roxb.) DC. | Rutaceae | Tree |
| Ziziphus xylopyrus (Retz.) Willd. | Rhamnaceae | Tree |
| Abutilon persicum (Burm.f.) Merr. | Malvaceae | Tree |
| Allophylus cobbe (L.) Raeusch. | Sapindaceae | Shrub |
| Allophylus concanicus Radlk. | Sapindaceae | Shrub |
| Allophylus serrulatus Radlk. | Sapindaceae | Shrub |
| Asystasia gangetica (L.) Anders. | Acanthaceae | Shrub |
| Baliospermum montanum (Willd.) Muell.-Arg. | Euphorbiaceae | Shrub |
| Bambusa bambos (L.) Voss | Poaceae | Shrub |
| Barleria acuminata Nees | Acanthaceae | Shrub |
| Barleria involucrata Nees var. elata (Dalz.) Clarke | Acanthaceae | Shrub |
| Barleria mysorensis Heyne ex Roth | Acanthaceae | Shrub |
| Barleria prionitis L. | Acanthaceae | Shrub |
| Breynia disticha J.R.Forst. & G.Forst. | Euphorbiaceae | Shrub |
| Briedelia stipularis (L.) Blume | Euphorbiaceae | Shrub |
| Capparis rheedei DC. | Capparaceae | Shrub |
| Chassalia curviflora (Wall. ex Kurz) Thw. var. ophioxyloides (Wall.) Deb & Krishna | Rubiaceae | Shrub |
| Chromolaena odorata (L.) King & Robins. | Asteraceae | Shrub |
| Cipadessa baccifera (Roth) Miq. | Meliaceae | Shrub |
| Clausena indica (Dalz.) Oliver | Rutaceae | Shrub |
| Colebrookea oppositifolia Smith | Lamiaceae | Shrub |
| Crotalaria obtecta Graham ex Wight & Arn. | Fabaceae | Shrub |
| Cycas circinalis L. | Cycadaceae | Shrub |
| Dendrocalamus strictus (Roxb.) Nees | Poaceae | Shrub |
| Dendrocnide sinuata (Blume) Chew | Urticaceae | Shrub |
| Dimorphocalyx glabellus Thw. var. lawianus (Muell.-Arg.) Chakrab. & Balakr. | Euphorbiaceae | Shrub |
| Dracaena terniflora Roxb. | Dracaenaceae | Shrub |
| Ecbolium ligustrinum (Vahl) Vollesen var. Ligustrinum | Acanthaceae | Shrub |
| Flemingia macrophylla (Willd.) Prain ex Merr. | Fabaceae | Shrub |
| Glycosmis macrocarpa Wight | Rutaceae | Shrub |
| Glycosmis pentaphylla (Retz.) DC. | Rutaceae | Shrub |
| Grewia hirsuta Vahl | Tiliaceae | Shrub |
| Grewia obtusa Wall. ex Dunn | Tiliaceae | Shrub |
| Grewia villosa Willd. | Tiliaceae | Shrub |
| Helicteres isora L. | Sterculiaceae | Shrub |
| Ixora elongata Heyne ex G. Don | Rubiaceae | Shrub |
| Justicia santapaui Bennet | Acanthaceae | Shrub |

