Description and Analysis of Natural Vegetation in Rubber (*Hevea brasiliensis*) Farming Ecosystem

Thesis submitted to the Mahatma Gandhi University in

partial fulfillment of the requirement for the degree of

Doctor of Philosophy in Botany

C. A. Sabina

Rubber Research Institute of India

Kottayam-686 009, Kerala, India

December 2008

Dedicated to

my parents ***Abraham*** *and* ***Lalitha***

and children ***Sarah, Theresa*** *and* ***Joshua***

डॉ के. आर. विजयकुमार
Dr. K.R. VIJAYAKUMAR
निदेशक
DIRECTOR
Liaison Officer (Exploitation Technology)
International Rubber Research and
Development Board (IRRDB)
Kulalumpur, Malaysia

रबड़ बोर्ड
THE RUBBER BOARD
वाणिज्य एवं उद्योग मन्त्रालय, भारत सरकार
(Ministry of Commerce and Industry, Govt. of India)
प्रशिक्षण विभाग
Department of Training
कोट्टयम-686 009, केरल, भारत
Kottayam-686 009, Kerala, India

DR(Trg)/84/2008 10/12/2008

CERTIFICATE

This is to certify that the thesis entitled "**Description and Analysis of Natural Vegetation in Rubber (*Hevea brasiliensis*) Farming Ecosystem**" submitted by Smt. C.A. Sabina in fulfillment of the requirements for the award of **Degree of Doctor of Philosophy in Botany** of the **Mahatma Gandhi University, Kottayam** under the faculty of Science is a *bona fide* record of research work carried out by her under my scientific supervision and guidance at the Rubber Research Institute of India's division of Plant exploitation. No part of this thesis has been presented before for the award of any other degree or diploma of any other University or Institution. It is also certified that Smt. C.A. Sabina has fulfilled the course requirements and is exempted from appearing for the qualifying examination for the Ph.D. degree of the university.

Dr. K. R. Vijayakumar

Research Supervisor

दूरभाषा / Tel: 91-481-2353201(Direct), 91-481-2353127(Extn. 303)
टेलि फेक्स / Telefax 91-481-2353187 ई मेल / E-mail: vijayakumar@rubberboard.org.in वेबसाईट / Website: www.rubberboard.

DECLARATION

I hereby declare that the thesis entitled "**Description and Analysis of Natural Vegetation in Rubber (*Hevea brasiliensis*) Farming Ecosystem**" is a *bona fide* record of research work carried out by me and that this thesis or any part thereof has not previously formed the basis of any award, degree, diploma, associateship, fellowship or similar title or recognition of any other university or society.

Place: Kottayam **C. A. Sabina**

Date: 10.12.08

Acknowledgements

I express my sincere gratitude to Dr. K. R. Vijayakumar, Director, Rubber Training Centre, Rubber Board for the constant guidance and for the facilitations needed for this research and the completion of my thesis. His moral support and constant encouragement has helped me through a trying period of my life. I thank him for the freedom of thought and the space he has given me, which to me, is the essence of research.

I am indebted to Dr N. M. Mathew former Director of Research and Dr. Jacob James present Director of Research, Rubber Research Institute of India, for providing the facilities needed from the institute for the completion of this thesis.

I am extremely thankful to Shri. Jacob Pothen former Director of Central Experiment Station, Chethackal for the facilities provided and for the provision of the vast areas of Rubber plantations required for sampling in and around Ranni forest and Chethackal plantations in Pathanamthitta.

I express deep gratitude to the authorities of the Forest division of Kollam and Mundakayam for providing the required facilities to sample the forests .My heartfelt thanks to the managers and authorities of TRNT estate, Mundakayam for providing the facilities and work force need to sample the Rubber plantations in Mundakayam.

My deep gratitude to Dr. K. Karunaichamy, Dr.R. Rajagopal, Dr. K.U. Thomas, Dr. C. Kuruvilla Jacob, Dr. Alice John, Dr. L. Sankariammal and the staff of instrumentation section of RRII for the space and help provided in their office while carrying out the research work. I thank Shmt. Mercy Jose and Accamma C. Korah, for the help provided in the library, Shri B. Biju and Lisa Joseph of the computer section for the help provided during my work.

My sincere thanks to, Dr. Robin Somes and Dr.Seaby Henderson of Pisces Conservation ltd., Lymington, U.K., for their patience and help with the software and statistical interpretations. Thanks are also due to Shri. Ramesh B. Nair of Agricultural statistics, RRII, for the statistical assistance rendered.

I am immensely thankful to the management og B.C.M. college, former principals Mrs.Remani Tharayil, Rev. Sr. Libiya, the present head of the institute Dr (Sr.) Karuna and my colleagues in the botany department Dr. Jossy Abraham, Selinamma Joseph, C.T. Chandralekha and Dr. Peter K. Mani for all the help and encouragement rendered.

Last but not the least my deep gratitude to my Parents Air Marshal Abraham Mathew and Lalitha Abraham for the constant, moral and financial support they provided, without which, this thesis would not have been complete. Thanks are due to my beloved children Sarah, Theresa and Joshua who shared their computer with me and suffered long hours of my absence.

My special thanks to UGC and the authorities of Mahatma Gandhi University for provided the much required FIP leave and financial sanctions to complete this research.

Place: Kottayam **C. A. Sabina**

Date: 12 December 2008

Abstract and Keywords

Abstract: An attempt was made to study the existing plant diversity in the Rubber plantations of three rubber growing districts of Kerala viz. Kottayam, Kollam and Pathanamthitta districts. A comparison was made with the existing diversity in adjacent Tropical forest and Open areas. Both qualitative and quantitative assessments were made of the three types of ecosystems. The quantitave data assessment was made using abundance data of the existing flora using frame quadrats and, statistically analyzed using a plant diversity analysis protocol. Rank on Abundance, Species richness estimates, Species accumulation and Rarefaction curves were plotted. The adequacy of the sampling was established. The species richness estimate was made using both parametric and non parametric species richness estimators. Both alpha indexes and Evenness indexes of these areas were computed. The Right tailed sum diversity profile showed that the rubber plantations are lower in diversity than the Tropical Forests and the Open areas. The qualitative and quantitative assessments revealed a low abundance of several plant species in the Rubber plantations. Qualitative assessments have also shown that Rubber plantations also foster the growth of 160 medical plants and 48 endemic species. The Non metric multidimensional scaling and Principal component analysis of the abundance data reveals that the rubber plantations are undergoing a successional change towards a floristic composition that is similar to the Open areas. The main vectors that are responsible for this change are *Ishaemum indicum, Oplismenus compositus, Cyathula prostrata* and *Cyrtococcum patens.* Life form spectrum shows a change of the plant composition of the rubber plantations that is adapted to a drier habitat. The site of Thenmala rubber plantations which are found well within the matrix of a tropical forest in Thenmala does not show the establishment of deep forested species in the ground flora of these rubber plantations.

The study emphasizes the importance of measures of species diversity based on relative abundance as well as richness in order to capture the full complexity of diversity in conservation studies. It is suggested that Rubber plantations if managed properly can be used as foster ecosystems to foster the growth of several medicinal plants, endemic plants and deep forested plant species.

Key words: *Hevea* plantations- Tropical rain forests- Diversity assessment - Understory vegetation – species richness – species accumulation-Non-parametric richness estimators – vegetation analysis - Rarefaction – Rank on abundance– Diversity profiles - Fitting distribution- SHE analysis-PCA- NMDS- deep forested species.

PREFACE

Hevea brasiliensis (Wild.ex A. de Juss.) Muell commonly known as 'Rubber' is a forest species indigenous to the forests of Central and South America and is the major commercial source of rubber. It is also one of the most domesticated crop species of recent times. Growth of the Indian rubber plantation industry has been mainly through the expansion of rubber cultivation in Kerala. Today about 15% of arable land in Kerala is used for rubber cultivation. Expanding the cultivation further has to be seen from an ecological point of view.

The Southern Western Ghats is one of the major centers of endemism. The state of Kerala forms a major chunk of the Southern Western Ghats. Today ecosystems and biomes are getting destabilized as web-nuts and bolts are being dismantled by man. Due to man induced changes in the form of road building, forestry plantations, construction of large multipurpose dams in areas of high conservation value, centers of endemism and species diversity, the original habitat is fragmented into isolated patches leading to fragmentation of species populations. This leads to more rapid rates of extinction. Tropical rain forests sustain the greatest productivity, and most efficient soil and moisture conservation systems and maintain the greatest diversity. Over the last century much of this heritage has been destroyed. Half the geographical area of the state is under intense agriculture of forest or non-forest plantations.

With increasing transformation and anthropogenic pressures on tropical forest tracts creating fragmented landscapes it becomes important to understand their effects on patterns of biological diversity and assess conservation. The importance of biodiversity for maintaining life support systems of the biosphere is well recognized. Documentation of biodiversity and the evaluation of the impact of disturbance on species diversity patterns are fundamental to any conservation programme. The state of Kerala is a rich resource of biodiversity, especially for plants. Several of these plants are endemic to the Western Ghats. The loss and extinction of species is a severe threat to endemic plants. The area of land being converted to rubber cultivation is on a steady increase over the past 20 years. It has one of the highest growth rates compared to other crops. One of the reasons of support the biodiversity that exists in the Tropical Rain Forests and the likes. The need for more effective and efficient use of land resources was one of the points highlighted at the earth Summit in Rio de Janeiro, Brazil, in 1992. Land use systems that degrade the resource base must be replaced by sustainable systems. One of the major parameters of the sustainability of rubber is whether it supports the growth of other plant and animal species. An inventory of the existing plant species and measurement of its ecological parameters is required to indicate whether rubber plantations support the growth of diverse vegetation in the required numbers (abundance). If so methods need to be evolved to preserve our vast disappearing species diversity and endemic flora.

This study is made in the expectation that understanding the pattern of distribution of the plant diversity under rubber plantations will give necessary inputs to make rubber farming ecosystems more sustainable. The study can also give insights to using these vast plantations can be used as foster ecosystems in order to help us preserve and conserve our fast disappearing biodiversity along with the added advantage of being a cash crop.

Contents

Certificate........(i)
Declaration........(ii)
Acknowledgements........(iii)
Abstract and Key words........(v)
Preface........(vi)
List of Tables........(x)
List of Figures........(xii)
List of Plates........(xv)
List of glossary and symbols used........(xvi)

Chapter1: Introduction........1-18

1.1 Historical perspectives........1
1.2 Features of Rubber growing areas........3
1.3 Biodiversity........5
1.4 Forest fragmentation and its repercussion........10
1.5 Significance of the study........14
1.6 Area of study........17
1.7 Objectives of the study........18

Chapter 2: Review of literature........19-44

2.1 Vegetation analysis........21
2.2 Anthropogenic disturbance and biodiversity........22
2.3 Global impact of human activity........23
2.4 Fragmentation of tropical rainforest........25
2.5 Biodiversity inventories and conservation practices........25
2.6 Review of work done........26
2.7 Ecological studies on natural rubber cultivation........37
2.8 Measurement of Biological diversity........40

Chapter 3: Materials and methods........45-111

3.1 Study location and experimental layout........45
3.1.2 Establishment of sampling units........51
3.2 Ecological parameters........60
3.2.1 Qualitative assessments........60
3.2.2 Medicinal plants........63
3.2.3 Endemism........64
3.2.4 Vegetation succession........64
3.2.5 Phenology........64
3.2.6 Quantitative assessments........64
3.2.6.1 Sampling........64
3.2.6.6 Plant diversity analysis protocol........70
3.2.6.6.1 Rank on abundance plot........70

3.2.6.6.2 Species accumulation curve 71
3.2.6.6.3 Species richness estimations 73
3.2.6.6.4 Fitting distribution 85
3.2.6.6.5 Measurement of diversity 90
3.2.6.6.5.3 Diversity ordering methods 102
3.2.6.6.6 SHE analysis 104
3.2.7 Community analysis 106
3.2.8 Allelopathy 110

Chapter 4: Results 112-220

4.1 Sampled area 112
4.2 Qualitative assessment 114
4.2.1 Floristic survey 114
4.2.2 Relative diversity 116
4.2.3 Physiognomy 119
4.3 Medicinal plants 123
4.4 Endemism 126
4.5 Vegetation succession 137
4.6 Quantitative assessment 140
4.6.1 Dispersion 140
4.6.2 Relative abundance index 141
4.7 Plant diversity analysis protocol 144
4.7.1 Rank on abundance plot 144
4.7.2 Species accumulation as a measure of sampling effort 146
4.7.3 Species richness estimation 148
4.7.4 Fitting distribution 171
4.7.5 Measuring diversity 180
4.7.5.1 Diversity indices 180
4.7.5.2 Diversity ordering 189
4.7.6 SHE analysis 196
4.8 Similarity measures 200
4.9 Ordinations 204
4.9.1 Principal component analysis 204
4.9.2 Non-Metric multidimensional scaling 205
4.10 Allelopathic test 209
4.11 Phenology 211

Chapter 5: Discussion 221-286

Conclusion 287-292

Summary 293-298

References 299-356

Appendix 357-437

LIST OF TABLES

Table No.	Table title	Page No.
1.1	Area under cultivation of Hevea in India, Kerala State and in the districts of Kottayam, Pathanamthitta and Kollam	3
1.2	Extent of effective forest area in Kerala	6
3.1	Area under *Hevea* cultivation, and under forest in Kerala State	45
3.2	The agricultural history of the rubber plantation (RP areas)	53
3.3	The geographical and meteorological characteristics of the sampled sites	54
3.4	Experimental layout summarizing the sampling mode and frequency site location, area, type of the RP, OP and Forest areas and their subsamples in Kottayam, Kollam and Patanamthitta districts of Kerala	68
4.1	The area of the sampled sites and the number of sampling units	112
4.2	Disturbance scores of the sites sampled	113
4.3	Qualitative floristic survey of the RP, OP and forest area(detailed) **(Appendix)**	358
4.4	Qualitative floristic composition of the sampled sites of the RP, OP and Forest areas (summarized)	114
4.5	List and details of plant species found in the qualitative floristic survey Rubber plantation areas **(Appendix)**	372
4.6	List and details of plant species found in the qualitative floristic survey of Open areas **(Appendix)**	390
4.7	List and details of plant species found in the qualitative floristic survey of Forest areas **(Appendix)**	395
4.8	Qualitative floristic composition of the subsets of RP, OP and Forest	115
4.9	Habit forms (the number of herbs, shrubs, trees and climbers) found in the RP, OP and Forest areas	119
4.10	The vertical stratification of the RP, OP and the Forest areas	120
4.11	The growth forms and the number of species found in each vertical stratum found in the floristic survey of the RP, OP and Forest sites	121
4.12	Medicinal plants found in the qualitative floristic survey of the RP areas **(Appendix)**	403

4.13 Medicinal plants found in the qualitative floristic survey of the OP areas **(Appendix)** 410

4.14 Medicinal plants found in the qualitative floristic survey of the Forest areas **(Appendix)** 412

4.15 Summary of the endemic and medicinal plants found in the RP, OP and Forest areas in the qualitative floristic survey 125

4.16 The number of endemic plants, the degree of endemism and the conservation status of the plant species found in the RP,OP and the Forest areas 127

4.17 Endemic plants found in the qualitative floristic survey in the RP areas of Kottayam, Kollam and Patanamthitta districts (detailed list) 128

4.18 Endemic plants found in the qualitative floristic survey in the OP areas of Kottayam, Kollam and Patanamthitta districts (detailed list) 133

4.19 Endemic plants found in the qualitative floristic survey in the Forest areas of Kottayam, Kollam and Patanamthitta districts (detailed list) 134

4.20 Proportion of plants with specific habitat preferences in the RP, OP and Forest areas 137

4.21 The pattern of dispersion of each plant species sampled in the Rubber plantations, Open areas and the Forest area **(Appendix)** 417

4.22 Species richness estimates based on species accumulation curves for the Rubber plantation areas, Open areas and the Forest areas 150

4.23 Species richness estimates in the RP, OP and Forest areas using non-parametric species richness estimators and the sample coverage 152

4.24 The statistical goodness of fit to the SAD models of the RP, OP and Forest areas 172

4.25 The Alpha diversity indices and the Evenness indices of the Rubber plantation areas, Open areas and the Forest areas 181

4.26 Similarity test values of ANOSIM and SIMPER on the sampled sites of RP, OP and Forest areas 201

4.27 The phenological stages of selected plant species found commonly in the RP, OP and the Forest areas 212

4.28 Zoochorous the plant species found in the ground flora vegetation of rubber plantation areas 218

LIST OF FIGURES

Figure No.	Figure title	Page No.
3.1	Diagrammatic representation of the orientation of the three types of quadrates established in the forest site sampled	67
4.1	Qualitative floristic composition of RP, OP and Forest areas	115
4.2	Qualitative floristic compositions of the subsets of RP.OP and Forest Areas	116
4.3 - 4.5	Relative diversity indexes of the top ten families found in Rubber plantations Open areas and Forest areas	117
4.6	The proportion of families with a relative diversity >1 and < in the RP OP and Forest areas	118
4.7	Habit of plant species found in the RP, OP and Forest areas	119
4.8	Number of species within each of the growth forms in the Rubber plantations, open areas and the Forest areas	122
4.9 - 4.13	The life form spectrum of the RP, OP and Forest areas as compared to the NBS of Tropical forests and Deserts	123
4.14 - 4.16	The proportion of the medicinal plants, endemic medicinal plants and the endemic plants found in the RP, OP and Forest areas	125
4.17 - 4.19	Proportion of plants with specific habitat preferences in the RP, OP and Forest areas	138
4.20	Percentage of plant species with different types of habitat preference in each ecosystem	139
4.21	Dispersion pattern of the plant species found in the RP, OP and Forest areas	141
4.22	The all sample index showing the number of species found in the individual of the sampled sites (sub samples.)	141
4.23- 4.26	All sample species index of each sampling of the sampled areas in Rubber plantations, Open areas and the Forest areas	142
4.27-4.30	Rank on abundance plots of the sampled areas of sampled rubber plantation, Open areas and the Forest areas	145
4.31-4.34	Species accumulation curves of the pooled samples of Rubber plantations, Open areas and Forest areas	146
4.35- 4.39	Species richness estimation based on the species accumulation curve for the Rubber Plantation, Open areas and Forest areas	150
4.40 -4.45	Non- parametric species richness estimations of the rubber plantation areas of with 92 randomizations	153

4.46-4.52	Non- parametric species richness estimations of the Forest areas with 35 randomizations	157
4.53- 4.59	Non parametric species richness estimations of the Open areas with 27 Randomizations	160
4.60- 4.62	Sample interpolation of the sampled areas of Rubber plantations, Open areas and the Forest areas	164
4.63 – 4.68	Pooled rarefactions and single sample rarefactions of the Rubber plantations, Open areas and the Forest areas	166
4.69 -4.70	Pooled rarefaction of the weeded and unweeded sites of the RP areas	169
4.71 – 4.72	Single sample rarefaction of the weeded and unweeded sites of the RP areas	170
4.73 – 4.75	Fitted distribution curve (SAD) of the pooled data Rubber Plantations, Open areas and Forest areas	173
4.76 – 4.89	Fitted distribution curve (SAD) of the subsamples (Mundakayam, Chetheckal, Puthupally, Neezhoor, Pampadi and Thenmala) RP, OP and Forest areas	176
4.90 - 4.96	Alpha diversity indices and the Evenness index of each subset of the Rubber plantation areas, Open areas and the Forest areas	182
4.97- 4.100	Alpha diversity index and Evenness index of the individual sampled sites (subsets) of Rubber plantation areas in Kottayam, Kollam and Patanamthitta district.	186
4.101	Diversity ordering profiles of the pooled samples of Rubber plantations, Open areas and Forest areas, using the Rényi family diversity index	189
4.102	Diversity ordering profiles of the individual Rubber Plantations areas (sub samples) sampled, using the Rényi family diversity index	190
4.103	Diversity profiles of the Rubber plantation, Open areas and Forest areas, using Right Tailed Sum diversity ordering grouping	190
4.104	Diversity profiles of individual Rubber Plantations (subsamples), using Right Tailed Sum diversity ordering grouping	194
4.105	Diversity profiles of the family level presence in Rubber Plantations, Open areas and Forest areas using the Renyi diversity ordering index	192
4.106	Diversity profiles of the family level presence of Rubber Plantation, Open areas and Forest areas using Right Tailed Sum diversity ordering index	193

4.107–4.110 The Diversity profiles of individual rubber plantation sites (Mundakayam, Chethackal and Thenmala) as compared to the adjacent Open areas and the Tropical forest area using the Right Tailed sum diversity ordering family index............ 194

4.111–4.113 SHE analysis of the Rubber plantation areas, Open areas and the Forest areas............ 197

4.114–4.115 SHE analysis of the weeded and unweeded areas in the Rubber plantations............ 199

4.116 The observed similarity between samples of an area as a contribution of each species (variable)............ 204

4.117 PCA ordinations of the Rubber Plantation, Open areas and Forest areas............ 205

4.118 Vectors responsible for vegetation change in the RP, OP and Forest areas.. 205

4.119 The plot of non metric multi dimensional scaling using Jaccard's index of similarity for the Rubber Plantation, Open areas and Forest areas............ 206

4.120 The plot of the stress against iteration number for the two-dimensional non-metric multidimensional scaling............ 207

4.121 The final stress value plotted against the dimension of the NMDS model............ 207

4.122-4.123 PCA ordinations of the sub-samples of the Rubber plantations, Open areas and Forest areas............ 208

4.124 The non-metric multi dimensional scaling plot of the sub-samples of the RP, OP and Forest areas............ 209

4.125 Effect of different concentrations of leachate of the leaves of *Hevea brasiliensis* on germination percentage of seeds of rice............ 210

4.126 Effect of different concentrations of leachate of the leaves of *Hevea brasiliensis* on germination percentage of seeds of *Chromolena odorata*............ 210

4.127 The effect of the aqueous leachate of the leaves of *Hevea brasiliensis* on the root and shoot length of test plant *Oryza sativa*............ 211

4.128–4.129 Correlation of flowering and RP, OP and Forest areas and the monthly rainfall............ 215

4.130–4.131 Percent of germination of naturally growing plants found in the ground flora of Rubber plantations as compared to the germination of rice seeds............ 217

LIST OF PLATES

Plate No.	Description	Page No.
Plate1:	Map of Kerala	46
Plate 2:	Location of the sampled sites	47
Plate 3:	Rubber plantation	48
Plate 4:	Open area	48
Plate 5:	Forest area	49
Plate 6a, 6b	Herb quadrat in a rubber plantation area	49
Plate7a, 7b	Herb quadrat in an Open area and a Forest area	50
Plate 8:	Varying light intensity on ground flora of rubber plantations (**Appenidix**)	424
Plate9a and **9b**:	Some pioneer species (vectors) found in the ground flora of Rubber plantations (**Appendix**)	425
Plate 10a, 10b, 10c, 10d and **10e**:	Some medicinal plants found in the Rubber Plantations (**Appendix**)	427
Plate11a and **11b**:	Some Endemic plants found in the ground flora of Rubber (Appendix) Plantations (**Appendix**)	432
Plate 12:	Some zoochorous species (deep forested) found in the ground flora of rubber plantations(**Appendix**)	434
Plate 13a, 13b and **13c**:	Some plant species with low abundance value found in the regenerated ground flora of rubber plantation(**Appendix**)	435

List of Glossary and Symbols/ Notations used and their Description

Alpha diversity	:	A single within-habitat measure of species diversity regardless of internal pattern, generally over an area of 0.1 to 1,000 hectares (Whittaker 1960, 1977).
Assemblages	:	A group of ecologically interrelated plant and animal species.
Beta diversity	:	The change in species diversity among different natural communities of a landscape; an index of between-habitat diversity (Whittaker 1960, 1977).
Biodiversity	:	The variety of life and its interrelated processes same as biological diversity.
Community	:	A group of interacting plants and animals.
Ecosystem	:	A biological community (ranging in scale from a small area to millions of hectares), its physical environment, and the processes through which matter and energy are transferred among the components.
Floristic	:	The plant species that make up the vegetation of a given area.
Habitat	:	The physical structure, vegetation composition, and physiognomy of an area, the characteristics of which determine its suitability for particular animal or plant species.
Phenology	:	The study of periodic biological phenomena, such as flowering, breeding, and migration, especially as related to climate.
Physiognomy	:	Physical features of the plant community.
Species richness	:	The number of species of a particular interest group found in a given area
Ecological amplitude	:	The limits of environmental conditions within which an organism can live and function.
Habitat	:	Place where an organism or a biological population normally lives or occurs.
Patchiness	:	Distributional pattern of the plant organism where individuals/ populations are aggregated on some spatial scale.
Sample	:	A frame quadrat that is representative of the whole area.
Area	:	Represents an ecosystem. Three ecosystems chosen are RP, OP and Forest areas.

Open areas (OP area) : Areas found adjacent to rubber plantations on its outskirts where no farming is done. There is no human interference in these areas except for occasionally disturbance due to animal or human movement.

eas found adjace

Rubber Plantation (RP area): Areas within the plantation having a full canopy. The age of the plantations ranged from 7 to 20 years. It may be noted that two areas of rubber plantation chosen for our study viz. Puthupally and Neezhoor have not been weeded for seven years.

Forest areas : Areas within the Tropical evergreen forest adjacent to the rubber plantation. These forests are reserved forest with no disturbance by human habitation or animal grazing.

Sub samples/Subsets : Individual rubber plantations, Open areas and Forest areas sampled in the three districts of Kottayam, Pathanamthitta and Kollam viz. Neezhoor, Pampadi, Puthupally, Mundakaym, Chetheckal and Thenmala.

Deep Forested species : Species found well within the forest.

S- observed (S_{obs}) : The number of species estimated by the species accumulation curve.

S-maximum (S_{max}) : The number of species estimated by the parametric and non-parametric species richness estimator.

S-true (S_{true}) : The number of species actually observed in the qualitative floristic assessment of the area.

RP : Rubber plantation

OP : Open area

RDI : Relative diversity index

RA plot : Rank on abundance plot

DI : Diversity index

ADI : Alpha diversity index

EI : Evenss index

RTS diversity profile : Right tailed sum diversity profile

Chapter 1

Introduction

1.1 Historical perspectives

Hevea brasiliensis (Wild.ex A. de Juss.) Muell. commonly known as 'Rubber' is a forest species indigenous to the forests of Central and South America and is the major commercial source of rubber. It is also one of the most domesticated crop species of recent times. The British successfully transported *Hevea* seeds from Brazil for planting in the then British India (Markaham 1876, Petch 1914). The domestication history of *Hevea* has been chronicled, analyzed and reviewed by many (Wycherley 1968, Drabble 1973, Schultes 1977, Dean 1987, Baukwill 1989, Jones and Allen 1992) The British planters were responsible for initiating rubber cultivation on large scale plantation. The state administration also encouraged them by providing land, labor, capital and trade facilities (Anon 1871).

Growth of the Indian rubber plantation industry has been mainly through the expansion of rubber cultivation in Kerala. Plantation agriculture in general had its early beginnings in the 1820s in South India, 1840s in Assam and Bengal and 1830s in erstwhile Ceylon. It emerged in the states of Travancore and Cochin and Malabar area of Madras Presidency, which later constituted the state of Kerala. The plantation regions of these states started with coffee and cardamom and then moved to tea and finally rubber. The geographical and agro climatic suitability proved congenial for rubber cultivation in Kerala. With commercialization of agriculture, rubber became the choice crop in the 20th Century (Baak, 1997). In 1910, in Cochin, 2753 hectares of land and in South and Central Malabar 2429 hectares of land were under rubber cultivation. Rubber cultivation was mainly confined to estates in the early 1960s. One of the striking developments of rubber since independence was the preponderance of the small holding sector in the 1950s.The small holding sector which accounted for 33.2 percent of the rubber area in India, in 1947 grew to 89% in 2006 (Indian Rubber Statistics 2006). In India, *Hevea* has been traditionally grown mostly in the state of Kerala and to a small extent in the southern region of the state of Tamil Nadu for more than a century. This traditional rubber growing belt lies between 8^{0} and 12^{0} N latitudes, between the Arabian Sea Coast and the Western slopes of the Western Ghats. This stretch of land is characterized by fertile soils, rich in organic matter, and receives fairly high rainfall during two distinct monsoon seasons. India is the 4^{th} largest producer of natural rubber next to Thailand, Indonesia and Malaysia. It shares 9% of the world rubber production. Today about 15% of arable land in Kerala is used for rubber cultivation. Expanding the cultivation further has to be seen from an ecological point of view. The area under rubber increased from 584,090 hectares in 2004-2005 to 594,000 hectares in 2005-2006 with a growth rate of 1.7 %. The rate of increase in area has increased during 2005- 2006 compared to the previous years due to the attractive price of rubber that prevails in the market. Compared to other plantation crops in the country, rubber has recorded higher annual growth rates in area, production and productivity during the period 1971-72 to 2004-005, the rate of growth being 6.9, 22.2 and 6.4 percent respectively (Indian rubber statistics 2006). Kerala alone holds 83 % of the Rubber holdings and estates in India. In Kerala the area of land under rubber cultivation in 1970-1971 was 1, 98,424 hectares which grew steadily to 4, 85,660 hectares in 2004-2005. Of this, 4, 46,093 hectares of land forms small holdings and 39,567 hectares are estates (Indian Rubber statistics 2006). Kottayam district has 1, 12,151 hectares, which is the highest area of land under rubber cultivation. Of this, 1, 08,112 hectares forms small holdings and 4039 hectares are estates. Kottayam, Kollam and Pathanamthitta districts alone account for 33% of the total land area under cultivation of rubber in Kerala.

Table 1.1 Area under cultivation of Hevea in India, Kerala State and in the districts of Kottayam, Pathanamthitta and Kollam.

	Area under rubber cultivation	**Year**	**Area in hectares**
1.	India	2004-2005	584090
2.	Kerala	1970-1971 2004-2005	198424 485660
3.	Kottayam district Small holdings Estates	2004-2005 2004-2005 2004-2005	112151 108112 4039
4.	Pathanamthitta district Small holdings Estates	2004-2005 2004-2005 2004-2005	47998 41958 6040
5.	Kollam district Small holdings Estates	2004-2005 2004-2005 2004-2005	36947 27877 9097

1.2 Features of Rubber growing areas

Rubber plantations are located in the humid tropical regions of the world. These regions characteristically have an annual rainfall which exceeds the annual loss of water by evapotranspiration. Dry periods (months in which evaporation exceeds precipitation) are typically less than three months duration, and, in favorable locations, may not occur in any month. Rain typically falls in every month, but there are seasonal drier and wetter periods associated with annual shifts in wind patterns. Rainfall is sufficiently high and well distributed and the temperature sufficiently high and even, to permit the growth of plants throughout the year. In locations where these ecological conditions are met, the ecological climax vegetation is evergreen, lowland tropical rain forest (Duckham & Masefield 1970, Grigg 1970, 1974, Williams & Joseph 1973, Andreae 1981). The optimum climatic requirements of *Hevea* according to Vijayakumar and SanjeevaRao (1992) are:

1. Rainfall of 2000mm or more, evenly distributed without any marked dry season and with 125-250 rainy days per annum.
2. A maximum temperature of about 29-34^{o} C, minimum of about 20 ^{o}C or more with a monthly mean of 25-28 ^{o}C.
3. High atmospheric humidity of the order of 80, with moderate winds.
4. Bright sunshine amounting to about 2000 hrs, at the rate of 6 hrs per day in all the months.

Only a few rubber growing regions qualify to fall within such a climate profile (Yew 1982, Domroes 1984, Chan *et al.* 1984). Major portion of the rubber growing area in India is confined to the west coast of the country extending from Kanyakumari district of Tamil Nadu in the south to Coorg district of Karnataka in the north (8^{o} to 12^{o} N). In traditional zones the rubber plantations are confined to the narrow belt, approximately 700 km in length, on the western side of the Western Ghats which enjoys both the southwest and the north east monsoon (Vijayakumar *et al.* 2000). Kottayam district is a major rubber growing region in India. It is located 9 ^{6}32' N, 76 ^{6}36' E, 73 m. Its mean temperature ranges from 23 ^{o}C to 31.6^{o} C. It has a mean annual rainfall of 3500 mm. It has a relative humidity of 76% and a mean wind speed of 1.0 m per second. The sun shine duration is 2546 hrs per year or 6.5 hours per day (Vijayakumar et. al. 2000).

The State of Kerala lies along the South- West corner of Peninsular India, between 8 ^{6}18' and 12^{6}48' N latitude and 74^{6} 52' and 77 ^{6}22' E longitudes. The State is bordered by the Lakshadweep Sea in the West, Tamil Nadu in the South and Karnataka in the North. The state of Kerala has an area of 38,864 km^2, which is 1.18 % of the total area of India. The State is administratively divided in to 14 districts. Physiographically the terrain is highly diversified. The altitude varies from sea level to 2695 m (Anamudi Peak) above mean sea level. Based on altitude, the land is divided into

High ranges (750m asl)	-	Constitutes 15% of the land area.
High lands (between 75- 750 m asl)	-	Average height of 900m. Constitute 43% of the land area.
Midlands (between 7.5- 75m asl)	-	Constitutes 32% of the land area
Low lands (below 7.5m asl)	-	Constitutes 10% of the land area

(Kerala State Land Use Board, 1997)

The state of Kerala has a tropical climate. The varied topographical features, high rainfall and geological conditions of the state favored the formation of different ecosystems. The most outstanding feature of the state is the occurrence of tropical rain forests along the windward side of the Western Ghats. The Western Ghats is one of the mega diversity centers in India and is also a Biodiversity Hotspot. The forests of Kerala, found along the southern Western Ghats are considered as very rich in species diversity and endemism.

1.3 Biodiversity

The diversity of vegetation has manifested in different forest types in the highlands of the state. The extent of the vegetation type is shown in Table 1.2. Periodic surveys of the forest areas of Kerala are made by the Kerala forest department and other agencies like the Land sat imageries, Forest Survey of India etc. Table 1.2 gives the estimates extent of forest coverage and plantation coverage according to a recent report of the Kerala forest department in Forest Statistics (2003).

According to the Forest Statistics (2003), the State of Kerala has a total area of 38,864 km^2.The total forest area in the state in the year 2003 is 11264.5 km^2. This includes reserve and vested forest area. According to the classification of forest area under land utilization, out of a total of 9,400 km^2 of effective forest area, the dense forest areas constitute 7356.5 km^2 while plantations constitute 2009.3 km^2. Thus 27% of the natural vegetation represented as forests in Kerala is, in the form of Plantations, 35% constitute Tropical Wet evergreen and Semi Evergreen forest while 43% is of the Tropical Moist deciduous type.

Table 1.2 Extent of effective forest area in Kerala

S No.	Type of Forest	Sq. Km
1.	Tropical wet evergreen forests.& Semi evergreen forest	3299
2.	Tropical moist deciduous forests	4100
3.	Tropical dry deciduous forest	100
4.	Montane subtropical and temperate forest	40
5.	Grasslands	17
6.	Plantations	1814
	Total	9400

The High lands of Kerala which covers approximately 20,000 km^2 are a forested zone with occasional plantation and inhabited area. It has extensive water bodies created by hydroelectric projects. Here natural vegetation flourishes and forms a natural habitat of the endemics. Tropical forests have received much attention in recent years because of their species richness (Whitemore 1984), high standing biomass ((Brunig 1983) and greater productivity (Jordan 1983). These forests also act as the major carbon sink (Lugo and Brown 1992). However, the structure, composition and functioning of forests undergo changes as a natural process or on account of human intervention. As a result, there is a lot of spatial and temporal variation in the reported values of species richness, composition and productivity. Monitoring of the vegetation stands, is useful to document the vegetation dynamics.

The Western Ghats is one of the 18 mega diversity centers of the world. It is also a biodiversity hotspot. The forests of Kerala are along the Southern Western Ghats, which is considered as the most species rich region and area of endemism in the Western Ghats. The most outstanding feature of the Southern Western Ghats is the formation of tropical rain forests along the wind ward side, remarkable for the rich biodiversity. Western Ghats has also been identified as a' hot spot'- an area of high level of diversity also under considerable threat (Myers, 1990). Inventorying and monitoring of the biological diversity of the Western Ghats is therefore a challenge before the community of systematists, biogeographers and ecologists of India (Gadgil 1996).The Western Ghats alone harbor around 5500 species of flowering plants (Nair& Daniel 1986). More recent estimates by Nayar (1996) have shown the presence of 5725 species of flowering plants. Globally, flowering plants are estimated to constitute 2.5% of the total number of species of all groups (Heywood 1995).This leads to an estimate of 2, 20,000 species over the Western Ghats (Ghate *et. al.* 1998).

The complete flora of Kerala has not yet been published although floras of the most of the districts have been studied during the last three decades. The angiosperm flora compiled by Nair 1997 shows that, the flora of Kerala consists of 10,035 plant species and form 22 percent of the flora of India (SBSAP for Kerala, 2005). Kerala occupies less than 2 % of the total land area of the country. Among these plant species 3,800 are flowering plants. Fungi outnumber the flowering plants with about 4,800 species followed by Lichens, Bryophytes, Algae and Pteridophytes. The richness and diversity of the flora of the state is evident because of the high number of endemics found in this area. As many as 1637 plant species endemic to the Western Ghats are found in Kerala out of which 263 species are only found in Kerala (Sasidharan 2004).

Endemic plants are the taxa which enjoy very restricted distribution because of geographical and ecological barriers. The Peninsular regions are almost identical to islands in having conditions that favour endemism (Turil 1964, Blasco 1970) observed that the South Indian hill tops are rich in endemic species. According to Muthuramkumar *et al.* (2006), out of the 4780 flowering plants found in the Western Ghats 2180 species (48.6%) are endemic. Nayar (1980b) reported that 56 genera are endemic to the Western Ghats.

Gadgil & Meher- Homji (1990) on the basis of endemism and speciation divided India into 20 phytogeographical regions. The Southern Western Ghats is one of the major centers of endemism. The state of Kerala forms a major chunk of the Southern Western Ghats. The endemic species in the flora of a geographical region are very significant. They reveal the biogeography of the area, center of speciation and adaptive evolution.

One of the major tenets of ecology is that, all ecosystems tend to move towards stability. The more diverse and complex the ecosystems, the more stable it is. The more the species there are and the more they interrelate, the more stable is their environment (Goldsmith *et al.* 1972). Today ecosystems and biomes are getting destabilized as web-nuts and bolts are being dismantled by man. Due to man induced changes in the form of road building, forestry plantations, construction of large multipurpose dams in areas of high conservation value, centers of endemism and species diversity, the original habitat is fragmented into isolated patches leading to fragmentation of species populations. Each isolated fragment behaves like an island (Mac Arthur and Wilson 1967). Most of the areas of the Western Ghats come under this category. In such fragmented systems, smaller fragments will initially contain more species than they can hold at equilibrium. The rate of extinction is faster in such smaller group than in bigger habitat as ecological niches available for the survival will be proportionally reduced (Nayar 1996).

India has less than 2% of the total forest area of the world and it supports 15% of the world population. We are losing 47,500 hectares of forest cover every year (National Strategy for Conservation and Sustainable Development 1990). FAO (1981) has estimated the closed forest cover area of India as 51,841 hectares and its deforestation rate as 0.3 % per year.

The habitat for man has taken precedence over habitat for plants and animals. Myers (1988) stated that "the demise of tropical forests brings in mass extinction of species". Endemic plants of narrow distribution are already facing the threat of becoming extinct. Biotic interference and deforestation have made even many non- endemic plants extinct. Raven (1977) reported that 63.3 % of the tropical rain forests in India, Burma and Sri Lanka have been destroyed for human use up to the year 1975. The existing protected area which is 4.2% of India's land area is under pressure and some of them threatened. Mass extinction of the narrow Indian peninsular endemics is an imminent possibility. Out of the 5725 endemics found in

India, 2500 are rare species. Of these 2015 species are endemic to Peninsular India and out of these 1500 are endemic to the Western Ghats alone. Nayar (1996) reported 60 endemic genera in the Western Ghats. A total of 1381 endemic taxa are reported in Kerala (Sasidharan, 2002b). Of these, 496 are placed in threat categories. However, the latest compilation reveals the presence of 1637 species endemic to Southern Western Ghats out of which 263 occur only in Kerala (Sasidharan, 2004). Most of the endemic species with small geographic range end up as rare species and later threatened species unless their habitat is protected. It is important to understand the biology and autecology of endemic species in order to find out intrinsic causative factors leading to rarity.

1.4 Forest Fragmentation and its repercussion

Global biodiversity loss is closely related to the destruction and fragmentation of the Tropical rainforests (Benitez- Malvido and Mart'inez-Ramos 2003). While plant species diversity is rapidly lost in forest areas cleared for agriculture the rate at which plant species diversity changes in the remaining fragmented forest is poorly known. Forest fragmentation in tropics severely affects large trees (Laurance *et al.* 1977, 1998a, 1998b, 2000, Curran *et al.* 1999 and Gascon *et al.* 2000) but its effects on other life stages and plant life forms is poorly understood (Benitez- Malvido 1998, Scariot 1999).

Among terrestrial ecosystems, Tropical rain forests sustain the greatest productivity, and most efficient soil and moisture conservation systems and maintain the greatest diversity. Over the last century much of this heritage has been destroyed, along with many of its material benefits. Deforestation has now seriously made soils less productive, water supply more erratic, floods more frequent and severe and diminished timber supplies all on a serious scale. We have only recently come to realize and appreciate many of the values of areas which are natural or near natural. In recent times a paradigm change in the use and valuation of forests has taken place in developed countries. Forests are valued for water quality, recreation, climate in urban societies. They are also valued globally for their effect on the atmosphere and for their store of genetic information. Hence there is an urgent need for their conservation.

Kerala state being highly populated and agro- climatically suitable for many crops, the wild and the domesticated biodiversity are under severe threat (SBSAP 2005). Half the geographical area of the state is under intense agriculture of forest or non-forest plantations. Between 1950-1970 About 3,500 km^{-2} of forest lands were transformed into non- forestry purpose (Nair and Daniel 1986). This is apart from the destruction of natural forest for 'productive purposes like plantation of tea, coffee, rubber and the monoculturing of exotic trees like the *Eucalyptus.* Over exploitation of plants from the forest for use in the indigenous systems of medicine also accelerates the process of destruction of individual species. This has affected the once rich biodiversity of the State and has also paved the way for the introduction of several exotic crops. In the case of domesticated plant diversity, improved varieties of crop species have replaced the indigenous species and strains. Genetic erosion has taken place in both domesticated plant and animal diversity. Protected forests are areas where, rich plant and animal diversity still exists.

One of the causes for the loss of precious biodiversity is, because substantial forest areas have been diverted for non forestry purposes and unscientific large scale conversion of natural forests into monoculture plantations. In general a healthy forest does not promote the growth of weeds. Invasion of weeds occur as a result of degradation of forest. It also leads to further degradation of existing forests. These weeds suppress regeneration of different species and tree growth causing substantial degradation of forests. Currently large chunks of forests are found to be invaded by weeds like *Chromolena odorata, Lantana camara, Mikania scandens.* These also act as a fuel of forest fire. Invasion of weeds is however an effect of the degradation of forest rather than a cause (SBSAP 2005). Menon and Bawa (1997) estimated that between 1920 and 1990 forest cover in the Western Ghats declined by 40 % with a fourfold increase of fragments and an 83% decrease in the size of the remnants.

Tropical rain forests are highly diverse. The rate of loss and fragmentation of these forests pose a great threat to biological diversity (Whitmore and Sayer 1992, Pimm and Raven 2000). Studies have shown, tropical forest fragmentation to cause ecological changes to the plant community and composition, by increasing tree mortality, damage and loss of live biomass(Lovejoy *et al.* 1986, Ferrreira and Laurance 1997; Laurance *et al.* 1998a,b; Laurance *et al.* 2000), reduction in under storey plant diversity and recruitment (Ben`itez- Malvido and Mart`inez- Ramos 2003), increase in pioneer species and weeds near edges (Laurance 1998, Laurance *et al.* 1998a) and increase in liana abundance (Oliveira-Filho *et al.* 1997, Viana *et al.* 1997, Laurance *et al.* 2001). Increasing fragmentation will result in the loss of original habitat and an increasing fragmentation of remnant patches (Jacquemyn, *et. al.* 2003)

Increasing fragmentation will result in the loss of a valuable portion of the forest ecosystem: the rare and shade tolerant species (Hill and Curran 2001). Rapid fragmentation of formerly vast uninterrupted forests has resulted in the present- day species composition, which is not in full equilibrium (Dupre and Ehrlen 2002). Tree species with small populations will be the first to be lost in the process of forest fragmentation (Zhu *et al.* 2004). Small fragments are likely to differ markedly in composition from the original forest (Tabarelli *et al.* 1999). Species richness declines over time following fragmentation (Turner and Corlett 1996). Fragmentation changes physical conditions through edge effects (Williams-Linera 2002). Although fragments may contain fewer plant species and is an altered community, they play an important role in the maintenance of regional diversity by providing habitat for plants and animals and increasing landscape connectivity (Shafer 1995, Turner & Corlett 1996, Laurance & Bierregaard 1997, Pither & Kellman 2002). Empirical data from the tropics could help in better understanding of the conservation potential of small forest fragments (Pither and Kellman 2002), especially from less studied groups such as plants (Turner 1996). Studies in the Amazonian rain forests which have high plant diversity have shown that plant life-forms show concordant patterns of variation across sites (Toumisto and Ruokolainen 1994, Ruokolainen *et al.* 1997). They associated this change with indicator taxa. They also established through their studies in the Amazonian rain forests that the understory plants are easier to sample and can be used to predict the general floristic pattern at a local scale for rapid biodiversity assessment.

Forest fragments contribute substantially to the conservation of biodiversity by, providing habitat for plants and food for animals, seed source for the expansion of forests in the future (Schelhas and Greenberg 1996) and by maintaining regional biodiversity of the natural ecosystem. In Malaysia, Thomas (2004) has reported that a large proportion of the regional tree diversity was represented in a dozen small fragments of tropical forests. With increasing transformation and anthropogenic pressures on tropical forest tracts creating fragmented landscapes it becomes important to understand their effects on patterns of biological diversity and assess conservation values and the need of such sub- optimal areas (Muthuramkumar *et al.*2006). In the present day landscape of the Western Ghats, much of the remaining tropical wet evergreen forest, which supports a large proportion of plant diversity, survives as fragments in a human dominated matrix of plantations such as tea, coffee, rubber and eucalyptus and developed areas (Muthuramkumar *et al.*2006).

1.5 Significance of the study

The 1990s have witnessed an upsurge of interest in the patterns of distribution of biological diversity, as a result of technological developments, which have opened up many possibilities of utilization of such diversity, and new regimes of sovereign rights of countries of origin over biodiversity, ushered in by the convention on Biological diversity (Heywood 1995). The CBD convention on Biological diversity commits parties to the convention, amongst them India, to take an inventory of their biodiversity resources, and to organize programs for regular monitoring, especially to assess the efficacy of conservation measures (UNEP- CBD 1991). Wild relatives of cultivated plants are amongst the resources CBD mentioned as of particular interest. India is an important centre for these resources.

Human intervention is a disturbance to natural habitats, be it in the name of development, agriculture or monocultures such as plantations. As a result of this, a complex mosaic of habitat is created giving rise to a very intricate pattern of distribution of organisms (Pramod *et al.*1997). This study is an endeavour to explore and understand these patterns. In the present day landscape of the Western Ghats, much of the remaining Tropical Wet Evergreen Forest supports a large proportion of plant diversity. Human development and environmental degradation are more or less inversely related. For every developmental activity there is an environmental cost. With increasing transformation and anthropogenic pressures on tropical forest tracts creating fragmented landscapes it becomes important to understand their effects on patterns of biological diversity and assess conservation values. The state of

Kerala is a rich resource of biodiversity, especially for plants. Several of these plants are endemic to the Western Ghats. Denudation of forests and large scales of plantations also affect plant diversity. The loss and extinction of species is a severe threat to endemic plants.

Hevea brasiliensis is grown mainly on the west coast of the country on the western side of the Western Ghats. They grow in the humid tropical region of the world where the ecological climax is naturally, Tropical Wet Evergreen Forest. The Tropical Rain Forest is also one of the redeeming features of the Western Ghats, which is one of the mega diversity centers of the world. The forests of the Western Ghats are also considered as 'Hot spots'. A total of 204,091.1 ha of land in Kerala are covered by rubber plantations. 15 % of the arable land of Kerala is thus under rubber cultivation(Indian rubber statistics 2006). The area of land being converted to rubber cultivation is on a steady increase over the past 20 years. It has one of the highest growth rates, compared to other crops. Kottayam district is one of the major rubber growing areas of Kerala. This is in the midland region of Kerala. Cultivation of rubber is extended to nearly all the districts. This includes regions of the highlands and the midlands of the state. Since the first plantations were established in India many plantations have undergone three planting cycles of approximately 30 years each.

One of the important features of rubber cultivation is that it is being grown as a 1^{st} generation crop in some areas and has been extended to 2^{nd} and 3^{rd} generation crop in most of the areas. A history of these areas shows that in these traditionally farmed areas, other crops had been cultivated such as Coconut, Banana, Arecanut, Cassava, Tea etc. Conversions of forests into rubber plantations are only recently being propagated in areas like Punalur, Nilambur and Agasthyavanam. Here a total of 57.2 km^2 of forest has been converted into rubber plantations. According to the Kerala Forest Department Statistics (Forest statistics 2003) only a small area of the forest has been converted in to plantations of Rubber which is considered to be a soft wood. The areas which are converted into rubber plantations are 12 km^2 in Agsthyavanam, 1.2 km^2 in Nilambur and 44 km^2 in Thenmala.

Conversion of forests into Rubber plantations is thus relatively low. Expanding the areas of rubber plantations in the state however must also be viewed from the ecological point of view. Our Tropical Rain Forests which is just 35 % of the protected area are heavily fragmented. One of the reasons of converting forests into plantations is because they are natural and are expected to support the biodiversity that exists in the Tropical Rain Forests and the likes. Several studies have revealed negative results or inconclusive results. Hence converting forests into plantations need to be reviewed. To preserve a species, the complete ecosystem that supports it, needs to be preserved. Studies are being made on the extent and size of the forest fragment that needs to be preserved in order to avoid the mass extinction of species. The fast rate of expansion of our plantations especially rubber plantations brings such areas under threat. One of the unique features of India is the 'sacred grove' which culturally taught us how to preserve our flora and fauna amidst a matrix of human population.

The need for more effective and efficient use of land resources was one of the points highlighted at the earth Summit in Rio de Janeiro, Brazil, in 1992. Land use systems that degrade the resource base must be replaced by sustainable systems. There are several claims that rubber is ecologically sustainable. Various conservation approaches have been developed which are widely practiced over the years. Terracing (Moore 1938), silt pitting and bunding (Haines 1929) and establishment of ground cover of naturally regenerating vegetation (Watson 1963). One of the major parameters of the sustainability of rubber is whether it supports the growth of other plant and animal species. Keeping this in mind several weeding techniques have been tried, which included the growth of natural covers. These experiments have not led to any conclusive proof.

It has yet to be seen whether rubber promotes the growth of other plant species. An inventory of the existing plant species and measurement of its ecological parameters is required to indicate whether rubber plantations support the growth of diverse vegetation in the required numbers. If so, methods need to be evolved to preserve our vast disappearing species diversity and endemic flora. This study is an endeavor to understand the pattern of distribution of the plant diversity under rubber plantations.

1.6 Area of study

The forests of Kerala are divided into five areas for the purpose of care taking by the Kerala forest department (Forest statistics 2003). They are

Northern Circle

Olavakode Circle

Central circle

High Range Circle

Southern Circle

The High range division comprises 2818 km $^{-2}$ of forest. The district of Kottayam falls within this area. The Southern circle comprises 2826 km^{-2} of forest area. Chetheckal in Pathanamthitta District and Thenmala in Kollam district, falls within this area. This is approximately 50 % of the total forest area of Kerala. The areas of forest in the study are

Kottayam - 100.8 sq.km

Ranni- 1059.1 sq.km

Thenmala- 114.2 sq.km

1.7 Objectives of the study

The present study aims at studying whether and how large scale plantations of rubber have affected the natural vegetation of Kerala. The objectives laid out for this study are.

1. To study the floristic composition of plants under Rubber Plantations of Kottayam, Pathanamthitta and Kollam districts.
2. To explore the medicinal and endemic plants found in these areas.
3. Make a vegetation analysis of the vegetation flora growing along with rubber.
4. Comparing the flora below Rubber plantations rubber and in adjacent Forest a and Open areas.
5. Make phenological studies on selected plants growing under Rubber and compare their phenology with plants growing outside rubber plantations.
6. Making allelopathic studies on the effect of rubber on the surrounding vegetation.
7. Offering suggestions for the conservation of biodiversity as well as eco-restoration.

Chapter 2

Review of literature

The floristic diversity of Kerala, like that of the Western Ghats, is of an ancient lineage (Nayar 1994). Such an ancient flora is not just a reservoir of botanical antiques but is a dynamic biological source where speciation is taking place at an accelerated speed (Ashton 1977). Hooker in 1907 observed that, the most distinctive characteristics of the 'Malabar flora' primarily are, species that belong to the family Arecaceae, Bambusaceae, Clusiaceae, Dipterocarpaceae, Myristicaceae, Anacardiaceae, Araceae, Gesneriaceae, Melastomaceae, Meliaceae, Myrtaceae, Orchidaceae, Piperaceae, Tiliaceae and Zingiberaceae. Documentation of the biodiversity of Kerala shows that there are 4679 species of flowering plants (Sasidharan 2004). A compilation based on floristic studies was made by Sasidharan (2004) has shown that there are 4679 taxa of flowering plants in Kerala. They belong to 1360 genera in 212 families. Muthuramkumar *et al.* (2006) has shown that the Western Ghats are a reservoir of 4780 plant species of which 2180 species are endemic which is 45.6% of the Western Ghats and 0.7 % of the earth's endemic plants. Nayar in 1996 has identified three hotspots of endemics centers in Kerala, viz. Agasthyamala which has 189 endemics, Anamalai High ranges having 94 species and Silent Valley in Palakad district. Literature on the presence and the number of endemics in Kerala are many and often varied in figures. The exact number of endemics has yet to be ascertained and endorsed authentically. A review of literature on the various endemics of Kerala reveals varying facts and figures.

According to Nayar (1996) there are approximately 3800 species of flowering plants in Kerala, of which 1272 are Western Ghat endemics. According to Sasidharan (2004) there are 1381 endemic taxa in Kerala, of which 496 are placed under threat categories. These categories are

Possibly Extinct-35,

Critically Endangered-146

Vulnerable- 147

Low risk – 142

Data Deficient -31

Not Evaluated – 5

Several Endemics of Kerala have wide distribution in the Western Ghats. Rough estimates based on literature and herbarium scrutiny have revealed that about 6.5 % of the Western Ghat endemic angiosperms are strictly confined to Kerala in their distribution. Nair and Basha in 1995 noted that the endemic taxa of angiosperms in Kerala belong to 40 families. Gurudev and Subramanian in 1991 have analyzed the occurrence of endemics in the three zones of Kerala. Basha and Nair reported in 1991 that there are 115 taxa of endemic angiosperms in Kerala. They reported the distribution of endemics in the highlands of Kerala as below

Upper ghats - 25 taxa

Middle ghats - 53 taxa

Lower ghats - 37 taxa

They also elucidated it further by reporting the distribution of endemic plants in different parts of the highlands of Kerala as follows

North Kerala -25 taxa

Central Kerala -29 taxa

South Kerala - 61 taxa

More than 30 species of Kerala's endemic flowering plants are trees. Among the herbs 6 species of orchids, 14 species of balsams, 8 species of legumes and 5 species of grasses are known to be endemic (Nair and Basha 1995). Nair and Basha in 1995 analyzed the pattern of endemics in Kerala and showed that they are more concentrated in the Wynad belt in North Kerala, high range belt of Central Kerala and the Thenmala- Agasthyamala stretch of the Western region of Kerala.

2.1 Vegetation analysis

The great diversity of ecological conditions, mainly determined by topography, has created environments conducive for the development of a wide variety of flora and fauna (EPA and MEDAC 1997, Yirdaw 2001). Vegetation analysis based on the plot method serves to characterize the community, describe its floristic composition and identify economically useful species as well as, species of special conservation concern (Keel *et al.* 1993). Quantitative analysis of vegetation of an area is an important indicator and tool for an ecological study and can form the basis for a documentation study in the following aspects (Pineda *et al.* 1994)

1. The analysis of structure and function in ecosystems
2. Important landscape component
3. A natural resource
4. A basis for biogeography
5. The study of human influence
6. A basis for nature conservation

Vegetation analysis as a result lays the ground work for objective assessment of conservation worthiness (Gentry 1988, Keel *et al.* 1993). It attempts to synthesize the ecological structure and function of the community and landscape at different scales. To develop a basis for natural resource management in marginal areas such studies are being made on increasingly detailed scales of geographical variation (equipotentiality), local and territorial variation (vectoriality) and local discontinuities referred to as mosaicity (González-Bernáldez 1981). The spatial distribution of plant species shows the phenomenon of mosaicity (González-Bernáldez and Pineda 1980, Levassor *et al.*1981). Several studies on the fine scales of spatial organizations have been made (Galiano 1982, Castro *et al.* 1986, Pineda *et al.* 1991). Procedures to detect spatial aggregates (Galiano 1982), multi specific patterns (Sterling *et. al.* 1984, Castro *et al.* 1986), diversity spectra (Pineda *et al.* 1991) and covariance matrix have been developed.,

2.2 Anthropogenic disturbance and biodiversity

Globally various types of anthropogenic disturbance threaten the diversity of biological systems (Soulé 1991, Barbeir, Burgess & Folke 1994; Heywood 1995; Swanson 1995; Njis and Impens 2000). The question is whether it degrades the functioning of these systems and become acute (Naeem *et al.* 1994, 1996, Schulze and Mooney 1994, Bolker *et al.* 1995, Hooper and Vitousek 1997, Tilman 1997, Knops *et al.* 1997). New perturbations like climate change may aggravate current losses of diversity (Peters and Lovejoy 1992; Gates 1993; Kareiva, Kingslover & Huey 1993, Boyle and Boyle 1994). Agricultural practices, over and premature harvesting and recreation constitute 18% of the aggregate threat to the plant diversity (Freemark *et al.* 2001). High human and other biotic pressures are detrimental to the vegetation structure of forests. In vast areas of the tropics forest has been displaced by crops and commercial cattle grazing, leaving land devoid of natural vegetation and the soil seed banks, seedling cohorts and suppressed saplings of mature forest trees that might restore it (Quintana-Ascencio *et al.* 1996, Miller 1999). The forest nuclei remain, but as fragments of a few hectares that inexorably loose species to local extinction (Turner 1996). Increasing human populations and concomitant land use intensification have changed the amount, quality and distribution of habitats available to native biota. Consequently, conservationists, land managers and resource planners are concerned with anticipating how natural or human-induced disturbance to ecosystems affect the pattern of commonness and rarity of the inhabiting biota (Lubchenco *et al.* 1991, Solbrig 1991).

2.3 Global environmental impact of human activity

There is an increasing concern for the global extent of the environmental impact of human activity (Vitousek 1994). The loss of species diversity is unique because it is irreversible and the understanding of the loss of species is critical (Chapin *et al.* 1998). Current extinction rates are 100 to 1000 times higher than pre human levels and the expected extinction of the current threatened species could increase this rate by a factor of 10 (Pimm *et. al* 1995). Many of the species that have been driven extinct are rare species that are endemic to small habitats (Pimm *et al.* 1995). Polynesians across the pacific islands have lost 2000 bird species in the past 1000 to 4000 years (Pimm *et. al.* 1995, Steadman 1995) which is 15% of the worlds' avian diversity. European settlements in the Hawaiian Island have eliminated 84 plant species almost 10% of the native flora. Of the island and another 133 are threatened and at the verge of extinction (Sohmer 1994). The Fynbos vegetation of South Africa has lost 36 species and another 618 species are threatened with extinction (Pimm *et. al.* 1995). Biodiversity has decreased in

Australia due to vegetation clearing since European settlement (Adamson & Fox 1982, Bradstock *et al.* 1995). The need to restore forested ecosystems and their conservation values has never been more important (Wang et. al. 2004).

In countries like Scotland with modest human population there are no consistent ecological differences between plant species that have increased in abundance over the past 50 years and those that have decreased. In countries like England and Netherland which have high human population densities, there are more habitat alterations and eutrophications. This has resulted in the growth of nutrient demanding plant species (weedy species) that are growing in abundance. The slow growing plants which were found in these areas have decreased (Thompson 1994). In response to the documented changes in biotic diversity, there also has been an international effort to understand and predict the consequences of these changes (Schulze and Mooney 1993, Mooney *et al.* 1996). Ecosystems that cover a small area may have large impacts on regional properties e.g. beaver ponds are hotspots for methane production (Brigham *et. al.* 1995), and riparian areas and wetlands collect sediments and nutrients (Peter-john and Correll 1984). Land-use heterogeneity has significant influence on regional trace gas flux in northeastern Colarado (Alvin Mosier and Ingrid Burke unpublished data). Regional methane consumption is the greatest in the rangelands and least in the irrigated crop lands (Bronson & Mosier 1993). Irrigated croplands constitute the major regional source of nitrous oxide to the atmosphere despite their small extent. To understand the regional impacts of landscape units, it is important to know their properties and areal extent (Chapin *et al.* 1998). Both species and landscape diversity have important ecosystem consequences (Chapin *et al.* 1998). Using models Prentice et. al. (1992) predicted changes in the relative abundance of biomes with climatic changes such as tripling of carbon-dioxide and predicted that rare biomes like the broadleaved evergreen forest will decrease by 69% due to the present climatic changes.

2.4 Fragmentation of tropical rainforests

The loss and fragmentation of tropical rainforest which holds a major proportion of the world's biological diversity remains a crucial global conservation problem (Whitmore 1997). Tropical rain forests are facing alarming rates of habitat fragmentation, and some of them are already archipelagos of small fragments (Gascon *et al.* 2000). Even large and still inaccessible continuous tracts of tropical forests, such as those of Central Amazonia, will probably suffer fragmentation in the near future (Peres 2001). Forest fragmentation drives populations to subdivision and isolation, increases human pressure, causes microclimatic changes and enhances forest invasion by exotic species (Zuidema *et al.* 1996). As a result, several groups of organisms, notably mammals, birds, amphibians and trees, are suffering drastic changes in their local abundance and regional distribution in the fragmented portions of tropical forests (Turner 1996, Bierregaard *et al.* 2001).

2.5 Biodiversity inventories and conservation practices

It is important to make comparisons of biodiversity resources between regions, to be able to decide where biodiversity conservation should be concentrated (Rennolls and Laumonier 2000). Forest land management in the tropics, including forest exploitation, replanting of plantations and /or conversion of land-use, the information that is currently available usually includes course maps of geology, soil, and possibly topographic map (Nohr and Jorgensen 1997). An additional source that is widely available is remotely sensed information. The main objective of biodiversity inventory is to map a region under management so as to highlight the sub regions of high conservation value so that they may be included in a management plan which ensures biodiversity conservation (Rennolls and Laumonier 2000). Within regions species-diversity analysis on two or more separate regions would lead to a number of species-diversity structures. One conservation strategy that is considered in forest land management is to leave conservation areas untouched within the operational area. This approach can also replicate conservation areas of similar species diversity and might fail to conserve areas of unique species-diversity structure. If the separate regions turn out to have diversity structures which are similar, an alternative strategy will be to conserve only one area from all the regions with a particular diversity signature. Such an approach could fail to identify unique areas which need to be conserved. An analysis of diversity structure from the subplots from all of the regions would be necessary to identify the overall diversity structure, its dimensionality, and the number of distinct diverse groups in the set of regions (Rennolls and Laumonier 2000). The conservation implication of the discovery of a higher dimensionality of diversity on such a combined analysis would be that conservation areas would need to span the regions and would need to be chosen in order to maintain this higher dimensional diversity, by including as conservation areas representatives of any groupings that may be observed in diversity space (Rennolls and Laumonier 2000). Farm forestry using native tree species not only has great potential for the timber industry and carbon credits (Cohn 1995, Anderson and Halpin 1998), but also provides opportunities for restoration of biodiversity on deforested land (Lugo 1992, Parrotta 1992, 1993, Keenan *et al.* 1997, Lamb 1998).

2.6 Review of work done

In recent years several studies of tropical lowland rainforests have documented that the distribution patterns of many plant groups correlate with topographic position and the associated local changes in soil drainage (Lieberman *et* *al.*1985, Balslev *et al.*1987; ter Steege 1993; Ferreira 1997). These studies have made detailed analyses of the small-scale spatial variation in species composition or diversity. Woody species diversity and ground layer vegetation cover were studied in plantations of *Pinus patula, Cupressus lusitanica, Grevillea robusta,* and *Juniperus procera,* and in surrounding natural forests in Wondo Genet, Ethiopia. In the understory of the plantations, a total of 53 naturally regenerated tree and shrub species belonging to 31 families were recorded (Yirdaw 2001).The understorey herbs were assessed as cover percent. Plant species composition in plantation monoculture of the native Gympie Messmate (*Eucalyptus cloeziana* F. Muell.) was assessed and compared with native Eucalyptus forest and cleared grazing land in southeast Queensland, Australia (Wang *et al.* 2004). The site comparisons included a total of 18 sites (11 in the plantations, four in native eucalypt forests and three on cleared grazing land). Wang *et al.* 2004 examined whether plantations established on cleared grazing land could help to address plant biodiversity loss due to land clearing for grazing purposes. Species richness, abundance, proportion of open-land, endemic and threatened vascular plants were examined in four vegetation types representing seral stages of succession and two human-made grassland alterations, namely abandoned vineyards and *Pinus* plantations (Cremene *et al.* 2005). Several studies have been made on the effect of plantations on the enhancement and recruitment, establishment and succession of native woody species by functioning as foster ecosystems (Parrotta 1992, 1995, Lugo *et al.* 1993, Geldenhuys 1997, Otsamo 2000, Viisteensaari et al. 2000). Studies made on forest plantations established on degraded sites long devoid of a native tree cover and their effect in facilitating the recolonisation of native flora have also been made (Parrotta 1995). However, comparative studies between native and exotic tree plantations on the understory woody species diversity are rare (Yirdaw 2001). Comparisons of understory vegetation and soil fertility were made in the plantations and adjacent natural forests in the Ethiopian highlands (Michelsen *et al.* 1996) Effect of forest management on the diversity and habitat heterogeneity in the temperate hardwood forests have been made(Bobeic 1998). Quantitaive information on tropical rainforest is rather scarce in literature (Paijmans 1970). Tuomisto and Paulsen (2000) studied the local variation in the density, species composition, species richness and species diversity patterns of pteridophytes at four western Amazonian sites. These studies attempted to compare the detailed patterns among distant sites and suggested that such among-site comparisons are necessary to understand to what extent the observed patterns are repeatable and predictable. They also found that reliable estimate of the species richness, species diversity, species composition or density of individuals at a given site should require an inventory of a rather large number of sample units. Sonwa *et al.* 2007 made an analysis of the floristic composition of the agroforests in the humid forest zone of Southern Cameroon. The study illustrated the multiple uses of native biodiversity in the cocoa agroforests. The recovery of native understory plant communities after timber harvest has received a great amount of attention worldwide (Jules 1998, Donohue 2000, Verheyen *et al.* 2003, Dignan and Bren 2003, Moola and Vasseur 2004) The recovery of plant communities after timber harvest has been the subject of a large pool of literature (Harris *et al.*1982, Franklin 1982, Oliver and Larson 1996, and Franklin *et al.* 2002). However, the results of these studies differ markedly (Dyrness 1973, Peet and Christensen 1988, Frost 1992, Sullivan *et al.* 2001, Battles *et al.* 2001, Costa and Magnusson 2002). Greenberg *et al.* (1995) found an increase in species richness and diversity following post fire salvage logging in a fire-adapted sand pine scrub forest. In other cases, diversity initially decreased, especially among forest interior species (Meier *et al.*1995, Roberts and Zhu 2002), then quickly recovered within a few decades (Peet and Christensen 1988, Hannerz and Ha'nell 1997, Gilliam 2002, Gilliam *et al.* 1995, Roberts 2002). This later pattern of community development was also documented in fixed plots measured prior to logging and 28 year later in a mixed Douglas-fir forest in the Pacific Northwest (Halpern and Spies 1995). In contrast, richness and herbaceous cover in eastern deciduous forests was lower in secondary forests recovering from timber harvest than in primary forests, even when the secondary forests were as old as 87 years (Duffy and Meier 1992). Puyrvaud *et al.* (2003) documented succession from grassland thickets to rain forest, to provide evidence for their potential as restoration tools. Tuomisto and Paulsen (2000) studied the Pteridophyte diversity and species composition of the Amazonian forests. Local variation in individual density, species composition, species richness and species diversity of terrestrial pteridophytes were studied at four sites in the tropical lowland rain forest of western Amazonia. Bobeic (1998) determined the influences of forest management on the herb-layer mosaics and intra-site variability in the oak-limehornbeam forest *(Tilio-Carpinetum stachyetosum)*. Biodiversity studies examining species richness and abundance, proportion of open-land, endemic and threatened vascular plants, gastropods, and diurnal and nocturnal Lepidoptera in six different vegetation types all originating from steppe-like grasslands in Transylvania, Romania was carried out by Cremene *et al.* (2005).

Loya and Jules (2008) made comparisons between forest stages and suggested that these investigations should be grounded in a thorough accounting of the species present in each community coupled with tests of within-stage sampling efficacy. This has also been recognized much earlier (Sanders 1968, Bunge and Fitzpatrick 1993) and methods for interpolating and extrapolating estimates that account for the relationship between number of individuals and species richness have been introduced in the ecological literature (Heck *et al.* 1975, Colwell and Coddington 1994, Gotelli and Colwell 2001). Yet these methods have not achieved widespread use (Goldberg and Estabrook 1998, Longino *et al.* 2002).

2.61 Effects of Plantations

Some studies have been made on the plant species composition on plantations. Literature survey reveals that very few minor studies have been made on the plant diversity found in rubber plantations. Wang *et al.* (2004) made comparisons of monoculture of native *Eucalyptus cloeziana* F. Muell with native Eucalyptus forest and cleared grazing land. They conferred that even small scale plantation can increase landscape heterogeneity and help biodiversity. Michelsen *et al.* (1996) studied the effect of plantations on their under storey and compared it to adjacent natural forest. They found the richness and biomass of herbaceous plant species in the plantations as high as those of the natural forest. They also noted that most of the herbs were wide spread plant species invading from a montane or wooded grassland. Aweto (2001) evaluated the impact of plantation monoculture of fast growing exotic species *Tectona grandis, Gmelina arborea* and *Eucalyptus* sp., *Pinus caribaea, Terminalia invorensis* on nutrient cycling in West Africa. They found that in general single species tree plantations, immobilize soil nutrients faster, and return fewer nutrients to the soil than native forest and savanna vegetation. They concluded that plantation monocultures of fast growing tree species are not likely to be sustainable in the long term. In India, there are very few reports of such studies made on plantations. A comparative study of the ground flora was made in the plantations of *Acacia auriculformis, Casurina equisetifolia, Eucalyptus terecticormis* and *Tectona grandis.* A study by Wesenbeeck *et al.* (2003) on afforestation with *Pinus* *patula* resulted in strong negative effect on diversity and composition of the subpuramo vegetation of the study site. Alcantara *et al.* (2004) showed that conversions of grassy cerrado into riparian forest on soil organic matter dynamics and showed significant changes in the soil under tropical conditions in a short period of time. Yang *et al.* (2004) showed that conversions of native forest vegetation to cropland and plantations in tropical region can alter soil carbon and nitrogen pools and nitrogen availability for the plant uptake. Ecological data by Hendon and Charman (2004) also suggests that peat lands surrounded by plantation forestry have become drier over the last 40 years. Mathew *et al.* (2004) showed that Teak monocultures reduced the species diversity of flora and fauna.

The review of the literature of 40 years reveals that a few systematic studies of the plant diversity existing under rubber plantations were done on a large scale. Abraham and Abraham (2000) made a survey of the weed flora associated with rubber plantations in Kerala. 72 dicots, 16 monocots which included 12 grasses, 2 sedges and 2 ferns were recorded. 26 weeds were recorded in the survey under the rubber plantations that were in the pre tapping stage. All these plants were also found in the plantations in the tapping stage. However their order of importance was different based on their SDR (Summed dominance ratio) value. *Mikania* and *Cynodon dactylon* were dominant in young plantations while they were not dominant in the tapping stages. *Cyathula prostrate, Justicia simplex* and *Synedrella nodiflora* were common in the tapping stages of the plantation. The ten most dominant weed in both the stages of the rubber plantation *were Chromolena odorata, Axonopus compressus, Clerodendron infortunatum, Ischaemum indicum, Borreria hispida* and *Mimosa pudica.* The change in the dominance of species is due to difference in light availability they reported. *Chromolena odorata, Axonopus compressus, Clerodendron infortunatum,* *Ischaemum indicum, Borreria hispida and Mimosa pudica, Cyathula prostrate, Justicia simplex, Aegeratum conizoides* constituted more than 50 % of the weed flora in rubber plantations. *Cyathula prostrata* was the most widely spread weed with a high SDR value followed by *Chromolena odorata* (Abraham and Abraham 2000).

Chakraborty *et al.* in 2002 studied the flora of rubber and other plantations in Tripura. They reported total of 81 species under 75 genera belonging to 4 pteridophyte and 36 angiosperm families from different plantations. The number of species was found to be the highest in rubber plantations (43) followed by Sal (34), Cashew (33), *Acacia* (28) and Teak (17) plantations. 24 species were exclusively found in rubber plantations while the number of exclusive species in Sal, Acacia, Cashew and Teak plantations were 10, 5, 2 and 2 respectively. This shows that rubber is more hospitable to more species than other plantations. They concluded that the introduction of rubber has not adversely affected the natural vegetation and its distribution pattern in the state. Occurrences of more species in rubber plantations indicate that the soil and microclimate under rubber plantation are favorable for their growth. The higher number of plant species in the rubber plantations of Tripura due to availability of suitable bioclimatic substratum compared to other plantations under study indicates that rubber plantations are ecofriendly and have not changed the vegetation of the area (Chakraborty *et al.* 2002).

Rubber research Institute of India, Kottayam carried out experiments on intercropping of some medicinal herbs inside rubber plantations. These plants grew well inside the plantations leading to a good yield of medicinal plant parts. Moreover rubber yield data showed no adverse effect of inter cropping of medicinal herbs (Anonymous 1987-1995). There are reports of many shade loving medicinal herbs that grow well in Rubber plantations (Vijayakumar *et al.* 1989). *Strobilanthus* *haenianus, Adathoda bedomii, Rawolphia serpentine, Phaseolus indica, Plumbago rosea, Kemferria galangal, Alpinia rotunda* has been successfully intercropped with rubber (I′ma *et al.* 2005). Rubber can be compared to any fast growing tropical forest growing species. The biomass added to the soil every year by way of leaf litter is considerable (Vijayakumar *et al.* 1989, Kothandaraman *et al.*1989).

Ng *et al.* (1997) showed the presence of more than 40 species belonging to 30 different families in rubber plantations. Commercial cultivation of another crop in mature rubber plantation is limited due to low light availability inside the rubber plantation. Shade loving crops such as orchids and some medicinal plants can grow in mature rubber plantations. Medicinal plants like *Phyllanthus niruri, Sida rhombiflia, Hemidesmus indicus, Asparagus officinalis, Hydrocotyle asiatica* and *Glycosmis pentaphylla* are frequently present in rubber plantations. *Chromolena odorata, Mimosa pudica, Cleome viscosa, Cassia tora, Euphorbia hirta, Lantana camera, Borrereia latifolia, Dendrophthoe falcate* and *Vanda sp* coexist with rubber in plantations. Crops such as banana and pineapple are grown in immature plantations where the canopy is not closed and light intensity is not a limiting factor. Shade tolerant accessions of grasses, legumes and broad leaved angiosperms are grown in young rubber plantations in Malaysia as forage species

A survey of weeds and trees in rubber plantations made in Hainan in 1963 found 1034 species under 154 families which were grouped into 11 types of plant covers (Bian Hauxin 1981, Investigation group 1988). Investigation into weed types was also conducted in Guangdong and Yunnan in 1970s and 1980s. After 1984 and 1992 surveys were made in Hainan mainly into the parasitic plants and their damage to rubber plantations. Three genera of parasitic plants were found to be distributed in rubber trees i.e. *Taxillus chinensis, Elytranthe and Viscum articulatum*. However no assessment of biodiversity has been made in rubber plantations.

Plantations are considered to be replacements for forests and are expected to support plant diversity in their ground flora. Studies made on rubber plantations are few and inconclusive. There is a need for a large scale survey to explore the existing plant diversity found in rubber plantations and make appropriate assessments of the changes in the biodiversity. There is also a need to make systematic biodiversity assessments using the practical tools of species richness and evenness to determine whether these plantations support plant diversity.

2.62 The changing biodiversity and need for conservation

Changes in biodiversity can have significant impact on ecosystem and landscape processes, both on a day-today basis and during extreme events. Ecosystem processes in turn, determine services, such as clean water, and air that are required for mankind (Ehrlich and Mooney 1983). Given the current rapid rates of environmental change, it will be wise to conserve the present levels of diversity as insurance against an uncertain future. As our understanding of the functional consequences of biodiversity improves, it is possible to pin point situations in which conservation is particularly critical (Chapin *et al.* 1998). Plant species diversity may also influence the response of ecosystems to global environmental change (Bolker *et al.* 1995). Chapin *et al.* (1998) have shown that species diversity can affect ecosystem processes (photosynthetic, carbon gain, productivity and nutrient cycling). The magnitude of the effect could vary depending upon the type of ecosystem, function type measured and the experimental conditions (Johnson *et al.* 1996). Most studies have been made on relatively simple systems in which a gain or loss of a few species is likely to have a detectable effect unlike, in the complex systems where disruption of the complex web of biotic interactions can result in a cascading effect. This requires diversity effects in more complex systems. Information on tropical plant species in all growth forms (apart from trees) is needed because of its potential usefulness in understanding the relative extent of plant biodiversity across natural and human-disturbed habitats and its implication for conservation and management (Gentry and Dodson 1987, Gentry 1991, Annaselvan and Parthsarathy 2001, Van Andel 2001).

2.63 Reconnecting fragmented ecosystems

The rain forest of the Western Ghats of India is a major element of the Biodiversity Hotspot of Southern India and Sri Lanka. It contains 63% of endemic trees (Ramesh *et. al.* 1993), and endangered animal species including the tiger. Despite an extensive network of national parks and a positive annual rate of forest change (that includes tree plantations) of 0.06% an year, between 1990 and 2000 (FAO, 2001), the rain forest continues to be fragmented (Ramesh *et al.* 1997, Narendra Prasad 1998), because of the multiple services it renders to the local populations (Gadgil and Guha 1992, Puyravaud and Garrigues 2002). Forest restoration could be a valuable alternative that would conserve soils, water, and biodiversity, and reconnect fragmented ecosystems (Puyrvaud *et. al.* 2003).

The main immediate threat to the rain forest ecotone is the policy of the Forest Department to destroy thickets with the objective of restoring the degraded land. As a consequence, species-rich vegetation with an abundant soil fauna and fertile soil (Basu *et al.* 1996) is replaced by mono-cultural plantations that decrease soil fertility and stop rain forest expansion. Establishing exotic tree plantations for industrial purposes in a rain forest area is questionable for other reasons as well. Contrary to the village woodlots of the social forestry programs, industrial plantations generally do not benefit farmers (Gadgil 1992, Sharma 1993), nor do they provide NTFPs (Non timber forest products). When industrial plantations are installed at the expense of useful vegetation, the farmers shift to the rain forest to meet their needs. Policies based on such vague concepts as restoration of degraded land do not help to identify clear environmental objectives (Puyrvaud *et al.* 2003).

In the present-day landscape of the Western Ghats, much of the remaining tropical wet evergreen forest, which supports a large proportion of plant diversity, survives as such fragments in a human dominated matrix of plantations such as tea, coffee, rubber and eucalyptus and developed areas (Muthuramkumar *et. al.*2006). Human development and environmental degradation are more or less inversely related. For every developmental activity there is an environmental cost. With increasing transformation and anthropogenic pressures on tropical forest tracts, creating fragmented landscapes it becomes important to understand their effects on patterns of biological diversity and assess conservation values and the need of such sub- optimal areas (Muthramkumar *et al.* 2006). The state of Kerala is a rich resource of biodiversity especially for plants with several of these plants endemic to the Western Ghats. Denudation of forests and large scales of plantations also affect plant diversity. The loss and extinction of species is a severe threat to endemic plants. Kerala is a state whose economy chiefly survives on agriculture. Around 15 % of the cultivable land of the state is presently under rubber cultivation. The remaining is under various plantation and cash crops. Whether this has affected the natural vegetation of the state has to be seen. Ecological studies of rubber claim rubber to be an ecofriendly plantation crop. Expanding the cultivation further has to be seen from an ecological point of view.

2.7 Ecological studies on natural rubber cultivation

Recent studies in the ecological impact of rubber cultivation has been compared to two other popular afforestation species namely Teak and Jarul (Jacob *et al.* 2002) have proven that none of the indicators of ecological health were seriously affected by rubber cultivation. Rubber soils had comparable or better physical, chemical and biological properties and improved biodiversity than the other two species when they were naturally grown with no external interference. The number of soil microbes and macro fauna (invertebrates) harboring per unit area was more in the rubber soils than in the other two species. The property chiefly desirable in the falling debris is rapidity of decay and this depends upon moisture and the nitrogen content more than upon any other factors (Akhurst 1933). Mature rubber trees shed their leaves annually (wintering) during the dry months which also adds to nutrients in the soil. A mature rubber plantation is an excellent repository for mineral nutrients which is comparable to that of native forests (Shorrocks 1965, Samarapuli 1996). Annual litter addition in rubber plantation amounts to 7 t per ha and nutrient recycling through litter decomposition is very high (Joseph 1991). The rate of decomposition of the litter is very fast in rubber plantations. This results in efficient nutrient recycling (Krishnakumar *et al.* 1991). The rate of decomposition of litter often reaches the level of forest ecosystems in mature rubber plantations (Shorrocks 1965, Morris and Lau 1990). The property chiefly desirable in the falling debris is rapidity of decay and this depends upon moisture and the nitrogen content more than upon any other factors (Akhurst 1933).

The substantial addition of organic matter to the soil from rubber trees and cover crops improves the soil organic matter and water content. It also improves the soil physical (bulk density, porosity), chemical (nutrient availability) and biological (soil microbes) properties (Krishnakumar *et al.* 1991, Krishnakumar and Potty 1992). A mature rubber plantation is dynamic and self sustaining ecosystem and a renewable source of rubber with minimum external agronomic inputs (Goldthorpe and Tan, 1996). Mature rubber ecosystems are viewed as nutritionally self sustaining ecosystems (Sivanadyan *et al.* 1995). Ecological studies made in rubber have claimed that continuous growing of rubber in India for the past one century has not resulted in any reduction in the productivity of the soil unlike several other agricultural systems. Rubber cultivation has actually improved and sustained soil productivity. Rubber cultivation does not deteorate the environment but it reclaims improves and preserves ecosystems such as the severely draught prone dry jungles in North Lankan and the extremely eroded and degraded jhummed lands in the North East. Rubber plantations have a green image and are inherently environment -friendly (Jones 1994, Wan and Abu 2002, Jones 1994). The carbon dioxide scavenging and oxygen recharging effects of the plantations are well known (Sethuraj and Jacob 1997). The rubber plantations are capable of producing a fairly high volume of wood per unit land area in a comparatively short span (Sivanadyan and Moris 1992). These plantations aid soil and water conservation (Krishnakumar *et al.* 1991, Krishnakumar and Potty 1992) and indirectly help flood control (Sethuraj and Jacob 1997). Rubber plantations are a self sustainable ecosystem and could maintain a fair degree of biodiversity if properly managed (Sethuraj and Jacob 1997). The influence of rubber trees on atmospheric carbon balance is also indicated by the amounts stored in the biomass with values comparable to that of forest ecosystems, particularly beyond a certain age of growth. Monoculture of rubber is considered to be a relatively efficient converter of solar energy into dry matter production (Templeton 1968). Dry matter production and efficiency of utilization of solar radiation in a stand of *Hevea* trees with a closed canopy has been calculated to be about 2.8 % (Templeton 1968).

2.71 Weeding in rubber/Practices/burning practice during replanting

Treatment of the undergrowth must be designed to suit the conditions aimed at. Indiscriminate slashing for controlling grass may destroy the very plant whose shade is so desirable by injuring them in early seedling stages before they are noticed (Haines and Pillay 1933). Claims have been made that selective rather than clean weeding is generally practiced in rubber plantations both during mature stages and immature stages of rubber growth. Only noxious weeds are removed leaving the desirable plant species which ensures the retention of diverse flora composition and the maintenance of some form of ground cover against possible soil erosion. The practicability of this type of weeding is questionable. Various conservation approaches have been developed over the years which are widely practiced over the years. Terracing (Moore 1938), silt pitting and bunding (Haines 1929) and establishment of ground cover of naturally regenerating vegetation (Watson 1963). To maintain an ecological balance and to control weeds rubber plantations have since 1960s been intercropped and multi layered with grain, oil crops like rice peanut, sweet potato, creeping legumes, perennial cash crops such as tea, black pepper so that farming can be sustainable(Zhiwei and Yide 1999). Recommended cover plants in Malayan RP Border sp *Cassia sp, Desmodium gyroides, Phaseolus angularis, Desmodium ovalifolium.* Creepers *Pueraria phaseoloides, Centrosema pubescens, Calopogonium caeruleum, Psophocarpus palustris, Calopogonium mucunoides, Phaseolus calcaratus.* Shrubs *Flemingia congesta Tephrosia candida Crotolaria anagyroides.* Ferns *Gleichenia linearis.*

2.8 Measurement of Biological diversity

The World Conservation Strategy recognizes that the concept of biodiversity conservation is closely linked with sustainable development of both human and natural resources (Ramakrishna 1992). Biodiversity refers to the natural variety among living organisms, the ecological complexes in which they naturally occur, and the way s in which they interact with each other and with the physical environment (Putz *et al.* 2001). Biodiversity encompasses all species of organisms and the ecosystems and ecological processes of which they are part. Biodiversity reflects the degree of native variety and is essential for overall environmental quality, the intrinsic worth of all species on earth (Ehrlich and Wilson 1991, McNeely *et al.* 1990, Wilson 1988). This natural variety and variability is distinguished from biotic patterns or conditions formed under the influence of human-mediated species introductions and substantially human-altered environmental processes and selection regimes (Noss & Cooperrider 1994, Bailey 1996). Thus biodiversity represents the complexity of life on earth. It has phenotypic, genotypic, taxonomic, and ecological dimensions that can be measured within taxa (e.g. genetic diversity), across taxa (e.g. species diversity) or across ecosystems (Wilson and Peter 1988, Solbrig *et al.* 1994, Gaston and Spicer 1998).

Biodiversity can be measured in terms of different components viz. land scape, ecosystem, community, population or species and genetic, each of which have structural, compositional and functional attributes. Structural refers to the physical organization or pattern of the elements. Composition refers to the identity and variety of elements in each of the biodiversity components. Function refers to ecological and evolutionary processes (Putz et al. 2001).

The important conceptual components of diversity include richness, evenness, dominance and rarity of species (Wilsey *et al.* 2005). These components are characterized by the way in which the presence of each species is weighted by an aspect of importance such as abundance or biomass (Hill 1973, Magurran 1988). With species richness, each species contributes to diversity in the same manner regardless of its abundance or biomass. Measures like species evenness weight species by its relative abundance. Species diversity indices like Simpson's 1/D or Shannon's H′ represent composite measures and are designed such that richness and evenness are mathematically independent (Smith and Wilson 1996). Species dominance (Berger parker index) is the relative importance of the one species contributing the most to the total abundance. In contrast, species rarity is a measure of the proportion of species that meet the restriction that their relative abundance or biomass is below some threshold (average relative abundance or <1/S, Carmargo 1993). Species richness has been recently used as surrogate for diversity in general (Schluter and Ricklefs 1993, Rosenzweig 1995, Gaston 1998, Tilman and Lehman 2002) especially in biogeography and conservation (Brown 1995, Andelman and Willig 2003, Willig *et al.* 2003). A key reason for using species richness to characterize diversity is, its relative ease of measure compared to other indices (Rosenzweig 1995, Gaston 1998). Accurate measurement of relative abundance of all species is more difficult. This viewpoint holds on the grounds that diversity is essentially a one- dimensional concept that can be estimated with species richness alone because it implicitly assumes the following.

1. Richness and evenness are correlated positively and strongly.
2. Species richness accounts for a large proportion of variance in diversity.

New empirical studies by Buzas and Hayek (1996) have tested these assumptions and suggested that diversity components, specifically richness and evenness, may not be correlated positively. They decomposed Shannon's diversity index into richness and evenness components. Stirling and Wilsey in 2001 found that correlation between species richness and evenness (*J'*) were negatively correlated for plants. Stevens and Willig (2002) showed that spatial variation in richness was independent of variation in evenness.

Univariate and multivariate relationships among a variety of measures of plant species diversity have been studied in simulated data (Pielou 1966, Hulbert 1971, DeBenedictis 1973, Hill 1973, Peet 1974, Kempton 1979) and with empirical data (Stirling and Wilsey 2001, Stevens and Willig 2002). Wilsey *et al.* in 2005 quantified relationships among different components of diversity to determine if richness accounts for most of the variation in diversity within sites. These empirical studies suggest that to completely characterize variation within sites or to estimate diversity in a more comprehensive manner measurement based on relative abundance and species richness are much better than species richness alone (Collins 1990, Buzas and Hayek 1996, Chapin *et al.* 2000, Purvis and Hector 2000, Stirling anf Wilsey 2001). A strong and consistent negative correlation between rarity and evenness suggested that rarity strongly influences diversity more through evenness dimensions than richness dimension (Wilsey *et al.* 2005). Studying richness and evenness enhances understanding of the concept of biodiversity as a whole (Buzas and Hayek 1996, Stirling and Wilsey 2001, Stevens and Willig 2002, Willig *et al.* 2005). Numerous studies have found that evenness and richness respond differently to grazing (Mc Naughton 1977, King and Pimm 1983, Altesor *et al.* 1998, Alados *et al.* 2003, Wilsey and Polley 2003), fertility (Piper 1995), top-predator control (Chalcraft and Resetarits 2003, Schmitz 2003), and latitude (Stevens and Willig 2002). However from a conservation perspective, species richness, evenness, and diversity may not respond in the same manner to habitat fragmentation or loss, making impacts difficult to forecast without the consideration of all these elements (Gorresen and Willig 2004). Species evenness and dominance can have important effects on net primary productivity, invasion resistance and local extinction (Nijs and Roy 2000, Wilsey and Potvin 2000, Foster *et al.* 2002, Wilsey and Polley 2002, Smith and Knapp 2003, Smith *et al.* 2004, Wilsey and Polley 2004) that are independent of species richness. Thus much of the variation in diversity remains unaccounted for when only species richness is used. Conservation studies should go beyond using species richness as the sole index of diversity to attain a more complete understanding of diversity (Wilsey *et al.* 2005). Studies made by Puyrvaud *et al.* in 2004 have emphasized that although the red data book is widely used as an analytical tool for impact assessments on vegetation, status of threatened plant species should be examined using quantitative methodology.

The present study aims at assessing the impact of rubber plantations on the diversity of plants using quantitative data of abundance. Literature survey has shown that such biodiversity assessments have not been made using quantitative data in vast scale plantations of rubber in India and the world. It is evident that Kerala has a rich source of plant diversity, and is an abode of a major part of the natural and endemic flora of the Western Ghats. A holistic assessment as to whether the undergrowth of the rubber plantations must be promoted is a question which needs to be answered. The review of literature, indicates, scanty efforts on such understanding. An in depth study on the importance of promoting under growth and the types of plants that survive naturally can help us conserve our natural plant diversity. This is vital for existence of the plant species, and to prevent the loss of biodiversity. Rubber being a natural forest species should, in principal support the growth of other forest species. It is also important that we cultivate rubber in a manner that we use this inherent potential of the plant and conserve the plants that grow naturally with it. In India although several methods of weeding are being practiced. The effect of maintaining the ground flora without weeding and with minimum tilling on biodiversity and latex production has not been studied sufficiently.

Further fragmentation of the forest has resulted in loss of several species. Reduction and fragmentation of the forests area by man also posses to be a major threat to the existing species in the forest if, they are not preserved in their required numbers along with their supporting ecosystem. It will be of importance to see if rubber plantations can be used as foster ecosystem in order to conserve the existing fragile diversity of the forest fragments.

Chapter 3

Materials and methods

3.1 Study location and experimental layout

3.1.1 Choice of study location

Three major rubber-growing districts were chosen for this study viz. Kottayam, Pathanamthitta and Kollam. These areas were chosen because of their vast extent of rubber cultivation and their proximity to natural Tropical evergreen forests. The areas under rubber cultivation in each of the state show that Kottayam, Kollam and Pathanamthitta districts alone comprise 42.2 % of the total land under rubber cultivation in Kerala (Table 3.1). 50% of the land of Kottayam district is under rubber cultivation. The forests which come in the study area of this study are Tropical wet evergreen forest which in Kerala covers 3299 km^2 (Forest statistics 2003). This is 45% of the protected forest area (Table 1.2)

Table 3.1 Area under *Hevea* cultivation, and under forest in Kerala State and in the districts of Kottayam, Pathanmthitta and Kollam (Source Forest statistics 2003).

Region	Total area of the region (km^2)*	Area under rubber cultivation (km^2)*	Area as forests (km^2)	Area of the district/state under rubber cultivation	Percentage area of the state under rubber cultivation
Kerala State	38864	5027.4	7356.5	18.90%	-
Kottayam district	2208	1118.5	81.4**	50%	24.53 %
Pathanamthitta district	2642	495.5	1059.1	20%	10.74 %
Kollam district	2491	352.8	814.4	11%	7 %

* Source Indian rubber statistics 2006

** Source Agricultural statistics 2002

Plate 1

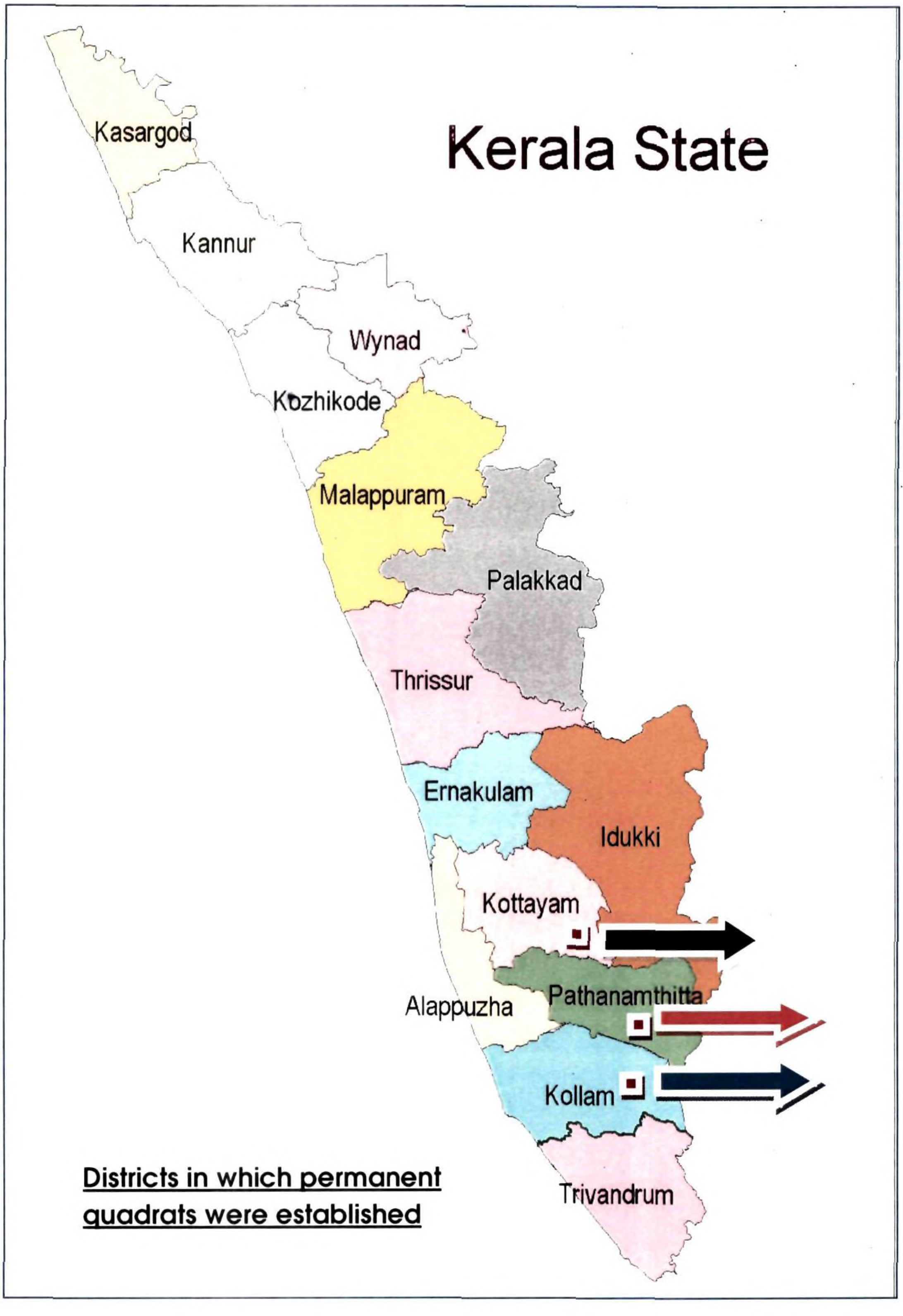

Kerala State
Kasargod
Kannur
Wynad
Kozhikode
Malappuram
Palakkad
Thrissur
Ernakulam
Idukki
Kottayam
Alappuzha
Pathanamthitta
Kollam
Trivandrum
Districts in which permanent quadrats were established

Plate 2: Location of the sampled sites of Rubber plantations, Open areas and the Forest areas

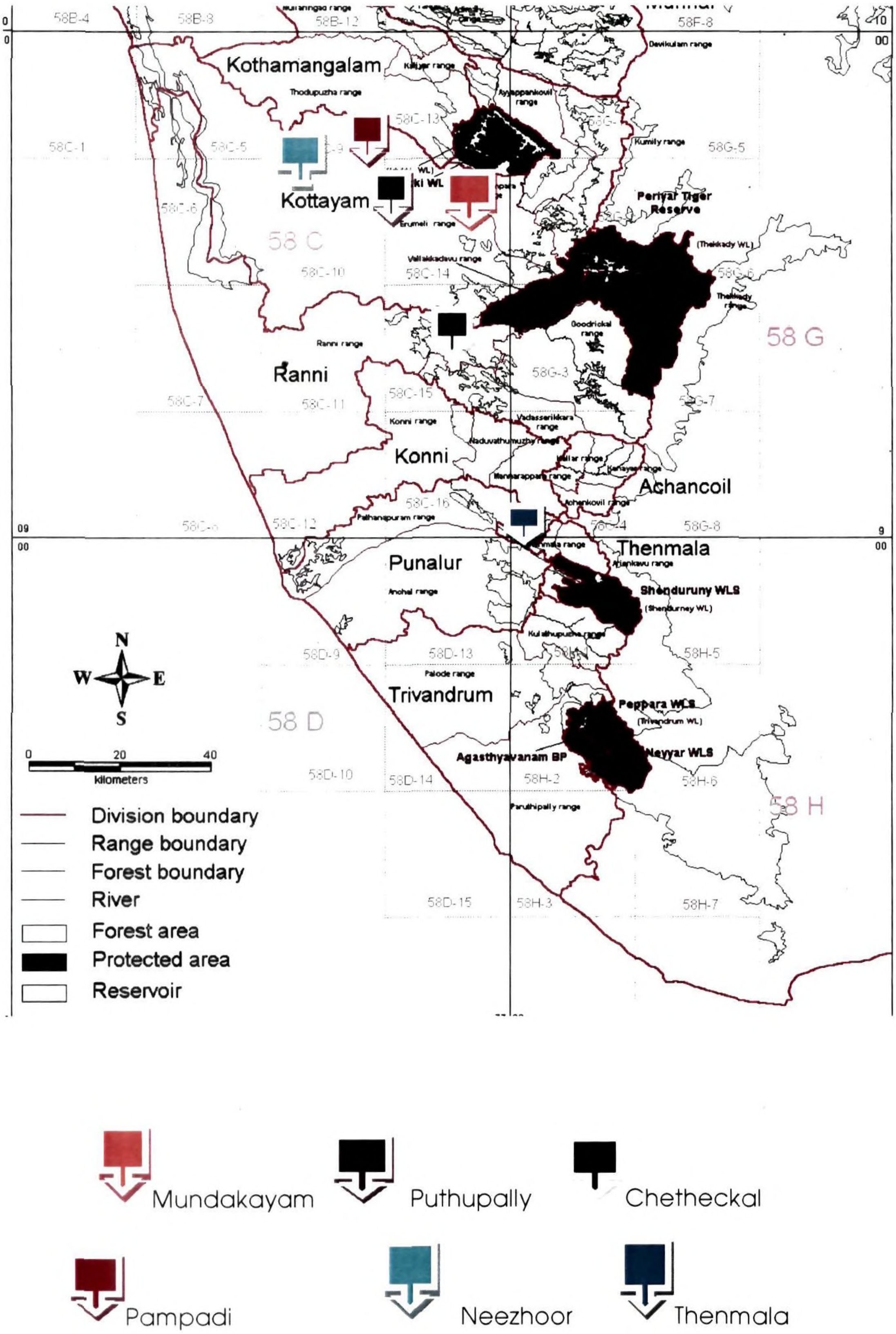


Plate 3 Rubber Plantation

Plate 4 Open area

Plate 5 Forest area

Plate 6 (a) Herb quadrat sample in Rubber plantation area

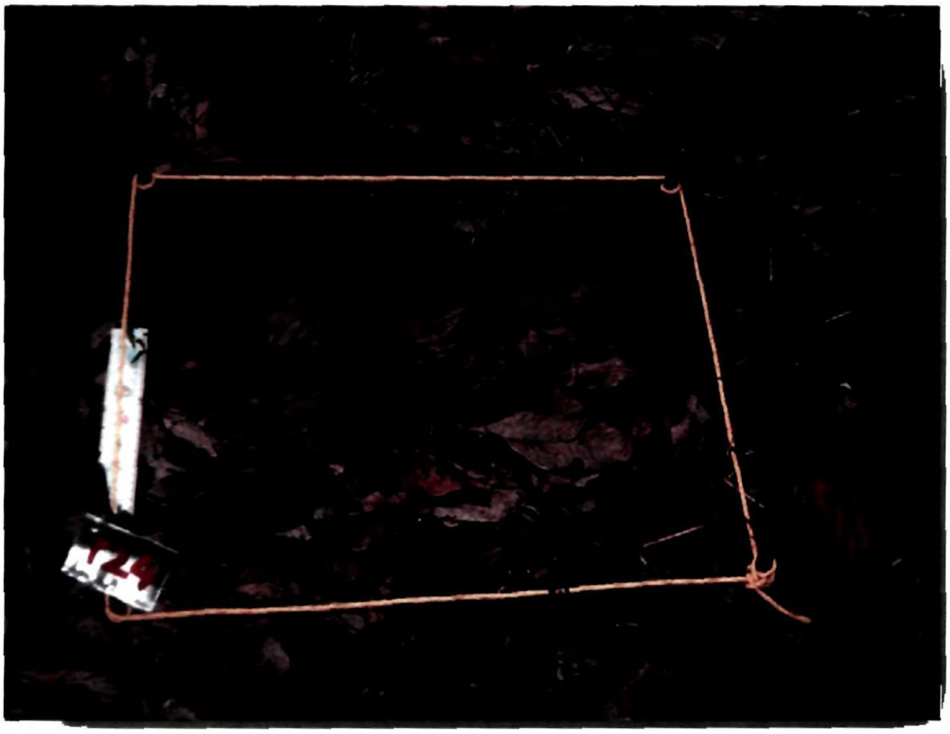


Plate 6 (b) Herb quadrat sample in Rubber plantation area

Plate 7(a) Herb quadrat in Open area

Plate 7 (b) Herb quadrat in Forest area

3.1.2 Establishment of sampling units

To study the ecological parameters the following steps were undertaken in the sites chosen for study.

1. Sites of rubber plantations were chosen in Kottayam, Kollam and Pathanamthitta district.
2. Areas of rubber plantations were chosen in the three districts were preferably adjacent to the natural Tropical Evergreen forests. These are referred as Rubber plantation areas (RP areas).
3. Sites were chosen in the areas adjacent to rubber plantations where the land is fallow and no cultivation is practiced. These areas are referred as Open areas (OP areas).
4. Sites were chosen in the forest areas lying adjacent to the rubber plantations, in the three districts. These are called the Forest areas.

5. Based on the species area curve the sampling size was established to sample the herbs, shrubs and trees of the area (Figure 3.1).
6. The number of quadrats to be established in each type of area (RP, OP and Forest) was determined by the species accumulation curve.
7. Permanent frame quadrats were established randomly within each area and observations made on a regular basis (Table 3.4) for a period of three years.

3.1.3. Salient features of the sites chosen

Important features of the sampling sites were noted and tabulated (Table 3.2 & 3.3) based on the agricultural history of the site and meteorological parameters.

3.1.3.1 Agricultural history of the site

The profile of the agricultural history up to, approximately 100 years was looked into. The disturbance level of each site was assessed. Sites were then classified as given below.

1. Type1- Forest areas which were converted onto plantation.
2. Type2- Area used to cultivate other crops and now cultivating rubber.
3. Type3- Area with rubber plantation for the second consecutive generation

Accordingly the sites chosen were classified in to these three categories. A brief description of the sites is given in Table 3.2.

3.1.3.2. Site characteristics

The geographical and meteorological site characteristics of the sites sampled are tabulated in Table 3.3. The information was based on the data obtained from the following sources

1. Kerala Forest statistics (2003)
2. Metereological center Rubber research institute of India, CES chetheckal and Thiruvananthapuram
3. Punalur observation center

4. TRNT estate Mundakayam
5. Remote sensing, KFRI Peechi
6. Remote sensing RRII Puthupally
7. Resource soil survey (1999)

Table 3.2- The agricultural history of the rubber plantation (RP areas) of Kottayam, Kollam and Pathanamthitta district of Kerala. Based on the history of disturbance levels these areas have been categorized into three types.

S No.	District	Site	History of the rubber plantation sites cultivation	Type
1.	Kottayam	Neezhoor	Area cultivated with different crops (Tapioca, Areca, Coconut, Banana etc) followed by the first cultivation of rubber in 1970. Rubber replanted in 1992.Unweeded for 7 years.	3
2.		Puthupally	Agriculture land converted to Rubber cultivation 50 years earlier, Presently second generation of rubber.Unweeded for 4 years	3
3.		Pampadi	Agriculture land converted to Rubber cultivation.	2
5.		Mundakayam	Forest acquired in 1900.Cultivated Tea until 1971. Since then Rubber cultivation.	2
4.	Pathanamthitta	Chetheckal	Forest acquired in 1967.Since then rubber plantation	1
6.	Kollam	Thenmala	Forest acquired and converted into Rubber Plantations. Less than 50 years old.	1

Table 3.3 - The geographical and meteorological characteristics of the sampled sites in Kottayam, Kollam and Pathanamthitta district of Kerala.

S No	Description	Kottayam district					Kollam district		Patahanmthitta district	
		Neez.	Pamp.	Puth.	Mund.	Mund. Forest	Then. Plant.	Then. Forest	Cheth. Plant.	Cheth. Forest
1.	Latitude	9° 47' 45N	9° 34' 22 N	9° 32' N	9° 31'N	9° 28'N	8°45'- 9°13'N	8°57' 45N	9° 22' N	9° 24' 43N
2.	Longitude	76° 32'15E	76° 37'46E	76° 36'E	76° 56'E	76° 57'E	77° 16'E	77^0 3' 51E	76° 50' E	76° 48' 56E
3.	Altitude	80m	60m	73m	180m	200m	100m	100m	80m	240m
4.	Annual rainfall	3027.1mm				3515.5mm	3093.5 mm		3589.1mm	
6.	Mean max. temp.	32.3 °C								
7.	Mean min. temp.	23.2 °C								
8.	Humidity	66.8%			79%		87.2%		74%	
9.	Mean wind speed	1.7 km/hr					2.0 km/hr			
10.	Rock type	Charconite	Charconite	Charconite	Charnickite	Charnickite	Khodalite	Khodalite	Charconite	Charconite
11.	Soil type	Moderately shallow to very deep	Moderately shallow to very deep	Moderately shallow to very deep	Deep well drained	Deep well drained	Sandy clay loamy soil well drained	Sandy clay loamy soil well drained	Moderately shallow to very deep	Moderately shallow to very deep
13.	Total Area of the sampling site (Ha)	4.7	27	30	2835	8140	607.5	20567	250	37
15.	Type	3	2	3	2	-	1	-	1	-

Neez.- Neezhoor **Mund. Forest**- Mundakayam forest **Then. Plant.**- Thenmala plantations **Pamp.**- Pampadi **Puth.**- Puthupally **Mund.** – Mundakayam **Then. Forest**- Thenmala forest **Chet. Forest**- Chetheckal forest

3.1.4 Site details

3.1.4.1 Kottayam district:

The district has a latitude that ranges from 9^{6} 15'to 10^{6} 21' N and an altitude of 10 to 300mm.It has a total area of 2208 km^2 of which 100.84 km^2 is under forests which is 4.5 % of the total area of the state. A total area of 1121.51 $km^2$of Kottayam is under rubber cultivation of which 1081.12 km^2 is under smallholdings and 40.39 km^2 are under estates. Nearly 50% of the cultivable land of the district is under rubber (Farm guide 2001). The total area under rubber constitutes 24.5 % of the total area of rubber cultivation in the state. The terrain ranges from 10 to 300m in elevation and the rock type is laterite and charconite. The hot season from March to May is followed by the southwest monsoon from June to September. October and November constitute the post monsoon season. December to February form the northeast monsoon. Rain ceases in January.

Four rubber-growing areas in Kottayam were chosen as area of study

(a) Neezhoor (Neez.)

This site comes under Vaikom Taluk, in Neezhoor panchayat. 4.7 hectares of rubber plantation was chosen for the study. This region has a history of high disturbance and is typed as 'type 3'catagory (Table 3.2). Rubber cultivations began in the year 1970 and a second generation of rubber plantation was planted in 1992. The plantation has been left unweeded for the past 7 years on an experimental basis. The site of study has latitude of 9^{6} 47' 45N and a longitude of 76^{6} 32'15E. It has an altitude of 80m and humidity of 66.8 %. Soil is moderately shallow to very deep and the rock type is charconite. Monsoon is similar to that of Kottayam district.

(b) Puthupally (Puth.)

This site comes under Kottayam Taluk, in Pampadi block panchayat. A 30-hectare plot of rubber plantation was chosen for the study. This is a second generation rubber plantation and has a high disturbance level. It is categorized under the Type 3 (Table 3.2).The entire area was not weeded for seven years. The site has latitude of 9^{6} 32' N and a longitude of 76^{6} 36'E.Its altitude is 73m and humidity of 63.7 %. Soil is moderately shallow to very deep and the rock type is charconite. Monsoon is the same as that of Kottayam district.

(c) Pampadi (Pamp.)

This site comes under Kottayam Taluk, in the Pampadi block panchayat. A 27-hectare plot of rubber plantation was chosen for the study. It is a first generation rubber plantation and has been under the Type 2 category (Table 3.2). It has latitude of a 9^{6} 34' 22 N and a longitude of 76^{6} 37' 46E. Its altitude is 60m and humidity of 66.5%. Soil is moderately shallow to very deep and the rock type is charconite. Monsoon is the same as that of Kottayam district.

(d) Mundakayam (Mund.)

This site is in Kottayam district, and is in the Kanjirapally Taluk in Kanjirapally block panchayat. The TRNT estate, which is 2835 hectares of plantation, was chosen as the area of study .The TRNT estates has a history of tea cultivation of approximately 50 years and is presently a first generation rubber plantation. It comes under the Type 2 category (Table 3.2). The site is adjacent to the Erumeli range of natural Tropical evergreen forest. The forest area has been termed Mundakayam forest for easier identification purpose in this study.

The site has a latitude of 9º31'N and a longitude of 76º 56'E. Its altitude is 180 m and humidity of 79.0%. Soil is moderately shallow to very deep and the rock type is charconite. Monsoon is the same as that of Kottayam district.

(e) Mundakayam forest (Mund. Forest)

It is a part of the Erumeli forest is in the High Range circle of the Forest and has a total area of 143.5 km^2. Of this 81.41 km^2 falls in Kottayam district. The forest type seen in this area is of the Tropical evergreen type of forest. Part of this forest lies next to the Mundakkayam TRNT estate and makes an ideal site for a comparative study. The site has a latitude of 9º28' 55N and a longitude of 76º 57' 49E. Its altitude is 200m and humidity of 77%. Soil is charnickite deep well drained soil. Monsoon is the same as that of Kottayam district.

3.1.4.2 Kollam district

.Kollam district lies in the latitude of 8º45'to 9º13'N and a longitude of 76º28'to77º16'E. The total area of the district is 2491sq. km. This district has a forest cover of 814.38 sq. km. 369.47 km^2 of land of this district is under rubber cultivation of which 278.77 km^2 are small holdings and 90.97 km^2 are estates. 11% of the area of the state is under rubber cultivation, which is 7 % of the total area of rubber cultivation in Kerala. The terrain has an altitude of 100m. The rock type is charconite and the soil type is laterite and forest loam. The average humidity is 87.2%. The hot season from March to May is followed by the southwest monsoon from June to September. The months of October and November constitute the post monsoon season. December to February form the northeast monsoon. Rain ceases in January. The area chosen for study in Kollam district were as follows

(a) Thenmala rubber plantation(Then. RP)

An isolated plot of rubber plantation of 607.5 hectares, and 8 km well into the forest was chosen as the area of study. This complete patch of rubber plantation was surrounded by Thenmala forest, which is a Tropical wet evergreen forest. This rubber plantations is a first generation plantation hence been typed as 'Type 1' category (Table 3.2). The latitude of the site chosen is 8^{6}45' to 9^{6}13'N and the longitude is 77^{6}16'E.It has an altitude of 100m and humidity of 87.2% .The rock type is Khondolite. The soil is sandy clay loamy soil well drained. Monsoon is similar to that of Kottayam district.

(b) Thenmala forest (Then. Forest)

This is a large patch of reserved forest of the Tropical wet evergreen type, in the foothills of the Western Ghats. The area of Thenmala forest comes under the Southern Circle of the range wise forest area and is 205.67 km^2 (Kerala forest statistics 2003)· The study site has latitude of 8^{6} 57' 45 N and the longitude is 77^{6} 03' 51 E. It has an altitude of 100m and humidity of 87.2%. The rock type is Khondolite and the Soil is sandy clay loamy soil well drained. Monsoon is similar to that of Kottayam district.