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|---|---|---|
| Lantana camara L. | Verbenaceae | Shrub |
| Lepianthes umbellata (L.) Rafin. | Piperaceae | Shrub |
| Leptonychia caudata (Wall. ex G. Don) Burrett | Sterculiaceae | Shrub |
| Maesa indica (Roxb.) DC., | Myrsinaceae | Shrub |
| Ochlandra travancorica (Bedd.) Benth. ex Gamble | Poaceae | Shrub |
| Pandanus thwaitesii Mart. | Pandanaceae | Shrub |
| Pavonia odorata Willd. | Malvaceae | Shrub |
| Pellionia heyneana Wedd. | Urticaceae | Shrub |
| Peristrophe montana Nees | Polygonaceae | Shrub |
| Persicaria chinensis (L.) Gross. | Acanthaceae | Shrub |
| Phoenix loureiroi Kunth var. loureiroi; Vajr. | Arecaceae | Shrub |
| Pogostemon benghalensis (Burm. f.) O. Ktze. | Lamiaceae | Shrub |
| Pseudarthria viscida (L.) Wight & Arn. | Fabaceae | Shrub |
| Psychotria nilgiriensis Deb & Gangop. | Rubiaceae | Shrub |
| Rungia wightiana Nees | Acanthaceae | Shrub |
| Saprosma foetens (Wight) K. Schum. | Rubiaceae | Shrub |
| Saprosma glomeratum (Gard.) Bedd. | Rubiaceae | Shrub |
| Sarcandra chloranthoides Gard. | Chloranthaceae | Shrub |
| Schefflera wallichiana (Wight & Arn.) Harms | Araliaceae | Shrub |
| Senna hirsuta (L.) Irwin & Barneby | Caesalpiniaceae | Shrub |
| Senna tora (L.) Roxb. | Caesalpiniaceae | Shrub |
| Sida rhombifolia L. | Malvaceae | Shrub |
| Solanum torvum Sw. | Solanaceae | Shrub |
| Solanum virginianum L. | Solanaceae | Shrub |
| Stachytarpheta jamaicensis (L.) Vahl | Verbenaceae | Shrub |
| Strobilanthes anceps Nees | Acanthaceae | Shrub |
| Strobilanthes asperrimus Nees | Acanthaceae | Shrub |
| Strobilanthes asperrimus Nees | Acanthaceae | Shrub |
| Strobilanthes gamblei Carine | Acanthaceae | Shrub |
| Strobilanthes lupulinus Nees | Acanthaceae | Shrub |
| Strobilanthes neoasper Venu & Daniel | Acanthaceae | Shrub |
| Strobilanthes tristis (Wight) Anders. | Acanthaceae | Shrub |
| Tabernaemontana gamblei Subram. & Henry | Apocynaceae | Shrub |
| Tarenna asiatica (L.) O.Ktze. ex K. Schum. | Rubiaceae | Shrub |
| Tephrosia pulcherrima (Wight ex Baker) Gamble | Fabaceae | Shrub |
| Thottea siliquosa (Lam.) Ding Hou | Aristolochiaceae | Shrub |
| Thunbergia erecta (Benth.) Anders. | Acanthaceae | Shrub |
| Triumfetta rhomboidea Jacq. | Tiliaceae | Shrub |
| Turraea villosa Bennett | Meliaceae | Shrub |
| Urena lobata L.ssp. Lobata | Malvaceae | Shrub |
| Ziziphus rugosa Lam. | Rhamnaceae | Shrub |
| Acalypha ciliata Forssk. | Euphorbiaceae | Shrub |

| | | |
|---|---|---|
| Acalypha indica L. | Euphorbiaceae | Shrub |
| Achyranthes aspera L.var.aspera; Hook. f. | Amaranthaceae | Herb |
| Ageratum conyzoides L. | Asteraceae | Herb |
| Alloteropsis cimicina (L.) Stapf | Poaceae | Herb |
| Amaranthus spinosus L. | Amaranthaceae | Herb |
| Amomum cannicarpum (Wight) Benth. ex Baker | Zingiberaceae | Herb |
| Amomum muricatum Bedd. | Zingiberaceae | Herb |
| Amorphophallus paeoniifolius (Dennst.) Nicolson | Araceae | Herb |
| Amorphophallus bulbifer (Schott) Blume | Araceae | Herb |
| Apluda mutica L. | Poaceae | Herb |
| Arisaema barnesii C.E.C. Fisch. | Araceae | Herb |
| Asclepias curassavica L. | Asclepiadaceae | Herb |
| Begonia fallax A.DC. | Begoniaceae | Herb |
| Biophytum reinwardtii (Zucc.) Klotzsch. | Oxalidaceae | Herb |
| Biophytum sensitivum (L.) DC.var. sensitivum; Hook. f. | Oxalidaceae | Herb |
| Blepharis maderaspatensis (L.) Roth | Acanthaceae | Herb |
| Boerhavia diffusa L. | Nyctaginaceae | Herb |
| Bothriochloa pertusa (L.) A. Camus | Poaceae | Herb |
| Canscora pauciflora Dalz. | Gentianaceae | Herb |
| Capillipedium assimile (Steud.) A. | Poaceae | Herb |
| Centella asiatica (L.) Urban | Apiaceae | Herb |
| Chloris dolichostachya Lagasca | Poaceae | Herb |
| Chrysopogon nodulibarbis (Steud.) Henrard | Poaceae | Herb |
| Commelina benghalensis L. | Commelinaceae | Herb |
| Commelina diffusa Burm. f. | Commelinaceae | Herb |
| Commelina erecta L. | Commelinaceae | Herb |
| Costus speciosus (Koenig) J.E. Smith | Zingiberaceae | Herb |
| Croton bonplandianus Baill. | Euphorbiaceae | Herb |
| Curculigo orchioides Gaertn. | Hypoxidaceae | Herb |
| Curcuma aromatica Salisb. | Zingiberaceae | Herb |
| Curcuma neilgherrensis Wight | Zingiberaceae | Herb |
| Cyanotis axillaris (L.) D. Don | Commelinaceae | Herb |
| Cyanotis villosa (Spreng.) Schult. f. | Commelinaceae | Herb |
| Cyathula prostrata (L.) Blume, | Amaranthaceae | Herb |
| Cyperus sps. | Cyperaceae | Herb |
| Dicliptera foetida (Forssk.) Blatt. | Acanthaceae | Herb |
| Digitaria bicornis (Lam.) Roem. & Schult. ex Loud. | Poaceae | Herb |
| Dimeria ornithopoda Trin. | Poaceae | Herb |
| Dipteracanthus prostratus (Poir.) Nees in Wall. | Acanthaceae | Herb |
| Elephantopus scaber L. | Asteraceae | Herb |
| Emilia scabra DC. | Asteraceae | Herb |
| Eragrostis unioloides (Retz.) Nees ex Steud. | Poaceae | Herb |

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|---|---|---|
| Eranthemum capense L.var. capense; Hook. f. | Acanthaceae | Herb |
| Globba sessiliflora Sim. | Zingiberaceae | Herb |
| Gomphostemma heyneanum Benth. | Lamiaceae | Herb |
| Haplanthodes neilgherryensis (Wight) Majumdar | Acanthaceae | Herb |
| Herissantia crispa (L.) Briz. | Malvaceae | Herb |
| Hydrocotyle javanica Thunb. | Apiaceae | Herb |
| Hypericum japonicum Thunb. ex Murr. | Hypericaceae | Herb |
| Impatiens parasitica Bedd. | Balasminaceae | Herb |
| Isachne globosa (Thunb.) O. Ktze. | Poaceae | Herb |
| Isodon wightii (Benth.) Hara | Lamiaceae | Herb |
| Justicia diffusa Willd.var. diffusa; Hook. f. | Acanthaceae | Herb |
| Justicia japonica Thunb. | Acanthaceae | Herb |
| Kyllinga nemoralis (J. R & G. Forst.) Dandy ex Hutch. & Dalz. | Cyperaceae | Herb |
| Laportea interrupta (L.) Chew | Urticaceae | Herb |
| Lepidagathis incurva Buch.-Ham. ex D.Don | Acanthaceae | Herb |
| Leucas chinensis (Retz.) R. Br. | Lamiaceae | Herb |
| Micrococca beddomei (Hook.f.) Prain | Euphorbiaceae | Herb |
| Mimosa pudica L., | Mimosaceae | Herb |
| Naregamia alata Wight & Arn. | Meliaceae | Herb |
| Ocimum americanum L. | Lamiaceae | Herb |
| Ophiopogon intermedius D. Don | Haemodoraceae | Herb |
| Ophiorrhiza brunonis Wight & Arn. | Rubiaceae | Herb |
| Ophiorrhiza mungos L. | Rubiaceae | Herb |
| Ophiorrhiza rugosa Wall. var. prostrata (D. Don) Deb & Mondal | Rubiaceae | Herb |
| Oplismenus compositus (L.) P. Beauv. | Poaceae | Herb |
| Parthenium hysterophorus L. | Asteraceae | Herb |
| Peliosanthes teta Andr. ssp. humilis (Andr.) Jessop | Haemodoraceae | Herb |
| Pellionia heyneana Wedd. | Urticaceae | Herb |
| Peperomia pellucida (L.) Kunth | Piperaceae | Herb |
| Phyllanthus amarus Schum. & Thonn. | Euphorbiaceae | Herb |
| Phyllanthus urinaria L. | Euphorbiaceae | Herb |
| Polygala rosmarinifolia Wight & Arn. | Polygalaceae | Herb |
| Pouzolzia zeylanica (L.) Bennett | Urticaceae | Herb |
| Rauvolfia serpentina (L.) Benth. ex Kurz | Apocynaceae | Herb |
| Rungia pectinata (L.) Nees | Acanthaceae | Herb |
| Rungia repens (L.) Nees in Wall. | Acanthaceae | Herb |
| Senna tora (L.) Roxb. | Caesalpiniaceae | Herb |
| Setaria intermedia Roem. & Schult. | Poaceae | Herb |
| Setaria palmifolia (Koenig) Stapf | Poaceae | Herb |
| Sida acuta Burm. f. | Malvaceae | Herb |
| Sida cordata (Burm. f.) Borss. | Malvaceae | Herb |
| Sida cordifolia L. | Malvaceae | Herb |