3.1.4.3 Pathanamthitta district

The district lies in the latitude of 9^{6}4'to 9^{6}30'N and a longitude of 76^{6}30'to 77^{6}17'E. The total area of the district is 2642 km^2. A total of 1059.1 km2 of this district is covered with forests. 479.98 km^2 of land of this district is under rubber cultivation of which 419.58 km^2 are smallholdings and 60.40 km^2 are estates. Thus 20% of the area of the state is under rubber cultivation, which is 10.7 % of the total area of rubber cultivation in Kerala. It has an altitude ranges from 100 to 200m. The rock type is charconite and the soil type is laterite and forest loam. The humidity is 63.7%. The hot season from March to May is followed by the southwest monsoon from June to September. October and November constitute the post monsoon season. December to

February form the northeast monsoon. Rain ceases in January. The area chosen for study in Pathanamthitta district were

(a) Chetheckal rubber plantation

The site chosen in Chetheckal is Chetheckal experimental station (CES), Manimala which is 250 hectares of forest converted into rubber plantation in the year 1971. It is a first generation rubber plantation and has been typed as type 1 category (Table3.2). A part of this plot has been left as a forest and has not been converted into plantation. This site is also adjacent to the Ranni reserved forest but is separated from the forest by a road and adjacent human habitation. The site has latitude 9º 22' N, longitude 76º 50' E and an altitude of 80 m. The humidity was 72%. The rock type is charconite and the soil is moderately shallow to very deep.

(b) Ranni Forest (Chetheckal forest)

A secondary forest lying adjacent to the rubber plantation was chosen as a site for comparative study. This is part of Ranni forests, which comes in the Southern circle of the forest ranges and is a Tropical evergreen forest. The Ranni forest has a total area of 1059.1 km^2, all of which falls in the district of Pathanamthitta. .The part of the forest which lay next to the plantation was chosen for a comparative study. This area was segregated from the Ranni forest by a long winding road and heavy human habitation. This area which was once a part of the Ranni forest was once cleared in the year 1980. No rubber plantations have been planted in this area. Thereafter it was left to regenerate so that it could recouperate and become the original forest. It has an area of 50.4 hectares. The site has a latitude 9º 24' 43N, longitude 76º 48' 56E and an altitude of 80 m. The humidity was 74%. The rock type is charconite and the soil is moderately shallow to very deep.This forest has also been refered to as Chetheckal forest in this study.

3.1.5 Area sampled

A total area of 3754 ha of rubber plantations (RP areas) and 3 ha of tropical rain forest (Forest areas) was sampled. Open areas(OP areas) were highly variable in size .They are open spaces left fallow without cultivation for very long periods of time, found adjacent to, or nearby rubber plantations. In total 144 herb quadrats (of the size 0.25 sq.m.), 62 undershrub quadrats (of the size 9.0sq.m) and 3 tree quadrats (of the size 10000 sq.m each) were sampled. A total of 54.6 sq.m of herbs, 4571 sq.m of undershrubs and 30000 sq.m area of trees were sampled respectively (Table 4.1). Disturbance factors were given a 0–6 score, computed as the sum of indices representing area impacted (0–3) and intensity (0–3), with 0 for none, 1 for low, 2 for medium, and 3 for high area/intensity of influence of the factor. Scores for various factors were summed to obtain a total disturbance score for each site (Table 4.2) (Muthukumar *et. al.* 2006).

3.2 Ecological parameters

Both qualitative and quantitative assessments were made of the sampled areas.

3.2.1 Qualitative assessments

This include the following studies

1. Floristic analysis
2. Relative diversity
3. Life form spectrum
4. Physiognomy
5. Phenological studies
6. Allelopathic studies
7. Compilation of growth forms, vertical stratification, medicinal plants, endemic plants and the natural habitat of the ground flora to show succession trends.

3.2.1.1 Floristic analysis

The area under study was scanned manually in each of the chosen sites for study and an enumeration of the type of vegetation and flora found in that region was made. The plants were identified, collected and preserved as a herbarium. Site descriptions and site characteristics were recorded meticulously as field notes. The floristic survey of the three types of areas (RP, OP and Forest) was made on increasing spatial and temporal scales. The RP sites are randomly chosen sites in the districts of Kottayam, Kollam and Pathanamthitta. The OP sites lie adjacent to the RP area surrounding the rubber plantation or are in the vicinity of the RP areas. Three RP areas chosen for the study were adjacent to Tropical rain forests with an assumption *a priori* that a comparison of the floristic change will test the null hypothesis that rubber plantations affect the diversity.

Floristic surveys were conducted on each site for the angiosperm, gymnosperm and Pteridophyte species present. Flowering and fruiting specimens were collected during different seasons of the year and relevant field notes were also recorded. The collected specimens were processed and herbarium specimens prepared as per the methodology given in Bridson and Forman in 1991. The specimen were first classified into families and subsequently identified into different genera with the help of taxonomic literature. They were further scrutinized for species identity with the help of dissected flowers and other diagnostic features. A few specimens were collected in the sterile stage. The species were identified using Flora (Gamble 1935, Gamble and Fischer 1935) and with the help of taxonomists and herbarium collections available at St. Thomas college Pala. Whenever required, revisions and monographs of genera or families were also consulted before arriving at the exact identity and up to date nomenclature of any species. The species names were made up to date in accordance with the *International code of Botanical Nomenclature* (Greutier *et al.* 1994). The up dated names were also referred and confirmed with The Biodiversity Documentation for Kerala: Flowering Plants (Sasidharan 2004). The species were enumerated alphabetically under various families arranged according to the classification of Bentham and Hooker in the year 1862-82. (Gamble 1935). All specimen cited in this work were deposited in the herbarium of Rubber Research Institute of India (RRII), Kottayam, India.

3.2.1.2 Relative diversity

Relative diversity is the number of species per family or genera found in the each area. The relative diversity of each family reveals the dominant families and the structure of the plant community within (Keel *et al.* 1993).

$$\text{Relative diversity} = \frac{\text{Number of species}}{\text{Total number of species}} \times 100$$

3.2.1.3 Physiognomy

(a) Habit

The number of herbs, shrubs, trees and epiphytes were enumerated.

(c) Vertical stratification and Growth forms

The growth forms viz. herbs, shrubs, trees, climbers and epiphytes were enumerated for each of the areas sampled. Stratification is the phenomenon of having more than one layer formed by different heights of plants growing in the same place. The composition of plants and their possible stratification and synusiae formed were studied for each area. The stratification used were as detailed by Smith and Smith in 2006.

3.2.1.4 Life form spectrum

Biological spectrum is the array of the percentages of various life forms of the floristic community of an area. Based on the floristic survey and the sampling of the quadrats, plants found in different areas were listed and different life forms were identified based on the position of the renewal bud or organ. The Biological spectrum of each of the areas sampled was prepared and compared with the Normal Raunkiaer's

Biological spectrum (NBS) and Dansereau proportion of Raunkiaer's life form (Raunkiaer 1934). The Raunkiaer's life form classification was followed. The species of the community distributed among different life forms viz. Phanerophyte, Cryptophyte, Chamaephyte, Hemicryptophyte and Therophyte on the basis of the position of the renewal bud or organ in the species (Raunkiaer 1934, Braun Blanquet 1951). A brief description of the life form is given below.

Phanerophyte - Plants which have buds, which are naked or covered with scales and are, situated high up on the plant. These life forms include trees, shrubs and climbers.

Chamaephytes - Plants usually less than 25-30cm in heights. Their buds are situated close to the ground surface.

Hemicryptophytes - Buds hidden under the soil surface protected by the soil itself. Their shoots die each year. They include most biennial and perennial herbs.

Cryptophytes - Buds are completely hidden in the soil as bulbs or rhizomes.

Therophytes - These are seasonal plants, completing their life cycle in a single favorable season remaining dormant throughout the rest unfavorable period of the year in the form of a seed.

3.2.2 Medicinal plants

The number of medicinal plants found in the rubber plantations, Open areas and the Forest areas were listed and their medicinal properties tabulated (Jain and Defillips 1991). The vernacular identification and the plants medicinal properties were confirmed with the help of local people of that area.

3.2.3 Endemism

The number of endemic plants found in the RP, OP and forest areas were listed using the Biodiversity documentation of the flora of Kerala (Sasidharan 2004) and the IUCN red data book (2002).The extent of endemism for these plants were also determined and tabulated.

3.2.4 Vegetation succession

The qualitative survey of the plant species observed in the habitat chosen (RP, OP and Forest) was used to see if the plant composition was showing a trend of change from the Tropical environment. By documenting the habitat preference of the species identified using floras (Sasidharan 2004), a composition profile of each area was prepared by compiling the number of species with specific habitat preferences. Although unnatural, sacred groves were included as a habitat preference, as they are natural habitats, which are allowed to flourish by restrictions imposed on the disturbance level (Parthsarthy and Karthikeyan 1997).

3.2.5 Phenology-

Phenological studies were made following Billet in 2004. Each phase is called a phenophase. The following observations were made.

Period of vegetative growth

Period of flowering

Setting of fruiting

Seed germination

3.2.6 Quantitative assessments

3.2.6.1 Sampling

To study the vegetation characteristics of the areas permanent experimental sampling units were placed for a period of five years (2001- 2006). The species-area curves clearly illustrate that to distinguish between ecological situations, field studies should use quadrats whose area value will be the minimum area that contains most species of the flora growing in the region (He and Legendre 2002) as used in this study. The term "quadrats" refers to such sampling units (Mao *et al.* 2005). The objective of this study was to examine the community structure at the spatial scale at which species interaction takes place. Separate quadrats were taken to sample herbs, shrubs and trees based on the species area curve (Table 4.2). This was done in order to sample the local variation at each site as completely as possible. The sampling units were frame quadrats. The methodology used is as detailed below.

3.2.6.2. Sample size

To determine the quadrat size the species area curve of the area was plotted (Krebs 1989). In all the areas sampled the species area curve reached asymptote at 0.5 m for the ground flora of Rubber plantations. To sample the shrubs an asymptote was obtained at 3m and for trees at 100m. Accordingly sampling sizes were fixed at

0.5mX 0.5m – for sampling of herbs

3mX 3m – for sampling of shrubs

100mX 100m- for sampling of trees

In the rubber plantations and the Open areas the tree saplings often are not allowed to grow to their full potential reach and reach their full form. Hence the saplings were enumerated as trees.

3.2.6.3 Sampling units

The quadrats were established using 0.5mm iron rods of 26inches height, which were embedded 1 foot into the ground. A 0.4mm plastic rope was tied to join the four corners at a height of 1 foot from the ground level. These areas were periodically surveyed. A surrounding area of 10 meters diameter was left undisturbed for the period of study. The number of quadrats to be established in an area was determined by determining the asymptote of the species accumulation curve. This was further confirmed using the parameters of abundance, distribution and species richness estimation. These quadrats were used to take the plant species count for the study of the ecological and phytosociological parameters and for phenological observations that were also made on a regular basis in these plots.

Three types of areas were chosen to establish the quadrats to make a comparative study of the vegetation. These areas are described below.

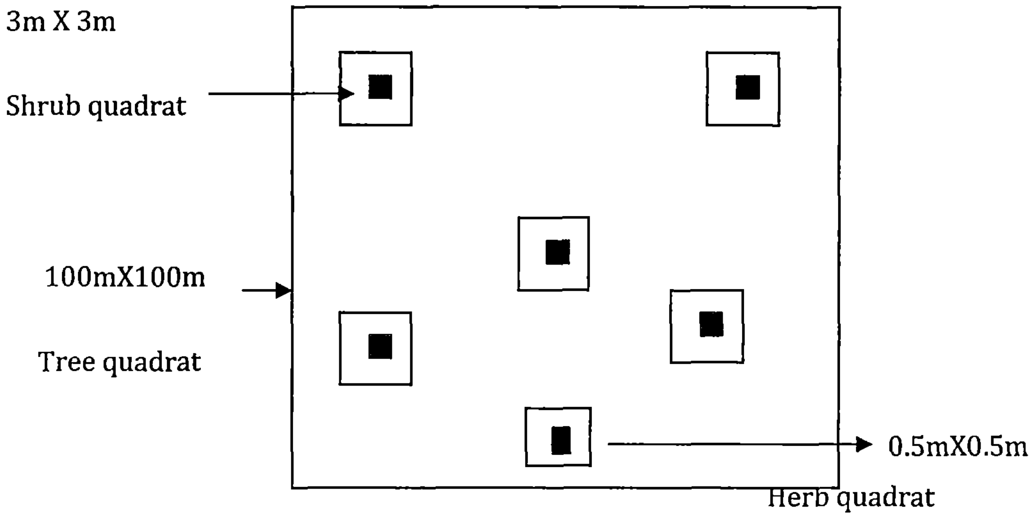
Open area (OP) - Areas found adjacent to rubber plantations on its outskirts where no farming is done. There is no human interference in these areas except for occasionally disturbance due to animal or human movement.

Rubber Plantation (RP) – Areas within the plantation having a full canopy. The age of the plantations ranged from 7 to 20 years. It may be noted that two areas of rubber plantation chosen for our study viz. Puthupally and Neezhoor have not been weeded for seven years.

Forest Areas -Areas within the Tropical evergreen forest adjacent to the rubber plantation. These forests are reserved forest with no disturbance by human habitation or animal grazing.

The quadrats were established along the edge of the forest adjacent to the plantation in order to sample the gradation of the vegetation change. A plot of 100m X 100m was taken into the forest from the edge and both shrub (3mX3m) and herb (0.5mX0.5m) quadrats were established within them (Bhat *et al.* 2000). To enumerate and study the vegetation of the trees all the woody plants (which include tree saplings, shrubs, lianas, climbers, etc.) with a circumference of > 10cm at breast height (i.e. 132cm) were enumerated as trees (Bhat *et al.*2000). The saplings of trees were included in our study in the herb and shrub quadrats. Plants were identified up to the species level. In case of uncertainty a specimen of the tree species and a photograph were used to identify them. The vernacular names and medicinal properties were confirmed with the help of local people.

Figure-3.1 A diagrammatic representation of the orientation of the three types of quadrats established in the forest sites sampled. (The sizes of the quadrat are not to scale).



3.2.6.4 Sampling method

The site location, area sampled the number and type of quadrats established and the sampling frequency are given in Table 3.2. A sampling protocol was followed wherein repeated observations were made at the sample locations selected to represent the community. This temporal replication over a period of 5 consecutive years on the same sampling site enabled collection of data needed to resolve the ambiguity between species absence and non detection when species are unobserved at sample locations (Dorazio *et al.* 2006).To sample the plant species the following steps were undertaken

Enumeration- Plant species was identified within the plot and a count of the number of individual plants present within the quadrat was made and noted. In the case of grasses and vegetative propagated plants, each tiller or shoot coming out of the soil is counted as an individual. When the plant flowers a single flowering plant was enumerated as one plant. An enumeration was done all year around for five years and the average number of the individual plant species was taken as a count for a single plant species.

Phenology- Plants selected for phenological observation were identified in the plot and tagged. Observations were made as per the schedule (Table 3.4).

Table 3.4 Experimental layout summarizing the sampling mode and frequency site location, area, type of the RP, OP and Forest areas and their subsamples in Kottayam, Kollam and Pathanamthitta districts of Kerala.

District	Name of the Place	Area In hectares	Type of plantation	Type of Area	Number of quadrats establ.	Frequency of observation Year				
						1	2	3	4	5
Kottayam	Neezhoor	4.7	Type3	OP	6	w	m	q	q	q
				RP	16	w	m	q	q	q
	Puthupally	30	Type2	OP	8	w	m	q	q	q
				RP	20	w	m	q	q	q
	Pampadi	27	Type2	OP	3	w	m	q	q	q
				RP	17	w	m	q	q	q
	Mundakayam	2835	Type2	OP	3	m	w	q	q	q
				RP	15	m	w	q	q	q
		>10000	-	For.	17	m	w	q	q	q
					14	m	w	q	q	q
Pathanamthittta	Chetheckal	101	Type2 and Type3	OP	3	m	w	q	q	q
				RP	21	m	w	q	q	q
		30	-	For.	12	m	w	q	q	q
Kollam	Thenmala	607.5	Type 1	RP	11	q	y	y	y	-
		>10000	-	For.	14	q	y	y	y	-
					12	q	y	y	y	-

OP- Open area **RP**- Rubber Plantation **For.**- Forest **q**- quarterly **y**- yearly **w**- weekly

3.2.6.5. Phytosociological characteristics

A community has a series of attributes that do not reside in its individual species components and have meaning only with reference to the community level of integration. The phytosociological characteristics of communities measured were as follows.

3.2.6.5.1. Abundance index

Abundance refers to population size and is the number of individuals in a given area. It is measured as

$$\text{Abundance} = \frac{\text{No. of individuals in all the quadrates}}{\text{No. of quadrat in which species occurs}}$$

Relative abundance is the abundance of a species (by any measure), divided by the total abundance of all species combined.

$$\text{Relative abundance} = \frac{\text{Abundance of a species}}{\text{Total abundance of all species}}$$

The computations based on the species abundance data are

1. Species number index
2. Rank abundance
3. Species accumulation

All the abundance indices computed from the data using Pisces conservation SDR version 4. (Seaby and Henderson 2006).

3.2.6.5.1.1 Species number index

The number of species found in each sample and the all sample index is computed and the result displayed as a graphical output. This gives the species composition i.e. a list of all the species in this defined unit, along with some measure of the abundance (relative abundance). Species composition can be considered a vector i.e. a column of numbers when based on relative abundance.

3.2.6 .6 Plant diversity analysis protocol

Mc Carthy *et al.* (2001) recommendations for plant diversity analysis for plant communities were followed in this study. The diversity analysis protocol is also based on several diversity studies (Colwell and Coddington 1994, Ludwig and Reynolds 1988, Magurran 1988, and Pielou 1975). They are as follows.

1. Construct rank on abundance plots (RA plot) - the shape of the plot will indicate what model to explore further.
2. Estimate species richness using the rarefaction method- this will permit comparisons between differently sampled communities.
3. Fit the logarithmic series or the lognormal curve to the data- if the R-A plot suggests.
4. Use the Simpson's and /or Shannon- Weiner diversity index- decide *a priori* which is more appropriate.
5. Determine evenness for the sample- Use the appropriate measure of E for the index calculated.
6. Construct SHE plots- explore the relationships and evaluate sampling efficiency.

3.2.6.6.1 Rank on abundance plot

This is the first step to analyzing the data (Taylor *et al.* 1978). It examines the pattern of relative abundance between species in the samples. The rank abundance plot is a very useful way to summarize both equitability in abundance between species and species richness. The distribution and abundance of the plant species were examined using rank on abundance plots. Abundance is the percentage of individuals of each species that contributes to the total number of individuals of all species. Rank on abundance is the order of species from most to the least.

The number of individuals of each species was sorted in descending order, and the proportion of the total number of individuals for each species was plotted on the log scale against the species rank. Rank on abundance plot (RA plot) is one of the many ways by which the species abundance and species diversity can be summarized. These plots summaries the equitability in abundance between species, and species richness. The shape of the RA plot provides an indication of dominance or evenness. A steep plot signifies assemblages with high dominance and shallower slopes indicate higher evenness. Plotting the logarithms of abundance and rank displays more of the structure in the data, and allows the pattern of relative abundance between different samples or communities to be more clearly compared.

3.2.6.6.2 Species accumulation curve

The species accumulation curve also called the collectors curve or acquisition curve was plotted for each site and for the pooled samples for each type of area (RP, OP, Forest) using SDR version 4.0. This gives a measure of the completeness of the inventory and allows the comparison of the species richness between the areas

During sampling, new species are initially encountered rapidly. The rate of encounter decline as the samples accumulates. The total number of species in the collection is approached asymptotically (Pielou 1966). This relation has been variously termed species-diversity curves (Sanders 1968), species-richness curves (Hurlbert 1971), collector's curve (Pielou 1975, Clench 1979), species-cover curves (Palmer 1991), species-area curves (Miller and Wiegert 1989, Solow and Smith 1991), cumulative species-area curves (Quinn and Harrison 1988, Beckon 1993) and species-accumulation curves (Grassle and Maciolek 1992).

The species–area relationship is an important tool for quantifying changes in species richness across a continuous range of spatial scales (Shmida and Wilson

1985, Rosenzweig 1995, Lomolino 2000, Crawley and Harral 2001, Scheiner 2003, Drakare *et al.* 2006). Species accumulation curve showing the cumulative increase in species with increasing rubber plantation area inventoried, are drawn for the entire study area and for the sub regions. Because a complete census is feasible only under a few special situations, it is necessary to estimate species richness by sampling the target species assemblage. The species accumulation curve, that is the plot of the expected number of detected species as a function of the sampling effort, arises as a graphical representation of the sampling process (Sanders 1968, Palmer 1990).The plot of the cumulative number of species, S(n), collected against a measure of the sampling effort (n) is termed the species accumulation curve. The sampling effort is measured as the number of quadrats taken. Species accumulation curves of the RP, OP and Forest areas sampled and their subsets were computed using Pisces conservation SDR version 4. (Seaby and Henderson 2006).

In some of the Open areas the rate of acquisition of new species greatly decelerated with sampling effort. An asymptote was not reached and the species accumulation curve increased very slowly and approximately linearly. Sampling for species at this stage was considered complete. Thus in such areas the species accumulation curve reached an asymptote with relatively small sampling efforts.

Species accumulation curve on one hand is a measure of sampling intensity and on the other is also a measure of the adequacy of the sampling effort. Apart from this, accumulation curve also extrapolate species richness vs. sample size data to an asymptote of total richness (Sobero′n and Llorente 1993). Thus the curve also provides an estimate of the number of species present in the community (S_{max}), which is the observed number of species (S_{obs}). The observed number of species is considered surrogate for the true number of species (S_{true}) and can exclude many rare species and underestimate S_{true} (the qualitative assessment in this study) which is the number of species actually present in the area (Palmer 1990, Baltana's 1992, Colwell and Coddington 1994, Martinez *et al.* 1999).

3.2.6.6.2.1 Randomization

To minimize arbitrary effects of sample order, randomizations were undertaken to smoothen the species accumulation curves. When calculating species richness or fitting a species accumulation curve, the order in which the samples are listed can have a large impact on the result. To avoid this problem the sample order is randomized many times to produce an average for, the number of species observe (Solow 1993). Randomization tests were undertaken using SDR version 4.0 for the individual rubber plantation areas and Open areas, and for the pooled data of Rubber plantation areas, Open areas and Forest areas of all the districts. The species acquisition curve indicated, whether the sampling has been of sufficient intensity, to capture most of the species present. These samples adequately characterized the community and summarized the completeness of the sampling effort.

3.2.6.6.3. Species richness estimations

3.2.6.6.3.1 Species accumulation based species richness estimators

The extrapolations of species accumulation based estimators viz. Henderson's plot, Pooled rarefaction, Sample interpolation and Heterogeneity are estimated and plotted using SDR version 4. (Seaby and Henderson 2006).

(a) Rarefaction

Rarefaction is a procedure for analyzing the number of species (species richness) among collections, when all collections are scaled down to the same number of individuals. This scaling procedure was termed 'rarefaction' by Sanders in 1968 who used an incorrect equation which was corrected by Hurlbert in 1971. The number of species, S_n, that can be expected from a random sample of n individuals, drawn without replacement from N individuals distributed among S species, is given by

$$E(S_n)=\sum_{i=1}^{s}\left[1-\binom{N-N_1}{n}\Big/\binom{N}{n}\right]$$

where S is the total number of species found in the collection, and N_i is the number of individuals of the i^{th} species.

The formula computes the expected number of species in a random sample of n individuals as the sum of the probabilities that each species will be included in the sample. The variance of the estimate was given by Heck *et al.* (1975) as:

$$Var(S_c)=$$

$$\sum_{i=1}^{s}\left\{\left[\binom{N-N_i}{n}\Big/\binom{N}{n}\right]\left[1-\binom{N-N_i}{n}\Big/\binom{N}{n}\right]\right\}$$

$$+2\sum_{j=i}^{s}\left\{\left[\binom{N-N_i-N_j}{n}\Big/\binom{N}{n}\right]\right.$$

$$\left.-\left[\binom{N-N_i}{n}\Big/\binom{N}{n}\right]\left[\binom{N-N_j}{n}\Big/\binom{N}{n}\right]\right\}$$

These procedures calculate the number of combinations of the data and thus require considerable amount of computation for large data sets. In addition to the estimated species richness the output also includes the standard deviation of the estimates. Sampling is assumed to be without replacement for the Finite version, and with replacement for the Infinite version. The above equations are for sampling without replacement.

Rarefaction curves were constructed from samples taken within habitats to determine the efficacy of sampling, the true species richness of a given habitat, and to compare species richness among habitats on an equal-effort basis. It also evaluates the adequacy of sampling by assessing whether the cumulative number of species has reached an asymptote, by comparing the S_{obs} to species-richness estimators, such as Chao2 or ICE, or by extrapolating the curve (Colwell and Coddington 1994, Ugland 2003, Colwell *et al.* 2004).

Total species richness was also estimated using rarefaction curves using the computer program Pisces conservation SDR version 4. (Seaby and Henderson 2006). Rarefaction is a procedure for analyzing the number of species (species richness) among collections, when all collections are scaled down to the same number of individuals. Both pooled and single sample rarefactions have been plotted using Pisces conservation SDR version 4.0. (Seaby and Henderson 2006).

(i)Pooled rarefaction

Pooled Rarefaction undertakes individual-based rarefaction on the pooled data for all of the samples within the data set. First all of the samples are summed to form a grand sample. Then the average number of individuals in a single sample is calculated. The standard method for both the finite and infinite versions of the rarefaction curve of Heck *et al.* (1975) is then used to calculate the species number as the number of individuals increases.

(ii) Sample rarefaction

This method estimates how the species number in a selected sample changes with the number of individuals. Sampling is assumed to be without replacement for the Finite version is used. The output presents the change in estimated species richness with the number of individuals and the standard error of the estimate.

(b) Henderson's plot

Magurran and Henderson (2003) argued that all communities can be divided into residents and tourists (migrants). While it can sometimes be assumed that a sampled habitat is closed to migrants, when sampling large scale systems over extended periods this cannot be the case. This method estimates the species richness of the resident species and the rate of arrival of migrants for a habitat open to migrants. The species acquisition curve is fitted to a hyperbolic-linear model that takes the form:

$$S(n)=\left[\frac{S_{max}n}{k_1+n}\right]+k_2n$$

where $S_{(n)}$ is the number of species recorded after n samples,

S_{max} is the total number of resident species,

k_1 is a parameter that determines the rate of acquisition of resident species it is the sampling effort needed to collect half the total number of resident species and

k_2 is a parameter that describes the rate of acquisition of migratory (non-resident) species.

The hyperbolic-linear model is fitted using non-linear regression. For some sets of data the initial values chosen by the program may be inappropriate, leading to a failure to find a solution. This is most likely to occur if you are using data which do not fit this model.

This equation is best fitted to a species acquisition curve smoothed by averaging the randomized order of the samples. The output gives the predicted increase in species number with sampling effort which is also presented graphically. The estimated model parameters are also given:

Resident Species: this is the estimated number of resident species living permanently in the habitat.

No Sample for 1/2 Sp. Max.: this gives the number of samples required to produce a species list comprising half the total number of resident species.

Migrant sp./sample: This gives the rate of acquisition of migrants in migrants per sample.

(c) Sample interpolation

This method estimates the number of species that would be observed for different numbers of samples ranging from zero to the total number of samples in the data set. To use this method all of the samples selected must come from the same community or habitat.

Some authors would refer to this method as a type of rarefaction. In the program SDR version 4 (Seaby and Henderson 2006) rarefaction is used only for methods based on numbers of individuals rather than samples. The calculations use the method of Colwell (2004) which calculates the species accumulation using a binomial mixture model. The method is based on the counts of species observed in 1, 2.. H samples (S_j) where the total number of samples is H. This method assumes without replacement.

For interpolation, there is an unbiased estimator E (*h*), the expected number after h samples that is based on the counts s_j, appropriately weighted by combinatorial coefficients.

Now Sobs, the total species number observed, is the sum of the S_j values. Colwell *et al.* (2004) showed that

$$E(h) = S_{obs} - \sum_{j=1}^{j=H} \alpha_{jh} s_j$$

where the combinatorial coefficients α_{jk} are defined by

$$\alpha_{jh} = \frac{(H-h)!(H-j)!}{(H-h-j)!H!}$$

Or zero for j + h > H.

The standard errors are calculated using the estimated variance equation:

$$\text{var}(h) = \sum_{j=1}^{H} (1-\alpha_{jh})^2 s_j$$

This is a highly conservative estimate of variance which assumes that the total number of unknown species that could eventually be caught is infinite. However a conservative approach to error is used because of the dynamic and clumped nature of natural systems. The upper and lower 95% errors are calculated as 1.96 times the standard deviations.

(d) Heterogeneity

As extrapolation to estimate the total species complement for the habitat, S_{max}, is only possible if the species accumulation curve is derived from a homogeneous (stable) community, the first task is to look for heterogeneity. The species abundance data was used to compare the mean randomized species accumulation curve with the curve expected if all the individuals caught over all the samples were randomly assigned to the samples. As suggested by Colwell and Coddington (1994), if the expected, the curve rises more steeply from the origin then heterogeneity is greater than could be explained by random sampling error alone. The expected curve calculated by SDR version 4 is that described by Coleman (1981) and Coleman *et al.* (1982). The increase in species number over a series of samples, S_a, is calculated as:

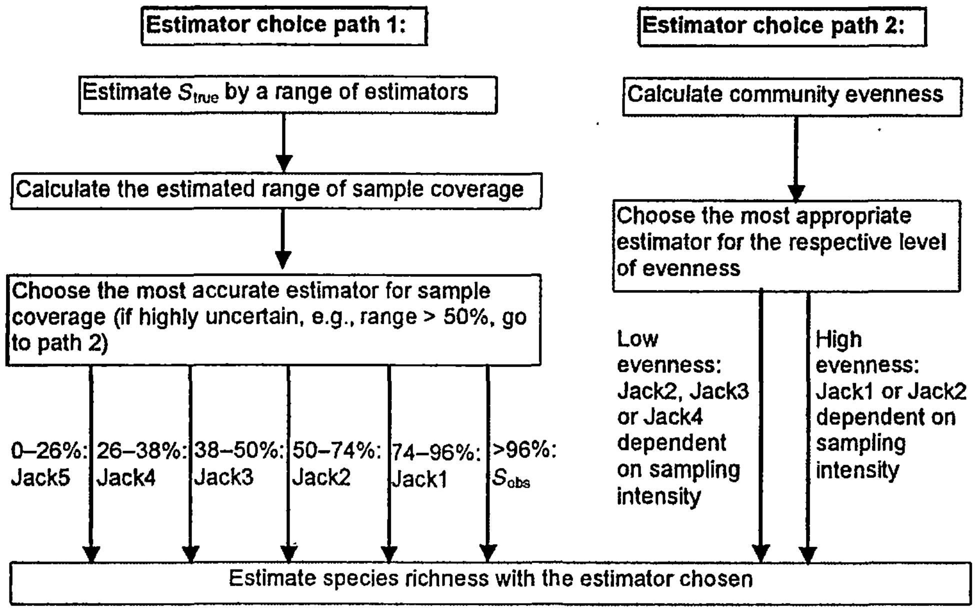
$$S_a = S_{TOT} - \sum_{i=1}^{i=S_{TOT}} (1-\alpha)^{n_i}$$

where S_{TOT} is the total species number recorded, n_i the total number of individuals belonging to species *i*, *a* the sample number and a the fraction of the total sampling effort undertaken by sample *a*.

3.2.6.6.3.2 Non parametric species richness estimators

In order to make a complete species inventory of a site (taken as a plant community), species richness estimators were used. Species richness estimations were made to get the S_{max} in RP areas which is considered surrogate to S_{true} which is the actual number of species present in the area sampled. Richness estimators are resampling techniques developed to reduce the bias of sample data (Small and McCarthy 2002). Because the number of species observed in a sampling effort is likely to underestimate the actual total number of species present in that community (Lande 1996), richness estimators more heavily weight rare or infrequent species such as uniques (species occurring in only one quadrat) and duplicates (species occurring in exactly two quadrats) for a given sample size (Palmer 1990, 1991and Chazdon *et al.* 1998). Literature studies have suggested the use of multiple non-parametric richness estimators to reduce sampling bias and to obtain more robust, reliable estimations of community richness (Chazdon *et al.* 1998, Gimaret-Carpentier *et al.* 1998).

To extrapolate species richness based in the RP, OP and Forest areas, eight non-parametric estimators were used for the three types of areas. The sample coverage, which is the proportion of species present in the samples (estimated as species number / observed species number), is calculated. To choose the best species richness estimator for the sites chosen the Brose, Martinez & Williams (2003) protocol was followed.



Accordingly the mean sample coverage indicated that the best species richness estimator was the Chao & Lee 1&2(ICE/ACE) or the Michelis Menten for the sites sampled. The estimator Chao & Lee 1 was chosen for this study. The two estimators (Chao& ICE) are known to provide reliable and consistent richness estimation with low sensitivity to sample size, patchy species distribution and sample order (Chazdon *et al.* 1998, Small and McCarthy 2002). Species richness estimations were made to get the S_{max} in RP areas which is considered surrogate to S_{true} which is the actual number of species present in the area sampled. The non parametric estimates used were

(a) Chao Quantitative

This is the first of the series of estimators of species richness. Using the observed number of species represented by one, a, or two, b, individuals in the sample Chao (1984) derived the simple estimator:

$$\hat{S}_{max} = S_{obs} + (a^2/2b)$$

Where, S_{obs} is the actual number of species in the sample 'a' the number of species represented by a single individual, and b the number of species represented by two individuals. Chao (1987) gives the variance of this estimate as:

$$\text{var}(\hat{S}_{max}) = b\left[\left(\frac{a/b}{4}\right)^4 + \left(\frac{a}{b}\right)^3 + \left(\frac{a/b}{2}\right)^2\right]$$

Note that when all the species have been observed more than twice, the census is considered complete.

(b) Chao & Lee 1

This is also known as an ACE estimator of richness (Abundance-based Coverage Estimator of species richness). The method was developed by Chao and Lee (1992). It is assumed that

$$S_{obs} = S_{rare} + S_{abund}$$

The sample coverage estimate based on abundance data is defined as:

$$C_{ace} = 1 - \frac{F_1}{N_{rare}}$$

Where

$$N_{rare} = \sum_{i=1}^{10} iF_i$$

Thus, this sample coverage estimate is the proportion of all individuals in rare species that are not singletons. Then the ACE estimator of species richness is

$$S_{ace} = S_{abund} + \frac{S_{rare}}{C_{ace}} + \frac{F_1}{C_{ace}} \gamma_{ace}^2$$

The estimate the coefficient of variation of the Fi's is

$$\gamma_{ace}^2 = \max\left[\frac{S_{rare}}{C_{ace}} \frac{\sum_{i=1}^{10} i(i-1)F_i}{(N_{rare})(N_{rare}-1)} - 1, 0\right]$$

The default Number of Random Selections (R) is set at 10. A plot of the way the estimate changes with the number of samples used is shown.

(b) Chao & Lee 2

This is also known as the ICE (Incidence-based Coverage) Estimator of species richness (Lee and Chao 1994). It is assumed that

$$S_{obs} = S_{infr} + S_{freq}$$

The sample coverage estimate based on incidence data is

$$C_{ice} = 1 - \frac{Q_1}{N_{infr}}$$

Where

$$N_{infr} = \sum_{j=1}^{10} jQ_j$$

In words, the sample coverage estimate is the proportion of all individuals in infrequent species that are not uniques. The ICE estimator of species richness is

$$S_{ice} = S_{freq} + \frac{S_{infr}}{C_{ice}} + \frac{Q_1}{C_{ice}} \gamma_{ice}^2$$

Where the estimate the coefficient of variation estimates the coefficient of variation of the Q_j's, is

$$\gamma_{ice}^2 = \max\left[\frac{S_{\inf r}}{C_{ice}}\frac{m_{\inf r}}{(m_{\inf r-1})}\frac{\sum_{j=1}^{10} j(j-1)Q_j}{(N_{\inf r})^2} - 1, 0\right]$$

The number of Random Selections (R) is set > 1 and the sequence samples are selected R times at random from the complete set of samples and the mean estimate calculated. This removes sample order effects. By looking at the progressive change in the estimates it is possible to assess if sufficient samples have been taken to stabilize the estimate.

(d) 1st Order Jackknife

This method was independently developed by Heltshe and Forrester (1983) and Burnham & Overton (1978).

$$\hat{S}_{max} = S_{obs} + a(n - 1/n)$$

Where n is the number of samples and a the number of species only found in one sample. Heltshe & Forrester (1983) give the variance of this estimate as:

$$\mathrm{var}(\hat{S}_{max}) = \frac{n-1}{n}\left(\sum_{0}^{S} j^2 f_j - \frac{L^2}{n}\right)$$

Where f_j is the number of samples holding j of the L species only found in one sample. Further jackknife estimators are also discussed in Burnham and Overton (1979) and Smith and van Belle (1984). A simple plot of the way the estimate changes with the number of samples used is shown. The number of Random Selections (R) is set > 1 then the sequence samples are selected R times at random from the complete set of samples and the mean estimate calculated. By looking at the progressive change in the estimates it is possible to assess if sufficient samples have been taken to stabilize the estimate.

(e) 2nd Order jackknife

Burnham & Overton (1978) developed the second-order jackknife estimator:

$$\hat{S}_{max} = S_{obs} + \left[\frac{L(2n-3)}{n} - \frac{M(n-2)^2}{n(n-1)}\right]$$

Where L is the number of species only found in one sample and M is the number of species only found in two samples.

(f) Bootstrap

A bootstrap estimate of species richness can be calculated as follows (Smith & van Belle 1984):

Randomly select with replacement n samples from the total available, and calculate:

$$S_{max} = S_{OBS} + \sum_{i=1}^{S} (1 - p_i)^n$$

Where p_i is the proportion of the n that has species i present.

The step is repeated 100 times , and the mean estimate of S_{max} is calculated. The variance is calculated as follows:

$$\text{var}(S_{Max}) = \sum (1-p_i)^n \left[1-(1-p_i)^n\right] + \sum\sum \left\{q_{i,j}^n - \left[(1-p_i)^n (1-p_j)^n\right]\right\}$$

where q_{ij} is the proportion of the n bootstraps which hold both species i and j.

The number of Random Selections (R) is set > 1 then the sequence samples are selected R times at random from the complete set of samples and the mean estimate calculated. By looking at the progressive change in the estimates it is possible to assess if sufficient samples have been taken to stabilize the estimate.

(g) Michaelis-Menten

The asymptotic behaviour of the accumulation curve can also be modeled as the hyperbola (Raaijmakers 1987):

$$S(n) = \frac{S_{max}\, n}{B + n}$$

Where S_{max} and B are fitted constants. The number of Random Selections (R) is set > 1 then the sequence samples are selected R times at random from the complete set of samples and the mean estimate calculated. By looking at the progressive change in the estimates it is possible to assess if sufficient samples have been taken to stabilize the estimate

3.2.6.6.4 Fitting distribution (Non parametric species richness estimation)

One type of assembly rule for abundance is the dominance-diversity relation, i.e. the distribution of species abundances within a community (Whittaker 1965). Several models of have been proposed to describe the species- abundance relationship of which four models have been chosen. The degree of fit to them enables some discrimination between models of community structure (Pielou 1975, Wilson 1991), A visual inspection of a single curve (RA plot) is insufficient to draw conclusions so the data was tested to fit the species abundance distribution models (SAD) viz. Geometric (Motomura 1932), Log series (Fisher *et al.* 1943, Kendall 1948), Log normal (Preston 1948) and Broken stick (MacArthur 1957, Sugihara 1980, Tokeshi 1993, 1996, Marquet *et al.* 2003). Results of the chi- squared test of the observed and expected are also calculated. If the value of p is <0.05 then the distributions are significantly different at the 5% level.

Given quantitative data, species abundance models describing the relative abundance of species within the community such as the log normal can be used to estimate the total species complement, S_{max}. If the data fit a log normal distribution then the number of unsampled species is given by the missing part of the distribution to the left of the veil-line. Alternative distributions which have been suggested include the Poisson-log normal (Bulmer 1974) and the log series (Williams 1964) amongst others. It is unlikely that parametric methods yield reliable estimates for S_{max} and thus has been avoided.

(a) Geometric

The geometric distribution is described by:

$$n_i = NC_k k(1-k)^{i-1}$$

Where

n_i = the number of individuals belonging to the i^{th} species;

N = the total number of individuals;

C_k is a constant to ensure that the total sums to *N*.

The parameter *k* is estimated by iteration, after which C_k is calculated.

The observed and expected abundances of the species, the estimated values for *k* and the results of a Chi-Squared test of the observed and expected observations are computed. If the value of p is < 0.05 then the distributions are significantly different at the 5% level. The goodness of fit results is tested.

(b) Log series

The log series distribution is described by:

$$, \frac{\alpha x^2}{2}, \frac{\alpha x^3}{3}, \ldots\ldots \frac{\alpha x^n}{n}$$

Where each term gives the number of species predicted to have 1, 2, 3, ...n individuals in the sample. The parameter a is estimated by iteration, after which x is calculated.

The observed and expected abundances of the species are displayed as a graphical output. These are arranged in abundance classes and the upper column gives the upper bound of each class. A plot of the observed and expected frequency distributions arranged by class is computed using Pisces Conservation SDR version 4 (Seaby and Henderson 2006). The Observed are plotted as a histogram and the Expected as a green line. The estimated values for a, x and the results of a Chi-Squared test of the observed and expected observations are calculated. If the value of p is < 0.05 then the distributions are significantly different at the 5% level. The goodness of fit results is tested.

(c) Truncated log-normal

The majority of communities display a log normal distribution. However, rarer species will not be fully represented in a finite sample so that in practice we lose the left-hand tail of the distribution. The veil line represents the distance from the right-hand edge of the distribution, at which species becomes too rare to occur in the sample. The output is displayed as a graphical output. The observed and expected abundances of the species are also computed. These are arranged in abundance classes and the upper column gives the upper bound of each class. The plot of the observed and expected frequency distributions is arranged by class. The observed are plotted as a histogram and the expected as a green line. The results of the Chi-squared test present the estimated values for the following parameters:

- The observed mean of the logged observations,
- The observed variance of the logged observations,
- The estimated mean of the log normal distribution,

- The estimated variance of the log normal distribution,
- The predicted total number of species in the community,
- The observed number of species,
- The species beyond the veil line, in other words the species number missing from the sample,
- Lambda, the diversity statistic (the estimated species number divided by the standard deviation).
- The observed and expected observations are calculated. If the value of p is < 0.05 then the distributions are significantly different at the 5% level. The goodness of fit results is tested.

(d) Broken stick

The broken stick model is calculated using the formula:

$$S(n) = \left[S(S-1) / N \right] \left(1 - n / N \right)^{s-2}$$

Where S(n) is the number of species in the abundance class of species with n individuals. The output is displayed. The observed and expected abundances of the species are displayed. These are arranged in abundance classes and the upper column gives the upper bound of each class. A plot of the observed and expected frequency distributions arranged by class is computed using Pisces Conservation SDR version 4 (Seaby and Henderson 2006). The observed are plotted as a histogram and the expected as a green line. The results of a Chi-Squared test of the observed and expected observations are computed. If the value of p is < 0.05 then the distributions are significantly different at the 5% level. The goodness of fit results is tested.

This is also an indication of evenness and dominance in the plant community sampled. Dominance progresses from the highest to the least in the Geometric SAD to the Broken stick in that order and is the exact reverse with regard to evenness The Log series and the Log normal SAD (species abundance distribution) are purely statistical models which tests the data by fitting frequency distribution of species vs. abundance in the former and on a log scale on the x- axis in the latter (Marquet *et al.*2003, McGill 2007). The geometric and the broken stick SAD models are based on niche partitioning (McGill 2007). These models use RA plots with abundance on log scale on Y-axis. Fitness to geometric distribution is found in early succession, degraded ecosystems and harsh ecosystems. On the other hand Broken stick distribution is best fit in narrowly defined communities with taxonomically related organisms. In these communities S (Total number of species) is an adequate measure of diversity. It indicates a biologically uniform distribution or equitable species abundance. Dominance/ diversity models also summarize the structure of a community, allow ecologists to search for general patterns, irrespective of pre-existing theory (Pielou 1975). The data was fitted to the SAD models using Pisces Conservation SDR version 4 (Seaby and Henderson 2006) and the goodness of fit was computed. It has been suggested that SHE analysis is one of the best ways of deciding if a log series log normal or broken stick model gives the best fit to the observed data.

3.2.6.6.5 Measurement of diversity

The diversity of the RP, OP and Forest areas were measured using a range of diversity indexes. Both alpha diversity indexes and Evenness indexes were used (Taylor 1978, Kempton 1979, Magurran 2004). All diversity indexes were computed using Pisces conservation SDR version 4 (Seaby and Henderson 2006).The indexes are as follows.

3.2.6.6.5.1 Alpha diversity index

(i) Shannon-Wiener Index

The Shannon-Wiener (also incorrectly known as Shannon-Weaver) diversity index for each sample is calculated. The function was originally devised to determine the amount of information in a code or signal, and is defined as:

$$H = -\sum_{i=1}^{S} p_i \log_e p$$

Where p_i = the proportion of individuals in the i^{th} species. Species Diversity &Richness calculates the index using the natural logarithm.

In terms of species abundance:

$$H = \log_e N - \frac{1}{N}\sum_{i=1}^{\infty} (p_i \log_e p_i)n_i$$

Where n_i = the number of species with i individuals. The information measure is nits for base e and bits per individual for base 2 logarithms.

According to Southwood and Henderson (2000) this diversity index is an insensitive measure of the character of the S: N relationship and is dominated by the abundant species". The value of the Shannon-Wiener Index usually lays between1.5 and 3.5 for ecological data and rarely exceeds 4.0. (May 1975). To compare the indices a randomization test for a significant difference in diversity between two samples is be undertaken (Solow 1993, 1994).

(ii) Simpson's Index

A diversity index is proposed by Simpson (1949), to describe the probability that a second individual drawn from a population should be of the same species as the first. A similar type of index had a few years earlier been proposed by G. Yule. The statistic, C (or Y) is given by:

$$C = \sum_{i}^{S_{obs}} p_i^2$$

Where, S_{obs} is the number of observations and, strictly,

$$p_i^2 = \frac{N_i(N_i - 1)}{N_T(N_T - 1)}$$

but is usually approximated as:

$$p_i^2 = \left(\frac{N_i}{N_T}\right)^2$$

Where N_i is the number of individuals in the i^{th} species and N_T the total individuals in the sample. The index is:

$$D = \frac{1}{C}$$

and the larger its value the greater the diversity

The statistic 1 - C gives a measure of the probability of the next encounter (by the collector) being with another species (Hurlbert 1971). May (1975) show that this index is strongly influenced for values of $S_{OBS} > 10$ by the underlying distribution. As Magurran (2004) states "Simpson's Index is heavily weighted towards the most abundant species in the sample, while being less sensitive to species richness." However Magurran (2004) also states "The Simpson index is one of the most meaningful and robust diversity measures available. In essence it captures the variance of the species abundance distribution. To compare the indices a randomization test for a significant difference in diversity between two samples is be undertaken (Solow 1993).

(iii) Margalef D

It is calculated as the species number (S) minus 1 divided by the logarithm of the total number of individuals (N).

$$D = \frac{(S-1)}{\ln N}$$

To compare the indices a randomization test for a significant difference in diversity between two samples is be undertaken (Solow 1993).

(iv) Berger-Parker Dominance

A simple index that was considered by May (1975) to be one of the best. It is simple measure of the numerical importance of the most abundant species.

$d = N_{max} / N$

Where N_{max} is the number of individuals in the most abundant species and N is the total number of individuals in the sample. The reciprocal of the index, 1/d, is often used, so that an increase in the value of the index accompanies an increase in diversity and a reduction in dominance. We plot the dominance index d. To compare the indices a randomization test for a significant difference in diversity between two samples is be undertaken (Solow 1993).

(v) McIntosh D

Proposed by McIntosh (1967) as:

$$D = \frac{N-U}{N-\sqrt{N}}$$

Where N is the total number of individuals in the sample and U is given by the expression:

$$U = \sqrt{\sum n_i^2}$$

Where n_i is the number of individuals in the i^{th} species and the summation is undertaken over all the species. U is the Euclidean distance of the community from the origin when plotted in an S-dimensional hyper volume. To compare the indices a randomization test for a significant difference in diversity between two samples is be undertaken (Solow 1993).

(vi) Brillouin D

The Brillouin index, HB, is calculated using:

$$HB = \frac{\ln N! - \sum_{i=1}^{s} \ln n_i!}{N}$$

Where N is the total number of individuals in the sample, ni is the number of individuals belonging to the i^{th} species and S the species number. The Brillouin index measures the diversity of a collection, as opposed to the Shannon index which measures a sample. Pielou (1975) recommends this index in all situations where a collection is made, sampling was non-random or the full composition of the community is known. The value obtained rarely exceeds 4.5 and both the Brillouin and Shannon Indices tend to give similar comparative measures. To compare the indices a randomization test for a significant difference in diversity between two samples is be undertaken (Solow 1993).

(vii) Fisher's alpha

This is a parametric index of diversity that assumes that the abundance of species follows the log series distribution:

$$\alpha x, \frac{\alpha x^2}{2}, \frac{\alpha x^3}{3}, \ldots\ldots \frac{\alpha x^n}{n}$$

Where each term gives the number of species predicted to have 1,2,3,....n individuals in the sample. The index is the alpha parameter. A number of authors argue strongly in favour of this index (Kempton, and Taylor 1976). To compare the indices a randomization test for a significant difference in diversity between two samples is be undertaken (Solow 1993).

(viii) Q statistic

This infrequently-used diversity measure was proposed by Kempton and Taylor (1976). It measures the interquartile slope of the cumulative abundance curve and is estimated by:

$$Q = \frac{\frac{1}{2}n_{R1} + \sum_{R1+1}^{R2-1} n_r + \frac{1}{2}n_{R2}}{\log(R2/R1)}$$

where n_r = the total number of species with abundance R;

S = the total number of species in the sample;

R1 and R2 the 25% and 75% quartiles of the cumulative species curve;

n_{R1} = the number of individuals in the class where R1 falls;

n_{R2} = the number of individuals in the class where R2 falls.

To compare the indices a randomization test for a significant difference in diversity between two samples is be undertaken (Solow 1993).

(ix) Menhinick Index

Menhinick's index, D_{mn} (Whittaker 1977), is calculated using:

$$Dmn = \frac{S}{\sqrt{N}}$$

where N is the total number of individuals in the sample and S the species number. To compare the indices a randomization test for a significant difference in diversity between two samples is be undertaken (Solow 1993).

(x) Strong's Index

Strong's dominance index, D_w (Strong 2002) is calculated using:

$$Dw = \max_i \left[\left(\frac{b_i}{Q} \right) - \frac{i}{R} \right]$$

Where b_i is the sequential cumulative totaling of the i^{th} species abundance values ranked from largest to smallest;

Q is the total number of individuals in the sample;

R is the number of species in the sample and max_i is the largest calculated i^{th} values

To compare the indices a randomization test for a significant difference in diversity between two samples is be undertaken (Solow 1993).

3.2.6.6.5.2 Evenness index

Equitability or evenness refers to the pattern of distribution of the individuals between the species. The following evenness indices were computed.

(i) Pielou J (All samples)

This measure of equitability compares the observed Shannon-Wiener index against the distribution of individuals between the observed species which would maximize diversity. If H is the observed Shannon-Wiener index, the maximum value this could take is log(S), where S is the total number of species in the habitat. Therefore the index is:

J = H/log(S).

(ii) McIntosh E

This is an equitability measure based on the McIntosh dominance index. McIntosh E is defined as (Pielou 1975):

$$D = \frac{N - U}{N - N/\sqrt{S}}$$

Where N is the total number of individuals in the sample and S is the total number of species in the sample.

(iii) Brillouin E

Evenness (E) for the Brillouin diversity index (HB) is calculated using:

$$E = \frac{HB}{HB_{MAX}}$$

where HB_{MAX} is calculated as:

$$HB_{MAX} = \frac{1}{N}\ln\frac{N!}{\{[N/S]!\}^{s-r}.\{([N/S]+1)!\}^{r}}$$

with [N/S] = the integer of N/S, and r = N – S[N/S]

(iv) Heip

The Heip evenness measure (Heip 1974) is defined as:

$$E = \frac{(e^H - 1)}{(S - 1)}$$

where

H is the Shannon diversity index and

S is species number.

Heip (1974) developed this index to remove the dependence on S that earlier indices possessed. This index remains constant when the numbers of all species is multiplied by a constant.

(iii) Simpson's E

This index is based on Simpson's diversity index, D and is defined as:

$$E = \frac{1/D}{S}$$

where D is Simpson's diversity index and

S is the number of species.

Krebs (1989) noted that for continuous data or data with large numbers of records the maximum value for Simpson's D is 1/S.

(iv) NHC

NHC is an abbreviation of Nee, Harvey and Cotgreave's evenness measure.

$$E = -2/\pi \arctan(b)$$

where b is the slope of the log abundance - rank curve fitted by linear regression. This is also termed the slope of the dominance-diversity curve.

(v) Camargo

The Camargo evenness index (Camargo 1993) is defined as:

$$E = 1 - \left[\sum_{i=1}^{S} \sum_{j=i+1}^{S} \left(\frac{p_i - p_j}{S} \right) \right]$$

where

pi is the proportion of species i in the sample;

pj is the proportion of species j in the sample and

S is the total number of species.

(vi) Smith & Wilson B

Smith and Wilson's evenness index B (Smith and Wilson 1996) is defined as:

$$E = 1 - \left[\frac{2}{\pi \arctan \left\{ \sum_{i=1}^{S} \left(\ln n_i - \sum_{j=1}^{S} \ln n_j / S \right)^2 / S \right\}} \right]$$

where

n_i is the number of individuals in species i;

n_j is the number of individuals in species j and

S is the total species number.

This index is based on the variance in abundance. The variance is calculated using log abundances which mean the index examines proportional differences between species. The variance obtained is multiplied by the factor -2/pi arctan() to give an index with the range 0 to 1 with 0 representing minimum evenness.

(vii) Smith & Wilson 1-D

Smith and Wilson's evenness index 1-D (Smith and Wilson 1996) is defined as:

$$E = \frac{1-D}{1-\frac{1}{S}}$$

where

D is Simpson's diversity index and

S is the total number of species.

(viii) Smith & Wilson -lnD

Smith and Wilson's evenness index 1/D (Smith and Wilson 1996) is defined as:

$$E = \frac{-\ln D}{\ln S}$$

where

D is Simpson's diversity index and

S is the total number of species.

(ix) Shannon maximum

This is simply the maximum value the Shannon-Wiener index could produce for the given data set and is given by ln(S), where S is the total number of species.

(x) Shannon minimum

This is simply the minimum value the Shannon-Wiener index could produce for the given data set and is given by

$$S\min = \ln(N) - \left[(N-S+1)\ln(N-S+1)/N\right]$$

where

N is the total number of individuals in the sample and

S is the total number of species.

(xi)Gini

The Gini coefficient is defined as (Gini 1912):

$$E = \frac{2}{mS^2}\left(\sum_{i=1}^{s}(S+1-i)x_i\right) - \frac{1}{S}$$

Where

S is the number of species in the sample

x_i is the abundance of the i^{th} species ranked from least to most abundant, i = 1 to S and

m is the mean abundance of a species - the mean of the x_i values.

The Gini coefficient is a measure of inequality developed by the Italian statistician Corrado Gini and published in his 1912 paper "Variabilità e mutabilità". It is usually used to measure income inequality, but can be used to measure any form of uneven distribution. The Gini coefficient is a number between 0 and 1, where 0 corresponds with perfect inequality and 1, corresponds with perfect equality (where each species has the same abundance). If every species has the same abundance then the species rank curve would be a straight line at 45 degrees. Because of inequalities in abundance the actual curve lies below this line. The Gini coefficient is ratio of the areas below these curves. These indices were bootstrapped for 95 % confidence limit and the Jackknife standard error was calculated for each index.

Species diversity incorporates both richness (measured as number of species) and evenness (measured as relative abundance of species). It is thus a function of the number of species and the evenness of the distribution of species abundance (Magurran 1988, Purvis and Hector 2000). No single diversity index can fully capture the complex patterns in species richness and relative abundances (evenness) inherent in natural systems (Hulbert 1971, Peet 1974, De Jong 1975). Little consensus has been reached as to how diversity should be measured and interpreted. Wide ranges of analytical techniques are commonly used (Peet 1975, Magurran 1988 and Smith and Wilson 1996). Measurement of diversity is also strongly influenced by spatial and temporal scales i.e. sampling frequency and sampling intensity (Small and Mc Carthy 2002).

(c) Randomizations

After a diversity index method has been run, a randomization test for a significant difference in diversity between two samples is undertaken. The method used is described by Solow (1993, 1994). The following procedure is followed

1. The diversity of each of the samples is calculated and the difference between these indices (delta) calculated.
2. The two samples to be tested for a significant difference in their index are added together to form a single joint sample.
3. The individuals in this joint sample are then randomly assigned to two samples each of which has the same number of individuals as the actual two samples.
4. The diversity index for each of these generated samples is then calculated and the difference between these indices (delta) is stored.
5. 10,000 random assignments and calculation of delta are undertaken.
6. The observed value of delta is compared against the observed distribution of delta values generated at random to determine if the observed value for the

difference between the indices of the two samples could have been generated by random chance.

7. If the observed value of delta is greater than that observed from 95% of the randomisations then a one-tailed test will find sample 1 to be significantly more diverse than sample 2.

8. If the absolute magnitude of the difference is greater than 95% of the absolute differences of the index generated at random then there is a significant difference between the indices.

3.2.6.6.5.3 Diversity ordering methods

Diversity indices weight species richness by relative abundance and allow comparisons of areas. Different diversity indices may differ in the ranking they give to communities (Hurlbert 1971, Tóthmérész 1995). Such inconsistencies are an inevitable result of summarizing both relative abundance and species number using a single number (Patil and Taillie 1979). When comparing the diversity of samples it is important to consider if the relative diversity changes with the diversity index used. If it does, then it is clear that any arguments based on relative magnitude of the index might not be robust. A single diversity index is not a good indicator that one community is more diverse than the other, since it can only be richer, or only be more even than another community.