| | | |
|---|---|---|
| Sida mysorensis Wight & Arn. | Malvaceae | Herb |
| Solanum americanum Mill. | Solanaceae | Herb |
| Stachyphrynium spicatum (Roxb.) Schum. | Marantaceae | Herb |
| Synedrella nodiflora (L.) Gaertn. | Asteraceae | Herb |
| Themeda triandra Forssk. | Poaceae | Herb |
| Vernonia cinerea (L.) Less. | Asteraceae | Herb |
| Zeuxine longilabris (Lindl.) Benth. ex Hook. f. | Orchidaceae | Herb |
| Zingiber neesanum (Graham) Ramam. | Zingiberaceae | Herb |
| Zingiber nimmonii Dalz. | Zingiberaceae | Herb |
| Zingiber officinale Rosc. | Zingiberaceae | Herb |
| Zingiber zerumbet (L.) J.E. Smith | Zingiberaceae | Herb |
| Abrus pulchellus Wall. ex Thw. | Fabaceae | Climber |
| Acacia caesia (L.) Willd. | Mimosaceae | Climber |
| Adenia hondala (Gaertn.) de Wilde | Passifloraceae | Climber |
| Anamirta cocculus (L.) Wight & Arn., | Menispermaceae | Climber |
| Ancistrocladus heyneanus Wall. ex Graham | Ancistrocladaceae | Climber |
| Argyreia elliptica (Roth) Choisy | Convolvulaceae | Climber |
| Argyreia hirsuta Wight & Arn. | Convolvulaceae | Climber |
| Asparagus racemosus Willd. | Liliaceae | Climber |
| Caesalpinia cucullata Roxb. | Caesalpiniaceae | Climber |
| Calamus rotang L. | Arecaceae | Climber |
| Calamus travancoricus Bedd. | Arecaceae | Climber |
| Calycopteris floribunda Lam. | Combretaceae | Climber |
| Cardiospermum canescens Wall. | Sapindaceae | Climber |
| Cayratia pedata (Lam.) A. Juss. ex Gagnep. | Vitaceae | Climber |
| Celastrus paniculatus Willd. | Celastraceae | Climber |
| Centrosema molle Benth. | Fabaceae | Climber |
| Cryptolepis buchananii Roem. & Schult., | Periplocaceae | Climber |
| Cissampelos pareira var.hirsuta | Menispermaceae | Climber |
| Cissus discolor Blume | Vitaceae | Climber |
| Clitoria ternatea L. | Fabaceae | Climber |
| Combretum albidum G. Don | Combretaceae | Climber |
| Connarus monocarpus L. | Connaraceae | Climber |
| Connarus wightii Hook. f. | Connaraceae | Climber |
| Coscinium fenestratum (Gaertn.) Colebr. | Menispermaceae | Climber |
| Croton caudatus Geisel. | Euphorbiacae | Climber |
| Cyclea peltata (Lam.) Hook. f. & Thoms. | Menispermaceae | Climber |
| Cyclea fissicalyx Dunn | Menispermaceae | Climber |
| Dalbergia horrida (Dennst.) Mabb. | Fabaceae | Climber |
| Desmos lawii (Hook. f. & Thoms.) Safford | Annonaceae | Climber |
| Dioscorea hispida Dennst. | Annonaceae | Climber |
| Dioscorea bulbifera L. | Dioscoreaceae | Climber |