To compare the entire diversity of communities, diversity-ordering methods have been developed. Diversity profiles offer a solution to this problem by identifying those communities that are consistent in their relative diversity. This requires the use of a diversity index family, of which there are a number to choose from (Tóthmérész 1995). Diversity ordering allows the relative magnitude across a range of indices to be compared. A range of diversity indices within a family shows varying sensitivity to rare and abundant species. These profiles display graphically, a family of diversity indices obtained by changing the scale parameter *a*. Diversity ordering results in a line for every sample. Two diversity-ordering methods have been used. The methodology used is as described below.

(i) The Rényi's family (Rényi, 1961 & Hill 1973)

This is a one-parametric diversity index family, which offers a scale-dependent characterization of the diversity. It is portrayed graphically by plotting diversities against a (scale) parameter. This curve is the diversity profile of the assemblage (Patil and Taillie 1979). Members of a one-parametric diversity index family have varying sensitivities to the rare and abundant species as the scale parameter changes. Tóthméréz 1995 showed that the Rényi profile is one of the most useful diversity ordering techniques. It is based on the concept of entropy. Rényi diversity index family has been recommended for a large set data. Here

$$H_\alpha = \left(\log \sum_{i=1}^{s} p_i^\alpha\right) \Big/ (1-\alpha)$$

where α is the order ($\alpha \geq 0$, $\alpha \neq 0$), pi the proportional abundance of the ith species and log the logarithm to a base of choice - often e.

Hill (1973) used an almost identical index N_α which is related to H_α by the equality

$$H_\alpha = \log(N_\alpha)$$

When substituting 0, 1 or 2 for scale parameter α, H_α will be directly related to the species number (i.e. the log of the species number), Shannon entropy and Simpson's dominance index respectively (Hill 1973). Thus for a near 0, richness will have more effect on H_α. But for larger values of the scale parameter species evenness has more effect. For scale parameters, which increase from 1 to 4 the influence of rare species, will be gradually replaced by the influence of dominant species. One community is more diverse than the other if its' diversity profile is equal to or above that of another, over the whole range of scale parameter. If the two profiles intersect at any point the communities can be considered non- comparable (i.e. different diversity indices would rank the communities differently). Evidently, the species richness is extremely sensitive to the rare species: detecting even only one individual of a species increases the number of species by 1. Just the opposite is the sensitivity of the Berger-Parker index of dominance: its value depends only on the dominance (relative frequency) of the most frequent species. These two traditional (classical) diversity indices are the starting and the end point of the scales of the Rényi diversity index family (Tóthmérész 1995, Southwood and Henderson 2000).

(ii) Right tailed sum (Liu et al 2007)

The proportion of the total community made up of each species is arranged in descending order of abundance. Given a total of S species and a proportion of each species given by p_j, then I_i is calculated as a coordinate pair where *'i'* is the number of species which are excluded from the summation, termed the order:

$$I_i = \left(i, \sum_{j=i+1}^{s} p_j \right)$$

Therefore in a sample where many species have a similar abundance, the plot will descend slowly with increasing number of species, whereas in a sample heavily dominated by large numbers of just a few species, the plot will drop away steeply as species number increases.

3.2.6.6.6. SHE analysis

The data was examined using SHE analysis (SHE: S = richness, H= H'diversity, E= evenness; Buzas and Hayek (1996) and Hayek and Buzas 1997). SHE analysis is a recently developed technique for diversity assessment that allows independent yet simultaneous evaluation of the relative contribution of richness and evenness to community diversity across sampling scales.

Critical to the analysis of diversity in rubber plantations is the understanding of S (species richness), H'(information measures as DI) and E (evenness). The separation of species richness and evenness as distinct components within the same system and the disassociation of diversity with sample size have been two intractable problems associated in biodiversity analysis. This is because H' may not vary at all even in the face of increasing species richness and in the other case H'can increase while E remains constant. An amazingly simple solution for this has been recently been derived (Buzas and Hayek (1996) and Hayek and Buzas 1997). Understory diversity patterns were assessed using observed richness (S; the number of species per sample), Shannon- Wiener diversity ($H' = -\sum p_i \text{in } p_i$, where p_i is the proportion of individuals of the i[th] species; Shannon and Weaver 1963), evenness ($E = e^{H'}/S$); the proportional abundance of species in each sample (Buzas and Gibson 1969).

In SHE analysis, the relative contribution of richness and evenness to H'diversity is partitioned using the decomposition formula $H' = In(S) + In(E)$. The equation is incisive, because for the first time, there is a direct decomposition of H'. Here H' is not used as a diversity measure per se, but rather as a vehicle to the decomposition of S and E. The SHE analysis decomposition equation is derived from the following conditions: (1) Maximum H' diversity occurs when all species are equally distributed ($H'_{\max} = In(S)$) and (2) E is related to H' by the equation $E = e^{H'}/S$. Thus the SHE decomposition formula, $H' = In(S) + in(E)$ indicates that H' diversity equals its maximum value, In*(S)* less the amount of unevenness In*(E)* (Subtracted because evenness is ≤ 1 and In*(E)* will be ≤ 0). In this way SHE analysis partitions H' diversity into richness and evenness components and allows independent evaluation of their contribution to H'.

Using SHE analysis In*(S)*, In*(E)* and H' were calculated cumulatively, with the addition of each sample. Results were examined graphically to evaluate relationship among diversity measures in the sampled areas. SHE analysis is also used to infer the species abundance distribution best representing each sample community, based on Hayek and Buzas in 1997and 1998. Species abundance distributions are statistical distributions that model the relative abundances of species in a community. These distributions are often used to describe the pattern of community organization or resource partitioning. Hayek and Buzas (1997, 1998) found that the broken stick distribution (Mac Arthur 1957) was distinguished by a constant In *(E)* across samples, the log series (Fisher *et. al* 1943) by constant H' across the range of samples and log normal distribution (Preston 1948) by a constant ratio of In*(E)*/ In*(S)* (Hayek and Buzas 1997).

3.2.7 Community analysis

3.2.7.1 Similarity measures

Two measures of similarities were used to test for similarities between and within the groups RP, OP and Forest. All similarity measures were undertaken using Community analysis package version 4.0 (Henderson and Seaby 2007).

(a) Analysis of similarity (ANOSIM)

This test was developed by Clark (1988, 1993) as a test of the significance of the groups that had been defined *a priori*. The idea is simple, if the assigned groups are meaningful, samples within groups should be more similar in composition than samples from different groups. The method uses the Bray-Curtis measure of similarity. The null hypothesis is therefore that there are no differences between the members of the various groups.

Clark (1988, 1993) proposed the following statistic to measure the differences between the groups:

$$R = \frac{\bar{r}_B - \bar{r}_W}{n(n-1)/4}$$

Where,

$\bar{r}B, \bar{r}W$ are the mean of the ranked similarity BETWEEN groups and WITHIN groups respectively and n is the total number of samples (objects). R scales from +1 to -1. +1 indicates that all the most similar samples are within the same groups. R = 0 occurs if the high and low similarities are perfectly mixed and bear no relationship to the group. A value of -1 indicates that the most similar samples are all outside of the groups.

To test for significance the ranked similarity within and between groups is compared with the similarity that would be generated by random chance. Essentially the samples are randomly assigned to groups 1000 times and R calculated for each permutation. The observed value of R is then compared against the random distribution to determine if it is significantly different from that which could occur at random. If the value of R is significant, you can conclude that there is evidence that the samples within groups are more similar than would be expected by random chance.

(b) Similarity Percentages (SIMPER)

This analysis breaks down the contribution of each species (or other variable) to the observed similarity (or dissimilarity) between samples. It will allow you to identify the species that are most important in creating the observed pattern of similarity. The method uses the Bray-Curtis measure of similarity, comparing in turn, each sample in Group 1 with each sample in Group 2. The Bray-Curtis method operates at the species level and therefore the mean similarity between Groups 1 & 2 can be obtained for each species.

3.2.7.2 Ordinations

Ordination primarily endeavors to represent sample and species relationships as faithfully as possible in a low-dimensional space (Gauch 1982). The objective of the ordination is to help generate hypotheses about the relationship between the species composition at a site and the underlying environmental gradients (Digby and Kempton 1987). Various Ordination plots were plotted to explore the vegetation structure of the three sites and their sub samples. Ordination has a number of multivariate techniques which adapt a multi dimensional swarm of data points in such a way that when it is projected into a 2 or 3 dimensional space. Any intrinsic pattern that the data may possess becomes apparent for visual inspection (Pielou 1984). It summarizes community data such as species abundance by producing a low dimensional space in which similar species and samples are plotted close together, and dissimilar species and samples are places far apart. All ordinations were undertaken using Community analysis package version 4.0 (Henderson and Seaby 2007).

(a) Principal Components Analysis – PCA

Principal component analysis (PCA) is one of the most frequently used ordination techniques in community ecology (Legendre and Legendre 1998, Digby and Kempton 1987, Kent and Coker 1992). When this analysis is undertaken on the variance-covariance matrix, it will reflect differences in abundance (Community analysis package version 4.0, Henderson and Seaby 2007). PCA will present major features of a complex community in only 2 or 3 dimensions and the ordination of samples (sites) along these new axes can be related to underlying environmental factors that are molding community structure.

PCA is a technique that may summarize the relationship between the samples in a small number of axes that can be plotted. For such a summarization to work, there must be some degree of correlation between the descriptive variables so that the effect of a number of these variables can be combined into a single axis (Digby and Kempton 1987, Kent and Coker 1992 and Legendre and Legendre 1983). PCA is undertaken on the variance-covariance matrix between the descriptors (the variables in the rows) using Community analysis package version 4.0.

(b) Non-Metric Multidimensional scaling

Multidimensional scaling (MDS) is a technique for expressing the similarities between different objects in a small number of dimensions.This allows a complex set of inter-relationships to be summarised in a simple figure. The method attempts to place the most similar objects (samples) closest together. The starting point for the calculations is a similarity or dissimilarity matrix between all the sites or quadrats. These can be non-metric distance measures for which the relationships between the sites/objects/samples (columns) cannot be plotted in a Euclidean space. The aim of non-metric MDS is to find a set of metric coordinates for the sites which most closely approximates their non-metric distances. The basic MDS algorithm is as follows:

1. Calculate the similarity or dissimilarity between sites.
2. Assign to each site a set of coordinates in p-dimensional space. These coordinates can be either chosen at random or chosen using Principal Coordinates Analysis. The value of p is chosen by the user.
3. Compute the Euclidean distance between these sites using the starting coordinates.
4. Compare the original dissimilarity between the sites with these Euclidean distances by calculating a stress function. The smaller the stress function the closer the correspondence.
5. Adjust the positions such as to reduce the stress.
6. Repeat 2 to 4 until the stress is minimized or the maximum number of iterations is reached.

The Kruskals's least squares monotonic transformationhas been used to minimise the stress (Kruskal 1964, Kruskal and Wish 1977).

3.2.8 Allelopathy

Water soluble phenolics have been preferred as primary allelochemicals because of their relatively easy identification and ready availability (Inderjit and Dakshini 1990, 1992, Alsaadawi *et al.* 1985).

3.2.8.1 Bioassay

Aqueous leachate was prepared by soaking freshly fallen dried leaves of *Hevea brasiliensis* (10gm/100ml) in sterile distilled water for 12 hours. This leachate was filtered through Whatman paper No. 1. To prevent contamination sterilized glass wares were used. Two layers of Whatmann filter paper were places in each sterilized Petri dish (60mm). Aqueous leachate was diluted to different dilutions viz. 10%, 5%, 2.5% and 1.25%.

Bioassays were performed under sterile conditions in a. Rice seeds *Oryza sativa* var.uma were germinated in Petri dishes (60 mm) containing 20ml of aqueous leachate of different dilutions prepared. For controls, Rice seeds were germinated in 20 ml of pure distilled water in a similar petri dish. Observations were made after 24 hours for 5 days. On the 5th day the length the plumule and radicle was measured using a millimeter scale and noted.

3.2.8.2 Viability tests

Seeds collected from the selected plants plant species found as undergrowth in the plantations were tested for viability. This was done by collecting the seeds and placing them in 60 mm Petri dishes with 20 ml distilled water. The seeds are observed at 24-hour interval and the number of seeds germinated is noted. The water was replenished in 5 ml volumes as per requirement. This experimental set up was kept for 20 days.

Chapter 4

Results

4.1 Sampled Area

In total 144 herb quadrats (of the size 0.25 m^2), 62 undershrub quadrats (of th size 9.0m^2) and 3 tree quadrats (of the size 10000 m^2 each) were sampled. A total of 54. m^2 of herbs, 4571 m^2 of undershrubs and 30000 m^2 area of trees were sample respectively (Table 4.1). Details of site characteristics and disturbance levels in the fiv sites are tabulated in Table 4.2.

Table 4.1 Description of the study sites and quadrat size in the Rubber plantations (RP) Open areas (OP) and Forest areas for herb quadrats (HQ), undershrub (UQ and tree quadrats (TQ).

S no	Site sampled	R_P		OP		Forest		
		HQ (0.25m^2)	UQ (9sq.m^2)	HQ (0.25m^2)	UQ (9sq.m^2)	HQ (0.25m^2)	UQ (9sq.m^2)	TQ (10000m^2
1	Neezhoor	16	16	6	6	0	0	0
2	Puthupally	20	20	8	8	0	0	0
3	Pampadi	14	14	3	3	0	0	0
4	Chetheckal	16	16	3	3	3	3	1
5	Mundakayam	15	15	3	3	12	18	1
6	Thenmala	11	11	4	4	10	14	1
7	Total no. of quadrats sampled in the three districts	92	92	27	27	25	35	3
8	Total area sampled in Sq. m	23	828	6.75	243	25	3500	30000
	Total area sampled in Hectares	0.0023	0.082	0.00067	0.024	0.0025	0.35	3
	Total area of each type of area sampled in hectares	3754.2		-		-		

Table 4.2 Disturbance scores of the sampling sites.

Variable site attributes	Site														
	Rubber Plantations						Open areas						Forest		
	Neez.	Puthu.	Pamp.	Mund.	Then.	Chet.	Neez.	Puth.	Pamp.	Mund	Then.	Chet.	Ranni	Mund.	Then.
Area(ha)	5	30	27	2835	608	250	-	-	-	-	-	-	-	-	-
Altitude(m)	80m	73m	60m	180m	100m	200m	80m	73m	60m	180m	100m	200m	200m	180m	100m
Ownership	M	M	M	M	M	M	UM	UM	UM	UM	UM	UM	P	P	P
Nearby plantations	rice	rp	rp	for.	for.	for.	rice	pw	pw	pw	for.	pw	rp	rp	rp
Weeding	0	0	3	6	5	4	0	0	0	0	0	0	0	0	0
Fertilizer	1	2	2	4	2	4	0	0	0	0	0	0	0	0	0
Insecticide	0	2	2	4	2	4	0	0	0	0	0	0	0	0	0
Pesticide	1	2	2	4	2	4	0	0	0	0	0	0	0	0	0
Surrounding plantations and settlements	3	1	3	2	0	1	5	5	5	3	1	2	2	1	0
Presence of pathways	1	2	3	1	0	1	6	5	5	3	1	0	0	0	0
Tree gaps due to felling	2	0	0	0	0	1	6	6	6	6	6	6	0	0	0
Rubber tapping	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
Livestock grazing	0	0	1	1	0	0	2	0	0	0	0	0	0	0	0
Nearness to roadways	2	1	2	1	0	1	6	5	4	4	1	0	1	0	0
Firewood collection	5	4	4	4	0	2	0	0	0	0	0	0	2	0	0
Total disturbance score	16	15	23	28	12	23	25	21	20	16	9	8	4	1	0

M- Managed **UM**- unmanaged **P**- protected **rp**- rubber plantations **for.**- forest **Neez.**- Neezhoor **pw**-pathway

Puth.- Puthupally **Pamp.**- Pampadi **Mund.**- Mundakayam **Then.**- Thenmala **Chet.**- Chetheckal

Rubber plantation areas **Open areas** **Forest areas**

4.2 Qualitative assessment

4.2.1 Floristic Survey

The floristic survey revealed a total number of 517 angiosperms, 1 gymnosperm and 21 pteridophytes in these areas. A detailed list of the plant species and the site from which it was sampled is given in Table 4.3 (Appendix).

The detailed qualitative floristic surveys of the sampled sites of the Rubber plantation areas (RP), Forest areas and the Open areas (OP) of Kottayam, Kollam and Pathanamthitta district, are given in Table 4.5 , 4.6 and 4.7(appendix). Taxonomic details of the plant species observed in these surveys are tabulate (Table 4.5, and 4.7 appendix). The tables also show the preferred habitat of the plant species identified, as compiled in the Biodiversity documentation of Kerala flora (Sasidharan 2004).

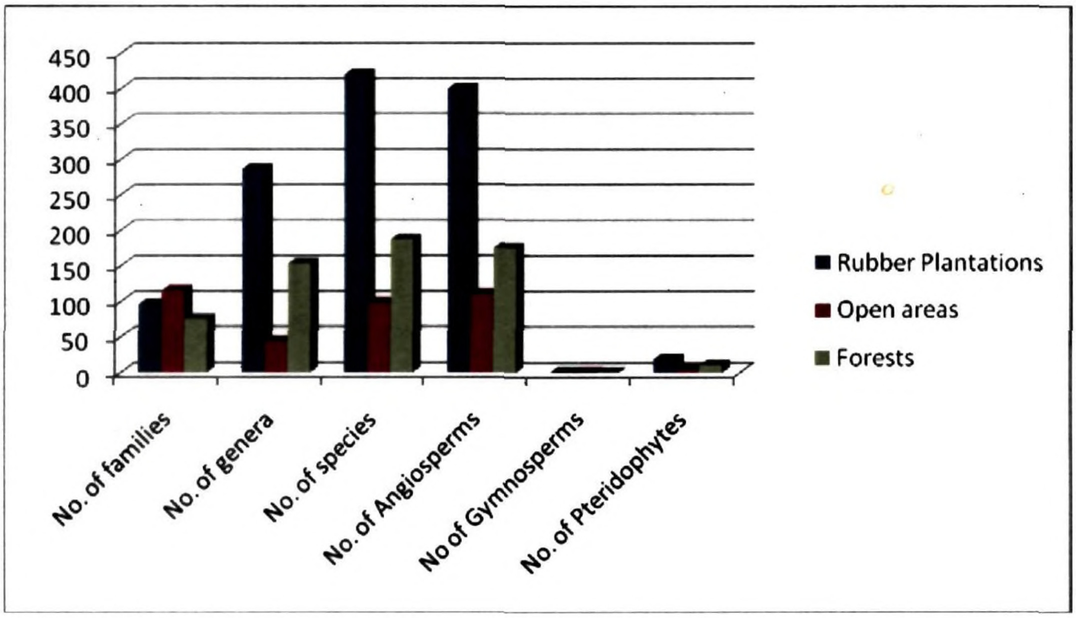
Table 4.4 Qualitative floristic composition of the sampled sites of the Rubber plantations, Open areas and Forest areas.

S. No.	Sampled site	No. of families	No. of genera	No. of species	No. of Angiosperms	No of Gymnosperms	No. of Pteridophytes
1	Rubber Plantations	96	286	420	400	1	19
2	Open areas	44	98	115	110	1	4
3	Forests	75	153	187	175	1	11

Qualitative Floristic surveys made in the rubber plantations sites, in the three districts reveals that there are 420 species, which belong to 96 families and 286 genera Table 4.4 and 4.5 (appendix). The survey reveals the presence of 400 Angiosperms, 19 Pteridophytes and 1 Gymnosperm. The survey of the Open areas show the presence of 115 species belonging to 44 families and 98 genera (Table 4.4, 4.6 (appendix)). There are 110 angiosperms, 1 Gymnosperm and 4 Pteridophytes in the OP areas. The Forests sampling sites show the presence of 187 species. They belong to 75 families and 153 genera (Table 4.4, 4.7 (appendix)). There are 175 angiosperms, 1 Gymnosperm and 11

Pteridophytes in the Forest sampling sites. A larger number of species were found in the RP areas as compared to the OP and Forest areas (Figure 4.1).

Figure 4.1 Qualitative floristic composition of the sampled sites of the Rubber plantations, Open areas and Forest areas.

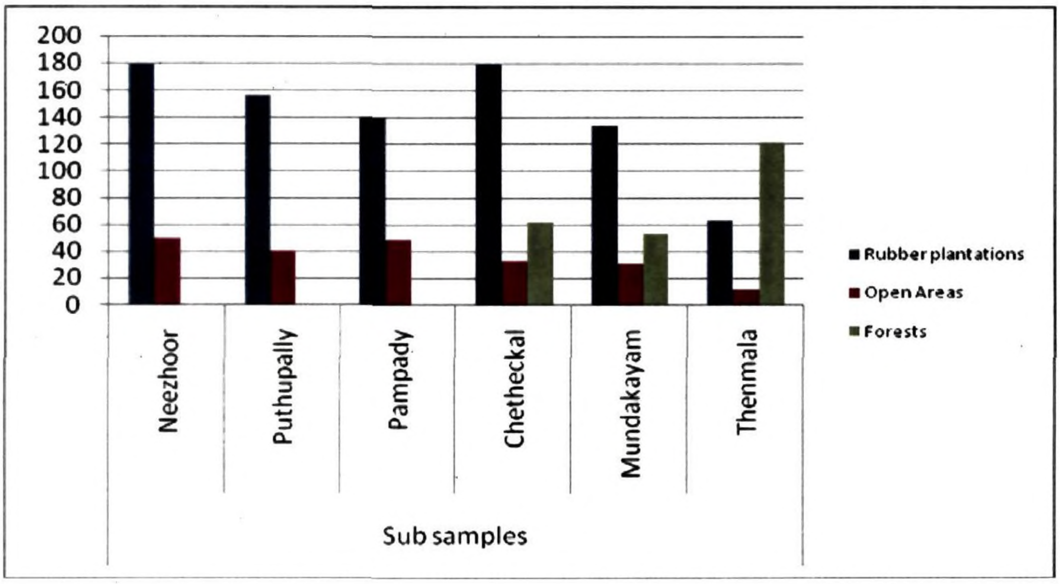


Each of these sampled sites is considered, a subset, within each category of the larger set (RP, OP and Forest area). The subsets are Neezhoor, Puthupally, Pampadi, Mundakaym, Chetheckal and Thenmala. A large number of plant species were observed in the qualitative survey of each sampled site (Table 4.8 and Figure 4.2).

Table 4.8 Number of species found in the qualitative floristic composition of the subsets of Rubber plantations, Open areas and Forest areas.

Area	Sub samples					
	Neezhoor	Puthupally	Pampadi	Chetheckal	Mundakayam	Thenmala
Rubber plantations	179	156	139	180	134	63
Open Areas	49	40	48	32	30	11
Forests	-	-	-	62	53	121

Figure 4.2 Number of species found in the qualitative floristic composition of the subsets of Rubber plantations, Open areas and Forest areas.



The highest numbers of plant species were observed in Chetheckal RP and Neezhoor RP. A total of 180 species in Chetheckal and 179 species in Neezhoor were observed in the qualitative floristic assessment of these areas. Thenmala RP showed the least number with 63 plant species. Comparatively lower number of species was observed in all the OP areas. Neezhoor OP had the highest number of plant species with 42 species and Thenmala OP had only 11 plant species. Among the Forest areas sampled adjacent to the rubber plantations, the highest number was observed in Thenmala Tropical forest with 121 plant species (Table 4.8 and Figure 4.2).

4.2.2 Relative diversity

There is a larger representation of species /family/ genera in the RP areas, than in the Forest and Open areas (Figures 4.3, 4.4 and 4.5). The family having the highest representation shows the highest Relative diversity index (RDI). The highest Relative diversity index (RDI) of OP, RP and Forest areas are 13.0, 8.33 and 4.81 respectively (Figures 4.3, 4.4 and 4.5). In the Forest areas the highest RDI are of the family *Fabaceae ,Rubiaceae* and *Apocyanaceae* (Figure 4.5*)*. The RP areas showed higher RDI of

Fabaceae, Euphorbiaceae and *Poaceae* (Figure 4.3). The RDI in the Open areas showed a higher representation of family *Poaceae, Asteraceae* and *Acanthaceae* (Figure 4.4).

Figure 4.3 Relative diversity index of the top ten families found in Rubber plantations. The number of genera and species found in each family is also shown.

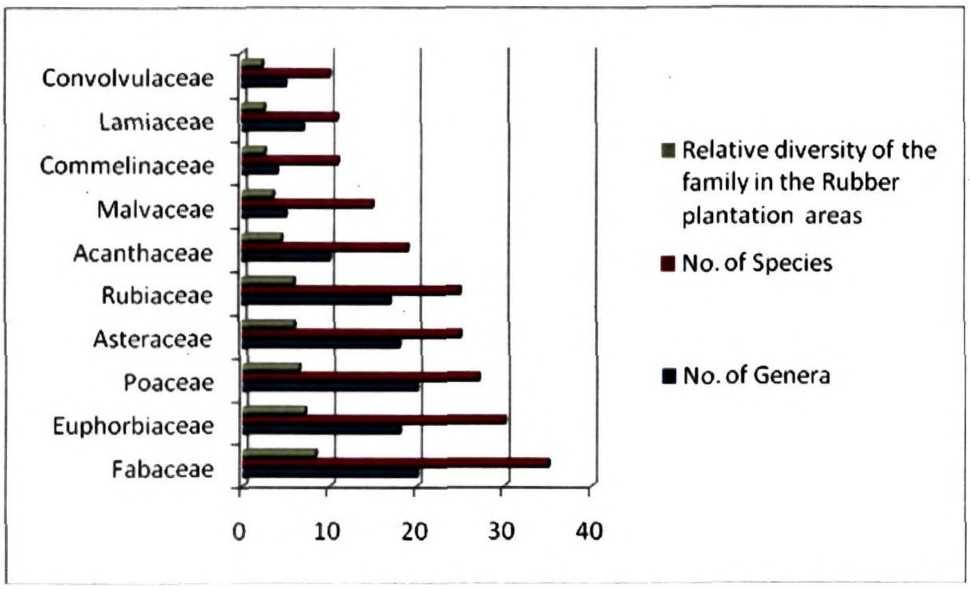


Figure 4.4 Relative diversity index of the top ten families found in Open areas. The number of genera and species found in each family is also shown.

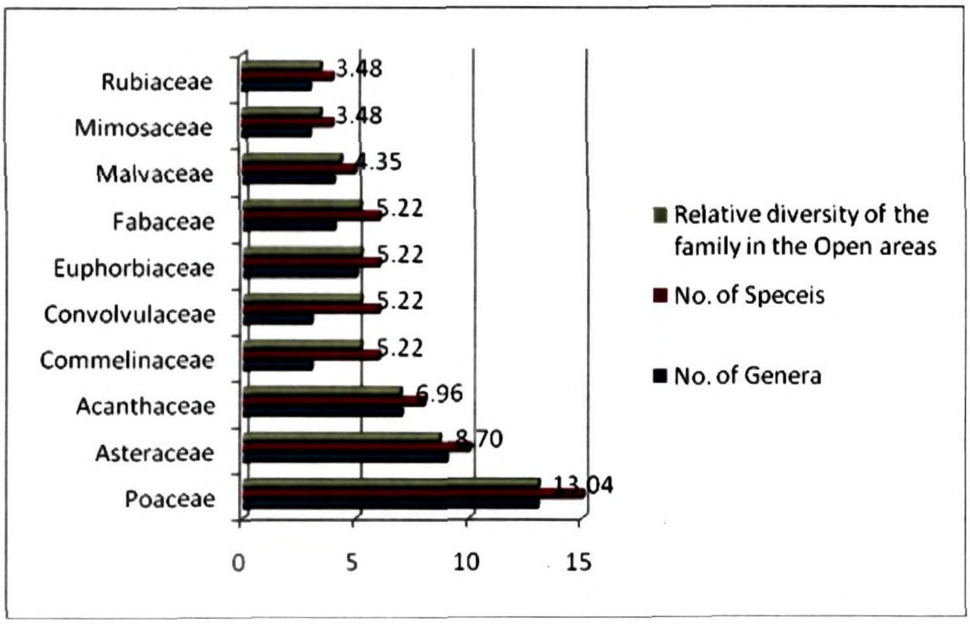
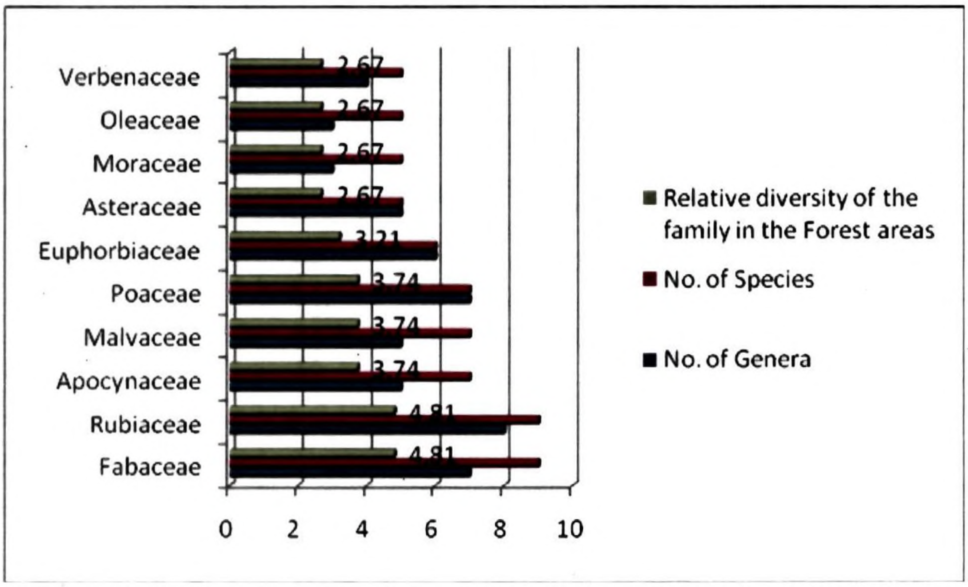
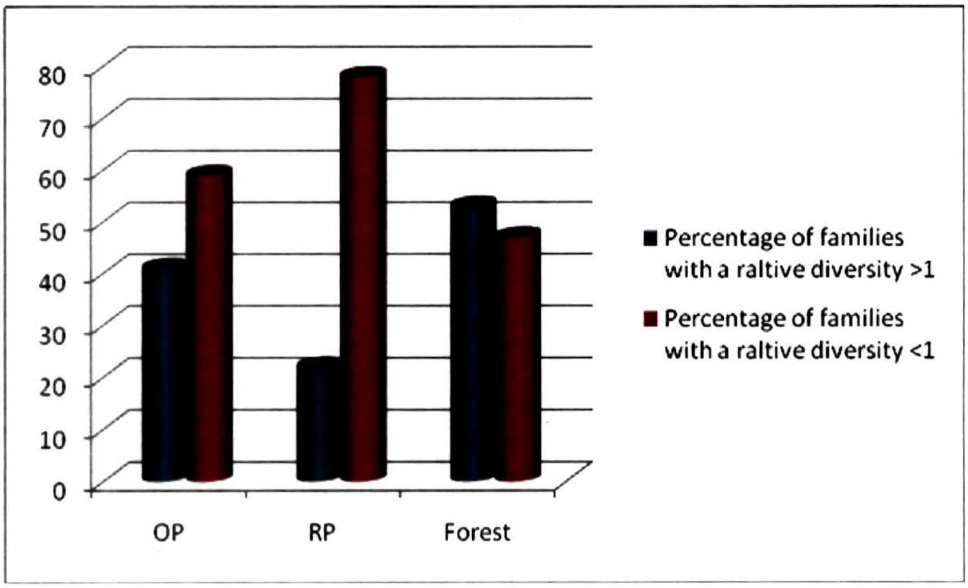


Figure 4.5 Relative diversity index of the top ten families found in Forest area. The number of genera and species found in each family is also shown.



The ten families having the highest relative diversity forms 61% of the total relative diversity in the OP areas whereas in the RP and Forest areas they represent 40%and 35% respectively. A large number of families represented by a single genera and single species in the RP areas (Figure 4.6).

Figure 4.6 Percentage of families with relative diversity of >1 and percentage of families with a relative diversity of <1 in the RP OP and Forest areas



4.2.3 Physiognomy

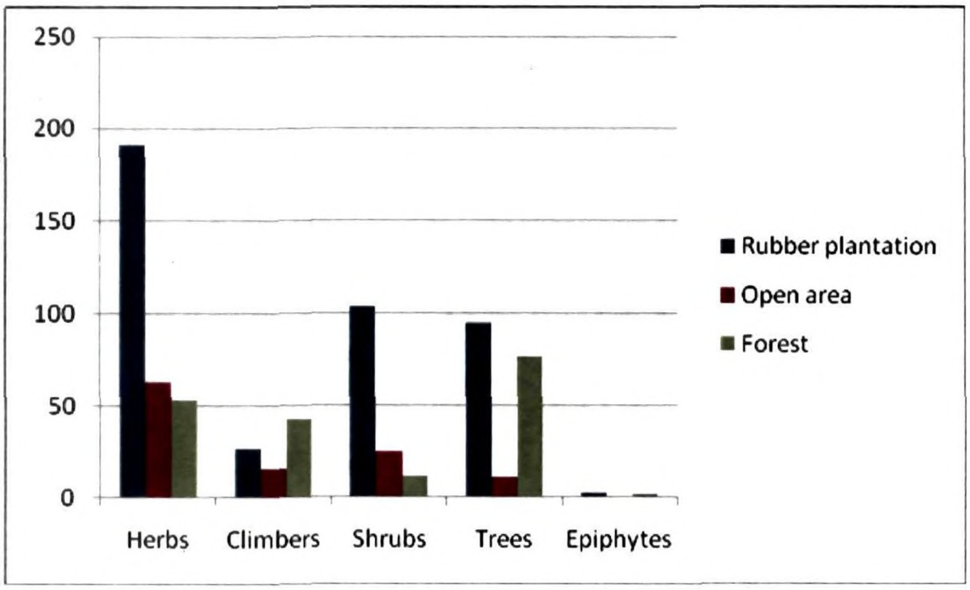
4.2.3.1 Habit

The qualitative floristic survey revealed the habit of the plants found in the three types of sites (Table 4.9 and Figure 4.7).

Table 4.9 Number of species under different habit types in the three ecosystems.

Habit type	Rubber plantation	Open area	Forest
Herbs	191	63	53
Climbers	27	16	43
Shrubs	104	25	12
Trees	95	11	77
Epiphytes	3	1	2

Figure 4.7 Number of species under different habit types in the three ecosystems.



A large number of herbs, shrubs and trees (saplings) are present in the rubber plantation areas. There are 221 herbs, 3 epiphytes, 104 shrubs and 95 trees (saplings) found in the ground flora of rubber plantations. In the Open areas there are 75 herbs, 1 epiphyte, 25 shrubs and 18 trees (saplings). In the Forest areas surveyed 53 herbs, 2 epiphytes, 57 shrubs and 77 trees were observed in sampled sites of Kottayam, Kollam and Pathanamthitta districts (Figure 4.7).

4.2.3.2 Vertical stratification and Growth forms

Qualitative floristic surveys revealed the major growth forms of the plants found in the three types of areas (Figure 4.7). The rubber plantations show the presence of herbs, shrubs, trees, climbers and very few epiphytes. The highest number of herbs, shrubs and trees were found in rubber plantations. The number of climbers and epiphytes were higher in the forests (Figure 4.7). There are 43 climbers in the forest, 27 in Rubber plantations and 16 in the Open areas. The numbers of epiphytes are low in all the three areas sampled (Table 4.9). The epiphytes in the forests, were found on the branches of tall trees and has resulted in the non sampling of the epiphytes.

Table 4.10 shows the vertical layering of the plant community viz. canopy, understory, shrub layer and ground layer, found in each types of the area sampled. Each major growth form shows a variety of minor forms, which is further, elaborated (Table 4.11).

Table 4.10 The vertical stratification of the RP, OP and the Forest areas as shown by the floristic survey of these areas in the Kottayam, Kollam and Pathanamthitta district. GF- growth form

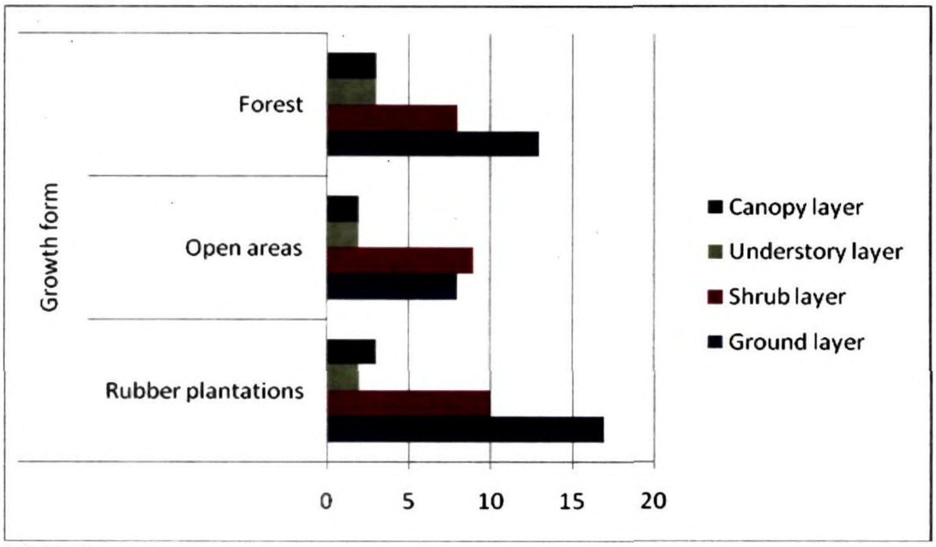
Vertical stratification	Rubber plantations		Open areas		Forest	
	GF	No. of Sp.	GF	No. of Sp.	GF	No. of Sp.
Ground layer	17	214	8	70	13	64
Shrub layer	10	111	9	26	8	45
Understory layer	2	44	2	12	3	32
Canopy layer	3	51	2	6	3	45

Table 4.11 Different growth forms and the numbers of species observed in each growth form in the vertical stratification of the three ecosystems.

S No	Vertical stratification	Growth forms	No. of species		
			Rubber plantations	Open areas	Forest
1	Ground layer	Creeping herbs	2	0	1
		Erect herbs	27	9	5
		Annual herb	114	42	29
		Perennial herbs	2	1	1
		Procumbent herb	1	0	0
		Prostrate herb	9	3	1
		Prostrate twining herbs	1	0	1
		Rhizomatous herbs	6	0	2
		Trailing herbs	2	1	1
		Tuberous herbs	1	1	0
		Twining herbs	1	0	0
		Woody herbs	1	0	2
		Terrestrial herb	18	4	7
		Lithophytic herb	0	0	1
		Aquatic herb	1	0	0
		Epiphyte	3	1	2
		Climbers	22	6	11
		Slender twiner	3	2	0
2	Shrub layer	Climbing shrub	25	4	12
		Diffused sub shrub	1	0	0
		Erect shrub	47	10	18
		Rambling shrub	1	1	1
		Scandent shrub	8	4	6
		Scandent sub shrub	1	0	0
		Small prickly shrub	1	1	0
		Sub shrub	18	5	5
		Twining shrub	2	0	1
		Woody climber	7	1	2
3	Understory layer	Small tree	43	11	31
		Small palm	1	1	1
		Climbing Palm	0	0	1
4	Canopy layer	Very large tree	1	0	2
		Large tree	20	2	21
		Medium tree	30	4	22

The number of minor growth forms which constitute each vertical layer, was found to be higher in the rubber plantations and the forests when compared to the Open areas. The total number of species in the ground and shrub layers is higher in the Rubber areas. The total number of species in the ground and shrub layers is higher in the Rubber plantations as compared to the Open areas and the Forests (Figure 4.8). The number of species and growth form in their canopy and understory layer are high in both the Forest and Rubber plantation areas (saplings found in RP areas are considered as mature trees).

Figure 4.8 - The number of the growth form and the number of species within each of the growth forms in the Rubber plantations, open areas and the Forest areas sampled in Kottayam, Kollam and Pathanamthitta district. GF-growth form



4.2.3.3 Life form spectrum

The life form spectrum of the RP, OP and Forest areas sampled in the three districts are depicted in Figures 4.9, 4.10 and 4.11 respectively. This has been compared to the Raunkiaer's Normal biological spectrum (NBS) of the world's phanerogamic flora of the Tropical rain forests (Figure 4.12).The rubber plantations show a deviation from the NBS of the tropical rain forests due to the high numbers of Phanerophytes and Therophytes in them. This deviation from the NBS of Tropical rain forest makes them more similar to the Raunkiaer's NBS of the Desert, where these life forms are abundant (Figure 4.13). The life form spectra of the forests sampled showed a deviation from the NBS of the Tropical rain forests, due to the relatively higher incidence of therophytes in them (Figure 4.11). The large representation of phanerogamic and Therophytic flora in the Rubber plantations is an indication of the succession trend of these plant communities towards a drier habitat.

Figure 4.9 - 4.13 The life form spectrum of the RP areas and the OP as compared to the Raunkiaer's NBS of the desert and the NBS of the world phanerogamic flora.

Figure 4.9 Life spectrum of the ground flora of rubber plantations

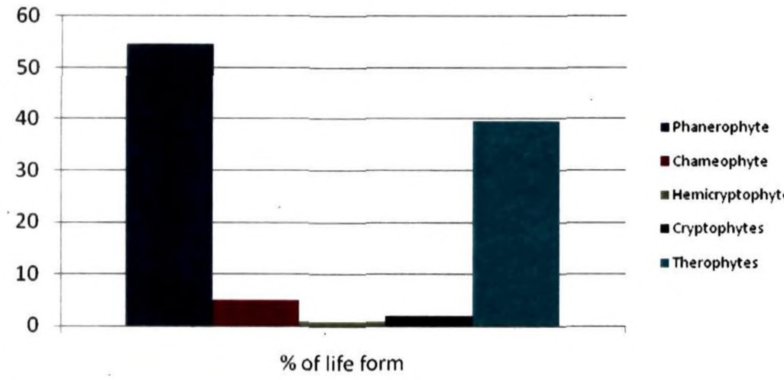


Figure 4.10 Life spectrum of the ground flora of open areas

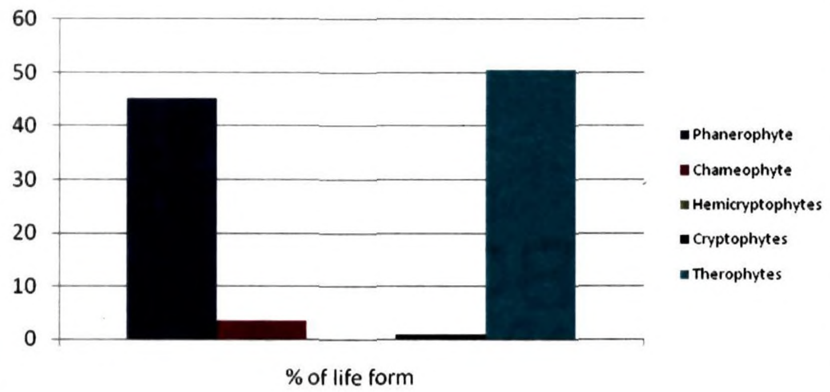
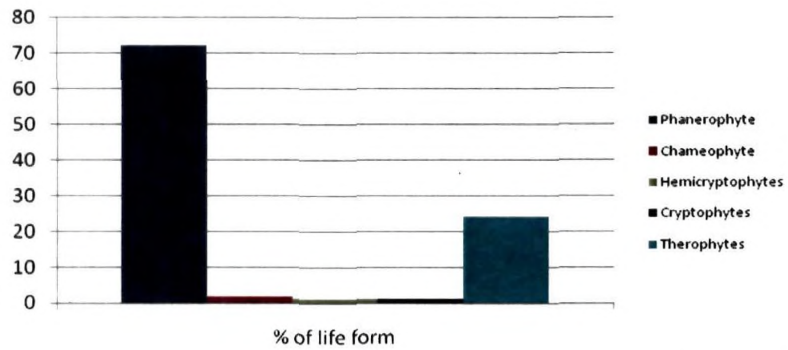
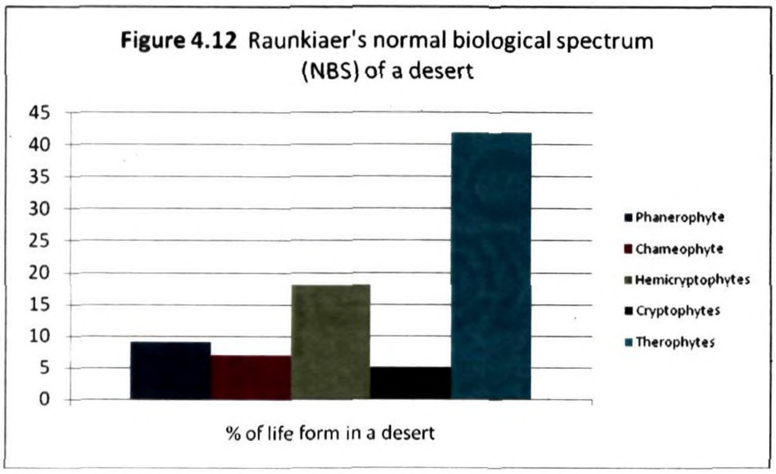
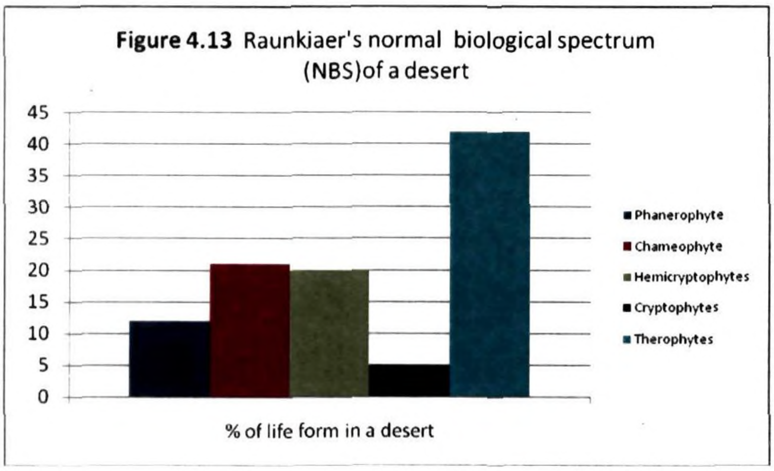


Figure 4.11 Life spectrum of the ground flora of the sampled forest areas







4.3 Medicinal plants

The medicinal plants found in the natural ground flora in RP, OP and Forest area are compiled (Table 4.12, 4.13 and 4.14 appendix). The RP areas have 160 medicinal plants belonging to 58 families. Seven medicinal plants in the RP areas are endemic. They are *Artocarpus hirsutus, Dalbergia horrida, Glochidion zeylanicum, Myxopyrum smilacifolium, Naragamia alata, Piper nigrum, Strobilanthus ciliatum.* Two medicinal plants *Naragamia alata, Piper nigrum* are in the vulnerable category (Nayar 1996). Out of the 420 plant species observed in the RP areas 38.1 % are medicinal plant species (Table 4.15 and Figure 4.14).

Table 4.15 Summary of the endemic and medicinal plants species in the three ecosystems.

	Open area	Rubber plantation	Forest
Total no. of medicinal plant species	43	160	91
Total no. of plant species	115	420	187
No. of endemic medicinal plants	0	7	6
% of plants that are medicinal	37	38.1	48.7

Figures 4.14 - 4.16 Percentage of the medicinal plants, endemic medicinal plants and the endemic plants found in the RP, OP and Forest areas.

Figure 4.14 Proportion of medicinal and endemic plants in Rubber plantations. The total number of plant species (N)= 420

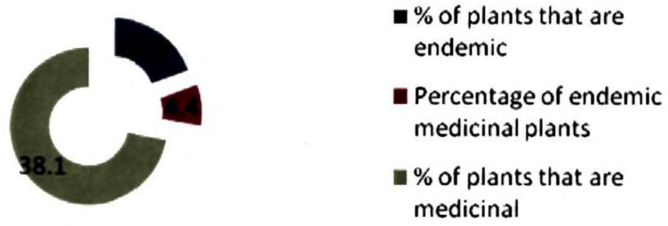


Figure 4.15 Proportion of medicinal and endemic plants in the Open areas sampled. The total number of plant species (N) = 115

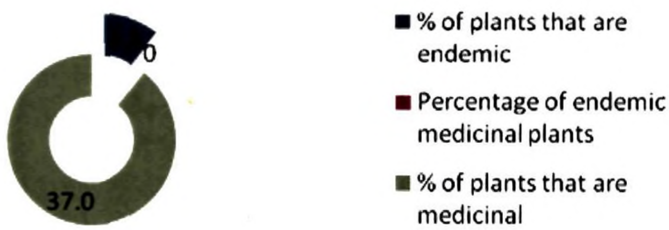
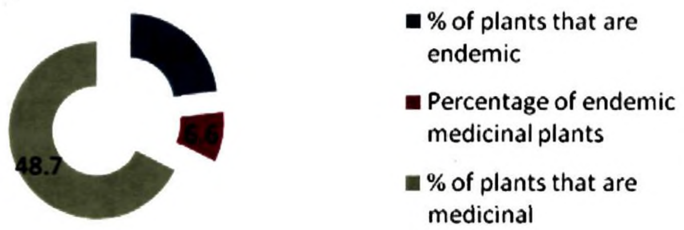


Figure 4.16 The proportion of medicinal and endemic plants found in the Forest areas.The total number of plant species (N)= 187



In the Forest area 91 medicinal plants belonging to 47 families were observed. Out of these six plant species were endemic medicinal plants. Out of the 187 plant species observed in the qualitative survey of the Forest area 48.7% are of medicinal value (Table 4.15, Figure 4.16). The endemic medicinal plant species in the forest area are, *Artocarpus hirsutus, Michelia nilagirica, Naragamia alata, Piper nigrum, Strobilanthus ciliatus, Tabernaemontana heyneana.* There are 43 medicinal plants belonging to 23 families in the OP areas surveyed. Out of the 115 plant species observed in these areas, 37% were medicinal plants. Endemic plants of medicinal value were not observed in these areas (Table 4.15, Figure 4.15).

4.4 Endemism

Out of the 420 plant species observed in the qualitative survey of the rubber plantations 43 plant species (10.2%) were endemic according to the IUCN red data book 2000 (Table 4.16 and Figure 4.14).

Table 4.16 Summary of the conservation status of plant species present in the three ecosystems viz. Rubber plantations (RP), Open areas (OP) and Forest areas.

S No.	*Conservation status (Endemic to...)	Plant species found in		
		RP	OP	Forests
1	Peninsular India	8	3	4
2	Central and Peninsular India	1	0	0
3	South India	3	1	5
4	Sri Lanka	1	0	0
5	South West India	1	0	0
6	South Western Ghats	16	1	7
7	Western ghats	9	0	7
8	Vulnerable IUCN 2000	5	0	2
9	Low risk conservation dependent	1	0	1
10	Rare	2	0	3
11	Threatened	1	0	0
12	Endangered	0	0	1
13	Possibly Extinct	0	0	1
	Total No. of endemic plants	48	5	31
	Total no. of species found in survey	420	115	187
	% of endemism	11.4	4.4	16.6

*Conservation status as per IUCN red data book 2000

Endemic plants are naturally restricted in their distribution due to specific habitat preferences. These plants belong to various categories of endemism and show various extents of geographic restriction. Some of these endangered plant species are categorized under levels of threats facing extinction by the IUCN red data book. A list of endemic plant species found in RP, OP, and Forest areas and their conservation status are provided in Tables 4.17, 4.18, and 4.19 respectively. In the Forest areas 31 plants are endemic out of the 187 plant species (16.6%) observed in the qualitative survey (Table 4.16 and Figure 4.14). In the Open areas only 5 plant species (4.4%) were endemic out of the 115 species found in the qualitative survey (Table 4.16 and Figure 4.15).

Table 4.17 Endemic plants found in the qualitative floristic survey in the RP areas.

Sno.	Name of the plant	Vernacular name	Family	Habit	Distribution		Status
Plants endemic to peninsular India							
1	*Neanotis monosperma* (Wall ex Wight & Arn.)		Rubiaceae	Herb	Grasslands		Endemic to peninsular India
2	*Aneilemma montana* (Wight) Clarke		Commelinaceae	Herb	Ev gr. For., Semi ev. Gr. For.		Endemic to peninsular India
3	*Barleria buxifolia* L.		Acanthaceae	Small prickly shrub	Open areas		Endemic to peninsular India
4	*Cucurma pseudomontana* Graham		Zingiberaceae	Herb	Grassland,Open areas		Endemic to peninsular India
5	*Cyanotis tuberosa* (Roxb.) Schult.f		Commelinaceae	Perennial herb	Grasslands,Wet rocks		Endemic to peninsular India
6	*Jasminum brevilobum* A.DC..	Kattumulla	Oleaceae	Climbing shrub	Shola for.		Endemic to peninsular India
7	*Strobilanthus ciliatus* Nees.	Karimkurinji	Acanthaceae	Shrub	Ev. Gr. For.,Semi ev. Gr. for		Endemic to Peninsular India
8	*Suregada augustifolia* (Baill.exMuell.-Arg.)Airy Shaw		Euphorbiaceae	Small tree	Ev gr. For.		Endemic to peninsular India
Endemic to central and peninsular India							
1	*Agrostistachys indica* Dalz.		Euphorbiaceae	Small tree	Ev. Gr. For., Shola for.		Endemic to central and peninsular India
Endemic to South India							
1	*Stachyphyrnium spicatum* (Roxb.) Schum.		Marantaceae	Herb	Semi ev. Gr. For.,Moist decd. For.		Endemic to South India
2	*Tylophora mollisma* Wight&Arn		Asclepiadaceae	herb	Shola for.		Endemic to South India

Endemic to South india & Sri Lanka							
1	*Turpinia malabarica* Gamble	Kanakkapalam	Staphyleaceae	Large tree	Ev. Gr. For.		Endemic to South india & Sri Lanka
Endemic to south west India							
1	*Strobilanthus heyneanus* Nees	Muttukurunji	Acanthaceae	Shrub	Ev.gr. For.		Endemic to south west India
Endemic to South Western ghats							
1	*Acrotrema arnottianum* Wight	Nilampunna	Dilleniaceae	Rhizomatous herb	Ev. Gr. For.		Endemic to South Western ghats
2	*Artocarpus hirsutus* Lam.	Anjili	Moraceae	Large tree	Semi ev gr,Moist decd.for,Plains		Endemic to South Western ghats
3	*Dalbergia horrida* (Dennst.) Mabb.	Aanamullu	Fabaceae	Climbing shrub	Semi ev.gr. Fro.,Moist decd.for.,Sacred groves		Endemic to South Western ghats
4	*Gomphostemma eriocarpa* Benth.		Lamiaceae	Slender herb	Ev . Gr. For.		Endemic to south western ghats
5	*Litsea laevigata* (Nees) Gamble		Lauraceae	medium tree	Semi ev.gr. For.		Endemic to South Western ghats
6	*Meiogyne pannosa* (Dalz.) Sinclair	Panthal maram	Annonaceae	Small tree	Ev. Gr. For.		Endemic to South Western ghats
7	*Memecylone randerianum* SM&MR Almeida	Kasavu	Melastomaceae	Small tree	Semi ev.gr. For.		Endemic to South Western ghats
8	*Psychotria nilgiriensis* Deb & Gangop.		Rubiaceae	Small tree	Ev. Gr. For.		Endemic to south western ghats
9	*Salcia beddomei* Gamble		Hippocrateaceae	Climbing shrub	Ev.gr.for.,Semi ev.gr. For.		Endemic to South Western ghats

10	*Sida beddomei* Jacob		Malvaceae	herb	Semi ev.gr.,Moist decd. For.,Plains		Endemic to South Western ghats
11	*Meiogyne ramarowii* (Dunn) Gandhi		Annonaceae	Small tree	Ev.gr. For.		Endemic to South Western ghats
12	*Theriophonum infaustum* N.E.Br.		Araceae	Herb	Moist decd. For., Marshy areas		Endemic to south western ghats
Endemic to Western ghats							
1	*Cyrtococcum longipes* (Wight&Arn.exHook.f.)A.Camus		Poaceae	herb	Evgr.for.,Dry decd.for.,Grassland		Endemic to Western Ghats
2	*Derris brevipes* (Benth.) Baker		Fabaceae	Woody climber	Moist decd.for		Endemic to Western ghats
3	*Drypetes venusta* (Wight) Pax & Hoffm.	Konnamaram	Euphorbiaceae	Medium tree	Ev.gr. For., Sem ev. Gr. For.		Endemic to Western ghats
4	*Glochidion zeylanicum* (Gaertn.) A Juss.	Neervetti	Euphorbiaceae	small tree	Ev. Gr for., Semi ev. Gr. For., Plains		Endemic to Western ghats
5	*Ixora brachiata* Roxb.ex.DC.	Marachetti	Rubiaceae	Small tree	Semi ev.gr.for.		Endemic to Western ghats
6	*Lagerstroemia microcarpa* Wight	Venthekku	Lythraceae	Large tree	Moist decd. For., Plains		Endemic to western ghats
7	*Mussaenda bellila* Buch- Ham.	Parathole	Rubiaceae	Scandent shrub	Semi ev gr for.,Moist decd.for,Plains		Endemic to Western ghats
8	*Salacia fruticosa* Heyne ex Lawson	Korandi	Hippocrateaceae	Climbing shrub	Ev.gr. For., Semi ev. Gr. For.,Sacred groves, Plains		Endemic to Western ghats
9	*Xanthophyllum arnottianum* Wight	Madakka,mottal	Polygalaceae	Small tree	Ev.gr.for,Semi ev.gr. For.		Endemic to Western ghats

Vulnerable Plants							
1	*Ixora malabarica* (Dennst.) Mabb.	Cherukaravu	Rubiaceae	Shrub	Semi ev.gr.for.,Moist decd.for.Sacred groves		Endemic to South Western Ghats. Vulnerable
2	*Antistrophe serratifolia* (Bedd.) Hook.f.		Myrsinaceae	Erect herb	Ev. Gr. For.		Endemic to south western ghats. Vulnerable (Nayar, 1997)
3	*Dalbergia latifolia* Roxb.	Eeti	Fabaceae	Large tree			Vulnerable IUCN 2000
4	*Pterospermum reticulatum* Wight& Arn.	Malayuram	Sterculiaceae	Large tree	Ev.gr. For., Semi ev. Gr. For.		Vulnerable IUCN 2000
5	*Syzygium occidentalis* (Bourd.) Gandhi	Attuchamba	Myrtaceae	Small tree	Ev gr. For., Banks of streams		Vulnerable IUCN 2000

Lower risk Conservation dependent IUCN 2000							
349	*Tabernaemontana gamblei* Subram. & Henry		Apocynaceae	Shrub	Ev. Gr. For.		Lower risk Conservation dependent IUCN 2000

Rare Plants							
1	*Cynanchum alatum* Wight & Arn.		Asclepiadaceae	Twining herb	Semi ev. Gr. For.		Endemic to south western ghats. Rare (Nayar,1997)
2	*Solenocarpus indicus* Wight &Arn.	Kattambazham	Anacardiaceae	Small tree	Ev. Gr. For.,Rock formations		Endemic to south western ghats,Rare (Nayar 1997)

Threatened							
1	*Boesenbergia pulcherrima* (Wall.)O.Ktze		Zingiberaceae	Annual herb	Evgr.for.,Semi ev.gr.for.		Threatened Nayar1997

Index of the plant species distibution. The areas are classified as per the flora (Sasidharan 2004)			
Tropical evergreen forest -		Cultivated areas-	
Tropical semievergreen forest-		Marshy and wet areas-	
Moist & Dry decidous forest-		Grasslands-	
Shola forest-		Sacred groves-	
Open areas-		Rocky areas -	
Plains-		Plantations-	

Table 4.18 -Endemic plants found in the qualitative floristic survey in the OP areas.