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|---|---|---|
| Diploclisia glaucescens (Blume)Diels | Menispermaceae | Climber |
| Diplocyclos palmatus (L.) Jeffrey | Cucurbitaceae | Climber |
| Elaeagnus indica Serv. | Elaeagnaceae | Climber |
| Entada rheedei Spreng. | Mimosaceae | Climber |
| Erycibe paniculata Roxb. | Convolvulaceae | Climber |
| Gnetum edule (Willd.) Blume | Gnetaceae | Climber |
| Hemidesmus indicus (L.) R. Br.var. indicus Hook. f. | Periplocaceae | Climber |
| Hippocratea bourdillonii Gamble | Hippocrataceae | Climber |
| Hippocratea obtusifolia Roxb. | Hippocrataceae | Climber |
| Hiptage benghalensis (L.) Kurz | Malpighiaceae | Climber |
| Hoya pauciflora Wight | Asclepiadaceae | Climber |
| Ichnocarpus frutescens (L.) R. Br. | Apocynaceae | Climber |
| Ipomoea cairica (L.) Sweet | Convolvulaceae | Climber |
| Jasminum flexile Vahl | Oleaceae | Climber |
| Jasminum coarctatum Roxb. | Oleaceae | Climber |
| Jasminum multiflorum (Burm. f.) Andr. | Oleaceae | Climber |
| Jasminum sps. | Oleaceae | Climber |
| Kunstleria keralensis C.N. Mohanan & N.C. Nair | Fabaceae | Climber |
| Lepistemon verdcourtii Philip Mathew & Biju | Convolvulaceae | Climber |
| Hippocratea obtusifolia Roxb. | Hippocrateaceae | Climber |
| Mikania micrantha Kunth | Asteraceae | Climber |
| Morinda reticulata Gamble | Rubiaceae | Climber |
| Naravelia zeylanica (L.) DC. | Ranunculaceae | Climber |
| Piper argyrophyllum Miq. | Piperaceae | Climber |
| Piper barberi Gamble | Piperaceae | Climber |
| Piper galeatum Cas. in DC. | Piperaceae | Climber |
| Piper nigrum L.var. nigrum; Hook. f., | Piperaceae | Climber |
| Piper sps. | Piperaceae | Climber |
| *Pothos thomsonianus* Schott | Araceae | Climber |
| Pothos armatus C.E.C. Fisch. | Araceae | Climber |
| Pothos scandens L. | Araceae | Climber |
| Pueraria tuberosa (Roxb. ex Willd.) DC. | Fabaceae | Climber |
| Smilax zeylanica L., | Smilacaceae | Climber |
| Solanum seaforthianum Andr. | Solanaceae | Climber |
| Stephania japonica (Thunb.) Miers | Menispermaceae | Climber |
| Strychnos colubrina L. | Loganiaceae | Climber |
| Thunbergia fragrans Roxb. | Acanthaceae | Climber |
| Toddalia asiatica (L.) Lam. | Rutaceae | Climber |
| Wattakaka volubilis (L. f.) Stapf | Asclepiadaceae | Climber |
| Ziziphus oenoplia (L.) Mill. | Rhamnaceae | Climber |
| Aerides ringens (Lindl.) C.E.C. Fisch. | Orchidaceae | Herb |
| Oberonia sebastiana Shetty & Vivek. | Orchidaceae | Herb |