Sno.	Name of the plant	Vernacular name	Family	Habit	Distribution		Status
Endemic to Peninsular India							
1	*Aneilemma montana* (Wight) Clarke		Commelinaceae	Herb	Ev gr. For., Semi ev. Gr. For.		Endemic to peninsular India
2	*Barleria buxifolia* L.		Acanthaceae	Small prickly shrub	Open areas		Endemic to peninsular India
3	*Suregada augustifolia* (Baill.exMuell.-Arg.)Airy Shaw		Euphorbiaceae	Small tree	Ev gr. For.		Endemic to peninsular India
Endemic to S.Western ghats							
1	*Hedyotis puberula* (G.Don) R.Br. Ex Arn.	Kunthamanian	Rubiaceae	Shrub	Grassland,Open ares		Endemic to S.Western ghats
Endemic to South India							
1	*Arundinella purpurea* Hochst		Poaceae	Herb	Grasslands		Endemic to south India

Table 4.19 -Endemic plants found in the qualitative floristic survey of the Forest areas.

Sno.	Name of the plant	Vernacula name	Family	Habit	Distribution		Status
Endemic to peninsular India							
1	*Aneilemma montana*(Wight) Clarke		Commelinaceae	Herb	Ev gr. For., Semi ev. Gr. For.		Endemic to peninsular India
2	*Chionanthus mala-elengi* (Dennst.) P.S Green	Mala-elengi	Oleaceae	Small tree	Semi ev. Gr. For Moist decd. For.		Endemic to peninsular India
3	*Jasminum brevilobum* A.DC..	Kattumulla	Oleaceae	Climbing shrub	Shola for.		Endemic to peninsular India
4	*Strobilanthus ciliatus* Nees.	Karimkurinji	Acanthaceae	Shrub	Ev. Gr. For.,Semi ev. Gr. for		Endemic to Peninsular India
Endemic to South Western ghats							
1	*Strychnos lenticellata*		Loganiaceae	Climbing shrub	Ev.gr. For.		Endemic to South Western ghats
2	*Acrotrema arnottianum* Wight	Nilampunna	Dilleniaceae	Rhizomatous herb	Ev. Gr. For.		Endemic to South Western ghats
3	*Actinodaphne bourdillonii* Gamble	Eeyoli	Lauraceae	Medium tree	Ev gr. For., Shola for.		Endemic to South Western Ghats
4	*Artocarpus hirsutus* Lam.	Anjili	Moraceae	Large tree	Semi ev gr,Mois decd.for,Plains		Endemic to South Western ghats
5	*Pilea kingii* Fischer		Urticaceae	Herb	Ev gr for.		Endemic to south western ghats
6	*Polyalthia fragrans*(Dalz.) Bedd.	Kodangi	Annonaceae	Large tree	Ev fr. For., Semi ev. gr. For.		Endemic to South Western ghats
7	*Actinodaphne malabarica* Balakr.	Kambilivirinji	Lauraceae	Medium tree	Ev. Gr. Fro.		Endemic to South Western ghats, Rare (Nayar,1997)

Endemic to south India							
1	*Stachyphyrnium spicatum* (Roxb.) Schum.		Marantaceae	Herb	Semi ev. Gr. For.,Moist decd. For.		Endemic to south India
2	*Tylophora mollisma* Wight&Arn		Asclepiadaceae	herb	Shola for.		Endemic to South India
3	*Piper barberi* Gamble	Kattukuru mulagu	Piperaceae	Climbing shrub	Evergreen forest		Endemic to south western ghats, Vulnerable (Nayar,19
4	*Tabernaemontana heyneana* Wall.	Koonam pala	Apocynaceae	Small tree	Moist decd. For. Sacred groves		Endemic to south western ghats,lower risk near threatened(IUCN,2000)
5	*Rauvolfia micrantha* Hook.f.		Apocynaceae	Shrub	Ev. Gr. For., Ser ev. Gr. For.		Endemic to South Western ghats.Endangered (Nayar,1997)
Endemic to Western ghats							
1	*Cinnamomum sulphuratum Nees*	Kattu karuva	Lauraceae	Medium tree	Ev. Gr. For., Sho for.		Endemic to Western ghats
2	*Hydnocarpus pentand* (Buch.-Ham.) Oken	Marotti	Flacourtiaceae	Medium tree	Semi ev. Gr., moist decd. For. Plains		Endemic to western ghats
3	*Knema attenuata* (Hook. F. & Thoms.) Warb.	Chorapayin	Chloranthaceae	Medium tree	Ev.gr. For., Sem ev.gr. For.,		Endemic to Western ghats
4	*Lagerstroemia microcarpa* Wight	Venthekku	Lythraceae	Large tree	Moist decd. For. Plains		Endemic to western ghats
5	*Michelia nilagirica* Zenk.	Kattuchem pakam	Magnoliaceae	Small tree	Ev.gr. For.		Endemic to western ghats
6	*Xanthophyllum arnottianum* Wight	Madakka, mottal	Polygalaceae	Small tree	Ev.gr.for,Semi ev.gr. For.		Endemic to Western ghats
7	*Myristica malabarica Lam.*	Panampalka	Chloranthaceae	Medium tree	Ev. Gr. For., Swamp for.		Endemic to Western ghats, Vulnerable (IUCN, 2000)

Rare							
1	*Polystichum moluccense* (Blume) T. Moore		Aspleniaceae	Small terrestrial herb	Ev. Gr. For		Rare
2	*Pteris scabripes* Wall.ex J. Agardh		Pteridaceae	Terrestrial herb	Ev gr. For.		Rare
3	*Actinodaphne malabarica* Balakr.	Kambiliviri nji	Lauraceae	Medium tree	Ev. Gr. Fro.		Endemic to South Western ghats, Rare (Nayar,1997)
Vulnerable							
1	*Piper barberi* Gamble	Kattukuru mulagu	Piperaceae	Climbing shrub	Evergreen fores		Endemic to south western ghats, Vulnerable (Nayar,19
2	*Myristica malabarica Lam.*	Panampal ka	Chloranthaceae	Medium tree	Ev. Gr. For., Swamp for.		Endemic to Western ghats, Vulnerable (IUCN, 2000)
Low risk ,Threatened							
1	*Tabernaemontana heyneana* Wall.	Koonam pala	Apocynaceae	Small tree	Moist decd. For. Sacred groves		Endemic to south western ghats,lower risk near threatened(IUCN,2000)
Endangered							
1	*Rauvolfia micrantha* Hook.f.		Apocynaceae	Shrub	Ev. Gr. For., Ser ev. Gr. For.		Endemic to South Western ghats.Endangered (Nayar,1997)
Possibly Extinct							
1	*Ceropegia maculata* Bedd.		Asclepiadaceae	Herb	Semi ev. Gr. For.		Possibly extinct(Nayar 1997

4.5 Vegetation succession

A compilation of the number of species found with specific habitat preferences is compiled in Table 4.20.

Table 4.20 Number of plant species of different types and its percentage in each ecosystem.

General habitat preference of the plant	No. of plant species / Percent of plant species*		
	Rubber Plantations	Open areas	Forests
Evergreen Forest	88 (19.8%)	18 (23.4%)	64 (23.8%)
Semi Evergreen Forest	99 (22.3%)	25 (32.5%)	67 (24.9%)
Deciduous forests	40 (9%)	9 (11.7%)	13 (4.8%)
Dry deciduous forest	44 (10%)	12 (15.6%)	26 (9.7%)
Moist deciduous forests	135 (30.3%)	40 (52%)	83 (30.9%)
Shola Forests	18 (4%)	4 (5.2%)	9 (3.4%)
Sacred Groves	21(4.7%)	4 (5.2%)	7 (2.6%)

The OP areas have a larger number of plants which naturally belong to the deciduous habitat (Figure 4.18). The proportion of these species is the least in the Tropical forests sampled (Figure 4.19). The RP habitat also supports a large number of plants that are found in the Deciduous forests (Figure 4.17). A comparatively larger number of Evergreen species are supported by the RP and Forest areas than by the OP areas (Figure 4.20). The proportion of Semi evergreen plant species appears to be nearly the same in all the three areas. The RP and OP areas also have a small percentage of plants that are found in the sacred groves. Figure 4.20 shows that in the OP areas there is a larger percentage of plants belonging to the decidous type of habitat. The RP areas show an increasing percentage of plants belonging to the deciduous type of habitat indicating a changing trend.

Figure 4.17 Percentage of the plants with habitat preferences in the vegetation composition of the RP areas

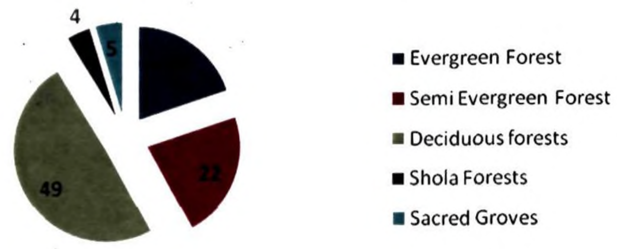


Figure 4.18 Percentage of the plants with habitat preferences in the vegetation composition of the OP areas

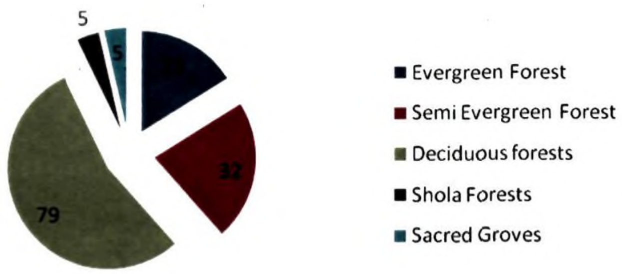


Figure 4.19 Percentage of the plants with habitat prefereces in the vegetation composition of the Forest areas

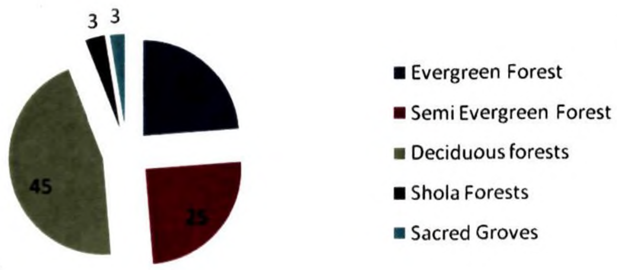
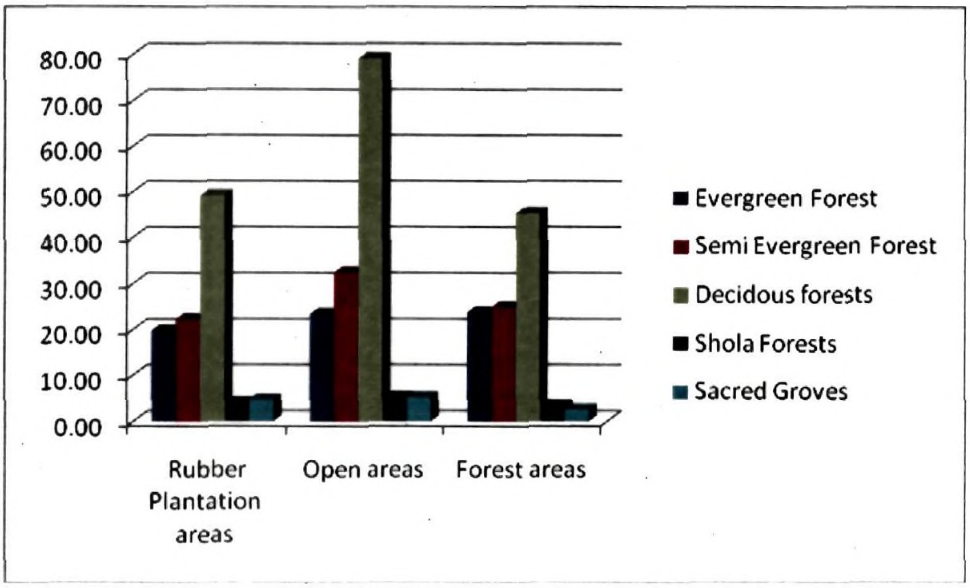


Figure 4.20 Percentage of plant species with different types of habitat preference in each ecosystem.



A non parametric equivalent of the paired-sample t-test known as the Wilcoxon test or the Signed-Rank test (QED version 1.1 2007) was used to compare the three samples. The RP areas were not significantly different from the Forest areas ($t = 0.169031$, $P = >0.05$) and the OP area ($t = 2.36643$, $P = >0.05$). The OP areas were significantly different from the Forest areas ($t = 2.1974$, $P = <0.05$). The results show that the RP areas have a vegetation composition which overlaps with the vegetation composition of the Forest and OP areas with respect to the habitat preferences of the individual species. The vegetation structure of the Forest areas shows a species composition which has a higher proportion of plant species that are naturally found in the Evergreen and Semi evergreen forests. The OP areas show signs of a succession change to dry deciduous whereas RP areas show a species composition with a preference to Moist deciduous species and can be considered the intermediate stage in succession between the Forest and the Open areas.

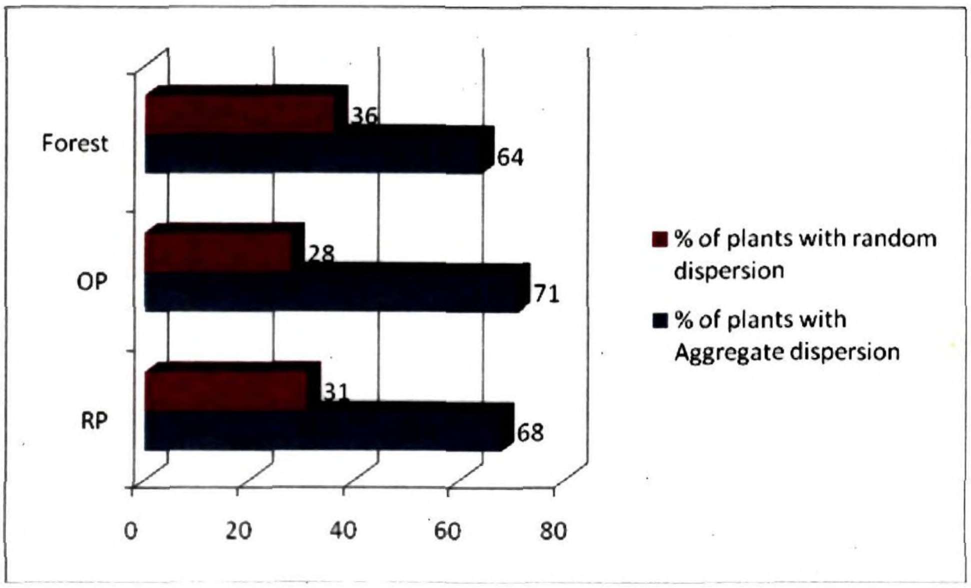
4.6 Quantitative assessment

4.6.1 Dispersion

The dispersion pattern of the plant species sampled in the Rubber plantations, Open areas and the Forests in the three districts using the abundance data was statistically analyzed using SDR version 4. (Seaby and Henderson 2006).The results are e tabulated in Table 4.21(appendix). A total of 322 plant species were observed in the samples taken in these three types of areas. The tabulation shows the dispersion pattern (Random or aggregate) of these species in the three areas.

Out of the 216 plant species observed in the samples of the RP areas, 147 plant species (68%) found in the rubber plantation areas show an aggregate dispersion pattern and 69 species (31%) show a random dispersion pattern. In the OP areas 115 plant species (71%) show an aggregate distribution while 45 species (28%) show a random dispersion pattern. In the forests sampled 108 species (64%) show an aggregate dispersion while 40 species (36%) show a random dispersion (Figure 4.21). A higher aggregate dispersion pattern is observed in the OP and RP areas. The forest areas show a comparatively lower aggregate and higher random dispersion.

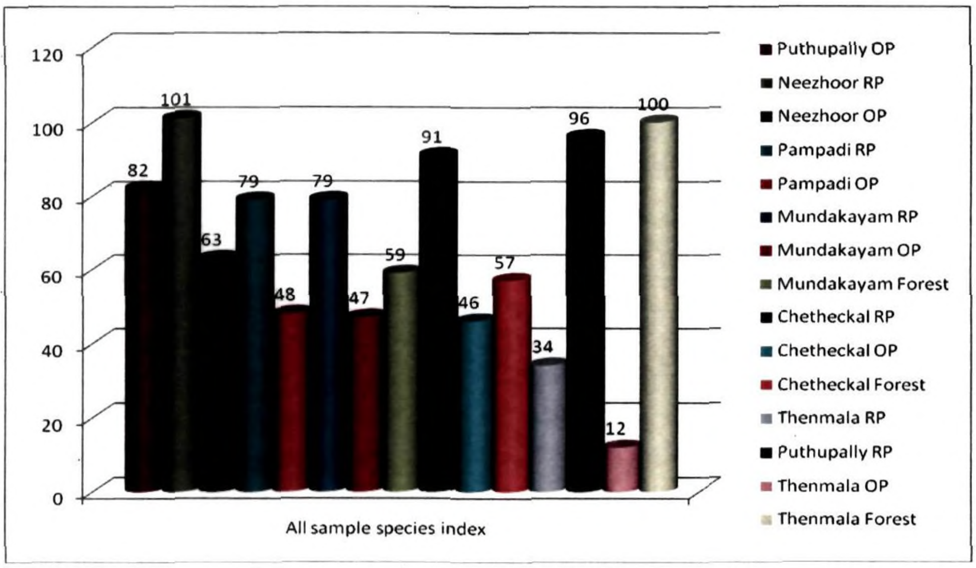
Figure 4.21 Dispersion pattern of the plant species found in the RP, OP and Forest areas



4.6.2 Relative abundance index

The abundance indices computed for each of the sampled site using SDR version 4. (Seaby and Henderson 2006) is presented in Figure 4.22. The results are described below.

Figure 4.22 The all sample index showing the number of species found in the individual of the sampled sites (sub samples.)



4.6.2.1 Species number index

The species number index of each sample and the all sample index of a sampled site is computed using SDR version 4. (Seaby and Henderson 2006). A graphical output for the RP, OP and Forest areas is given in Figures 4.23 - 4.26.

The species number index found in each sample ranged from 2 to 35 plant species in the RP samplings (Figure 4.23), from 5 to 35 in the OP samplings (Figure 4.24) and the Forest samplings (Figure 4.25). The all sample index of the all the RP areas is 216, and 160 and 168 for the OP and Forest areas respectively. The all sample index of the three areas collectively is 309 (Figure 4.26).

Figure 4.23 - 4.26 The all sample species index of each sampling of the sampled areas in Rubber plantations, Open areas and the Forest areas.

Figure – 4.23- Rubber Plantation areas

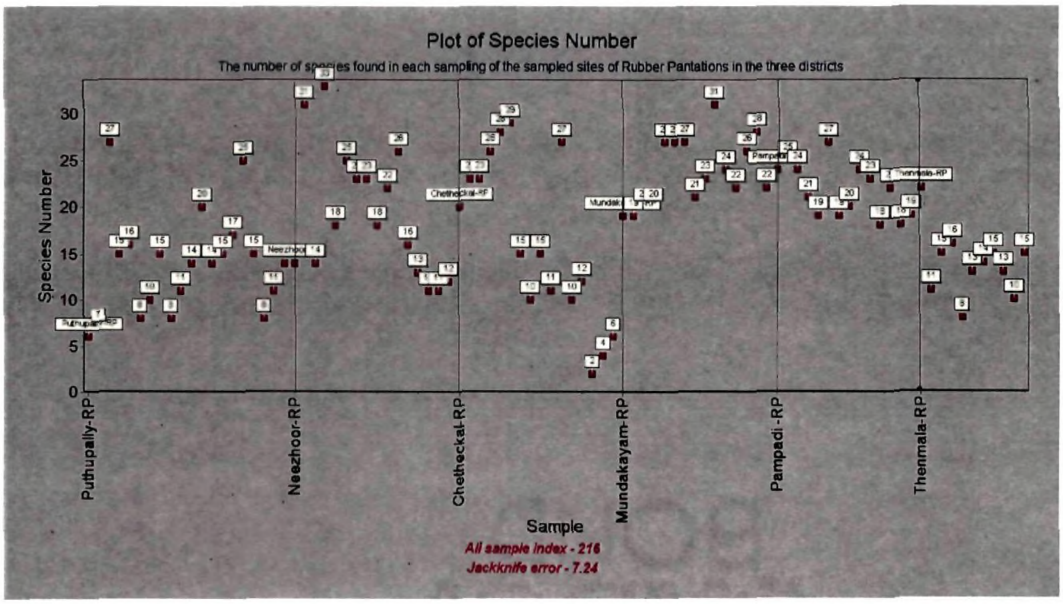


Figure 4.24 – Open areas

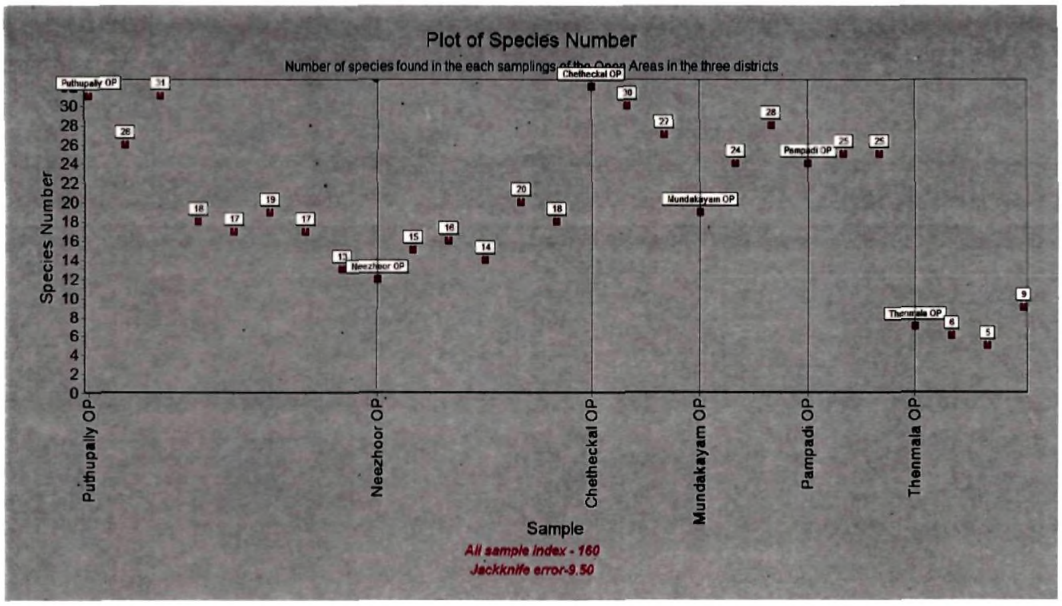


Figure 4.25 - Forest areas

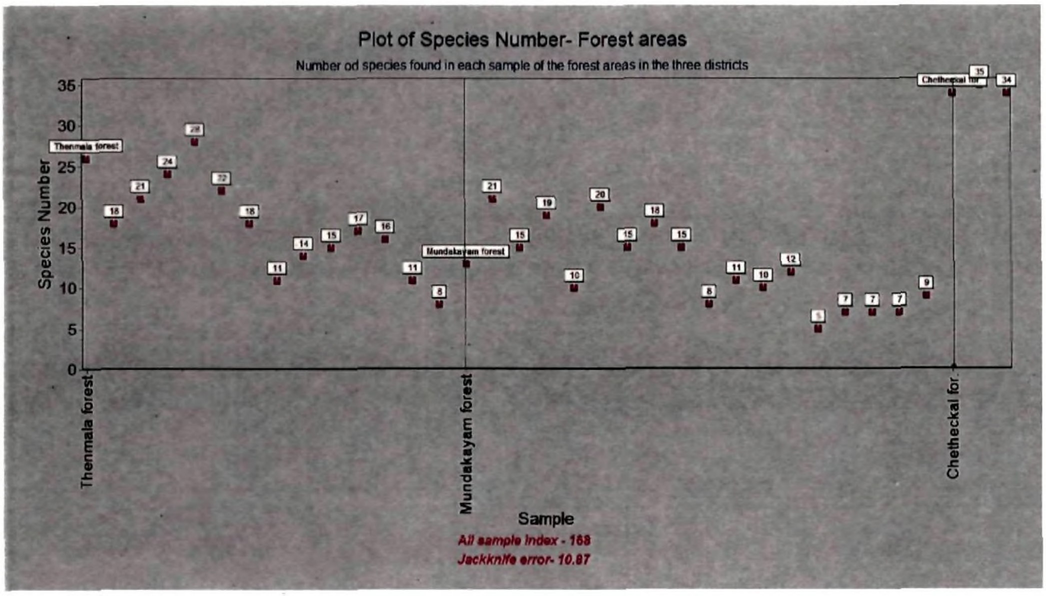
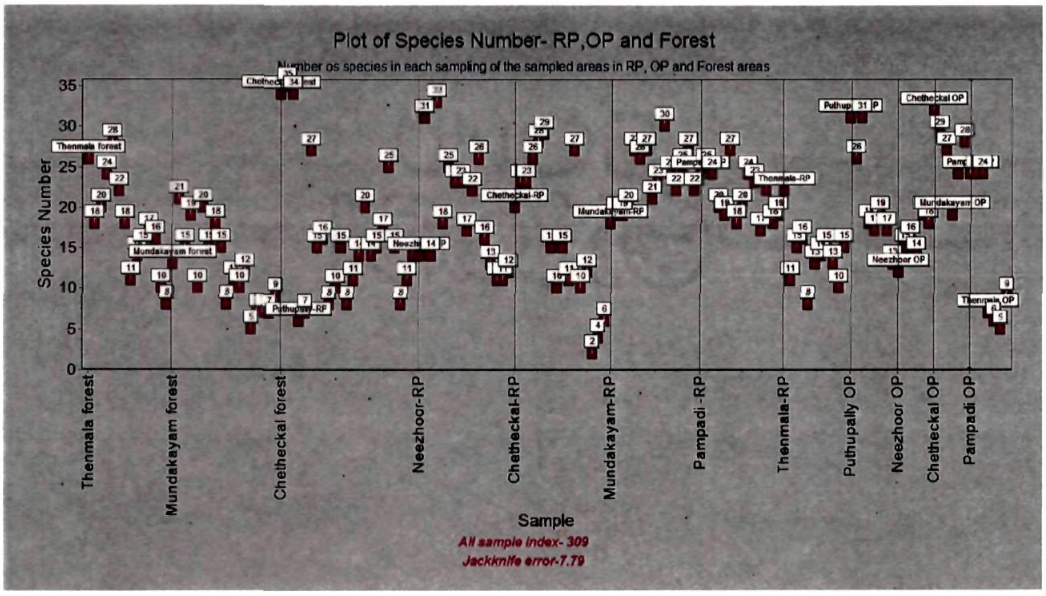


Figure 4.26 Rubber plantations, Open areas and the Forest areas



4.7 Plant diversity analysis protocol

A protocol for plant diversity analysis of the RP, OP and Forest areas was followed. The following results were obtained.

4.7.1 Rank on abundance plot

Rank on abundance plots were constructed for the pooled sample and the subsamples (Figures 4.27- 4.30). The RA plot of the pooled RP, OP and Forest sites is shown in Figure 4.27. The slope of the RA plot (rank on abundance plot) of RP is steeper than those of OP and Forest RA plots. This indicates that RP areas are less even, compared to the Forest and OP areas. The RA plots of the RP areas indicate an ecologically disturbed area, which has more of edge species and is simple in biodiversity because of the presence and dominance of a few species, ecologically and numerically. The RA plot of the RP areas also shows the presence of a very large number of rare species (i.e. species that are found as singletons or doubles in the samples).

Figure 4.27-4.30 Rank on abundance plots of the sampled areas of sampled Rubber plantation, Open areas and the Forest areas.

Figure 4.27

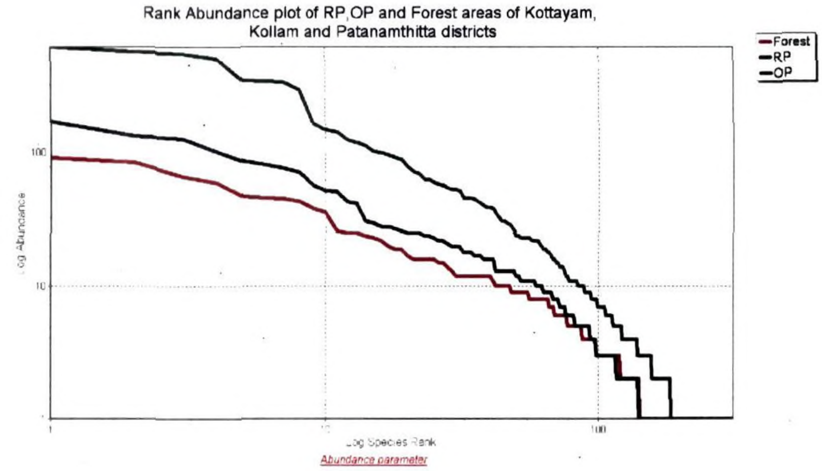


Figure 4.28

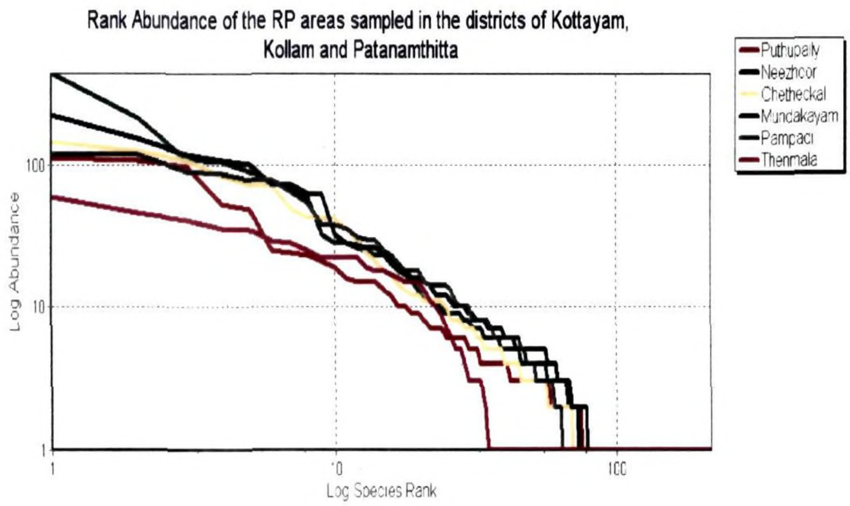


Figure 4.29

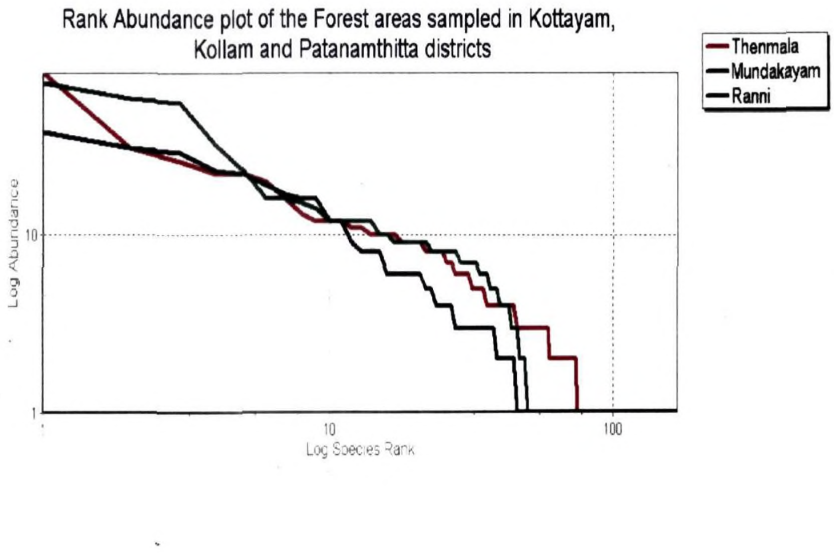
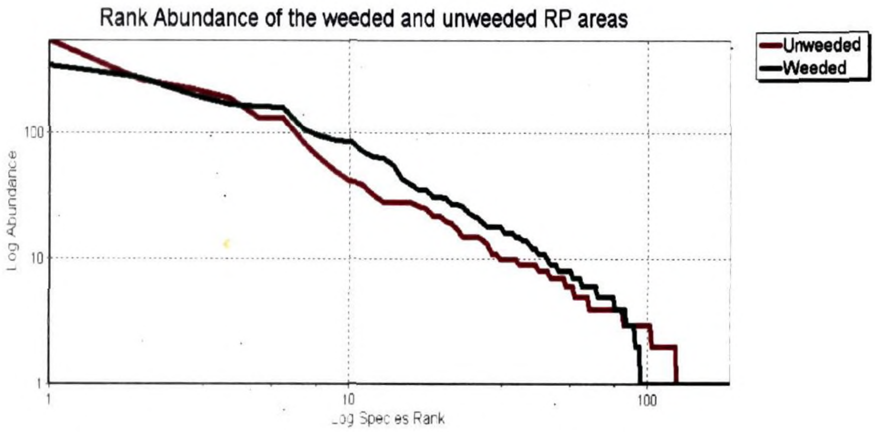


Figure 4.30



4.7.2 Species accumulation as a measure of sampling effort

Species accumulation curves of the RP, OP and Forest areas sampled and their subsets were computed using SDR version 4. (Seaby and Henderson 2006). The results are given in Figure 4.31- 4.34.

Figure 4.31 - 4.34 Species accumulation curves of the pooled samples of Rubber plantations, Open areas and Forest areas with 10 randomizations.

Figure 4.31

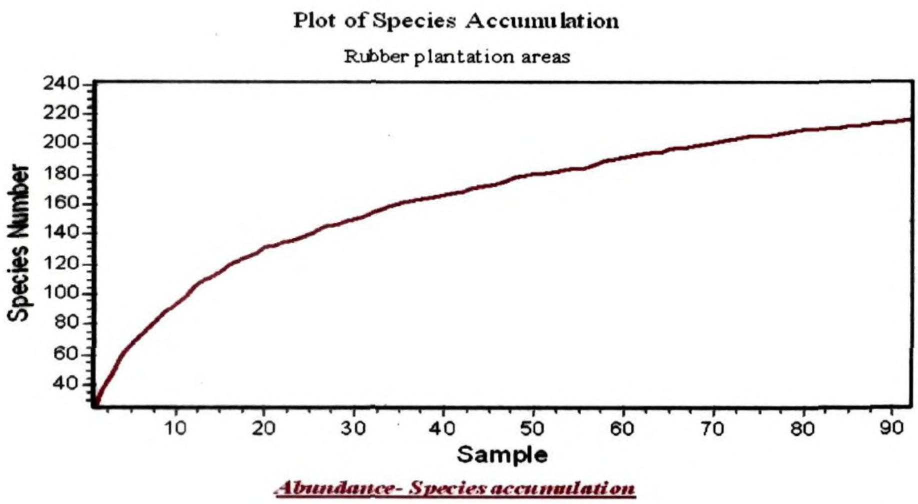


Figure 4.32

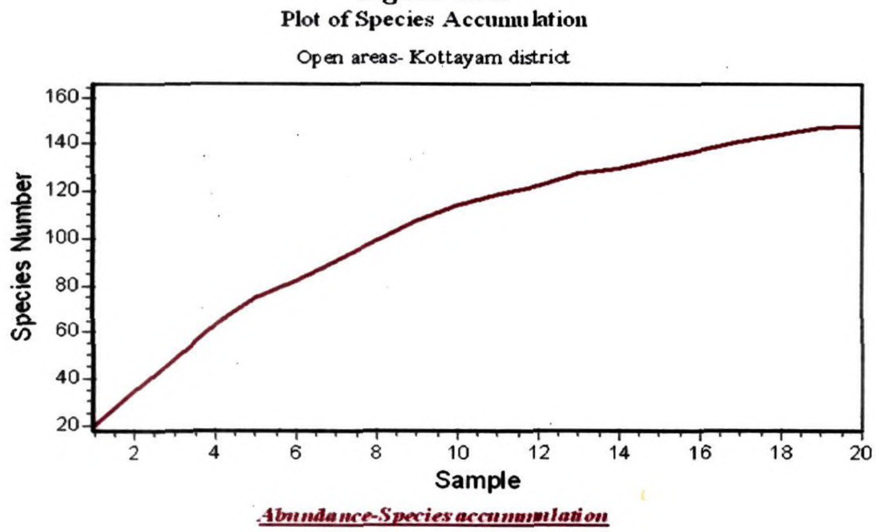


Figure 4.33

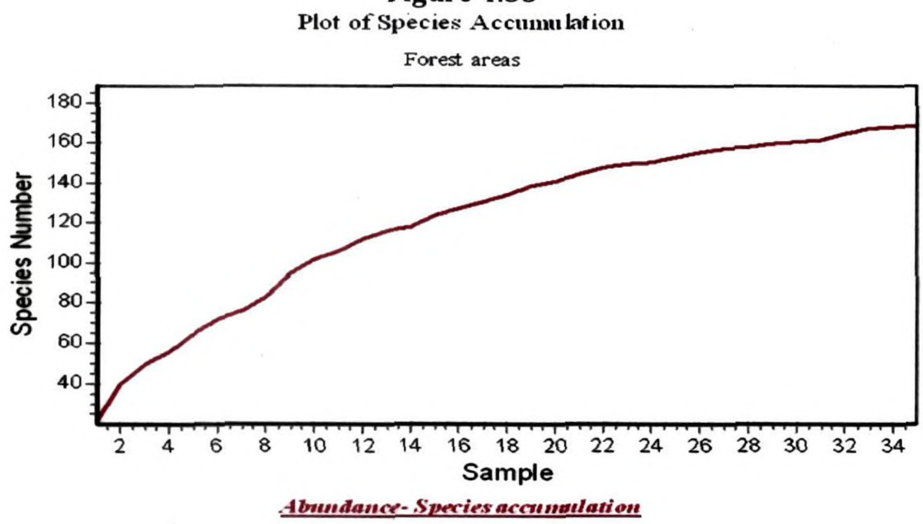
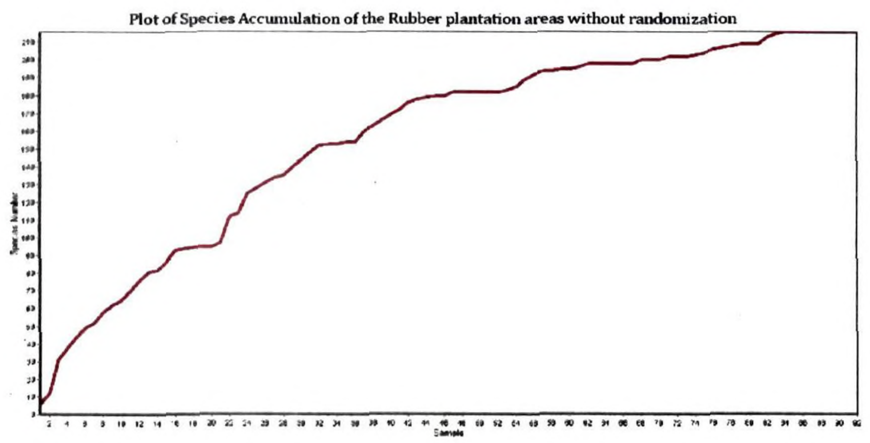


Figure 4.34 Species accumulation curves of the pooled samples of Rubber plantations without randomizations.



The species accumulation curves showed an asymptote at 92 samplings with the acquisition of 216 species in the RP areas (Figure 4.31), with 35 samples and the acquisition of 168 species in the Forest areas (Figure4.33) and with 27 samples and the acquisition of 160 species in the OP areas (Figure4.32). This indicated a slow acquisition of species in the RP areas compared to the OP and the Forest areas. The species accumulation curve, which shows the increase in the plant species observed with sampling effort, summarized the completeness of the sampling effort. As effort increases, gradually more and more of the species found in the habitat were sampled, until eventually only the rarest species remain unrecorded. When this occurred increased effort did not increase the recorded species number. The species accumulation curve reached an asymptote. The species accumulation curve indicated that the sampling has been of sufficient intensity, to capture most of the species present.

4.7.3 Species richness estimation

4.7.3.1 Species richness estimation based on species accumulation curve

The species accumulation curve also called the Collectors curve or Acquisition curve was plotted for each site with 10 randomizations (Figures 4.31 – 4.33). The species accumulation curve without randomizations is shown in (Figure 4.34).

The species accumulation curve of individual sites did not show clear asymptotes hence more rubber plantation sites were included until a clear asymptote was obtained. With 92 samplings needed to reach asymptotes in rubber plantations it can be said that they were sampled more intensively and that there is a slow acquisition of species. Figure 4.31 shows the species accumulation curve of the pooled samples of Rubber plantations. The number of species at which the asymptote is reached is considered the S_{max}. This is also the number of species observed in the quantitative samplings (S_{obs}) as indicated by the species number index (Figure 4.23). Sampling was abandoned at this stage. The S_{max} of the rubber plantations fell short with respect to the qualitative floristic survey (S_{true}, the number of plant species found in the qualitative survey), which recorded a higher number of plant species (420 species) in the rubber plantations (Table 4.4)

A similar pattern was followed for the Open areas and the Forests sampled. Both the areas chosen were adjacent to or circumventing rubber plantations within a distance of 200m. Being limited in size and accessibility the number of samples obtained in the Open areas was limited. Clear asymptotes were not obtained even after pooling the data in the case of Open areas and the Forest areas sampled. The S_{max} (in this study the same as S_{obs}) for forest was 168 species and for Open areas 160 species. This was more than the estimate of the qualitative survey (S_{true} in this study) in the open areas and approximately the number observed for the forest samples (Table 4.4).

The extrapolations of species accumulation based estimators viz. Henderson's plot, Pooled rarefaction, Sample interpolation and Heterogeneity of the pooled data of RP, OP and Forest areas are presented are tabulated in Table 4.22 graphical presented in Figures 4.35-4.39. The S_{max} ranges from 215.6 (Heterogeneity test) to 218 (Henderson's plot) for the RP areas, from 156.3 (Heterogeneity test) to 160 (pooled rarefaction and sample interpolation) for the OP areas and 168 for the Forest areas in all the extrapolations (Table 4.22 and Figures 4.35-4.39). Thus the S_{max} value of all the three areas are approximately the same as the S_{obs} values (Figures 4.23 - 4.25).

Table 4.22 –Species richness estimates (S_{max})based on species accumulation curves for the Rubber plantation areas, Open areas and the Forest areas.(Sp. accum.-Species accumulated).

Species accumulation curve based estimator	Rubber plantations		Forest areas		Open areas	
	Estimate	Sp. accum.	Estimate	Sp. accum.	Estimate	Sp. accum.
Heterogeneity test	215.6	216.0	167.2	168.0	156.3	160.0
Pooled rarefaction	216	216.0	168	168.0	160	160.0
Henderson plot	218	216.0	167.4	168.0	159.9	160.0
Sample interpolation	216	216.0	168	168.0	160	160.0

Figure 4.35- 4.39 Species richness estimation based on the species accumulation curve for the Rubber Plantation, Open areas and Forest areas (These estimates are the S_{max} which is approximately the same as the S_{obs}).

Figure 4.35

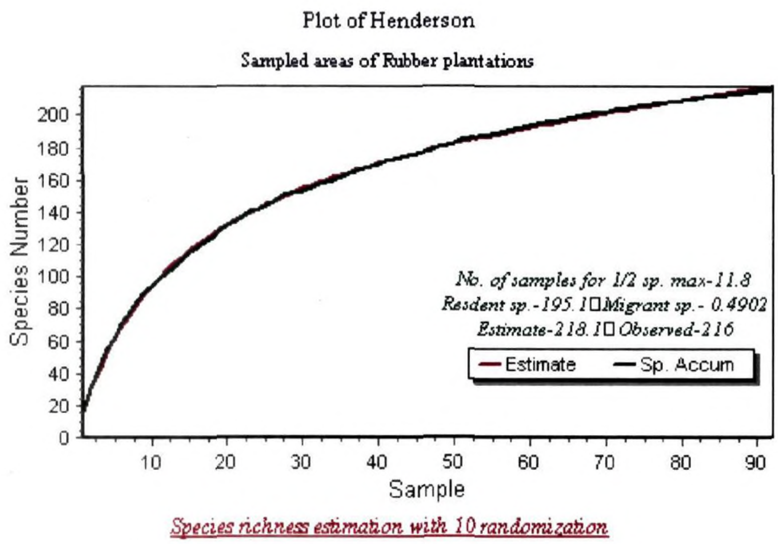


Figure 4.36

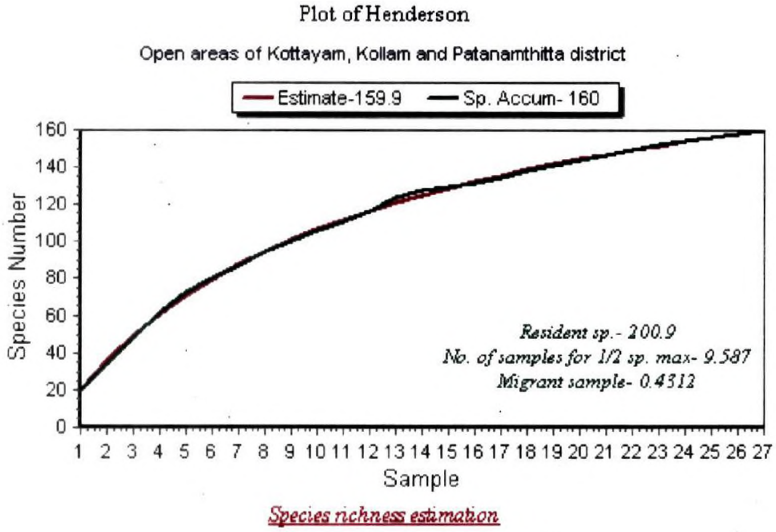


Figure 4.37

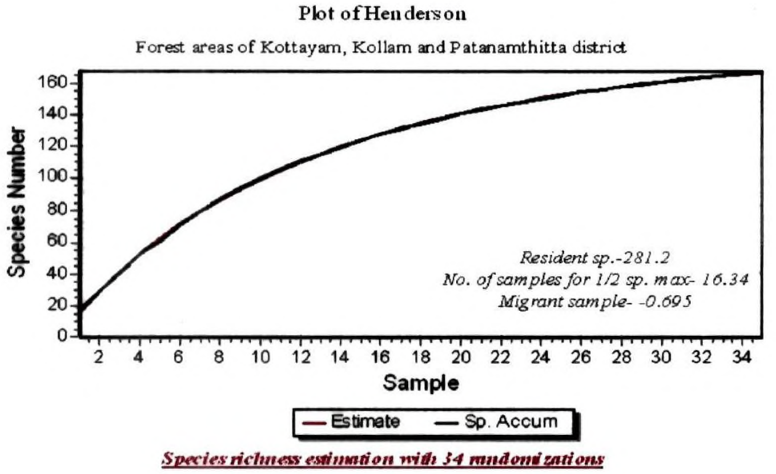


Figure 4.38

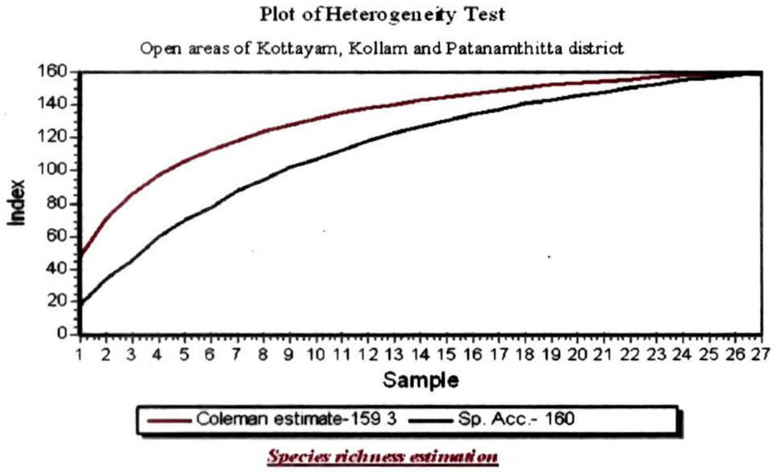
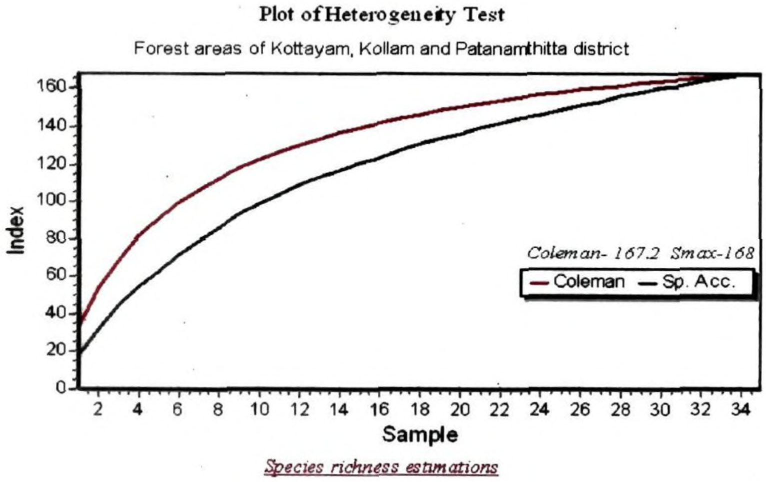


Figure 4.39



4.7.3.2 Species richness estimation using non parametric estimators

The non-parametric estimators were used to extrapolate species richness for the three types of areas are summarized in Table 4.23. The table summarizes the extrapolation of the species richness estimates using the non- parametric estimators and measures the sample coverage.

Table 4.23 Species richness estimates (S_{max}) in the three sampled areas using non-parametric species richness estimators and the sample coverage (SC).

Non- parametric estimator	Rubber plantations		Forest areas		Open areas	
	Estimate	SC (%)	Estimate	SC (%)	Estimate	SC (%)
Chao quantitative	236.2	91.4	185.4	90.6	166.8	95.9
Chao& Lee 1	217	99.5	170.9	98.3	161.3	99.2
Chao& Lee 2	217	99.5	170.9	98.3	161.3	99.2
1st order Jackknife	260.5	82.9	212.7	79.0	204.3	78.3
2nd order Jackknife	261	82.8	220.4	76.2	211.3	75.7
Bootstrap	239.8	90.1	191.3	87.8	183.5	87.2
Michelis M	242.5	89.1	229.5	73.2	217.7	73.5
Mean estimated sample coverage		90.8		86.2		87.0

These estimators have extrapolated the value of S_{max} as 217 (Table 4.23, Figures 4.40-4.45) which is approximately same as of that of S_{obs}(216) or S_{max} of the species accumulation curve of the quantitative samplings of rubber plantations (Table 4.22, Figures 4.31).. All species accumulation based extrapolations (Heterogeneity, Pooled rarefaction, Hendersons and Sample interpolation) show estimates which range from 216 to 218 in RP areas (Table 4.22 and Figures 4.35-4.39).

Figure 4.40-4.45 Non- parametric species richness estimations of the rubber plantation areas of with 92 randomizations (The extrapolated S_{max} is the estimated number of species that can be found in the area).