| | | |
|---|---|---|
| Eria pauciflora Wight | Orchidaceae | Herb |
| Oberonia santapaui Kapad. | Orchidaceae | Herb |
| Acampe praemorsa (Roxb.) Blatt. & Mc Cann | Orchidaceae | Herb |
| Bulbophyllum sterile (Lam.) Suresh | Orchidaceae | Herb |
| Dendrobium heterocarpum Lindl. | Orchidaceae | Herb |
| Conchidium braccatum (Lindl.) Brieger | Orchidaceae | Herb |
| Luisia evangelinae Blatt. & McCann | Orchidaceae | Herb |
| Oberonia mucronata (D. Don) Ormerod & Seidenf. | Orchidaceae | Herb |
| Oberonia brachyphylla Blatt. & McCann | Orchidaceae | Herb |
| Gastrochilus flabelliformis (Baltt. & McCann) Saldanha | Orchidaceae | Herb |
| Vanda tessellata (Roxb.) Hook. ex D. Don | Orchidaceae | Herb |
| Dendrobium heyneanum Lindl. | Orchidaceae | Herb |
| Pholidota imbricata Hook. | Orchidaceae | Herb |
| Rhynchostylis retusa (L.) Blume | Orchidaceae | Herb |
| Remusatia vivipara (Roxb.) Schott | Orchidaceae | Herb |
| Dendrobium ovatum (L.) Kranz. | Orchidaceae | Herb |
| Vanda testacea (Lindl.) Rchb.f. | Orchidaceae | Herb |
| Luisia tristis (G.Forst.) Hook.f. | Orchidaceae | Herb |
| Belosynapsis vivipara (Dalz.) C.E.C. Fisch. | Commelinaceae | Herb |
| Peperomia portulacoides (Lam.) Dietr. | Piperaceae | Herb |
| Procris crenata Robins. | Urticaceae | Herb |
| Cymbidium aloifolium (L.) Sw. | Orchidaceae | Herb |
| Oberonia verticillata Wight | Orchidaceae | Herb |

# APPENDIX V

## LIST OF PUBLICATIONS

1. **Magesh, G.** and A.R.R.Menon 2011. Vegetation Status, Species Diversity and Endemism of Sulimudi Forests in Southern Western Ghats of Kerala, India. *Indian Forester* Vol.137. No.3, 304-311.
2. Robi.A.J, **Magesh, G**. and A.R.R.Menon 2008. "Pothos thomsonianus Schott (Araceae): An addition to the Angiosperm Flora of Parambikulam Wildlife Sanctuary, Kerala, India". *Journal of Economic and Taxonomic Botany* Vol.32. No.3.
3. M.K. Renjith, S. Sreekumar, A.R.R.Menon and **G.Magesh** 2010. Vegetation pattern analysis of Karuvannur watershed, Kerala using remote sensing and GIS. *Indian Journal of Forestry*, Vol.33 (2): 143-148.
4. **Magesh, G.** and A. R. R.Menon 2010. Phytosociological Observations on Tree Diversity of Tropical Forest of Parambikulam Tiger Reserve, Kerala, India. In: proceedings of national seminar on 'Tropical Ecosystems: Structre, Function and Services' Organised by Indian Council of Forestry Research and Education at Institute of Forest Genetics and Tree Breeding, Coimbatore.
5. **Magesh, G.** and A. R. R.Menon 2009. Watershed management of Parambikulam wildlife Sanctury-A geospatial approach. In: proceedings of Kerala Environment Congress 2009. 265-271.
6. **Magesh, G.,** Roby.T.J and Menon.A.R.R. 2010. *Bio resource Quantification and Mapping of Western Ghats.* In: Proceedings of 22nd Kerla Science Congress (ed. EP. Yesodharan) 28-31 January 2010, Peechi, Thrisur Kerala.
7. **Magesh, G.**, and A. R. R.Menon 2010. *Geospatial Approach for Phytodiversity Assessment in Parambikulam Wildlife Sanctuary, Western Ghats, Kerala.* In: Proceedings of 22nd Kerla Science Congress (ed. EP. Yesodharan) 28-31 January 2010, Peechi, Thrisur Kerala.

# PLATES

Evergreen forest

Semi evergreen forest

Moist deciduous forest

Dry deciduous forest

Plate I. Vegetation types of PKTR

Valley view

Dam view

Marshy lands (*Vayals*)

Grasslands on the top of Karimala

Plate II. Different views from PKTR