Figure 4.40

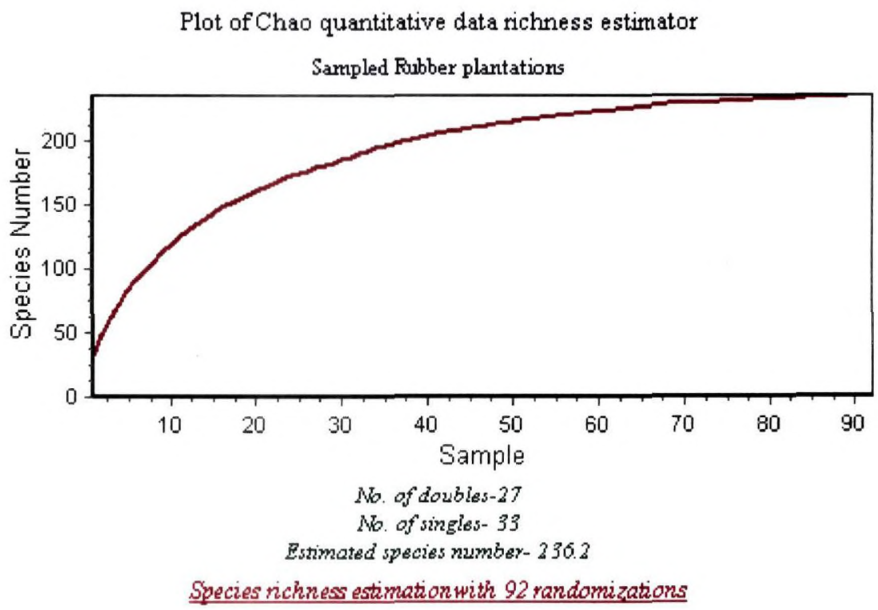
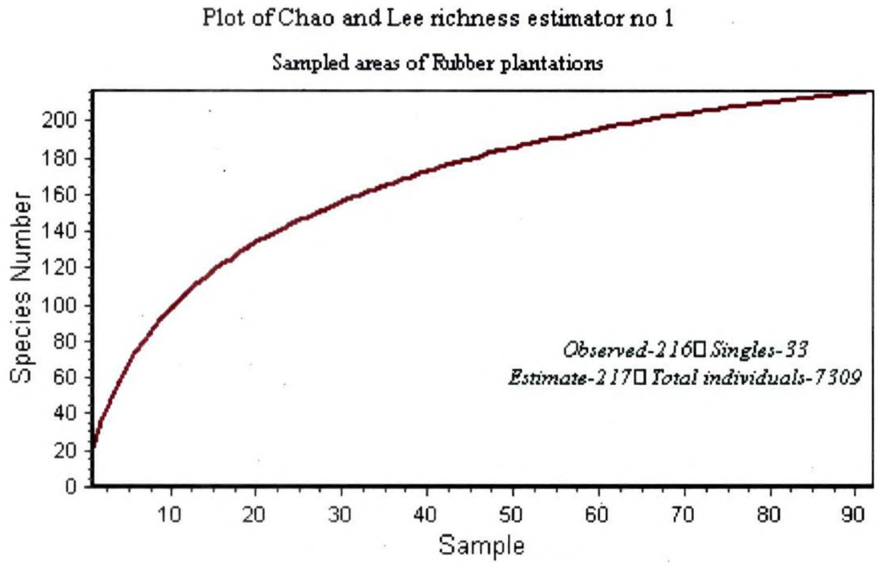
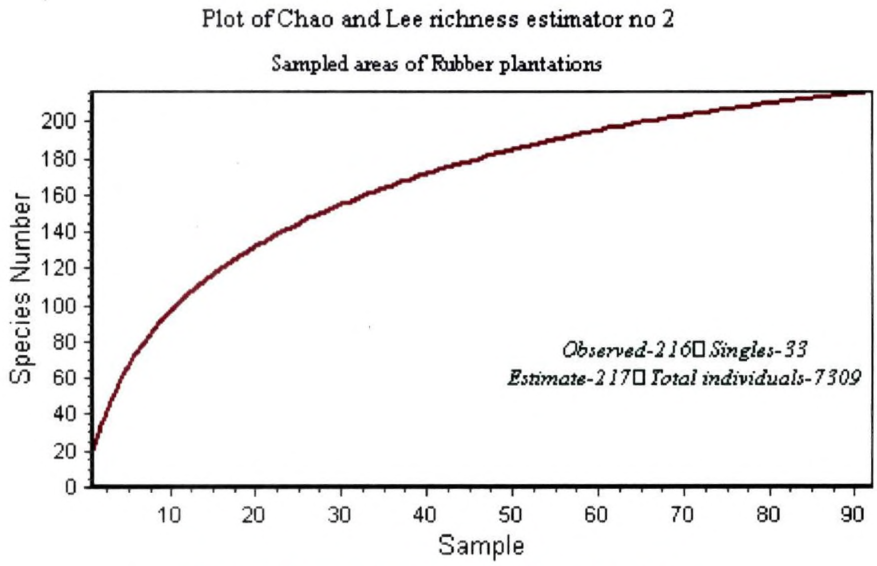


Figure 4.41



Species richness estimation

Figure 4.42



Species richness estimation with 92 randomization

Figure 4.43

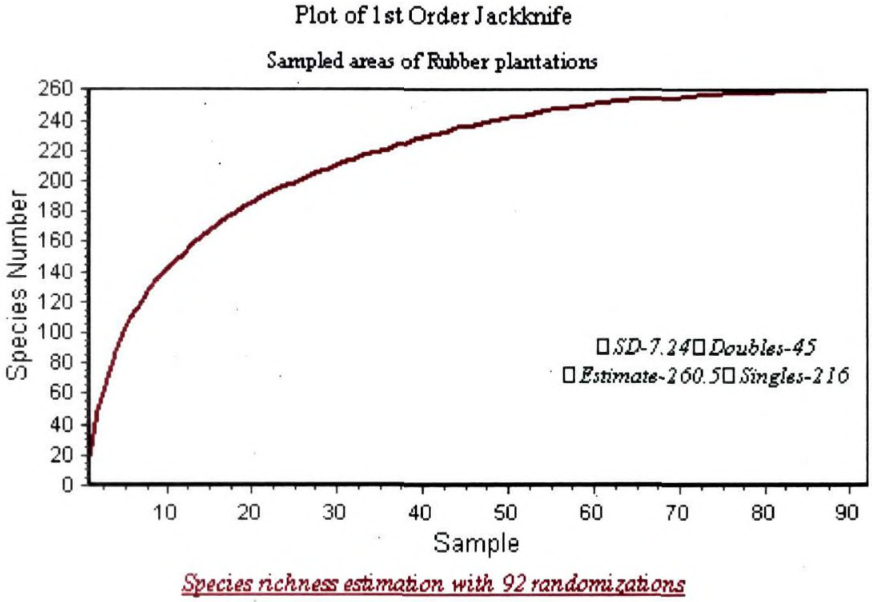


Figure 4.44

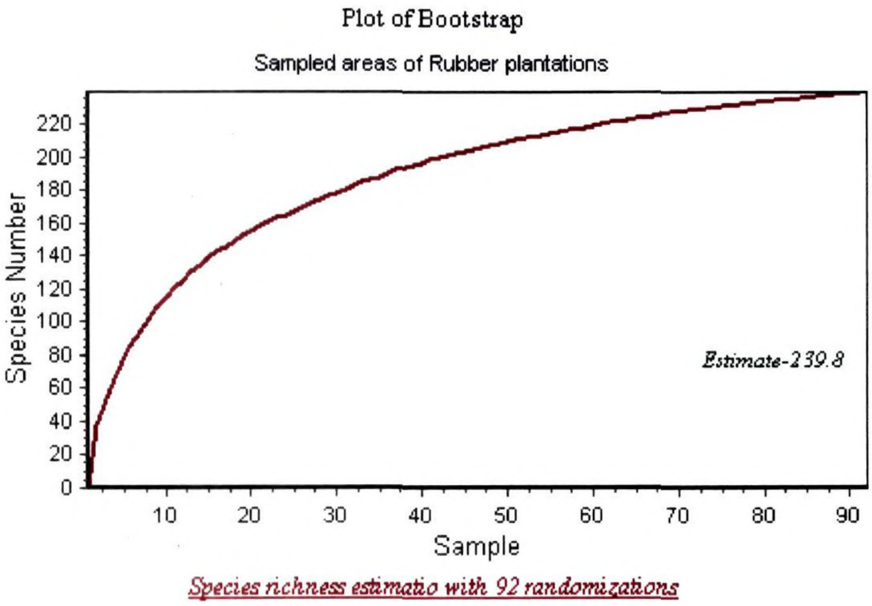
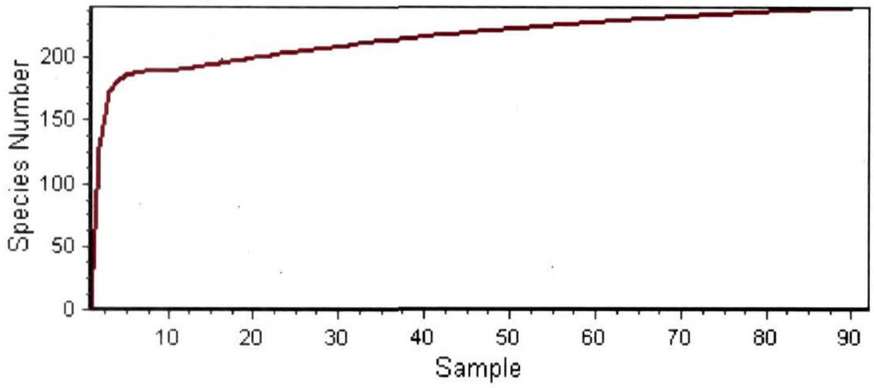


Figure 4.45

Plot of Michaelis-Menten estimation of total species richness

Sampled areas of Rubber plantations
in Kottayam,Kollam and Patanamthita district



Observed species number- 216
Estimated species number-236.6

Species richness estimation with 92 randomizations

The non parametric species richness estimates of the RP areas shown in Table 4.23 ranges from 217 (Chao& Lee1 and Chao& Lee 2) to 260.5 species (1st order Jackknife). The non parametric estimate of Chao Lee 1(ACE) is chosen as per the Brose,Martinez and Williams 2003 protocol. S_{max} estimated by ACE(Abundance based coverage) is the same as the S_{obs} for both the OP and Forest areas (Figure 4.46-4.52 and Figures 4.53–4.59). The values were 160 species and 168 species respectively for the OP and Forest areas.

Figure 4.46 - 4.52 Non- parametric species richness estimations of the Forest areas with 35 randomizations (The extrapolated S_{max} is the estimated number of species that can be found in the area).

Figure 4.46

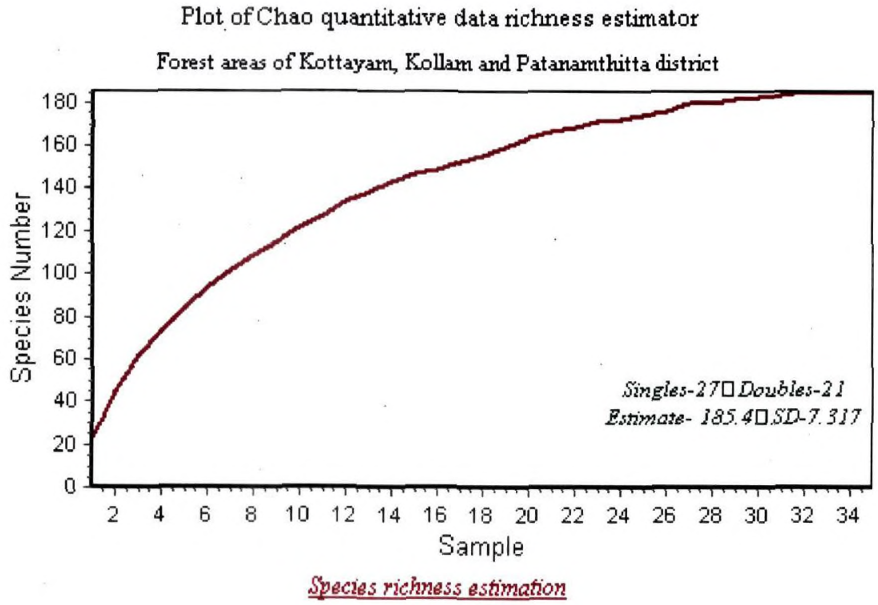


Figure 4.47

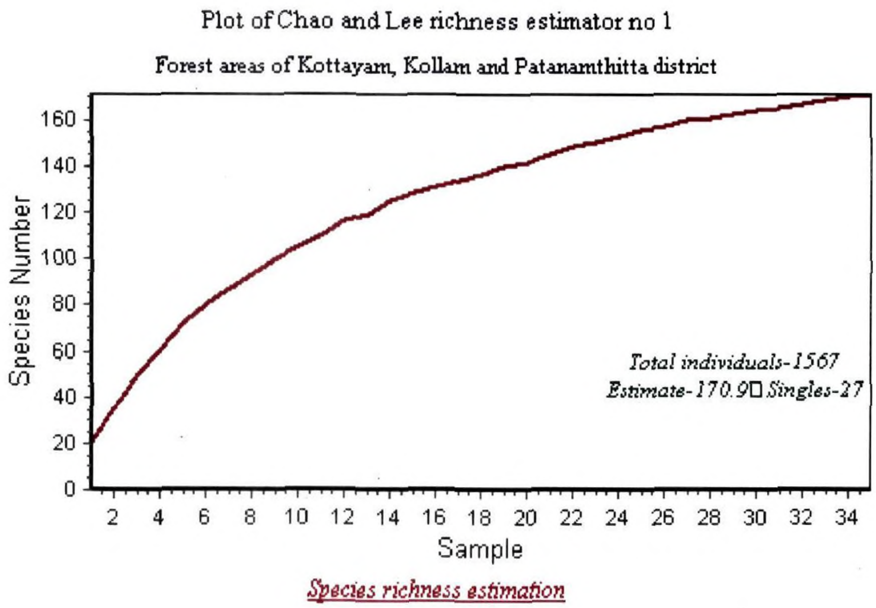
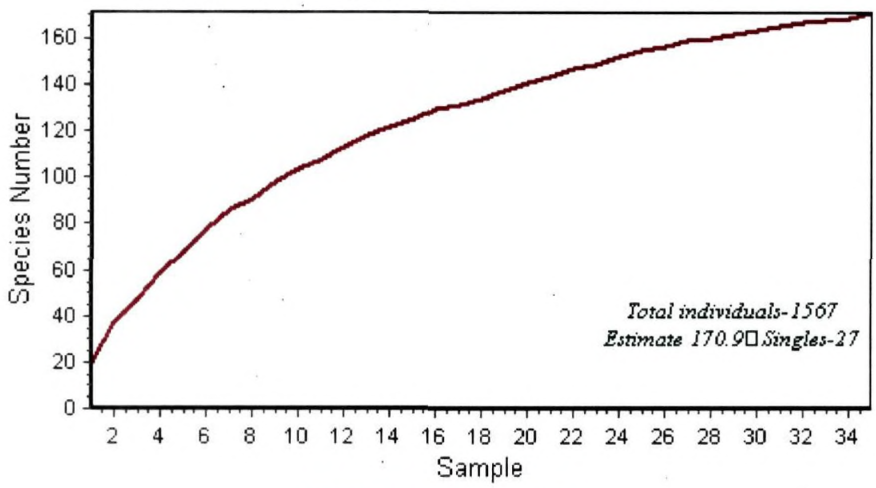


Figure 4.48

Plot of Chao and Lee richness estimator no 2

Forest areas of Kottayam, Kollam and Patanamthitta district

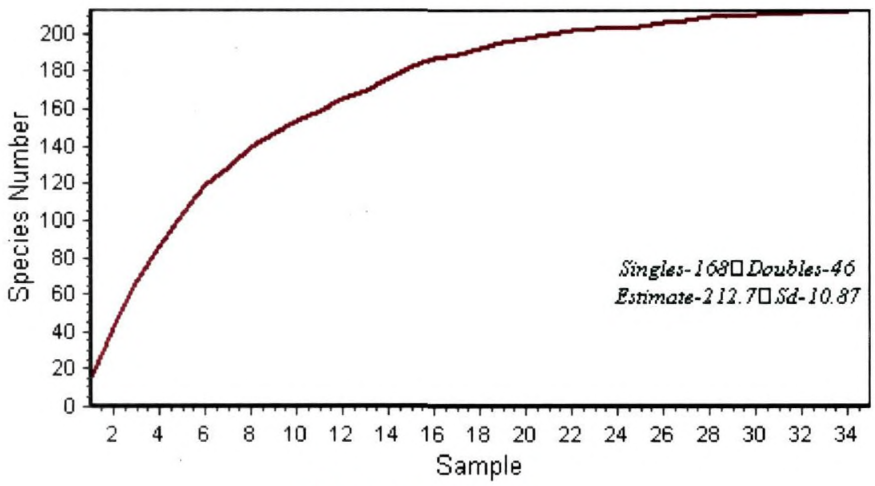


Species richness estimation

Figure 4.49

Plot of 1st Order Jackknife

Forest areas of Kottayam, Kollam and Patanamthitta district



Species richness estimation

Figure 4.50

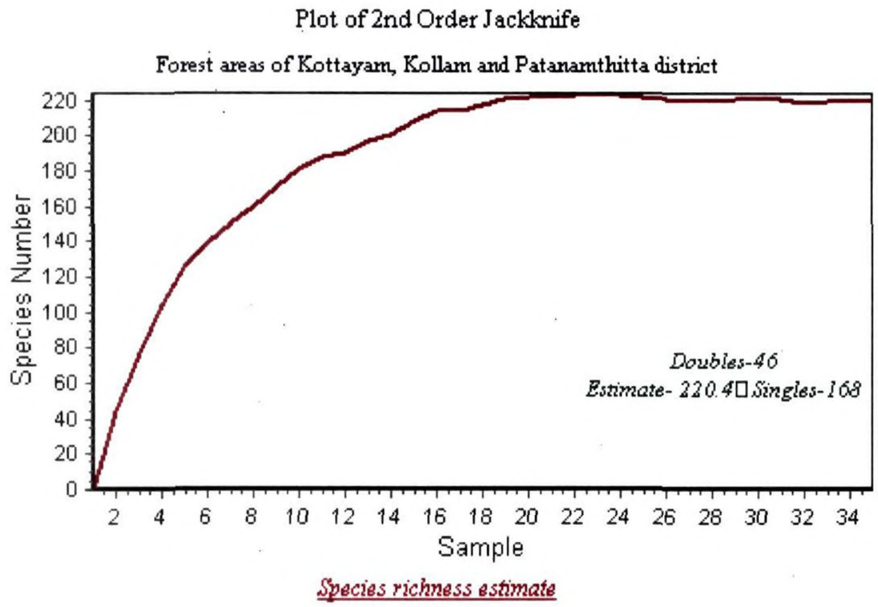


Figure 4.51

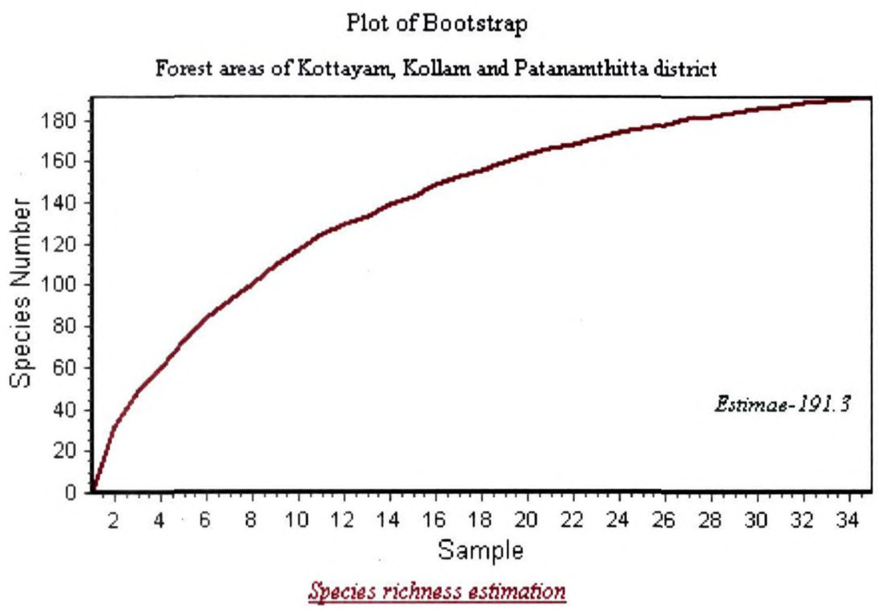


Figure 4.52

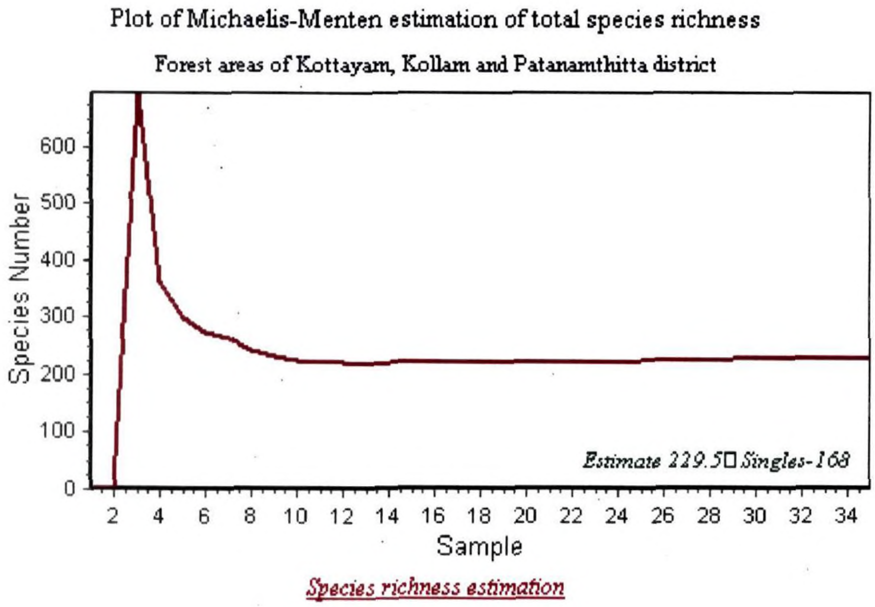


Figure 4.53- 4.59 Non parametric species richness estimations of the Open areas with 27 randomizations (The extrapolated S_{max} is the estimated number of species that can be found in the areas).

Figure 4.53

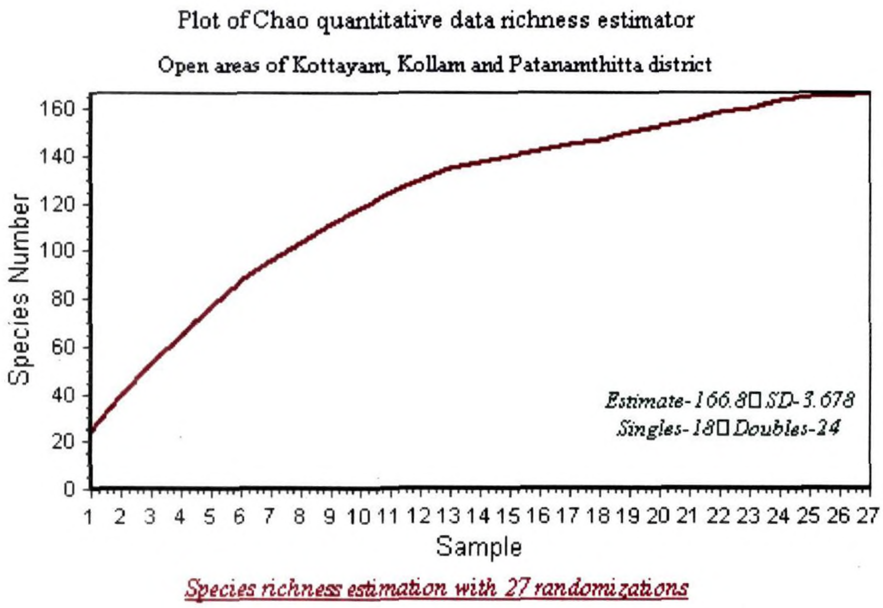
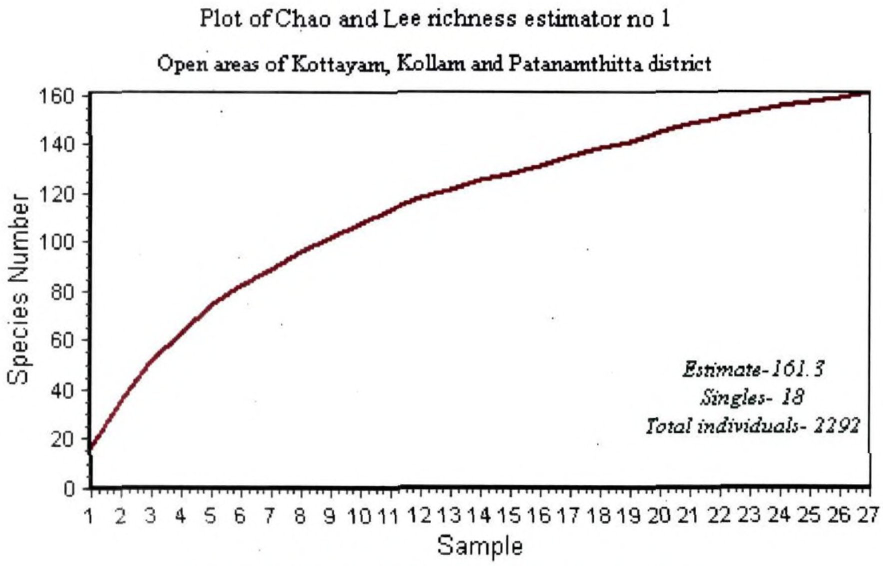
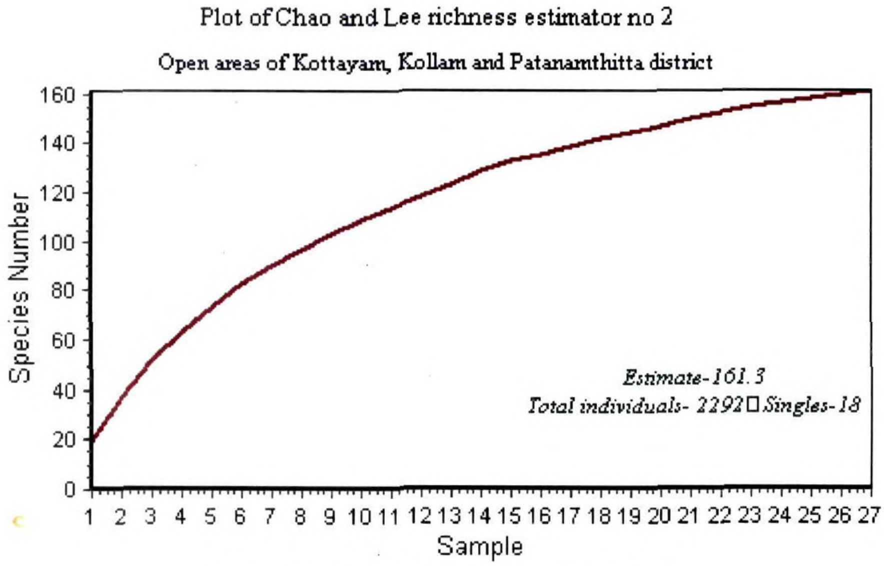


Figure 4.54



Species richness estimation with 27 randomizations

Figure 4.55



Species richness estimation with 27 randomizations

Figure 4.56

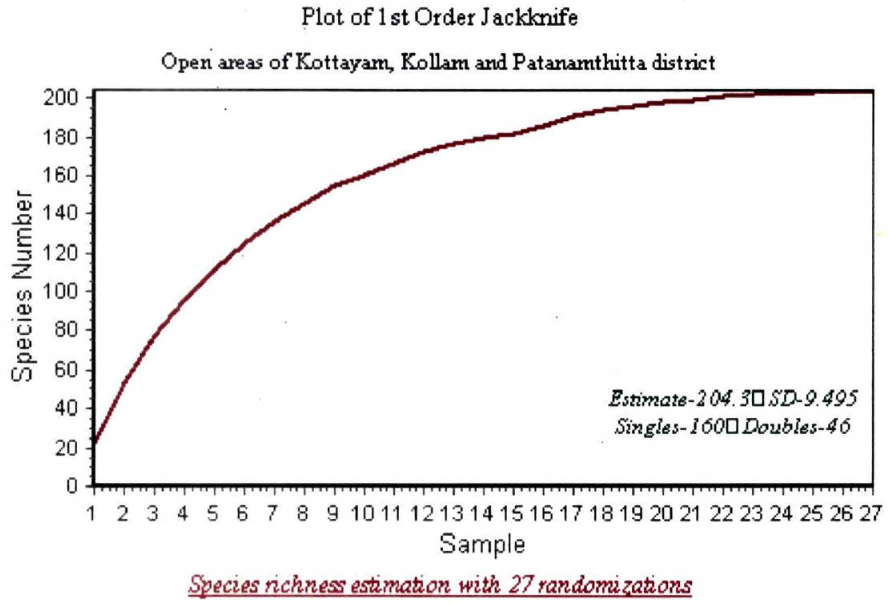


Figure 4.57

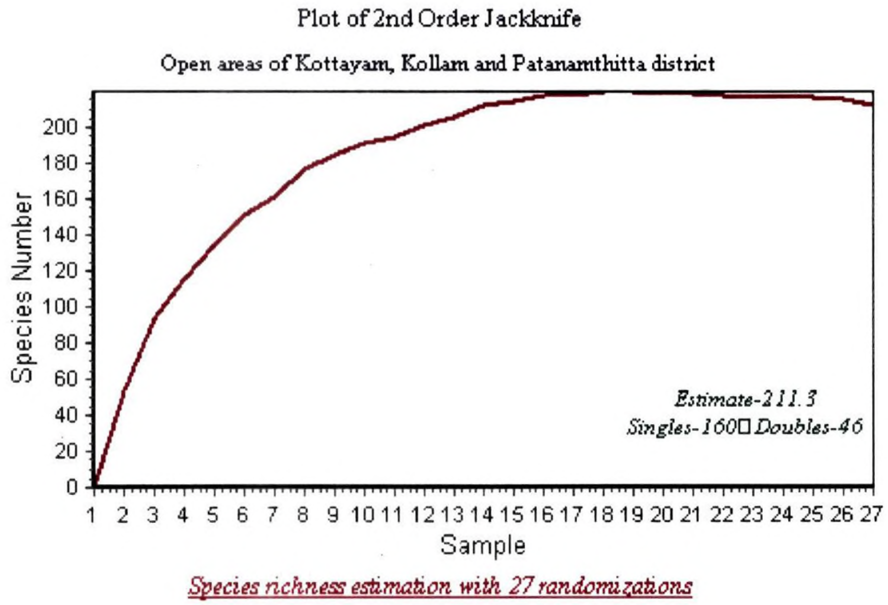


Figure 4.58

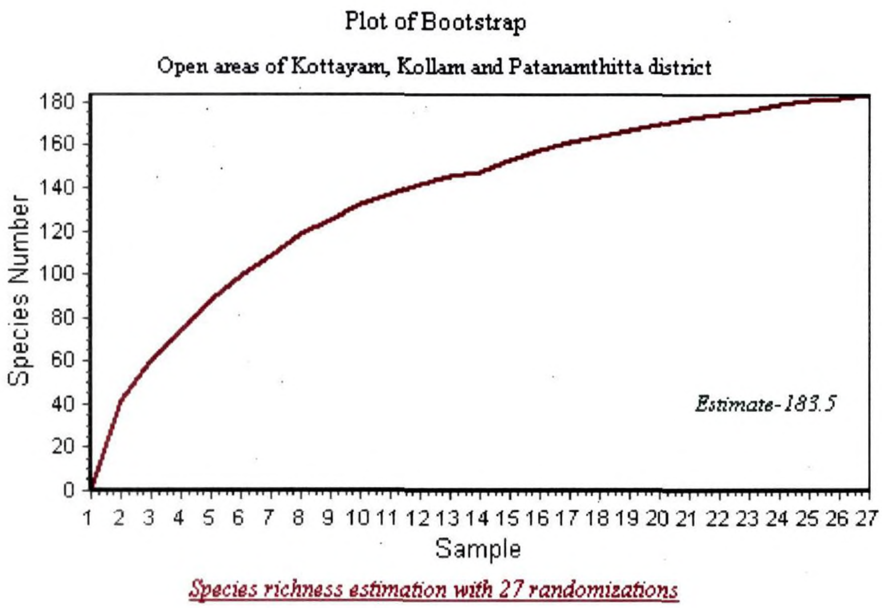
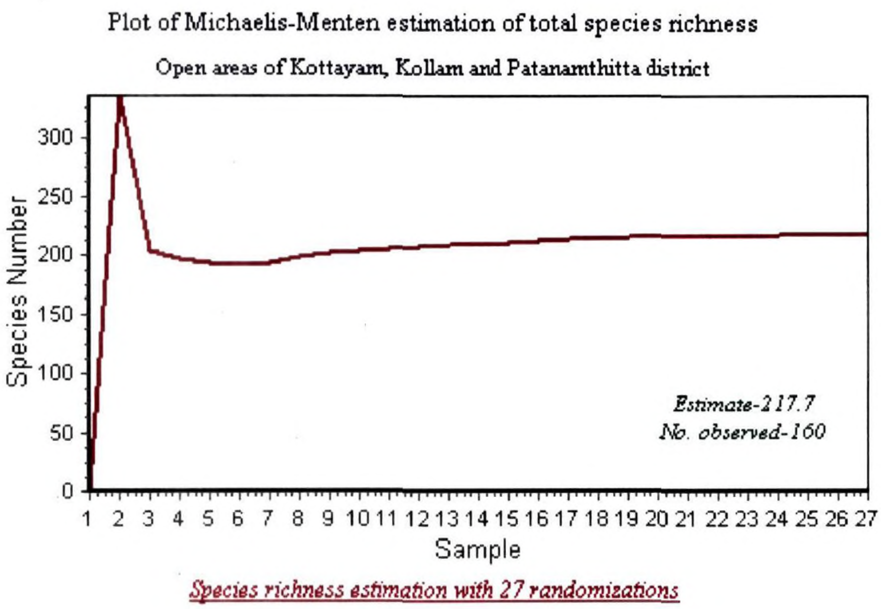


Figure 4.59



4.7.3.3 Sample interpolation

The number of species that would be observed for different numbers of samples ranging from zero to the total number of samples in the data set (Figures 4.61 and 4.62) shows that 20 samples yield 135 species in the RP areas, 145 species in the OP areas and 140 species in the Forest areas. This however does not show any distinction in the species richness of the three types of ecosystems.

Figure 4.60- 4.62- Sample interpolation of the sampled areas of Rubber plantations, *Open areas and the Forest areas (The extrapolated S $_{max}$ is the* estimated number of species that can be found in the area).

Figure 4.60

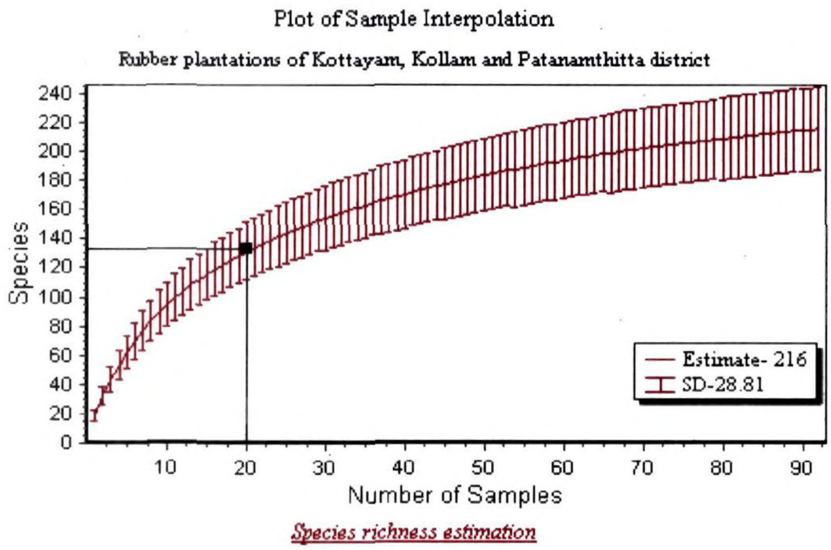


Figure 4.61

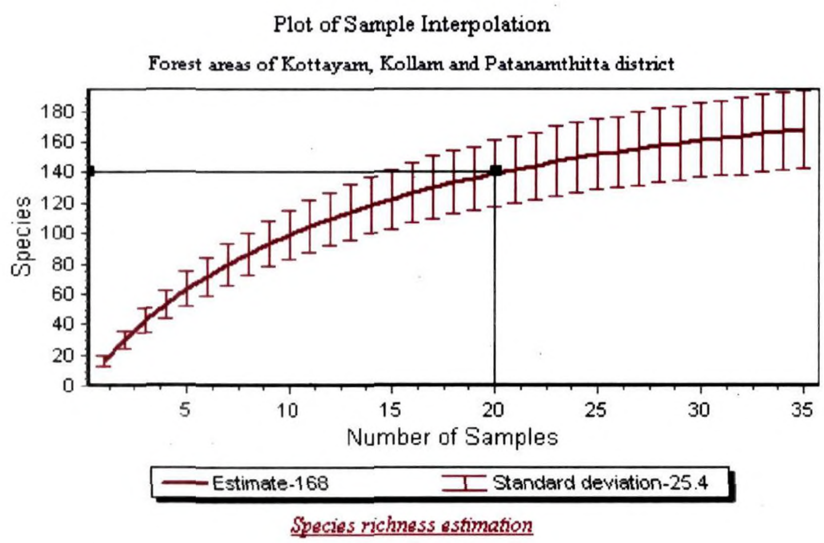
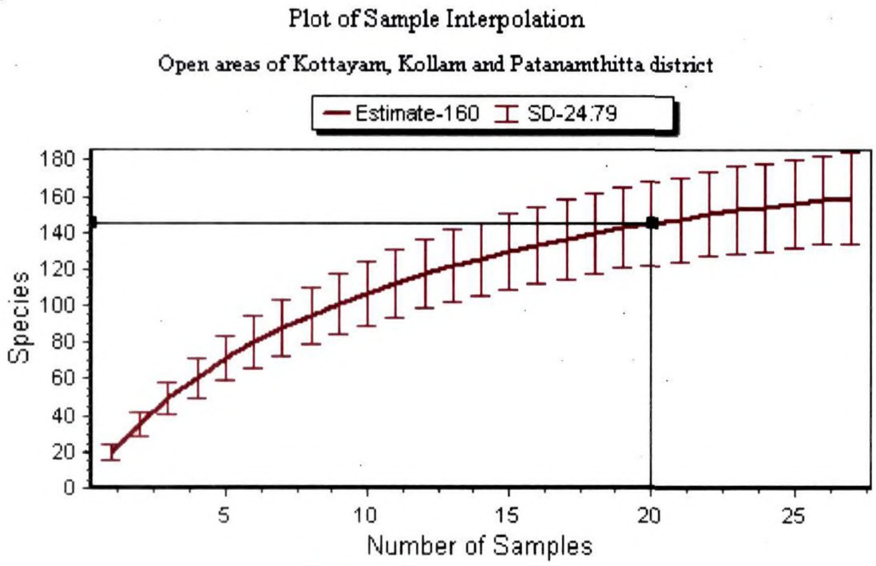


Figure 4.62



Species richness estimation

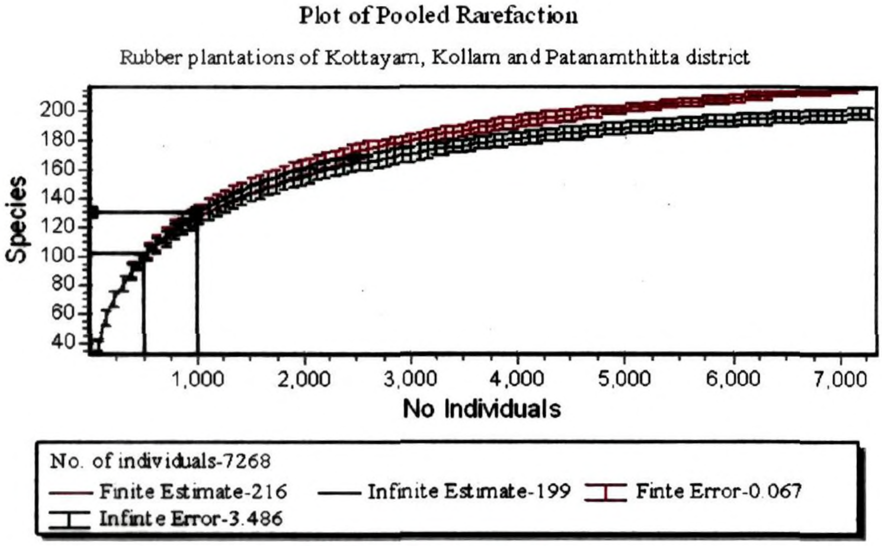
4.7.3.4 Rarefaction

Rarefaction curves were constructed from samples taken within habitats to determine the efficacy of sampling, the true species richness of a given habitat, and to compare species richness among habitats on an equal-effort basis). It also evaluates the adequacy of sampling by assessing whether the cumulative number of species has reached an asymptote, by comparing the S_{obs} to species-richness estimators, such as Chao2 or ICE, or by extrapolating the curve (Colwell and Coddington 1994, Ugland 2003, Colwell 2004).

The pooled data of the rubber plantation areas, Open areas and the Forest areas (Figures 4.63-4.65) and the single sample rarefaction of these areas (Figures 4.66-4.68) give the number of species that can be found in a random number of individuals in each of the area sampled.

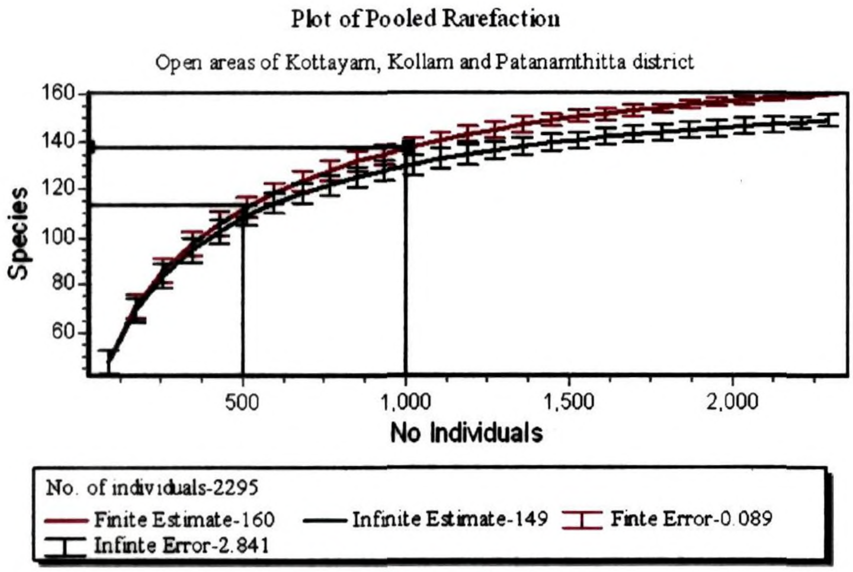
Figure 4.63-4.68 Pooled rarefactions and single sample rarefactions of the Rubber plantations, Open areas and the Forest areas (The number of species that can be expected from the area, in a randomly chosen number of individuals is indicated for each area).

Figure 4.63



Species richness estimation

Figure 4.64

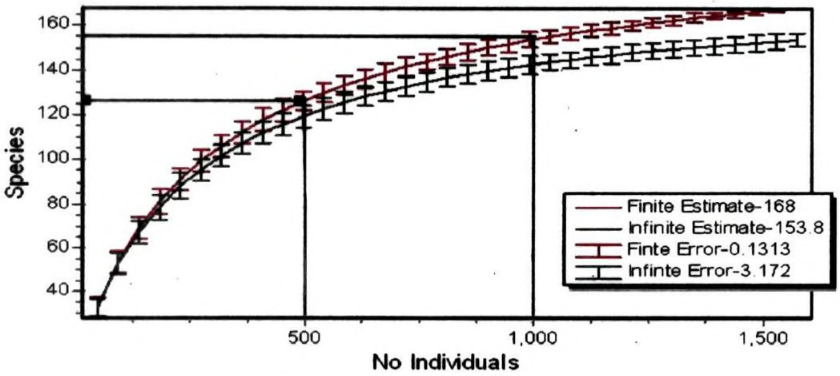


Species richness estimation

Figure 4.65

Plot of Pooled Rarefaction

Forest areas of Kottayam, Kollam and Patanamthitta district

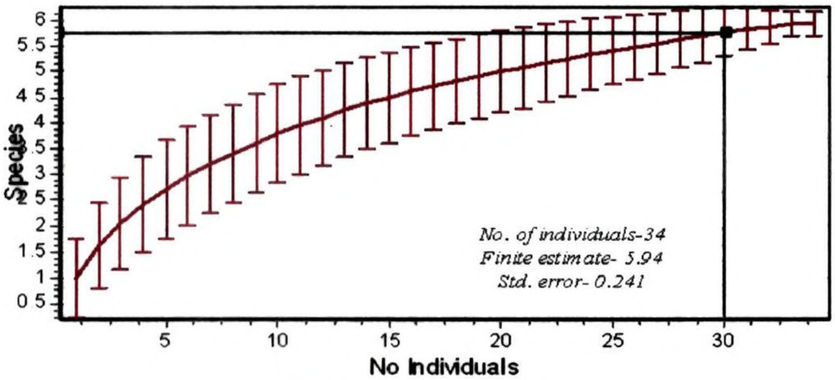


Species richness estimation

Figure 4.66

Plot of Sample Rarefaction - Rubber Plantations

Single sample rarefaction of the rubber plantation area samples of Kottayam, Kollam and Patanamthitta district

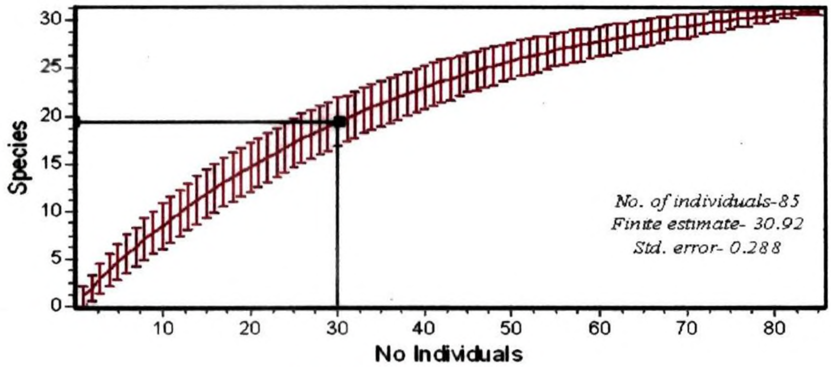


Species richness estimation

Figure 4.67

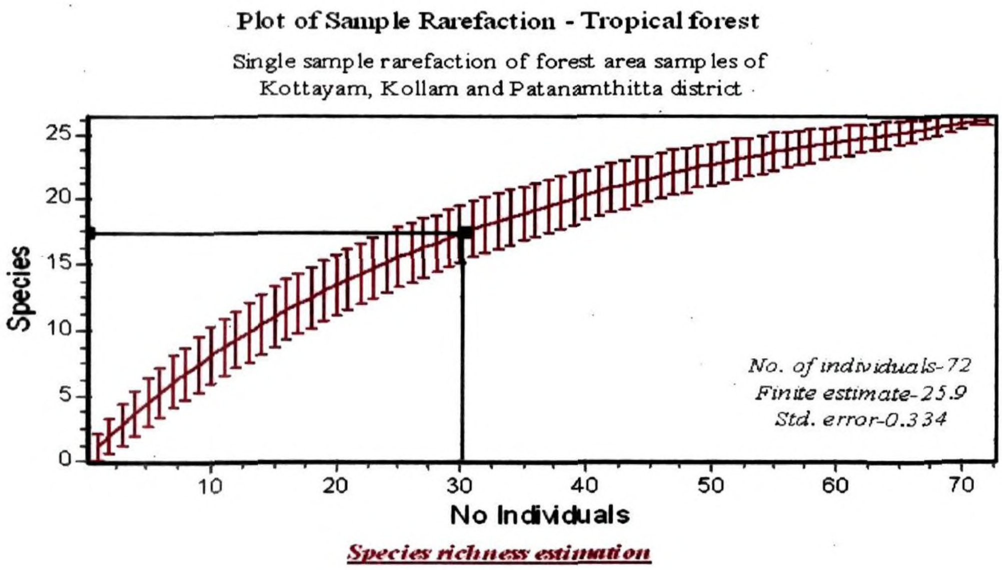
Plot of Sample Rarefaction - Open Areas

Single sample rarefaction of the open area samples of Kottayam, Kollam and Patanamthitta district



Species richness estimation

Figure 4.68



The single sample rarefaction method estimates how the species number in a selected sample changes with the number of individuals. Sampling is assumed to be without replacement for the Finite version, and with replacement for the Infinite version. The difference in richness is also evident from the observation that the total number of individuals sampled to obtain 216 species is 7268 (Figure 4.63) where areas in an Open area 160 species were obtained when 2265 individuals were sampled (Figure 4.64)and in a forest 168 species were obtained when 1575 individuals were sampled (Figure 4.65). Sample rarefactions of the pooled data show that in a subsample of 30 individuals in the RP areas 5.75 species can be expected (Figure 4.66) whereas in a similar sample of an OP are 19 species (Figure 4.67)and for a Forest area 17 species can be expected (Figure 4.68).

Pooled rarefactions of the weeded and unweeded areas have shown that the number of species increased considerably when the areas were left undisturbed. 154 species were found when 2628 species were sampled in the unweeded RP plantations (Figure 4.70), whereas the same number of species (154 species) was obtained only when 4704 individuals were sampled in the weeded areas (Figure 4.69). Single sample rarefaction estimates how the species number in a selected sample changes with the number of individuals. Single sample rarefactions of the weeded and unweeded sites undertaken show that a subset of 10 individuals will yield 3.8 species in a unweeded area (Figure 4.72), while the same subset will yield 6.0 species in a weeded area (Figure 4.71).

Figure 4.69 & 4.70 The pooled rarefaction of the weeded and unweeded sites of the RP areas (The number of species that can be obtained from a subsample of 500 individuals is shown).

Figure 4.69

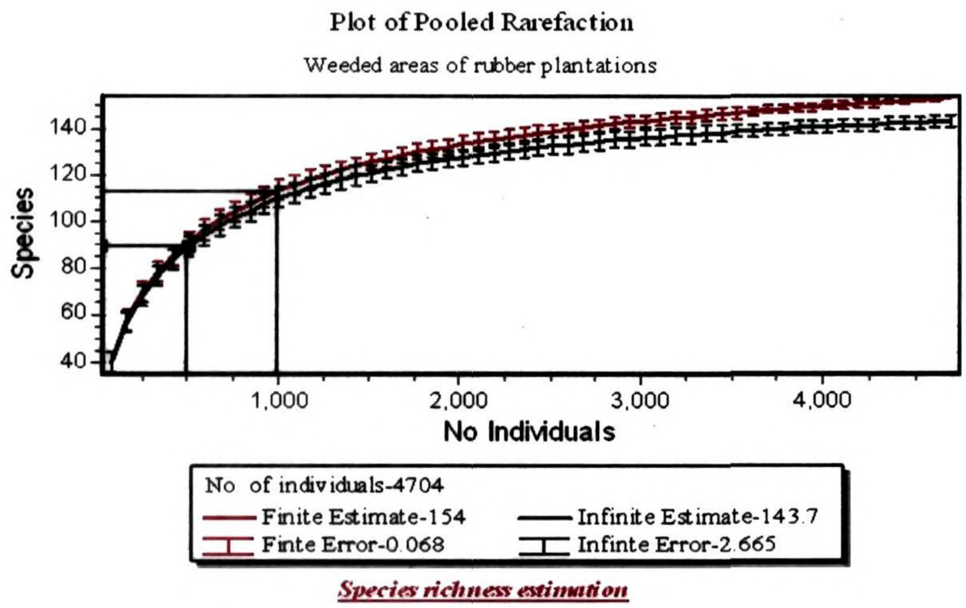


Figure 4.70

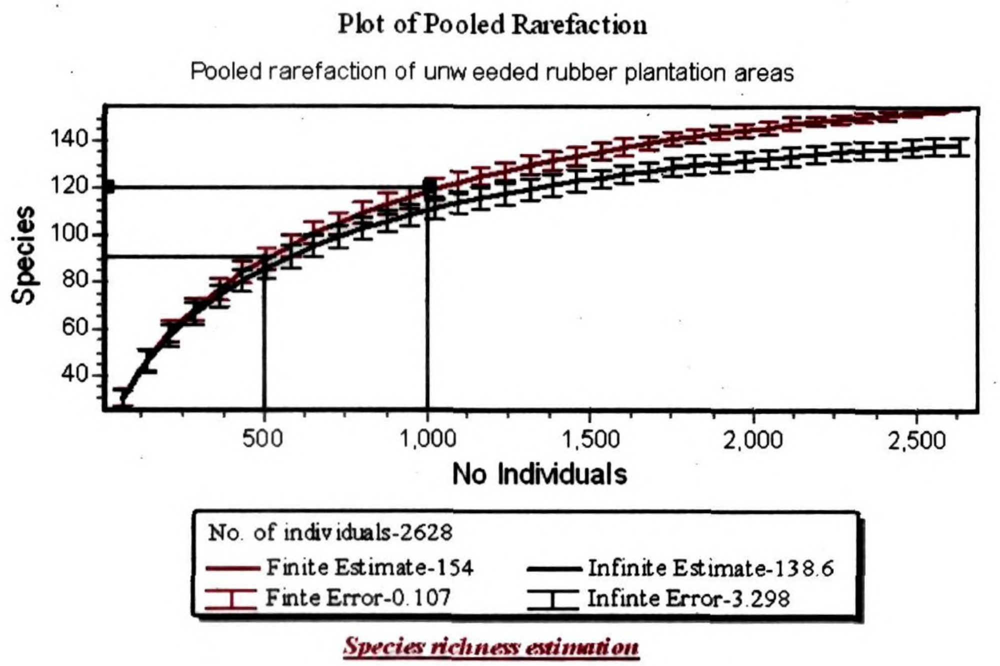


Figure 4.71 & 4.72 The single sample rarefaction of the weeded and unweeded sites of the RP areas (The number of species that can be obtained from a rarefied subsample of 10 individuals is shown).

Figure 4.71

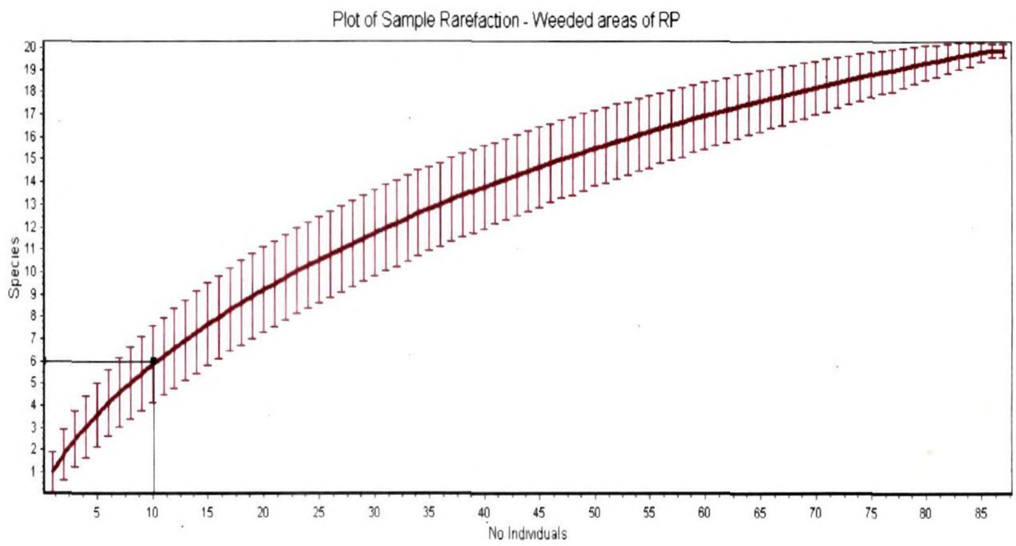
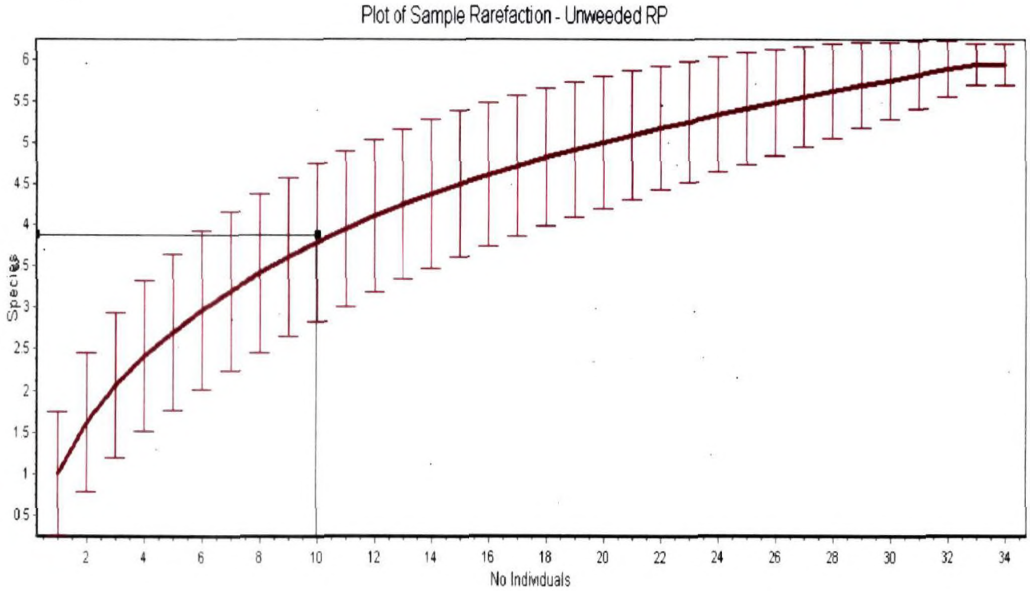


Figure 4.72



4.7.4 Fitting distribution (Non parametric species richness estimate)

The second step in the plant diversity analysis is the fitting of the data in to the log normal distribution as suggested by the RA plots.

The data was tested to fit the SAD models and the goodness of fit was tested for each type of sample (RP, OP and Tropical Forest) and its subsets using Pisces conservation SDR version 4.0 (Table 4.24).

Table 4.24 The statistical goodness of fit to the species abundance distribution (SAD) models of the RP, OP and Forest areas surveyed.

Forest	Open areas	Rubber plantation
Log Series Model Fit	**Log Series Model Fit**	**Log Series Model Fit**
x = 0.970664	x = 0.983473	x = 0.994363
alpha = 47.2978	alpha = 38.2988	alpha = 41.3576
Goodness of fit test	Goodness of fit test	Goodness of fit test
Chi = 20.1916	Chi = 14.959	Chi = 15.0313
Degrees of freedom = 5	Degrees of freedom = 6	Degrees of freedom = 8
P = 0.00115037	P = 0.0205782	P = 0.0585389
The data does not fit a log series model	The data does not fit a log series model	The data fits a log series model
Truncated Log Normal	**Truncated Log Normal**	**Truncated Log Normal**
Observed Log10 Mean = 0.694711	Observed Log10 Mean = 0.808763	Observed Log10 Mean = 0.902713
Observed Log10 Variance = 0.228283	Observed Log10 Variance = 0.288934	Observed Log10 Variance = 0.474396
Estimated Log10 Mean = 0.63779	Estimated Log10 Mean = 0.7438	Estimated Log10 Mean = 0.765204
Estimated Log10 Variance = 0.284962	Estimated Log10 Variance = 0.361029	Estimated Log10 Variance = 0.639921
Total predicted species in Community = 173.834	Total predicted species in Community = 163.717	Total predicted species in Community = 235.498
Total observed species = 167	Total observed species = 157	Total observed species = 214
Species behind the Veil Line = 6.83432	Species behind the Veil Line = 6.71666	Species behind the Veil Line = 21.4978
Lambda, Diversity Statistic = 325.643	Lambda, Diversity Statistic = 272.472	Lambda, Diversity Statistic = 294.39
Goodness of fit test	Goodness of fit test	Goodness of fit test
Chi = 4.9358	Chi = 6.22341	Chi = 7.3392
Degrees of freedom = 5	Degrees of freedom = 6	Degrees of freedom = 8
p = 0.423765	p = 0.398635	p = 0.500517
The data fits a truncated log normal model	The data fits a truncated log normal model	The data fits a truncated log normal model

The species-abundance distribution is presented as a graph of the number of species (ordinate) vs. the number of individual's censuses (abscissa). The Pooled samples show that RP areas fit the lognormal and log series distribution and do not fit the geometric or Broken stick model (Figure 4.73a and 4.73b). The OP and Forest areas only fit the log normal distribution and do not fit the log series (Figure 4.74 and 4.75).

Figure 4.73- 4.75 Fitted distribution curve(SAD) of the pooled data Rubber Plantations, Open areas and Forest areas showing the lognormal distribution .The Rubber Plantation areas also fit the log series distribution and Log normal distribution (Figure 4.73a and 4.73b).

Figure 4.73a

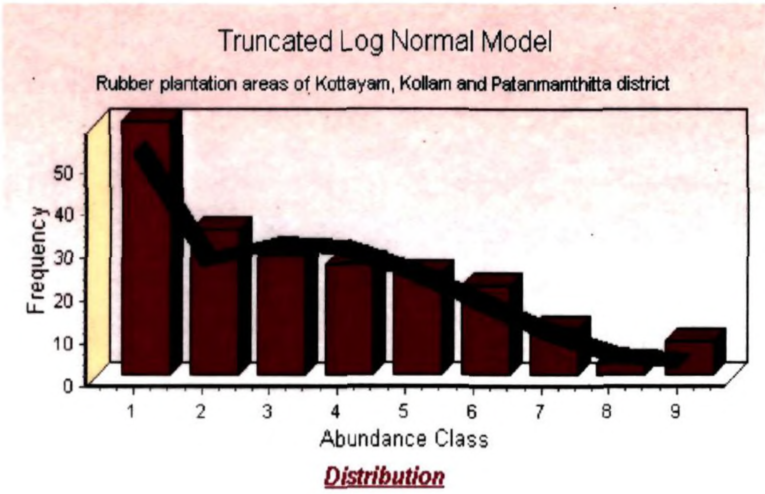


Figure 4.73b

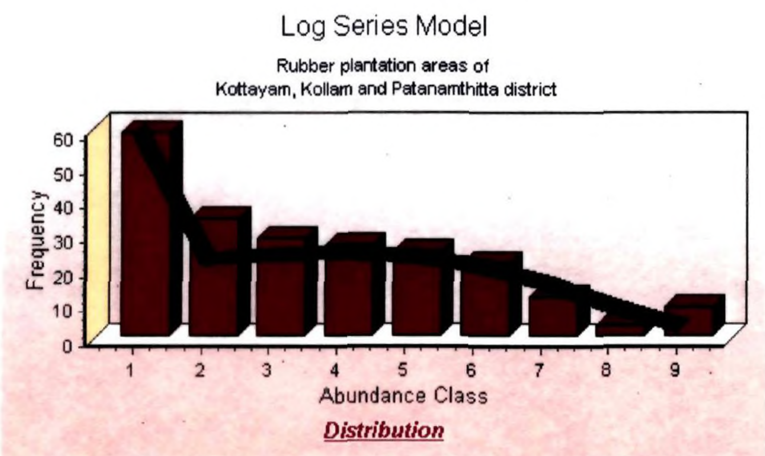


Figure 4.74

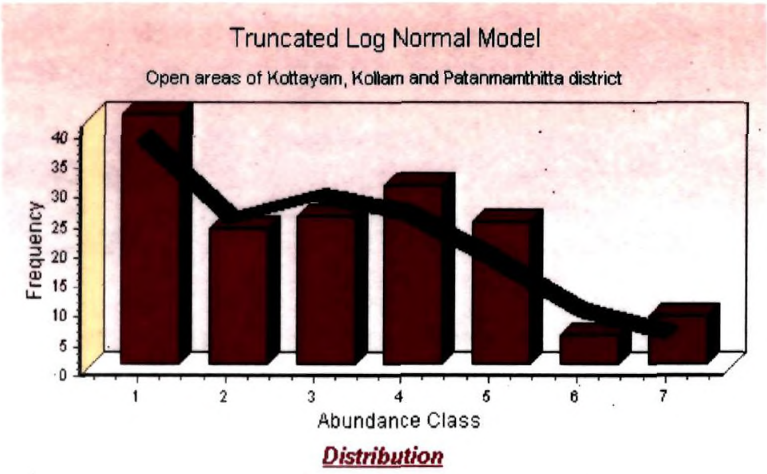
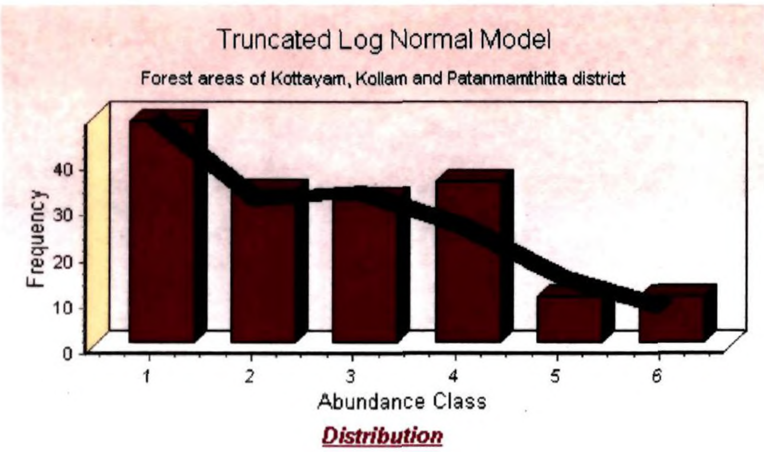


Figure 4.75



The truncated lognormal is the lognormal distribution of the abundances of various species whose individuals curve terminates at its crest (Preston 1962a, b). This model represents the situation where abundances of individuals or pairs of individuals are distributed at random among species. In this distribution, the individuals or pairs are not clumped (few species with most of the individuals) at one extreme, and they are not overly regulated (all species equally abundant) at the other extreme (Miller and Weigert 1989). The entire lognormal distribution of species abundance in a community can never be sampled. Some species are too rare to be represented by one or more individuals in a sample. These species fall below the veil line of the distribution, and only increasing the total number of individuals examined can reveal their presence. When the size of a sample doubles, the modal abundance of species moves one octave to the right (the abundance of all species doubles, on average), and additional species, each represented by one individual, appear in the distribution at the veil line.

The tests of the subsets of RP, Forest and OP areas showed that Mundakayam forests data fits the broken stick model and shows maximum evenness. All the other subsets in the RP and OP areas fit a log normal distribution (Figures 4.76-4.89). Thenmala, Puthupally, Chetheckal and Mundakayam RP areas also fit a log series distribution indicating lower evenness in these areas. Among the OP areas Neezhoor, Mundakayam and Pampadi also fit the log series and Puthupally, Mundakayam and Thenmala OP fit the geometric series indicating very low evenness and dominance of single species in these areas.

Figure 4.76- 4.89 Fitted distribution curve (SAD) of the subsamples (Mundakayam, Chetheckal, Puthupally, Neezhoor, Pampadi and Thenmala) RP, OP and Forest areas showing the goodness of fit to SAD models.

Figure 4.76

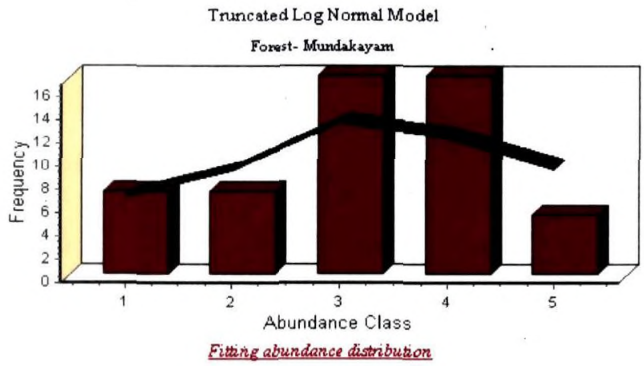


Figure 4.77

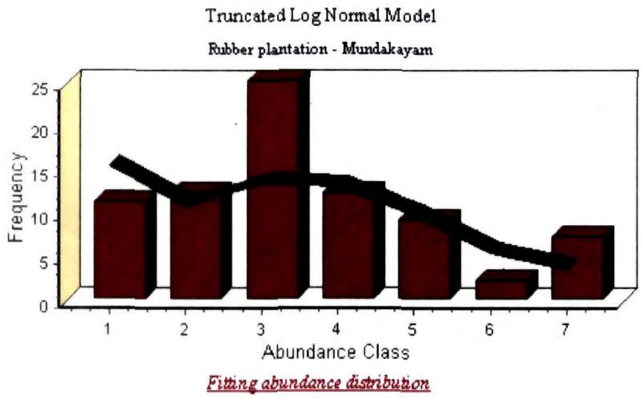


Figure 4.78

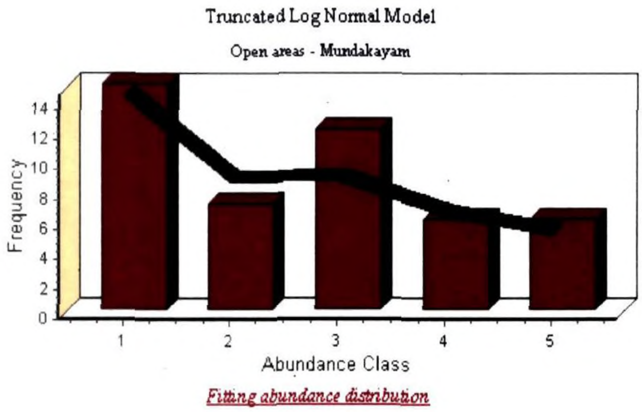


Figure 4.79

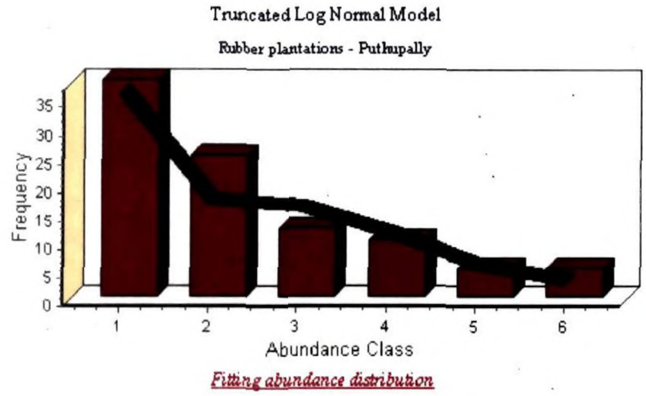


Figure 4.79

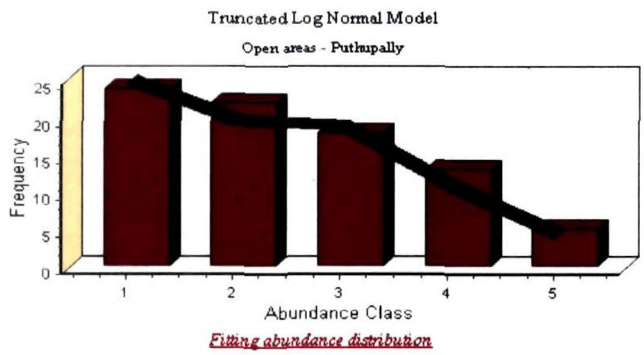


Figure 4.80

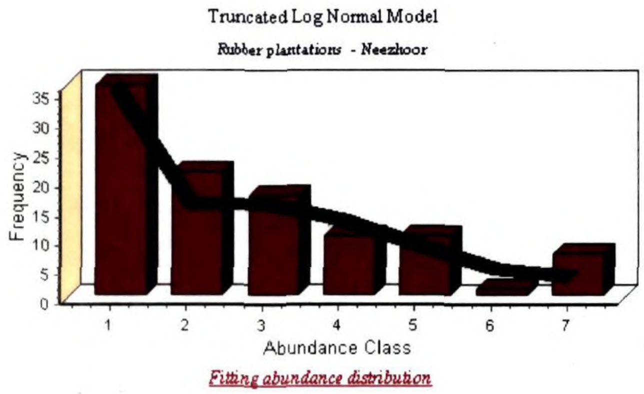


Figure 4.81

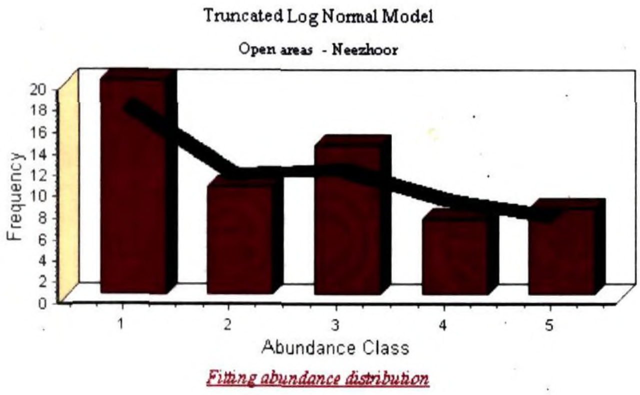


Figure 4.82

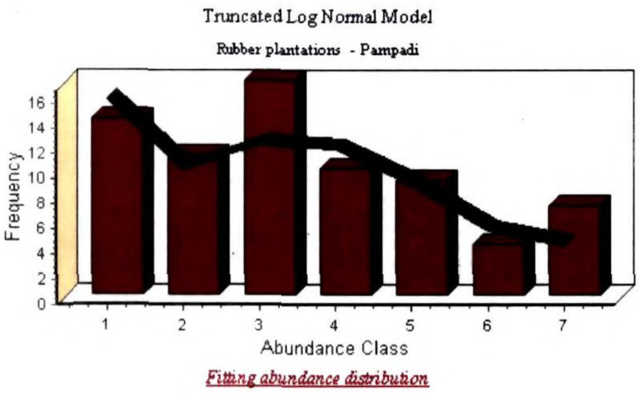


Figure 4.83

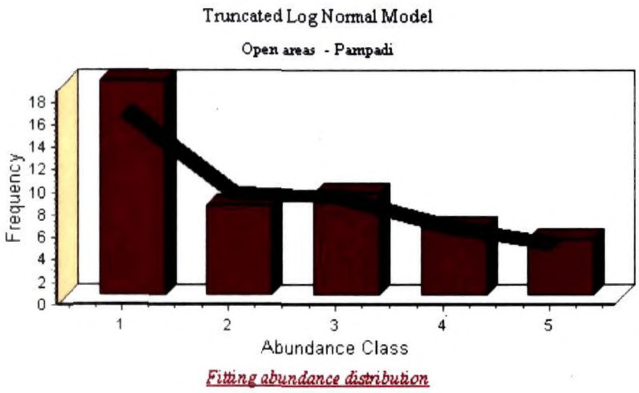


Figure 4.84

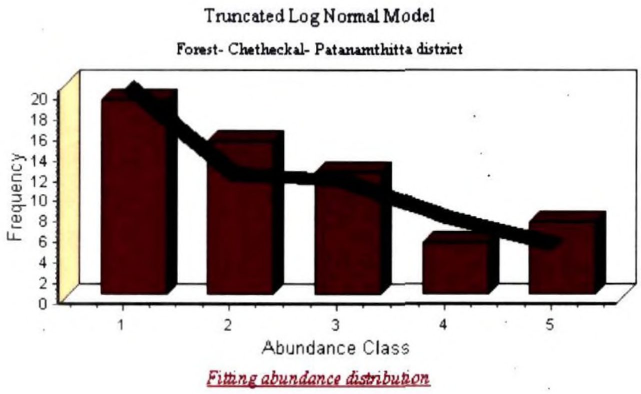


Figure 4.85

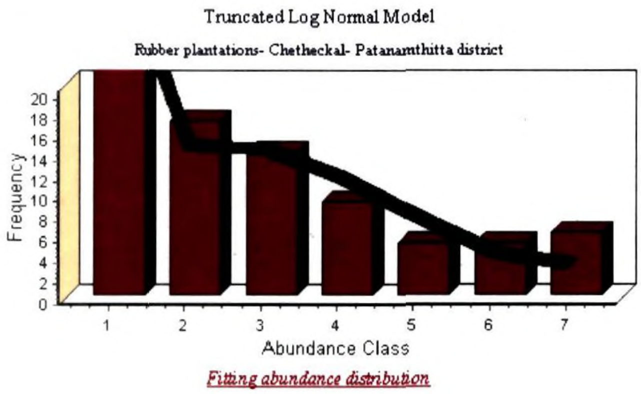


Figure 4.86

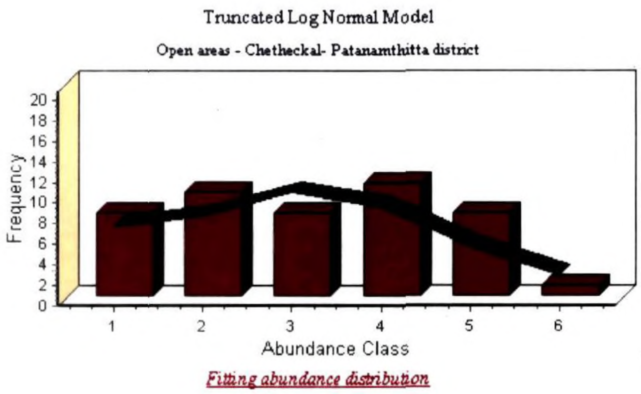


Figure 4.87

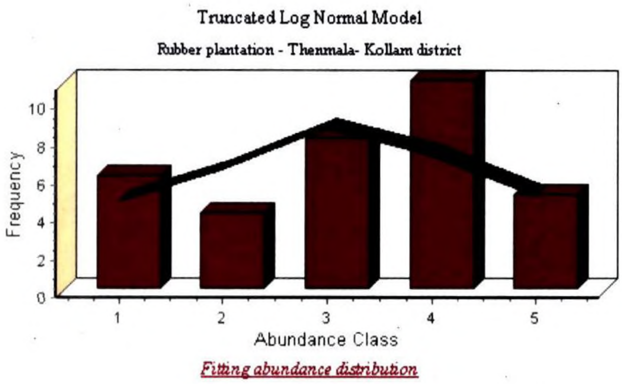


Figure 4.88

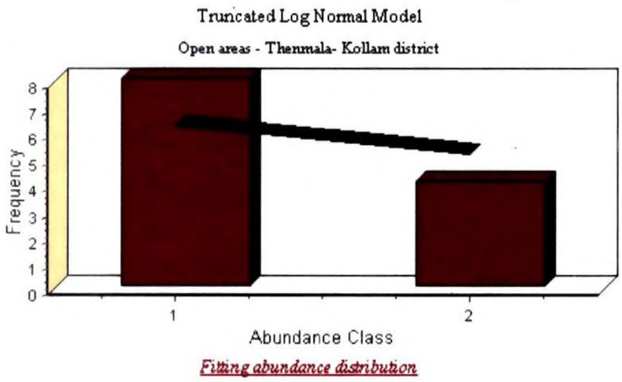
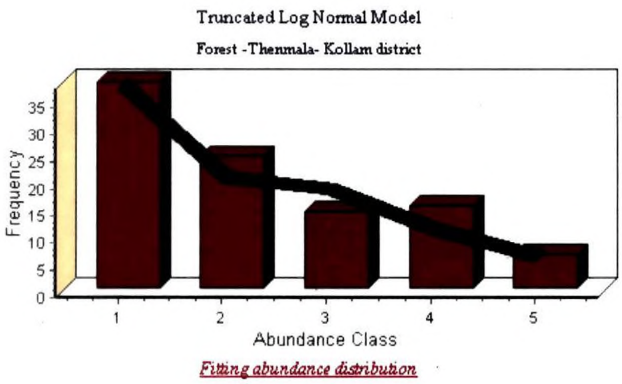


Figure 4.89



4.7.5 Measuring diversity

4.7.5.1 Diversity Indices

A range of diversity indices (DI) was plotted for the three types of areas (RP, OP and Forest) and their sub samples in the three districts (Figures 4.90 - 4.96, 4.97 - 4.100 and Table 4.25).

Table 4.25 - The Alpha diversity indices and the Evenness indices of the Rubber plantation areas, Open areas and the Forest areas.

S.No	Diversity Index	Rubber plantation	Jackknife error*	Open areas	Jackknife error	Forest	Jackknife error
Alpha diversity index							
1	All sample index	216	7.24	160	9.495	168	10.87
2	Shannon Weiner	4.002	0.053	4.295	0.088	4.48	0.085
3	Simpsons	27.85	2.106	42.88	5.796	55.46	7.692
4	Margalef	24.17	0.803	20.55	1.181	22.7	1.234
5	Berger Parker dominance	0.084	0.009	0.074	0.014	0.058	0.014
6	Mc Intosh	0.819	0.007	0.864	0.011	0.885	0.009
7	Brilluoin	3.945	0.052	4.166	0.081	4.306	0.089
8	Fisher alpha	41.82	1.726	39.19	2.973	47.67	3.027
9	Q statistics	47.5	7.442	43.76	7.24	53.75	10.2
10	Menhinick	2.527	0.096	3.342	0.221	4.244	0.188
11	Strongs	0.629	0.011	0.478	0.028	0.429	0.021
Evenness index							
1	Pielou J E	0.744	0.01	0.846	0.017	0.876	0.016
2	Mc Intosh E	0.869	0.008	0.919	0.011	0.935	0.009
3	Brilluion E	0.745	0.01	0.846	0.018	0.877	0.011
4	HeipE	0.249	0.014	0.455	0.045	0.526	0.03
5	Simpsons E	0.129	0.01	0.268	0.041	0.33	0.038
6	NHC	0.112	0.004	0.145	0.008	0.163	0.01
7	Carmago	0.917	0.022	0.997	0.034	1.05	0.028
8	Smith & Wilson B	0.242	0.012	0.374	0.048	0.442	0.03
9	Smith & Wilson D	0.968	7.043	0.982	9.235	0.987	10.92
10	Smith & Wilson- in D	0.618	0.014	0.737	0.028	0.777	0.023
11	Shannon Weiner Maximum	5.375	0.033	5.075	0.06	5.124	0.065
12	Shannon Weiner Minimum	0.291	0.014	0.603	0.056	0.885	0.062
13	Gini	0.216	0.009	0.364	0.042	0.419	0.072

4.7.5.1.1 Alpha diversity index

Alpha diversity indices (ADI) that measures diversity were computed for each of the pooled sample of RP, OP and Forest areas (Figures 4.90 - 4.96) and for the individual sites (subsets) of each type of area (4.97 - 4.100) using Pisces conservation SDR version 4.(2006). These indices were bootstrapped for 95 % confidence limit and the Jackknife standard error was calculated for each index (Table 4.25). Six indices (Shannon Weiner, Simpsons, Mc Intosh, Brilluoin, Q statistics and Menhenick) showed that the Rubber plantation areas had the lowest diversity among the three areas while the Forest areas were highest in diversity (Table 4.25). The Margalef, Berger parker, Fisher alpha and the Strong's alpha diversity index were highest for the Rubber plantations whereas the diversities of the OP and Forest area varied in these indices (Table 4.25).

Figures 4.90-4.96- Alpha diversity indices and the Evenness index of each subset of the Rubber plantation areas, Open areas and the Forest areas.

Figure 4.90

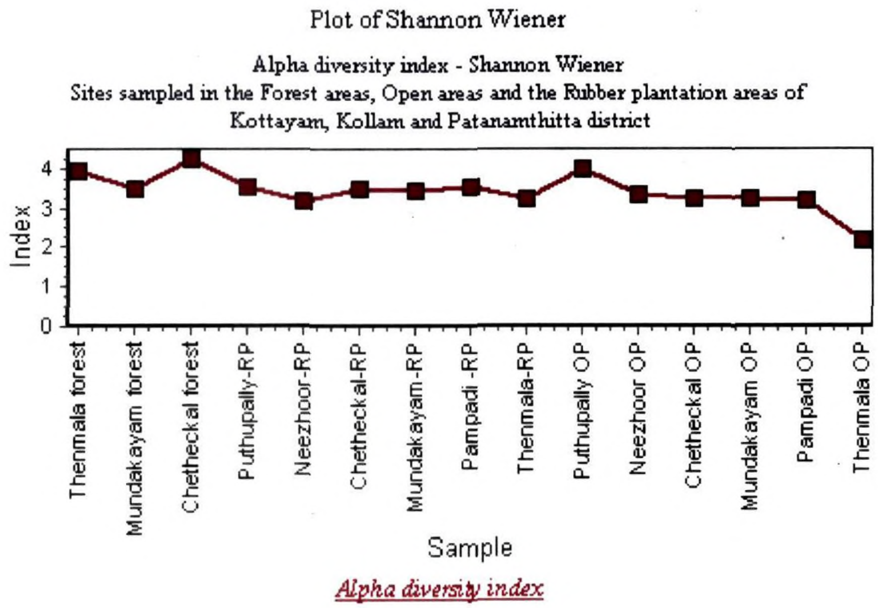
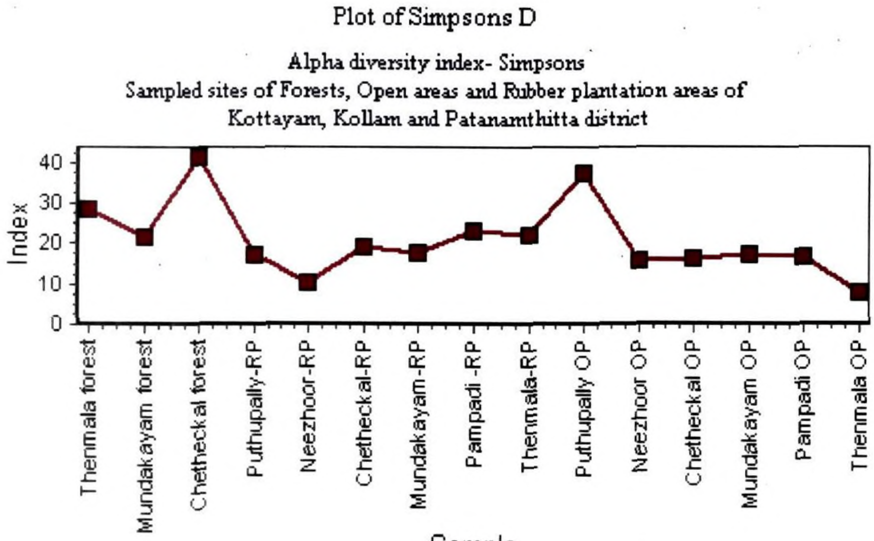
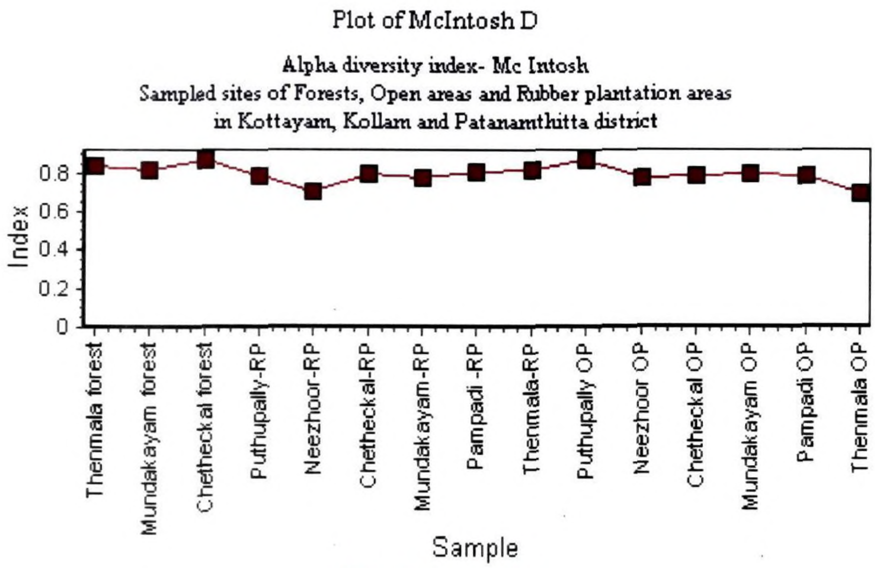


Figure 4.91



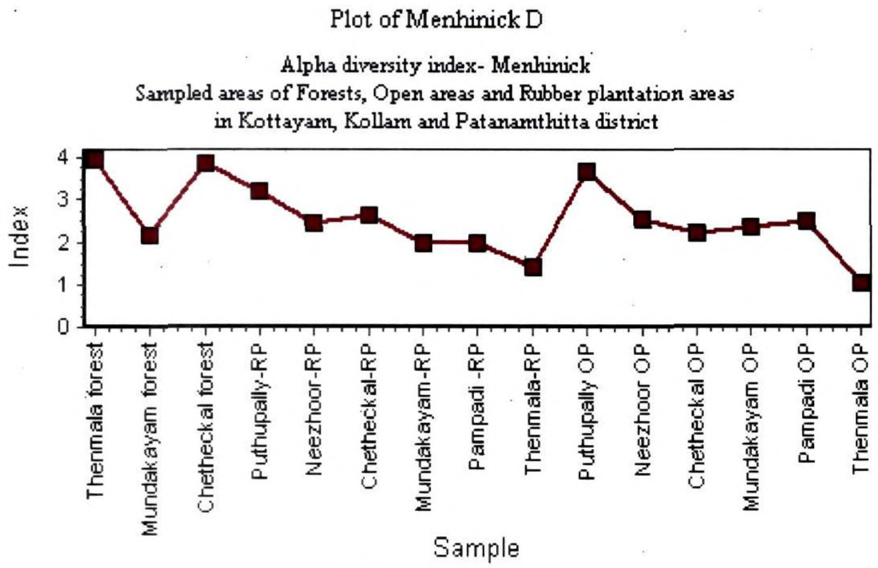
Alpha diversity index

Figure 4.92



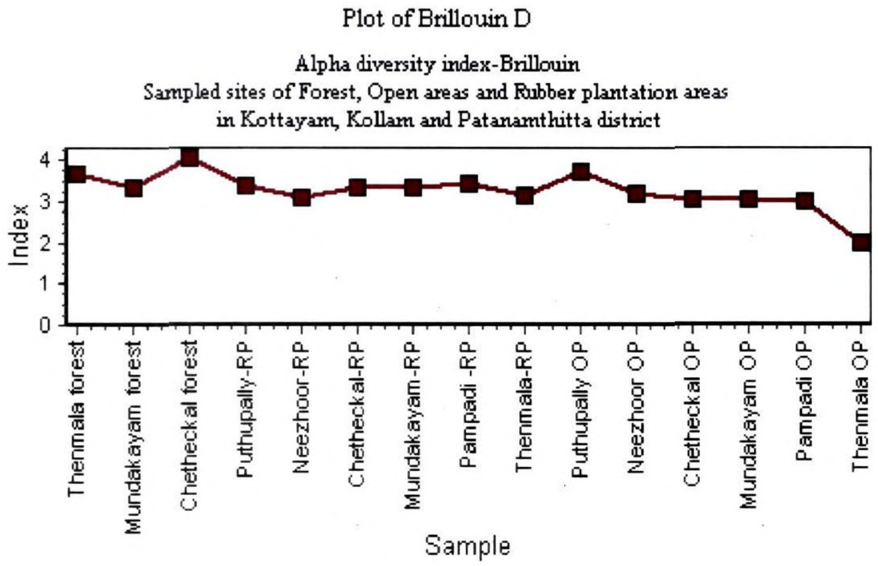
Alpha diversity index

Figure 4.93



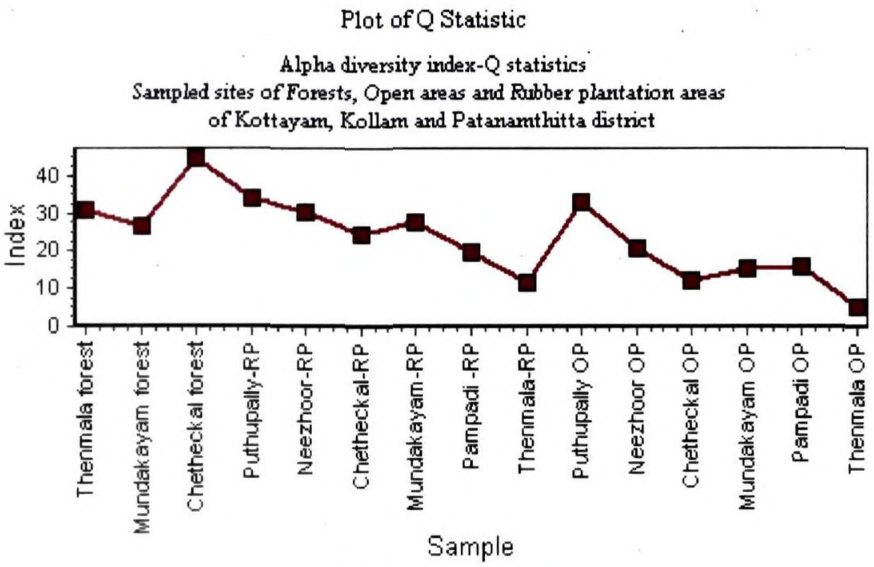
Alpha diversity index

Figure 4.94



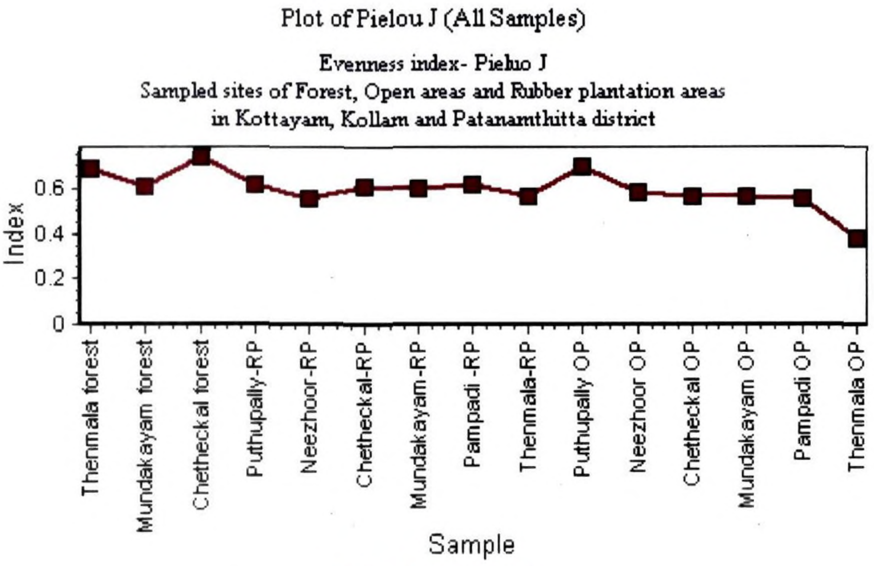
Alpha diversity index

Figure 4.95



Alpha diversity index

Figure 4.96



Alpha diversity index

4.7.5.1.2 Evenness index

A range of 13 Evenness indices (EI) that measures equitability were computed. These indices were bootstrapped for 95 % confidence limit and the Jackknife standard error was calculated for each index (Table 4.25). All the evenness indices computed showed that the Forest areas were the highest in evenness and that the Rubber plantations showed the lowest evenness index (Table 4.25).

4.7.5.1.3 Diversity index of the subsets

The alpha diversity indices chosen for the individual sites sampled (subsets) were Shannon Wiener, Simpson, Brilluoin, McIntosh, Q statistics and Menhinick and the Evenness index Pielou- J. The diversity and equitability of all the subsets are plotted in Figures 4.97- 4.100. The graphs also show that the indices vary marginally in the individual sites in each type of area (Figures 4.97-4.100).

Figure 4.97-4.100 - Alpha diversity index and Evenness index of the individual sampled sites (subsets) of Rubber plantation areas (The diversity index of each subset is displayed in the legend).

Figure 4.97

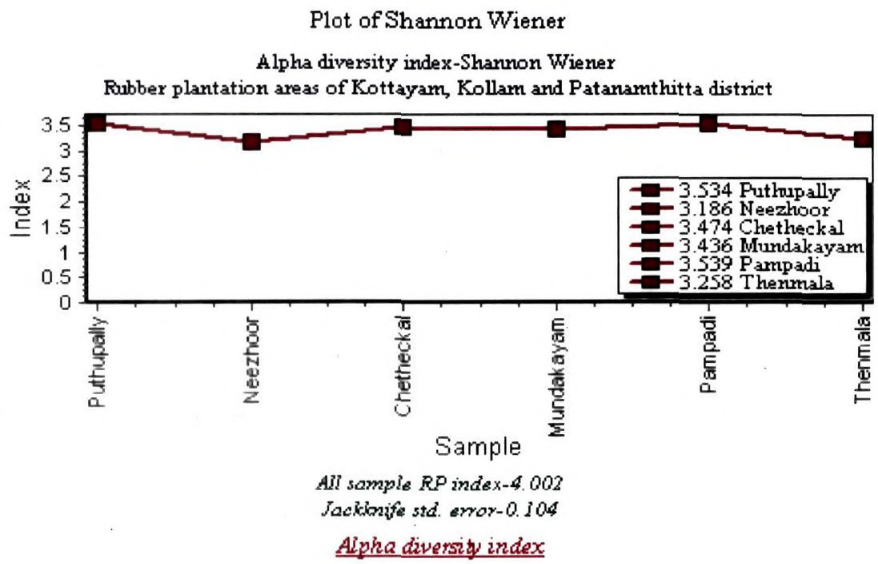
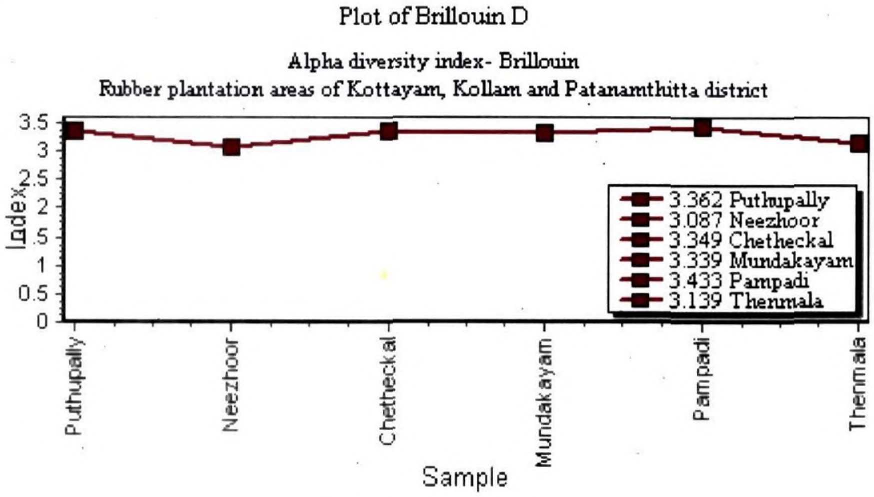


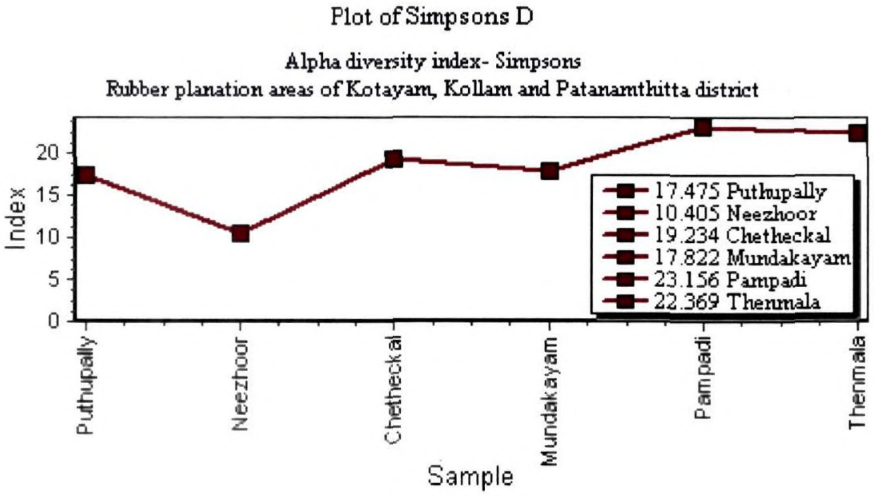
Figure 4.98



All sample RP index- 3.945
Jackknife std. error- 0.981

Alpha diversity index

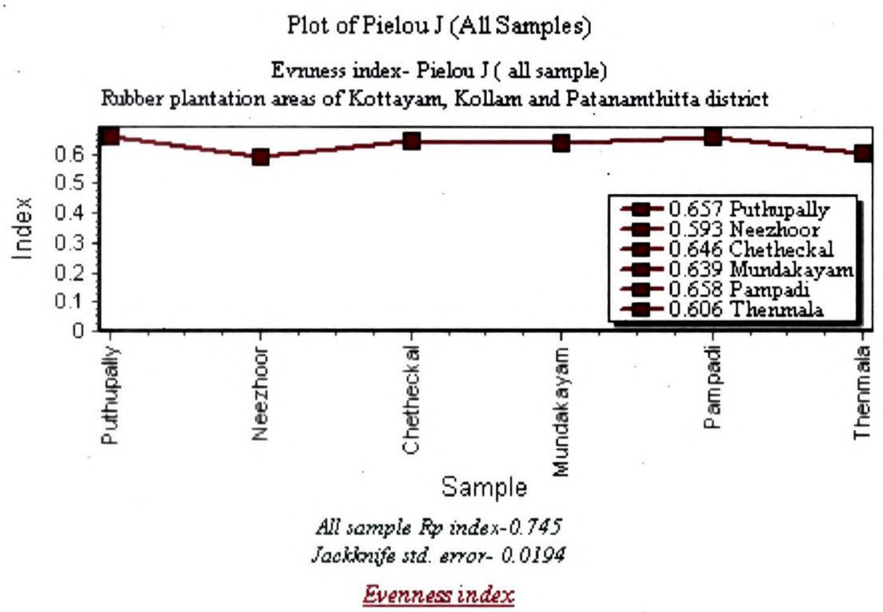
Figure 4.99



All sample RP index-27.85
Jackknife std. error-3.917

Alpha diversity index

Figure 4.100



4.7.5.1.4 Randomization tests

The Shannon Wiener alpha diversity index of the Tropical forest area is 4.48 and is 4.295 and 4.002 for the Open areas and the Rubber plantation areas respectively (Table 4.25). Randomization tests of Solow (1993, 1994) to compare the diversity indices of these areas to see if the differences were significant at the 5 % level. Two tailed randomizations tests with 1000 random partitions were undertaken to compare the individual sites to test for significant level of difference at the 5% level. The tests show that the differences in the ADI and EI of the individual sites sampled in the RP and the Forest areas were, significant at the 5% level whereas all the OP areas except Thenmala OP had the same diversity.

Plot of ADI and EI of the Rubber plantation areas of each individual site (Figure 4.97-4.100) display show a comparatively consistent low DI in Neezhoor RP and the Thenmala RP areas. Randomization tests show that the differences among the sites are significant at the 5 % level. A randomization test between the Thenmala

RP and the Neezhoor RP have shown that the Thenmala plantations and Neezhoor plantations are significantly different.

4.7.5.2 Diversity ordering

Two diversity ordering methods were used viz. Rényi and Right tailed sum.

4.7.5.2.1 The Rényi's family (Rényi 1961 and Hill 1973)

Diversity ordering of the three areas (Figure 4.101) and of the subsets of the RP areas (Figure 4.102) were undertaken using SDR version 4 and the results displayed graphically.

Figure 4.101- Diversity ordering profiles of the pooled samples of Rubber plantations, Open areas and Forest areas, using the Rényi family diversity index.

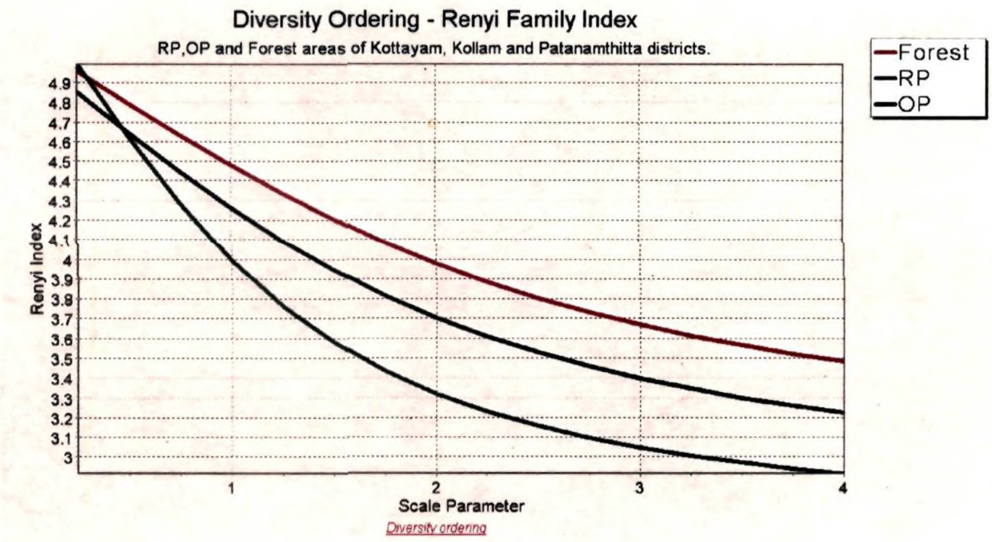
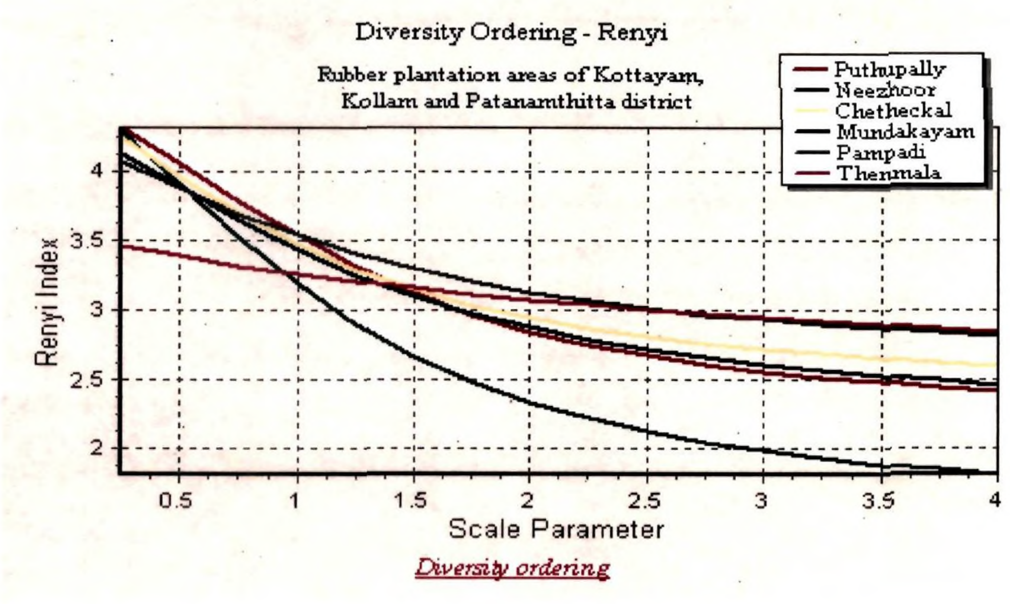


Figure 4.102 - Diversity ordering profiles of the individual Rubber Plantations areas (sub samples) sampled, using the Rényi family diversity index.



4.7.5.2.2 Right tailed sum (Liu *et al.* 2007)

Diversity order of the three areas (Figure 4.103) and the subsets of the RP areas (Figure 4.104) were plotted using Pisces conservation SDR version 4.

Figure 4.103 Diversity profiles of the Rubber plantation, Open areas and Forest areas, using Right Tailed Sum diversity ordering grouping.

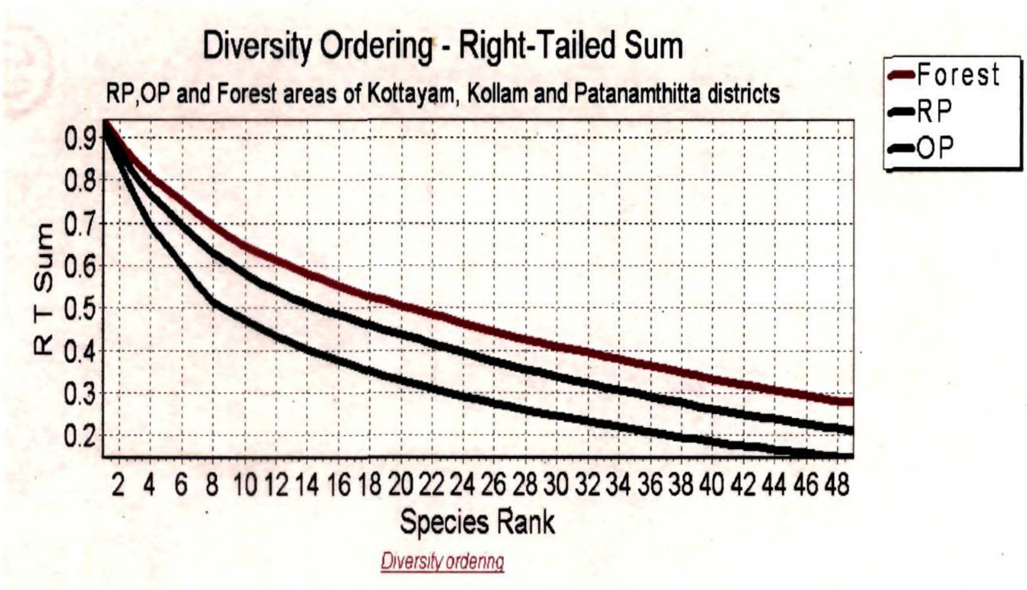
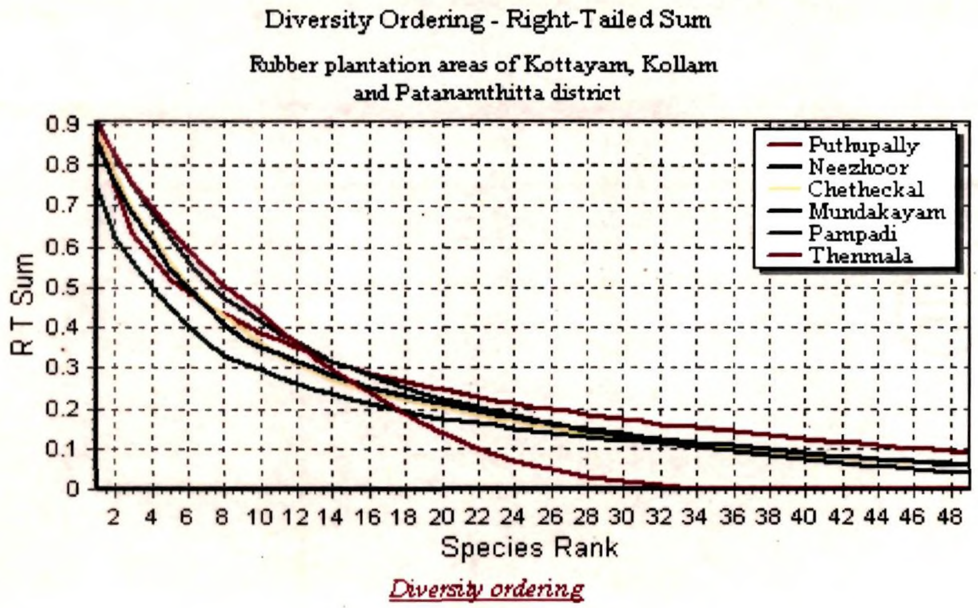


Figure 4.104 Diversity profiles of individual Rubber Plantations (subsamples), using Right Tailed Sum diversity ordering grouping.



A diversity profile using Rényi family (RF) and Right Tailed sum (RTS) for the pooled data of Rubber plantation areas, Open areas and the Forest areas show that rubber plantations are comparatively lower in diversity than the OP and the RP areas (Figure 4.101 & Figure 4.103). The Rényi index shows that the RP and OP areas intersect each other and are likely to be ranked differently by different diversity indices (Figure 4.101). However the RTS diversity profile (Figure 4.103) clearly indicates that the three areas are likely to be ranked similarly by majority of the diversity indices (Table 4.25).

The diversity profile of individual sites sampled in the RP areas in the three districts (Puthupally, Neezhoor, Pampadi, Mundakayam, Chetheckal, Thenmala) are plotted using Renyi and RTS diversity ordering(Figure 4.102 and 4.104). Both the diversity-ordering methods give a similar pattern of diversity profiles for these areas. The Thenmala RP areas show a non –comparable diversity with respect to the other plantations. It can also be seen that Neezhoor has the lowest diversity index. The RTS diversity ordering was used for further insights into diversity of the individual areas.

The RF and RTS diversity profile based on the family level and genera level presence (Figure 4.105 and 4.106) also show that the three areas vary in their diversity. The OP areas are lower in their family diversity than the RP and Forest areas. The latter two are similar in diversity but will be ranked differently by different indices. The graph indicates that the forest areas are more species rich and more even.

Figure 4.105 Diversity profiles of the family level presence in Rubber Plantations, Open areas and Forest areas using the Rényi diversity ordering index.

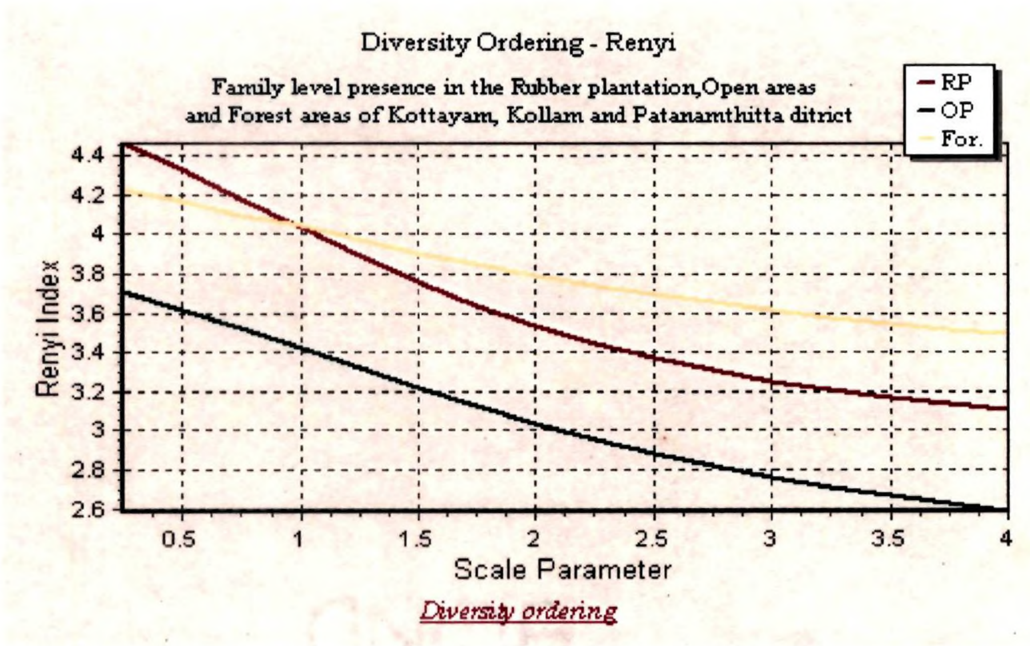
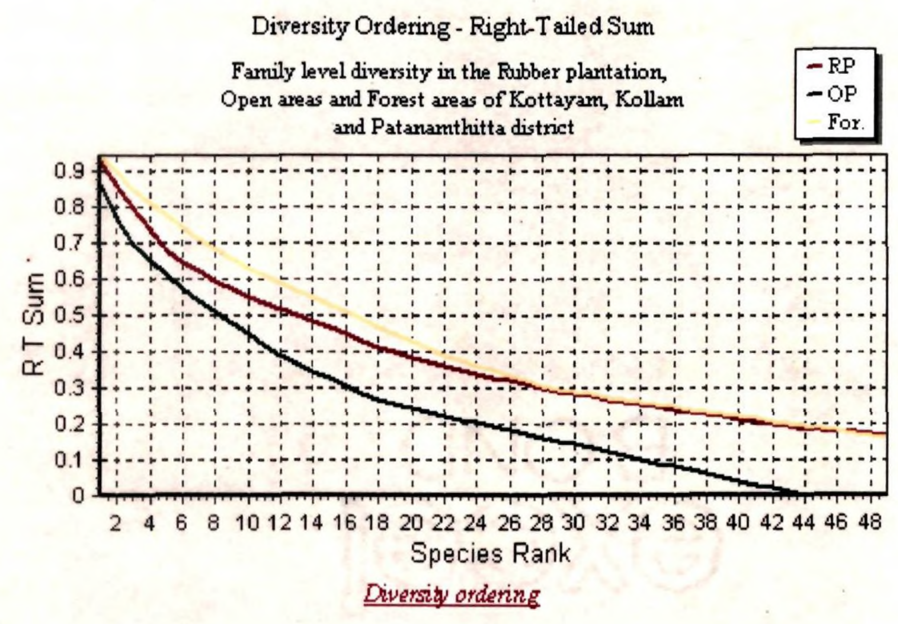


Figure 4.106 Diversity profiles of the family level presence of Rubber Plantation, Open areas and Forest areas using Right Tailed Sum diversity ordering index.



Individual sites of rubber plantations were compared to their adjacent Open area and Forest area using RTS diversity profile (Figures 4.107- 4.110). The three areas are closely similar and intersecting each other in Chetheckal and Mundakayam(Figures 4.107 and 4.109) and very low in diversity in Thenmala (Figure 4.108).A diversity profile of the weeded and unweeded areas showed a lower diversity in the unweeded areas (Figure 4.110).The diversity profiles of the weeded and unweeded areas (Figure 4.110) show that thwe two areas will be ranked differently by different indices and will be non comparable. The unweeded areas show a higher slope and are more even than the weeded areas which have higher species richness.

Figure 4.107-4.110 The Diversity profiles of individual rubber plantation sites (Mundakayam, Chetheckal and Thenmala) compared to the adjacent Open areas and the Tropical forest areas using the Right Tailed sum diversity ordering family index.

Figure 4.107

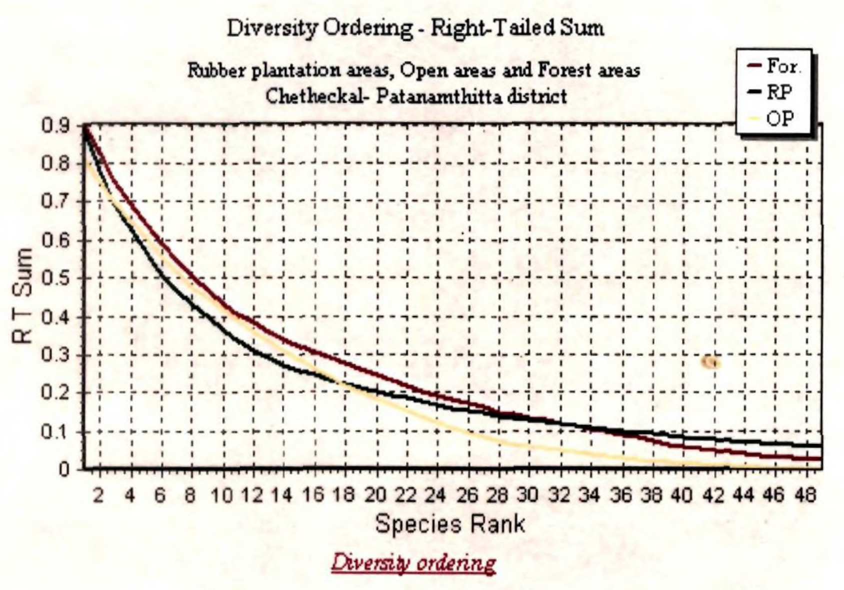


Figure 4.108

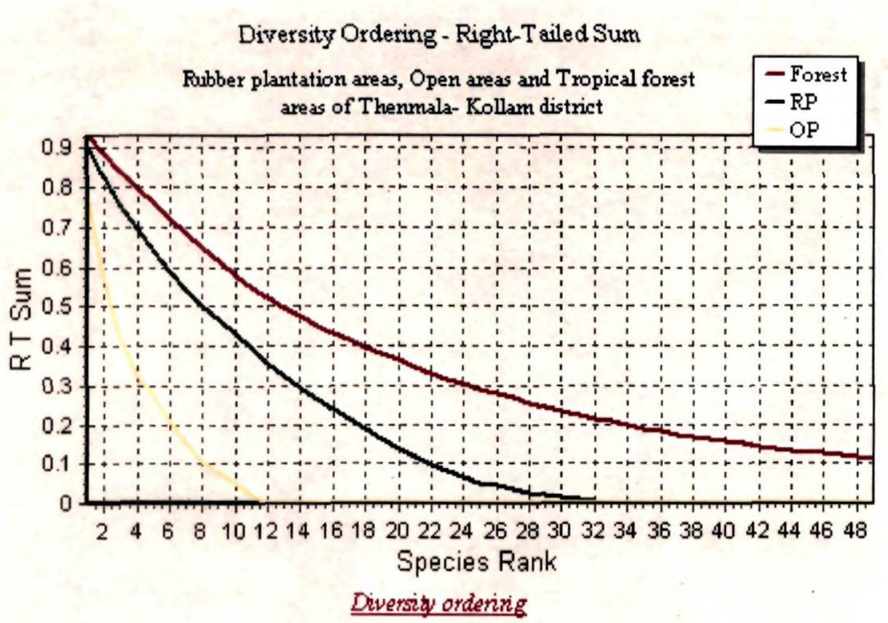
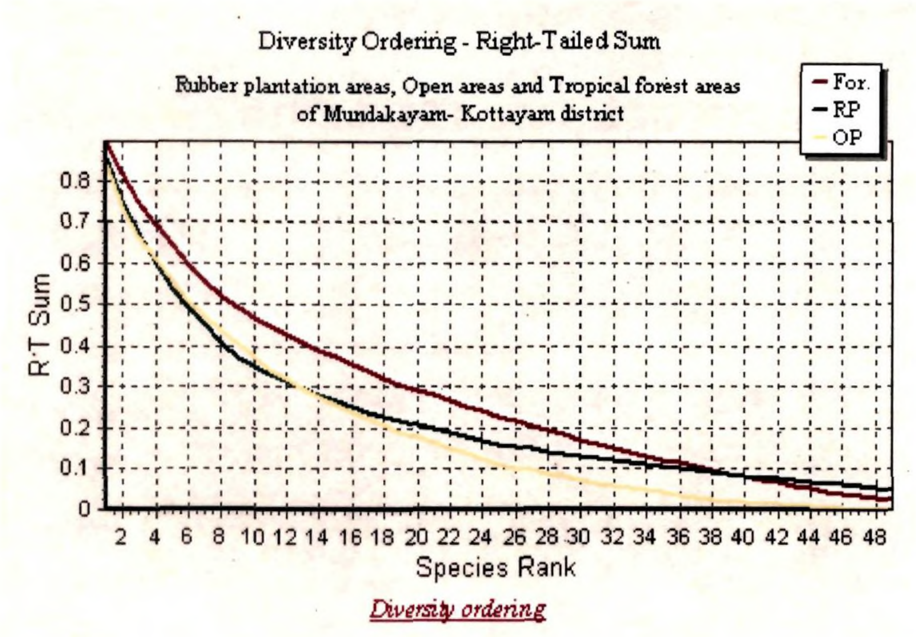
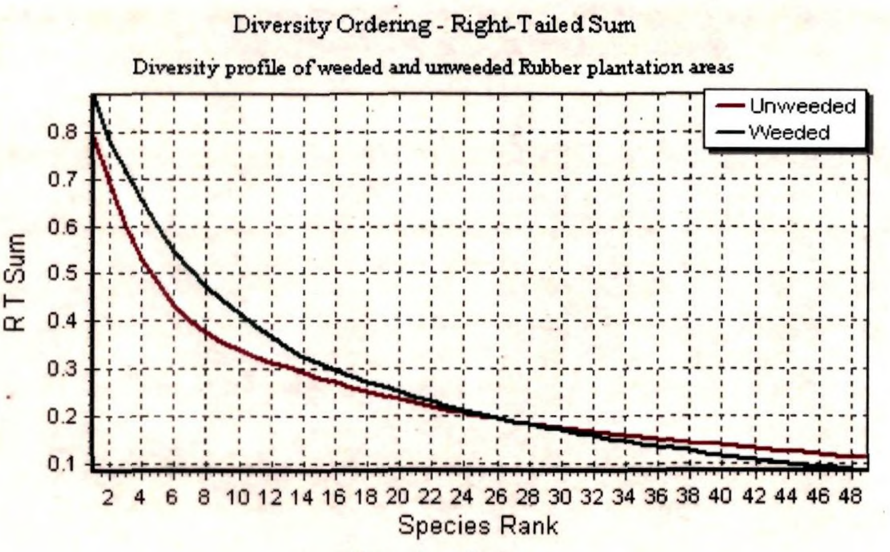


Figure 4.109



A diversity profile of the weeded and unweeded areas showed a lower diversity in the unweeded areas (Figure 4.110).The diversity profiles of the weeded and unweeded areas (Figure 4.110) show that thwe two areas will be ranked differently by different indices and will be non comparable. The unweeded areas show a higher slope and are more even than the weeded areas which have higher species richness.

Figure 4.110



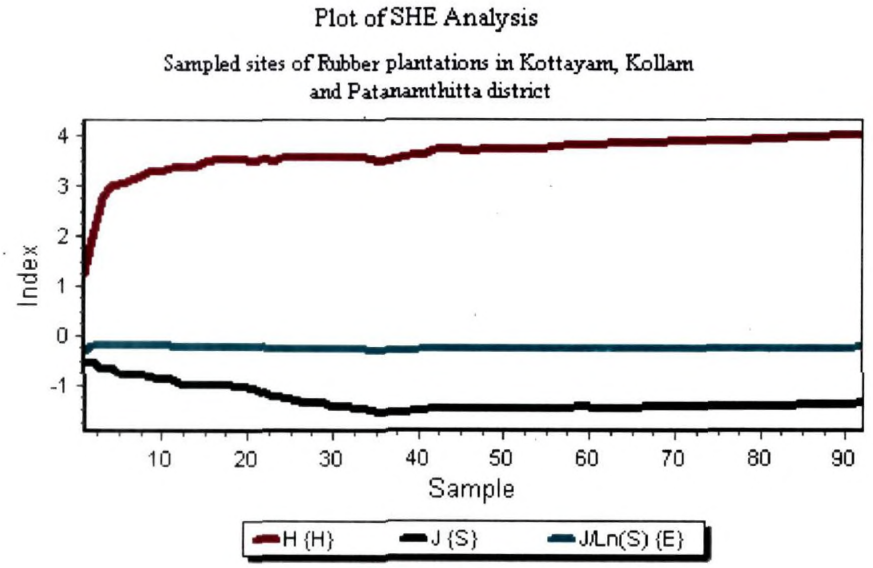
Diversity ordering

4.7.6 SHE analysis

The data and the graphical out puts of the SHE analysis of the RP, OP and Forest areas(Figures 4.111, 4.112 and 4.113 respectively) show, the simultaneous graphing of evenness and richness data over spatial scales. Over similar scales (35 samples) diversity H' is high in the Forest and OP (4.488, 4.295) areas but lower in the RP areas comparatively (3.493) over these spatial scales (Table not included). The equitability varied in the three areas. It decreases with more sampling effort in the OP and RP areas whereas it remains fairly constant in the Forest areas (Figures 4.111 and 4.112 respectively). With a small sampling effort a high diversity H' is observed in the OP areas (Figure 4.112). But after an initial increase, H' only shows a marginal increase compared to the Forest areas (Figure 4.113). The evenness decreases as sampling effort increases (Figure 4.112). The diversity does not increase in spite of increase in species richness due to the low evenness in the OP areas (Figure 4.112). The RP areas show a low diversity in the initial samplings. As the spatial scales increase the diversity increases more rapidly and remains fairly constant in spite of a sharp decrease in the evenness (Figure 4.111).

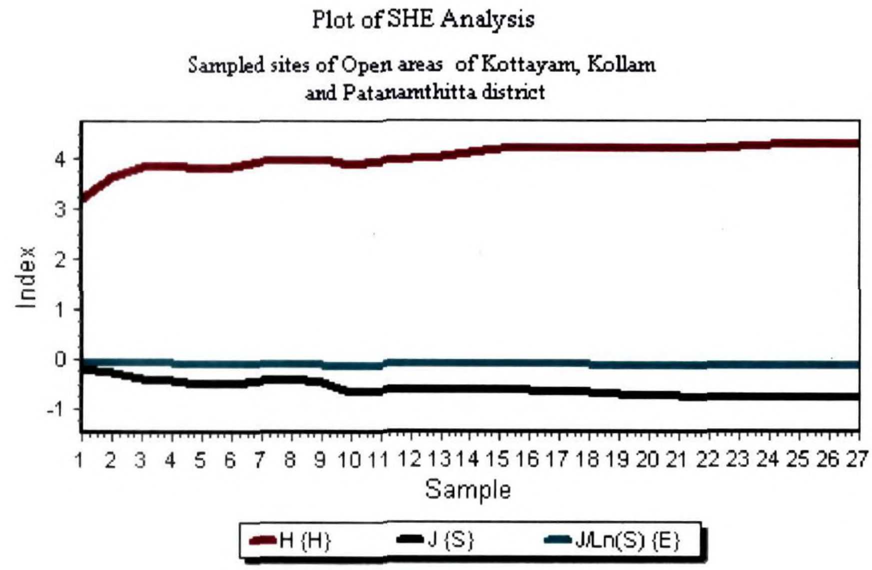
Figure 4.111- 4.113 SHE analysis of the Rubber plantation areas, Open areas and the Forest areas (H(H) - Shannon Weiner diversity index, J(S) In *(E)*or evenness and $J/L_n(S)(E)$ - In*(E)*/ In *(S)*).

Figure 4.111



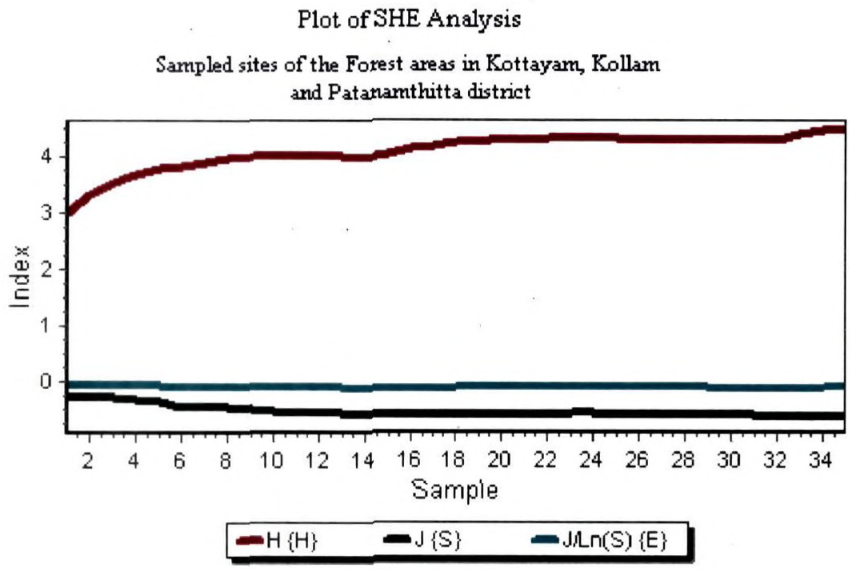
SHE analysis

Figure 4.112



SHE analysis

Figure 4.113



SHE analysis

The analysis of the subsets of weeded and unweeded areas of Rubber plantations show that diversity is lower in the unweeded areas compared to the weeded areas (Figure 4.115 and 4.114 respectively). Evenness is lower in the weeded areas and is constantly low over the spatial scales. In the unweeded areas evenness is higher and there is a gradual decline over the spatial scale.

Figure 4.114 & 4.115 SHE analysis of the weeded and unweeded areas in the Rubber plantations(H(H) - Shannon Weiner diversity index, J(S) - In *(E)*or evenness and J/L_n(S)(E) -In*(E)*/ In *(S)*).

Figure 4.114

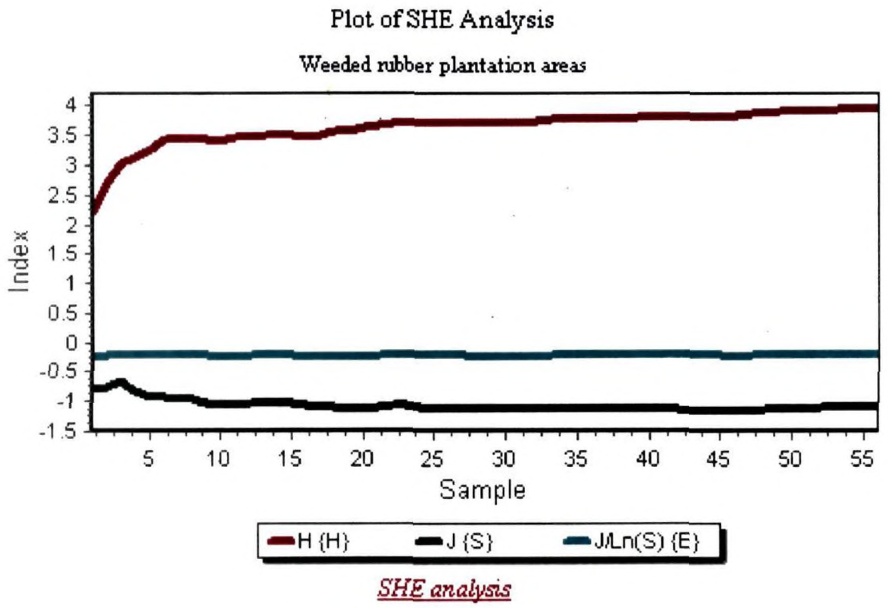
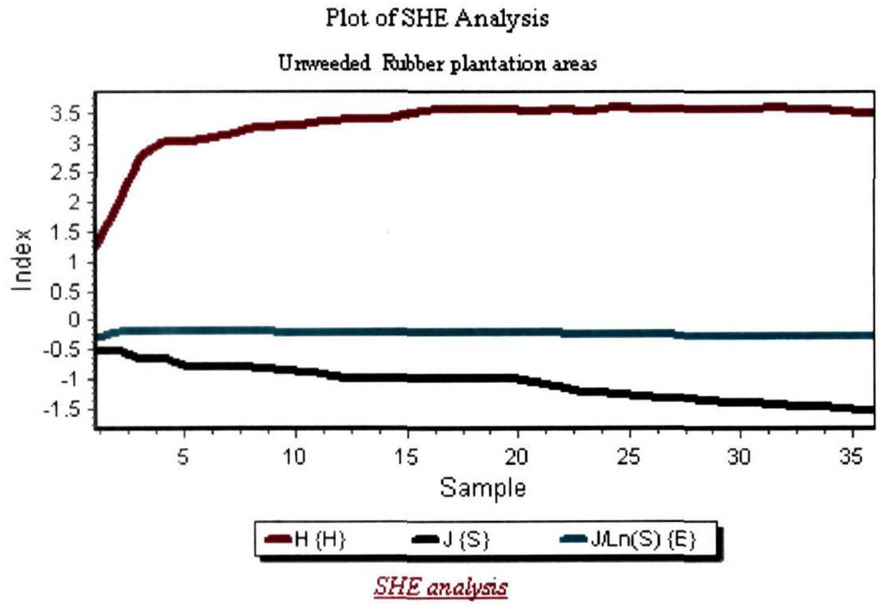


Figure 4.115



Finally SHE analysis was used to indicate the species abundance distributions represented in the data (Figure 4.11, 4.112 and 4.113). Cumulative In E/InS remained relatively constant in each plot, indicating that each sample community was bet fit by log normal species abundance distribution.

4.8 Similarity measures

Similarity tests (ANOSIM and SIMPER) using CAP version 4.0 (Henderson and Seaby 2007), were used to test for similarities between the groups assigned *a priori* viz. RP, OP and Forest areas, both within each group (quadrat samples within each type of area) and between the groups. It also shows the species which contribute to the similarity within the group and between each groups.

ANOSIM (Clark 1988, 1993) using the Bray-Curtis measure of similarity for OP, RP and Forest areas was undertaken (CAP version 4., Henderson and Seaby 2007). This statistical test shows if the similarity within samples or dissimilarity between samples is greater than the similarity that would occur by random. The results (Table 4.26) show that the value of R (0.57) is significant with probability of 0.001%. This leads to the conclusion that the samples within groups are more similar than would be expected by random chance. Pair wise tests between Forest and OP, between Forest and RP and between RP and OP areas show that the three areas are significantly dissimilar (Table 4.26). However the OP and RP areas appear to be less dissimilar. The RP areas show a significant dissimilarity to the Forest areas with respect to the species composition (statistical significance of 0.74). The Forest areas are also not similar in species composition to the OP areas with a statistical significance of 0.64 (Table 4.26).

Table 4.26 Similarity test values of ANOSIM and SIMPER on the sampled sites of RP, OP and Forest areas and the subsamples. The ANOSIM 'R value' is the statistical value of similarity within each group with a probability of 0.001 and a significance level of 0.1%. SIMPER between values is the average dissimilarity between the compared sites.

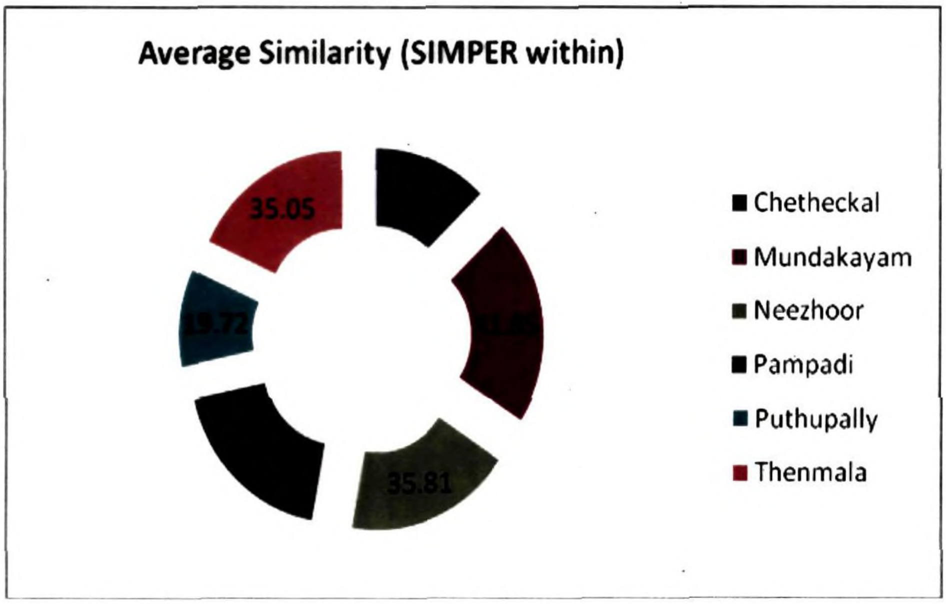
Site (No. of samples)		ANOSIM (R value)	SIMPER between(Average dissimilarity)
Forest (35)	OP (27)	0.64	97.93
Forest (35)	RP (92)	0.75	97.18
OP (27)	RP (92)	0.32	89.43
Comparison between the RP subsamples			
Chetheckal (16)	Mundakayam (15)	0.50	79.24
Chetheckal (16)	Neezhoor (16)	0.57	82.17
Chetheckal (16)	Pampadi (14)	0.57	82.40
Chetheckal (16)	Puthupally (20)	0.42	87.16
Chetheckal (16)	Thenmala (11)	0.75	90.40
Mundakayam (15)	Neezhoor (16)	0.69	75.05
Mundakayam (15)	Pampadi (14)	0.41	67.87
Mundakayam (15)	Puthupally (20)	0.46	84.08
Mundakayam (15)	Thenmala (11)	0.92	85.06
Neezhoor (16)	Pampadi (14)	0.65	76.19
Neezhoor (16)	Puthupally (20)	0.28	80.06
Neezhoor (16)	Thenmala (11)	0.92	87.67
Pampadi (14)	Puthupally (20)	0.55	87.13
Pampadi (14)	Thenmala (11)	0.86	82.60
Puthupally (20)	Thenmala (11)	0.69	92.14

The statistical test of similarity using SIMPER to test for similarity between the three groups was also undertaken. SIMPER identifies the species that are most important in creating the observed pattern of similarity and dissimilarity. The tests of SIMPER between, the three OP, RP and Forest areas have shown a high dissimilarity between the three areas (Table 4.26). The prevalence of plants like *Axonopus compressus, Mitracarpus villosus* and *Hedyotis auricularis* are the main contributors to the dissimilarity between Forest and Open areas. A high abundance of *Cyrtococcum patens, Oplismenus compositus* and *Ishaemum indicum* are the cause of dissimilarity between Forest areas and the RP areas. The RP areas have a higher abundance of species like *Oplismenus compositus, Cyathula patens* and *Cyrtococcum patens* and they are the main contributors to the dissimilarity with the OP areas. The abundance of grass species and plants like *Mitrocarpus villosus, Hedyotis auricularis* in the RP and OP areas are a result of the invasion of weedy species in disturbed areas. The SIMPER within, tests shows the similarity within the samples of RP, OP and Forest. The species composition more abundant and prevalent in the Forest sites is *Strychnos colubrina, Xylia xylocarpa, Michelia nilagirica, Helectris isora*. These plant species are more common in the forest samples and this contributes to the similarity within. Plant species like *Axonopus compressus, Ottochloa nodosa, Mitracarpus villosus, Mikania macrantha* are abundant in the OP areas while species like *Cyrtococcum patens, Oplismenus composites, Cyathula prostrate* and *Axonopus compressus* characterize RP areas. It is also notable that the average similarity between the Forest and the OP samples (11.7 and 12.9 respectively) is less than that found in the RP areas (17.4) (Table 4.26).

The ANOSIM tests for the individual sampling sites viz. Chetheckal, Puthupally, Pampadi, Neezhoor, Mundakayam and Thenmala reveal R value of 0.53. This indicates a significant similarity within the groups assigned *a priori*. Comparison between the different sampling sites has indicated that the species composition of some sites is significantly dissimilar while others are less dissimilar (Table 4.26). Thenmala RP vegetation is distinctly different from the other RP sampled sites with an R value ranging from 0.92 to 0.74. Less dissimilarity can be seen between the samples of Neezhoor and Puthupally which are both the unweeded areas. The remaining sites (weeded) show a range of dissimilarity ranging from 0.28 to 0.50 (Table 4.26).

Tests of SIMPER on these groups reveal the structure of the vegetation further. Tests of SIMPER within the Rubber plantation sampling sites have shown that the Puthupally and Chetheckal sampling sites are more heterogeneous (average similarity 19.7 and 24.4 respectively) compared to the remaining sites (Neezhoor, Pampadi, Mundakayam and Thenmala). Mundakayam has the highest average similarity of 41.9 which indicates comparatively more homogenous vegetation (Figure 4.116). The ground flora plant species which are common to these plantations are *Oplismenus compositus* in Chetheckal, *Cyrtococcum patens.* in Mundakayam, *Ishaemum indicum* in Neezhoor, *Axonopus compressus* in Pampadi, *Ishaemum indicum* in Puthupally and *Cynodon dactylon* in Thenmala. In all RP areas grass and other members have become the major contributors to the similarity measures and the largest vectors that contribute to the change in vegetation (Figure 4.118). SIMPER between (Tables 4.26) have shown that the Puthupally and Thenmala areas are distinct groups with the highest dissimilarity (average dissimilarity 92.1) and that Mundakayam and Pampadi have more similarity (average dissimilarity 67.9).

Figure 4.116 The observed similarity between samples of an area as a contribution of each species (variable). 'SIMPER within' identify the species that are most important in creating the observed pattern of similarity.



4.9 Ordinations

4.9.1 Principal Component Analysis (PCA plot)

PCA analysis was undertaken on the between-sample variance-covariance matrix, for the three sampled sites and their subsamples, as an exploratory tool and a preliminary step (Figure 4.117 and 4.118) shows the PCA plot and the vectors that are responsible for more than 30% of the variance. *Ishaemum indicum, Oplismenus compositus, Cyathula prostrata* and *Cyrtococcum patens* are responsible for the change in vegetation. Figure 4.117 shows these vectors are a response to the variables found in the RP, OP and Forest areas.

Figure 4.117 & **4.118** PCA ordinations of the Rubber Plantation, Open areas and Forest areas. The vectors responsible for the change are indicated in Figure 4.117.

Figure 4.117

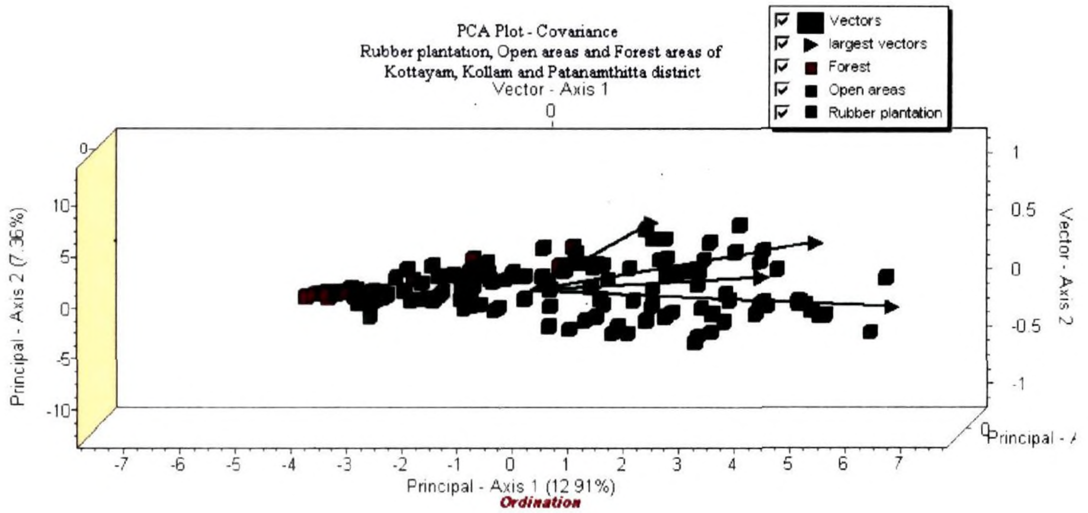
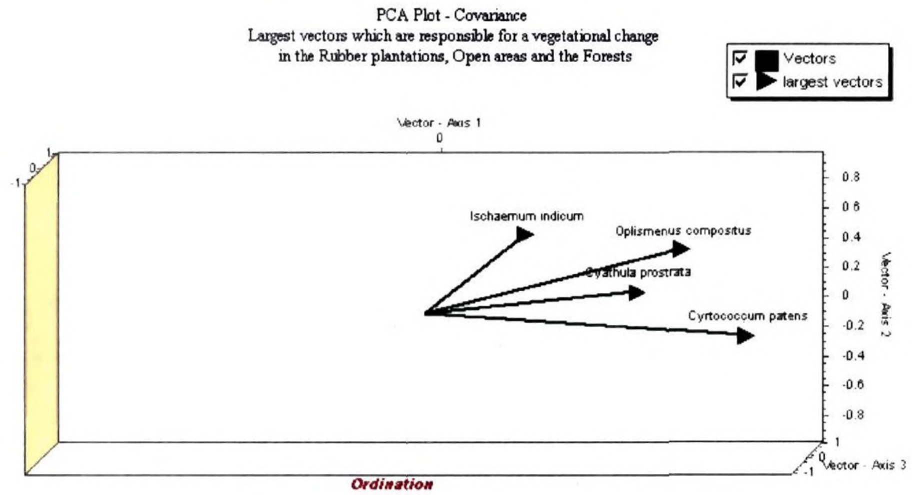


Figure 4.118



4.9.2 Non- Metric Multi Dimensional Scaling

Multivariate analysis was chosen because they are ideally suited for analyzing complex ecological data, which require a flexible and robust method that can address nonlinear relationships, high order interactions, and missing values (D´eath and Fabricius 2000, Bhagwat *et al.* 2005). Tuomisto and Poulsen(2000) found when the abundances of species were taken into account in the ordinations as in this study, finer subdivisions within sites were found, and often subunits in similar topographic positions from different sites. The MDS of the RP, OP and Forest areas using the abundance data of the variables (species) in this case show that the RP areas are clearly more similar to the OP areas and less similar to the forest areas (Figure 4.119). The stress against iteration values for the two dimensional NDMS plot has been plotted (Figure 4.120) and the final stress value plotted in Figure 4.121. The NDMS plot of the individual subsamples of the RP areas show that the weeded areas Mundakaym and Pampadi are more similar to each other with respect to their vegetation. The unweeded areas Neezhoor and puthupally overlap in their vegetation. Thenmala forms a more distinct group. Chetheckal has similarities with the weeded and unweeded areas (Figure 4.124).

Figure 4.119 The plot of non metric multi dimensional scaling (nMDS) using Jaccard's index of similarity for the Rubber Plantation, Open areas and Forest areas (The perimeter outlines the three plant communities indicating their similarities and distance between them).

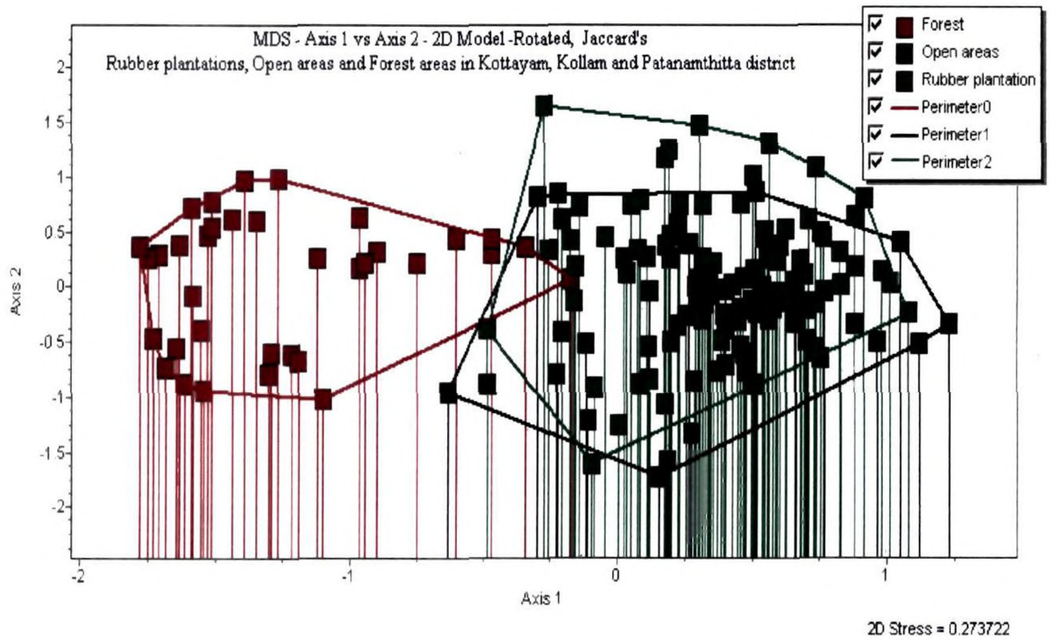


Figure 4.120 The plot of the stress against iteration number for the two-dimensional non-metric multidimensional scaling (The data has been square root transformed).

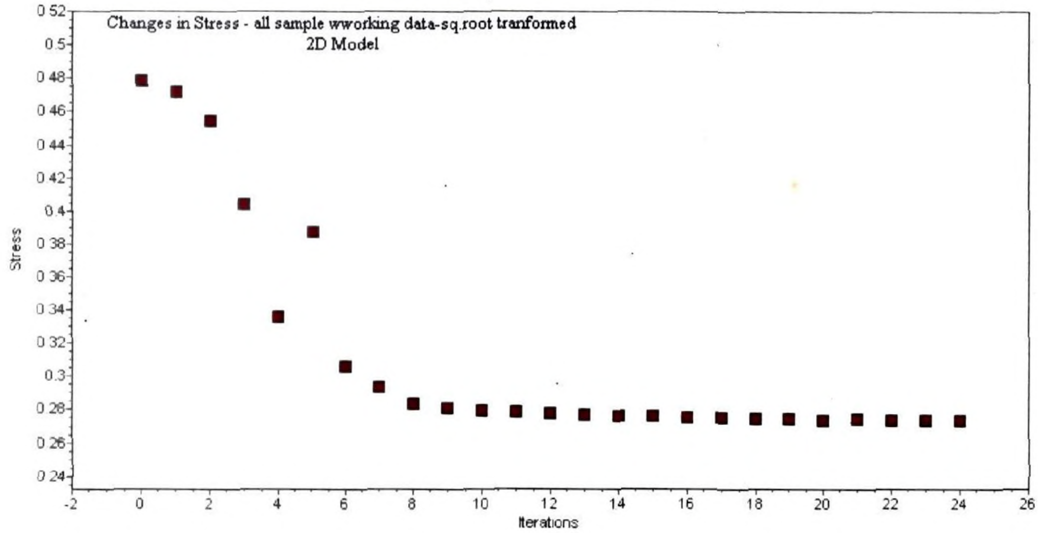
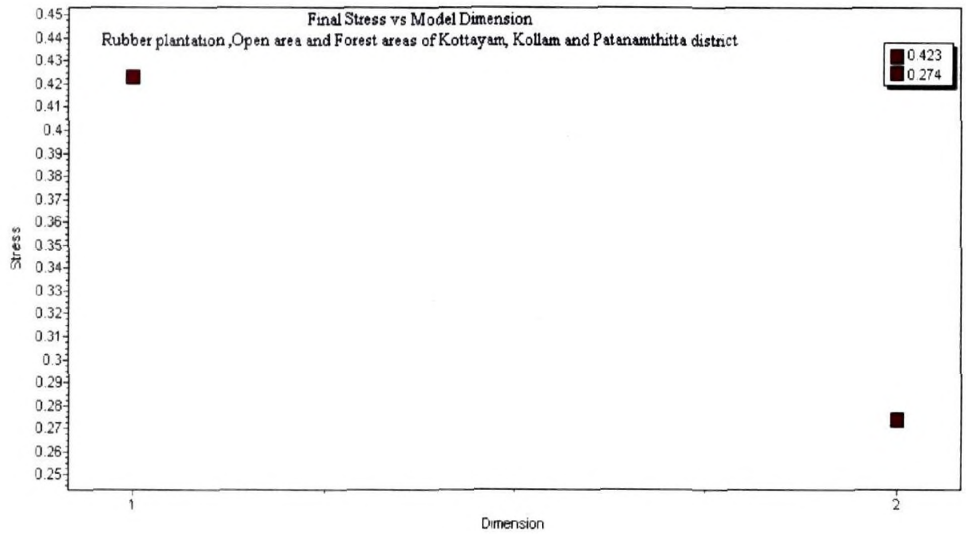


Figure 4.121 The final stress value plotted against the dimension of the nMDS model (The maximum dimension on the plot is the maximum number of dimensions selected).



The PCA plots of the subsamples of RP areas showed the vectors that are responsible for change in the vegetation in each of the sampled sites (Figure 4.122 and 4.123). The largest three vectors are *Ishaemum indicum*, *Cyrtococcum patens* and *Cyathula prostrate*. Different areas of RP sites sampled show the predominance of different species. The various sites are overlapping in their vegetation and homogenous with respect to the coexisting plants except in the unweeded areas Puthupally and Neezhoor. These areas show more distinct vegetation (Figure 4.123).

Figure 4.122 & 4.123 PCA ordinations of the sub-samples of the Rubber plantations, Open areas and Forest areas. The vectors responsible for the change are indicated in Figure 4.121.

Figure 4.122

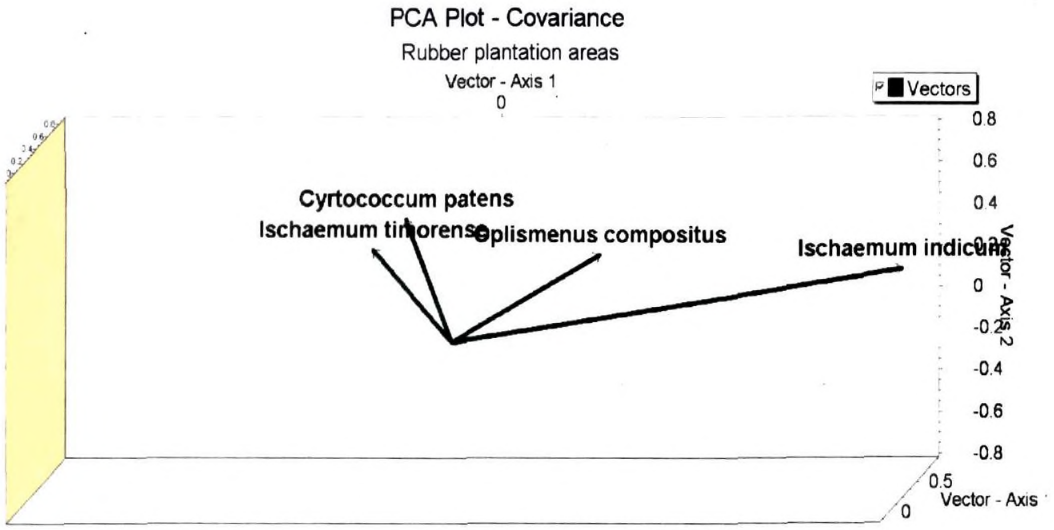


Figure 4.123

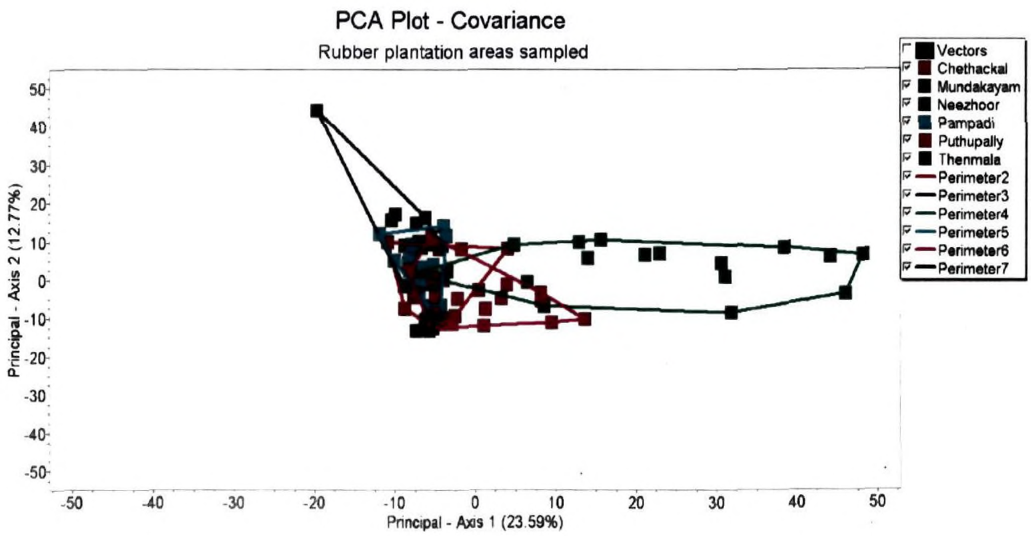
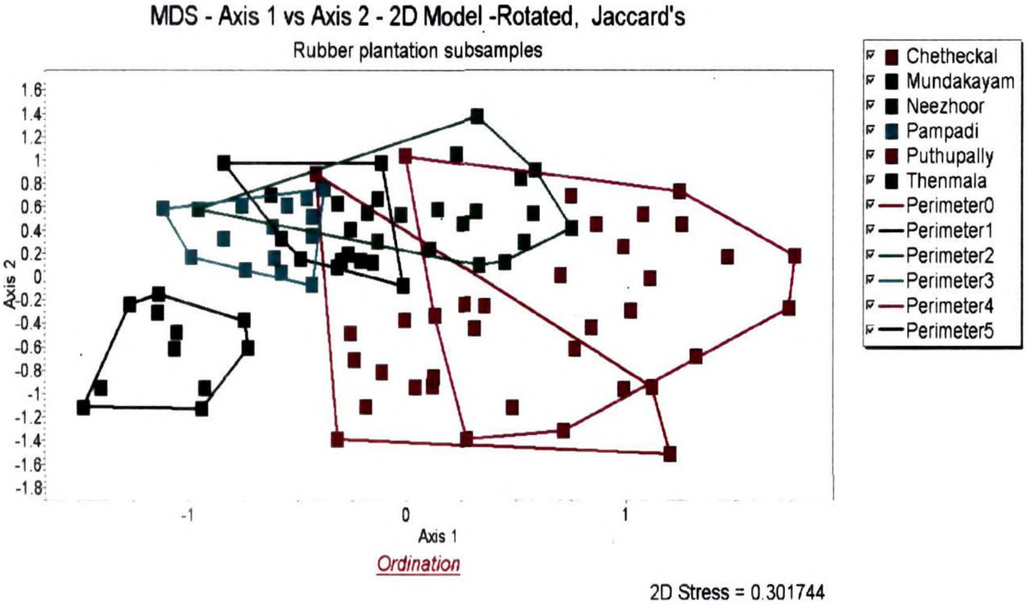


Figure 4.124 The non-metric multi dimensional scaling plot of the sub-samples of the RP, OP and Forest areas.

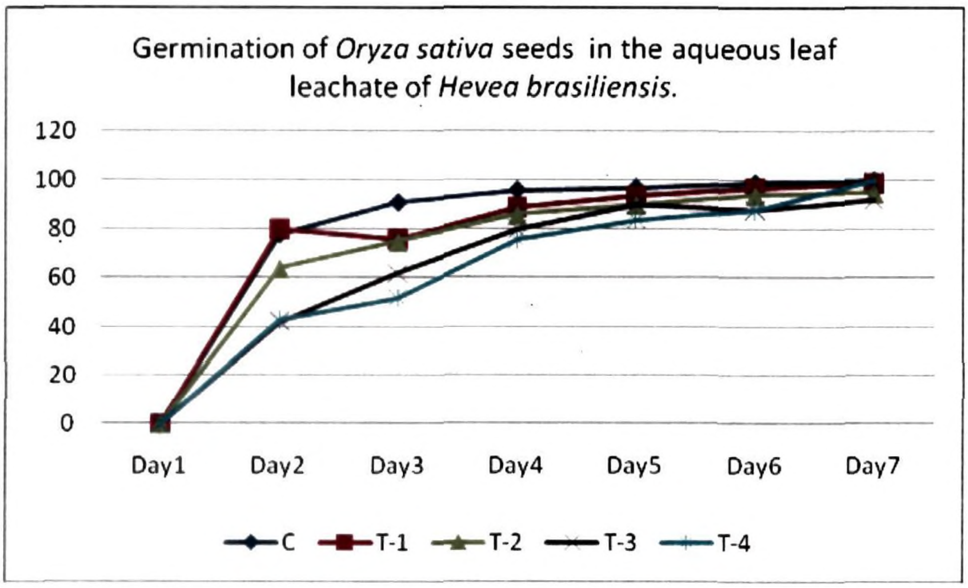


4.10 Allelopathic test

The effect of aqueous leachate on the rate of germination of the test seeds *Oryza sativa* (Rice seeds) have shown an initial inhibition in the rate of germination (Figure 4.125). The average rate of germination for 7 days is tabulated (Figure 4.125). The rate of germination reaches comparable values by the 7th day (Figure 4.125). In the case of rice seeds the germination is delayed (Figure 4.125). One way tests of ANOVA -repeated measures have shown the difference between the treatments is significant ((F = 4.91056, DF1 = 4, DF2 = 24, P = <0.05). The effect of aqueous leachate on the rate of germination of *Chromolena odorata* seeds has shown a strong allelopathic inhibition (Figure 4.126). The viability of the seeds of *Chromolena odorata* is severely impaired. Some germination can be seen at low concentrations of 1.25% and 2.5% but no germination was seen at the higher concentrations of 5% and 10%. One way ANOVA test -repeated measures also shows these differences in treatment on *Chromolena odorata* seeds are significant (F = 12.0063, DF1 = 2, DF2 = 12, P = <0.05). These seeds did not germinate even after 37 days.

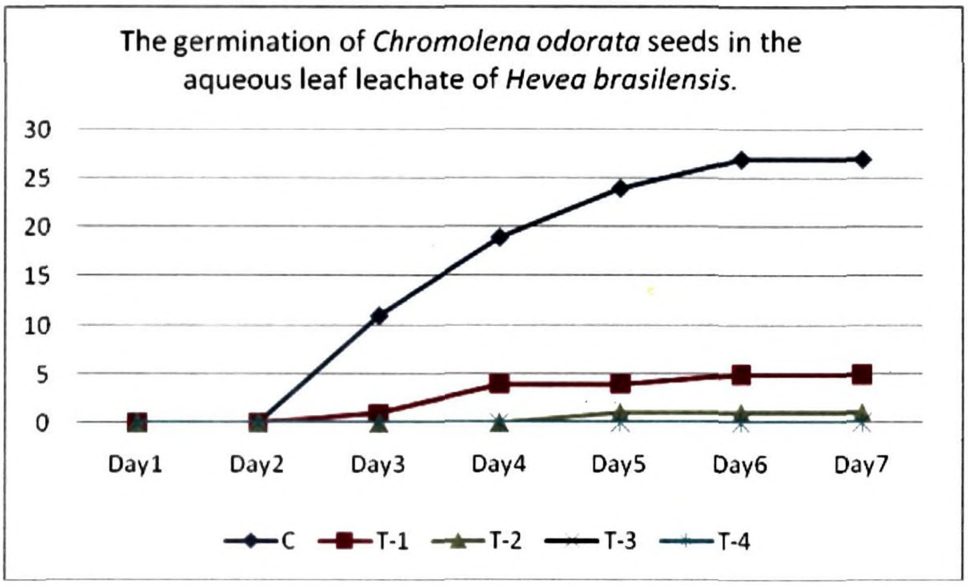
Figure 4.125 & 4.126 Effect of different concentrations of leachate of the leaves of *Hevea brasiliensis* on germination percentage of seeds of rice (Oryza *sativa* var. *Uma*) and the seeds of *Chromolena odorata* (C- Control, T-1: 1.25%, T-2: 2.5%, T- 3: 5%, T-4: 10%).

Figure 4.125



(F = 4.91056, DF1 = 4, DF2 = 24, P = <0.05)

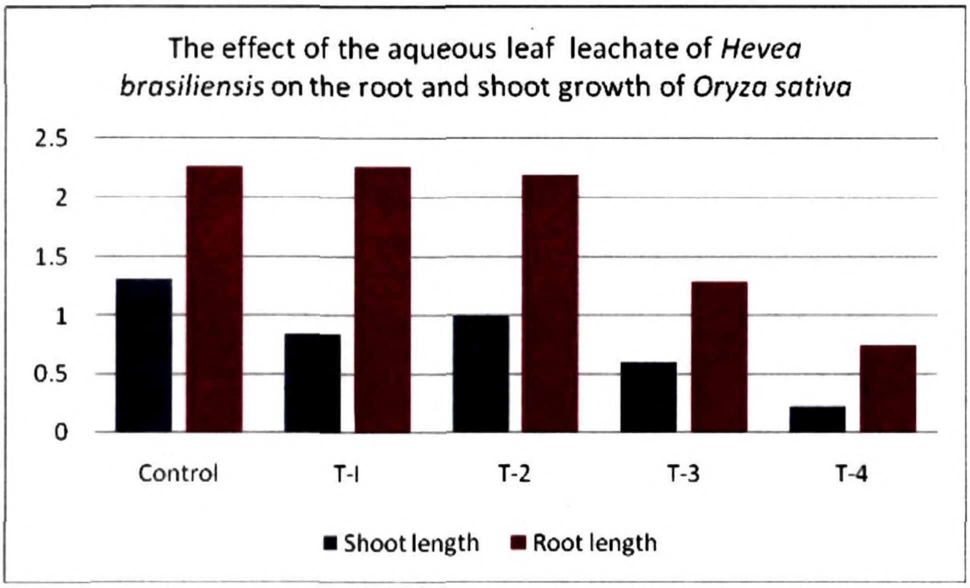
Figure 4.126



(F = 12.0063, DF1 = 2, DF2 = 12, P = <0.05)

Figure 4.127 shows the effect of aqueous leaf leachate on the seedling growth of the test seeds (rice). Inhibition was observed on the shoot and root growth of the seedlings of *Oryza sativa* Statistical test using One way ANOVA using Bonfernni's method of multiple comparison using QED satitstics 1.0 (Seaby and Henderson 2006) showed that there is a significant difference in means between the treatments (F= 8.35, DF1=4, DF2= 95, p=< 0.05) on the test seeds. *Chromolena odorata* shows negligible growth at lower concentrations of the leachate.

Figure 4.127 The effect of the aqueous leachate of the leaves of *Hevea brasiliensis* on the root and shoot length of test plant *Oryza sativa* var *Uma* on the 5th day of growth. The results show the average shoot and root length of 20 seeds subjected to treatment (T) -1(*1.25%*), T-2 (2.5%), T-3 (5%) and T-4 (10%) of aqueous leachate.



One way ANOVA test of significance (F = 8.34671, DF1 = 4, DF2 = 95, P = <0.05)

4.11 Phenology

24 plant species of the natural ground flora of rubber plantations also growing in the OP and Forest areas sampled were chosen for phenological studies. The emergence, maturation, flowering and fruiting of the plants was observed. The life cycles of these plants (Table 4.27) shows the period of the year during which the plants flowers and fruits in the OP, RP and Forest areas.

Table 4.27 The phenological stages of selected plant species found commonly in the RP, OP and the Forest areas .

	Name of the plant	Sampling site	Month											
			J	F	M	A	M	J	Ju	A	S	O	N	D
1	*Axonopus compressus*	RP	→	V	→	→	V	→	→	→	→	→	→	→
		OP	→	V	→	→	V	→	→	→	→	→	→	→
		FOR.	→	V	→	→	V	→	→	→	→	→	→	→
			J	F	M	A	M	J	Ju	A	S	O	N	D
2	*Canthium augustifolium*	RP	V	→	→	→	V	V	→	→	→	→	V	V
		OP	V	→	→	→	V	V	→	→	→	→	V	V
		FOR.	V	→	→	→	V	V	→	→	→	→	V	V
			J	F	M	A	M	J	Ju	A	S	O	N	D
3	*Centrosema pubescens*	RP	→	→	V	V	V	V	V	→	→	V	V	V
		OP	→	→	→	→	V	V	→	→	→	V	V	V
		FOR.	→	→	V	V	V	V	V	→	→	V	V	V
			J	F	M	A	M	J	Ju	A	S	O	N	D
4	*Chromolena odorata*	RP	V	V	→	→	→	→	V	V	V	V	V	V
		OP	V	→	→	→	→	→	V	V	V	V	V	V
		FOR.	V	V	→	→	→	→	V	V	V	V	V	V
			J	F	M	A	M	J	Ju	A	S	O	N	D
5	*Clerodendron viscosum*	RP	V	V	→	→	→	→	V	V	V	V	V	V
		OP	V	→	→	→	→	→	V	V	V	V	V	V
		FOR.	V	V	→	→	→	→	V	V	V	V	V	V
			J	F	M	A	M	J	Ju	A	S	O	N	D
6	*Cyathula prostrata*	RP	→	V	V	V	V	V	V	V	V	→	→	→
		OP	→	→	→	V	V	V	V	V	V	→	→	→
		FOR.	→	V	V	V	V	V	V	V	V	→	→	→
			J	F	M	A	M	J	Ju	A	S	O	N	D
7	*Cyrtococcum patens*	RP	→	→	→	→	→	→	→	→	→	→	→	→
		OP	→	→	→	→	→	→	→	→	→	→	→	→
		FOR.	→	→	→	→	→	→	→	→	→	→	→	→
			J	F	M	A	M	J	Ju	A	S	O	N	D
8	*Grewia nervosa*	RP	V	→	→	→	→	→	→	→	→	V	V	V
		OP	V	→	→	→	→	→	→	→	→	V	V	V
		FOR.	V	→	→	→	→	→	→	→	→	V	V	V
			J	F	M	A	M	J	Ju	A	S	O	N	D

9	*Hedyotis auricularis*	RP	→	→	→	→	→	→	→	→	→	→	→	→
		OP	→	→	→	→	→	→	→	→	→	→	→	→
		FOR.	→	→	→	→	→	→	→	→	→	→	→	→
			J	F	M	A	M	J	Ju	A	S	O	N	D
10	*Hibiscus hispidissimus*	RP	V	V	→	→	→	→	V	V	V	→	→	→
		OP	V	→	→	→	→	→	V	V	V	→	→	→
		FOR.	V	V	→	→	→	→	V	V	V	→	→	→
			J	F	M	A	M	J	Ju	A	S	O	N	D
11	*Ixora coccinea*	RP	→	→	V	V	V	V	→	→	V	V	V	V
		OP	→	→	→	→	V	V	→	→	V	V	V	V
		FOR.	→	→	V	V	V	V	→	→	V	V	V	V
			J	F	M	A	M	J	Ju	A	S	O	N	D
12	*Justicia procumbens*	RP	→	→	V	V	V	V	→	→	→	V	→	→
		OP	→	→	→	→	V	V	→	→	→	V	→	→
		FOR.	→	→	V	V	V	V	→	→	→	V	→	→
			J	F	M	A	M	J	Ju	A	S	O	N	D
13	*Memecylone randerianum*	RP	→	→	→	→	→	V	V	V	V	V	V	V
		OP	→	→	→	→	→	V	V	V	V	V	V	V
		FOR.	→	→	→	→	→	V	V	V	V	V	V	V
			J	F	M	A	M	J	Ju	A	S	O	N	D
14	*Merremia vitifolia*	RP	V	V	→	→	→	→	→	V	V	V	V	V
		OP	V	V	→	→	→	→	→	V	V	V	V	V
		FOR.	V	V	→	→	→	→	→	V	V	V	V	V
			J	F	M	A	M	J	Ju	A	S	O	N	D
15	*Mikania macrantha*	RP	V	V	V	→	→	→	V	V	V	V	V	V
		OP	V	→	→	→	→	→	V	V	V	V	V	V
		FOR.	V	V	V	→	→	→	V	V	V	V	V	V
			J	F	M	A	M	J	Ju	A	S	O	N	D
16	*Mitracarpus villosus*	RP	V	V	→	→	→	→	→	V	V	V	V	V
		OP	V	→	→	→	→	→	→	V	V	V	V	V
		FOR.	V	V	→	→	→	→	→	V	V	V	V	V
			J	F	M	A	M	J	Ju	A	S	O	N	D

17	*Naragamia alata*	RP	V	V	→	→	→	→	V	V	V	V	V	V
		OP	V	→	→	→	→	→	→	V	V	V	V	V
		FOR.	V	→	→	→	→	→	V	V	V	V	V	V
			J	F	M	A	M	J	Ju	A	S	O	N	D
18	*Oplismenus compositus*	RP	→	→	→	V	V	V	V	V	V	V	V	V
		OP	→	→	V	V	V	V	V	V	V	V	V	→
		FOR.	→	→	→	→	→	V	V	V	V	V	V	V
			J	F	M	A	M	J	Ju	A	S	O	N	D
19	*Rungia parviflora*	RP	→	→	→	→	→	V	V	V	V	V	V	V
		OP	→	→	→	→	→	→	V	V	V	V	V	V
		FOR.	→	→	→	→	→	V	V	V	V	V	V	V
			J	F	M	A	M	J	Ju	A	S	O	N	D
20	*Sebastiana chamaelea*	RP	→	V	V	V	V	V	V	→	→	→	→	→
		OP	→	V	V	V	V	V	→	→	→	→	→	→
		FOR.	→	V	V	V	V	V	V	→	→	→	→	→
			J	F	M	A	M	J	Ju	A	S	O	N	D
21	*Spermacoce latifolia*	RP	V	→	→	→	→	→	→	→	V	V	V	V
		OP	V.	→	→	→	→	→	→	→	V	V	V	V
		FOR.	V	→	→	→	→	→	→	→	V	V	V	V
			J	F	M	A	M	J	Ju	A	S	O	N	D
22	*Stachytarpheta indica*	RP	→	→	→	→	→	→	V	V	V	V	V	V
		OP	→	→	→	→	→	→	→	→	V	V	V	V
		FOR.	→	→	→	→	→	→	V	V	V	V	V	V
			J	F	M	A	M	J	Ju	A	S	O	N	D
23	*Synedrella nodiflora*	RP	→	→	→	→	→	→	V	V	V	V	V	V
		OP	→	→	→	→	→	→	→	V	V	V	V	V
		FOR.	→	→	→	→	→	→	V	V	V	V	V	V
			J	F	M	A	M	J	Ju	A	S	O	N	D
24	*Urena lobata*	RP	→	→	→	V	V	V	V	→	→	→	→	→
		OP	→	→	→	V	V	V	V	→	→	→	→	→
		FOR.	→	→	→	V	V	V	V	→	→	→	→	→

Vegetative growth	V
Reproductive phase	→

Hedyotis auricularis and *Cyrtococcum patens* flower and fruit throughout the year. *Axonopus compressus* have prolonged flowering periods (Table 4.27). Most plants flower during the monsoon period (Figure 4.128 and 4.129). The flowering extends in to the fruiting stage which falls within the period when the rainfall is high. This however is not a thumb rule. Several plants like *Sebastiana chamaelea, Justicia procumbens, Urena lobata* and *Centrasema pubescens* flower during the months of August to March (Table 4.27, Figure 4.128). The plants *Chromolena odorata, Clerodenron viscosum, Mikania micrantha, Mitracarpus villosus* and *Naragamia alata* in the OP areas initiate flowering earlier than in the RP and Forest areas The flowering and fruiting of the plants ends at approximately the same time in all the three areas. Extended flowering periods have been observed in the plants species *Centrasema pubescens, Ixora coccinea, Cyathula prostrata* and *Justicia procumbens* in the OP areas (Table 4.27). Figure 4.128 shows that the largest number of plants flowers during the period February to June. This coincides with the onset of the pre monsoons showers (Figure 4.129).

Figure 4.128 The number of plants that are flowering in the Rubber Plantations, Open areas and Forest areas.

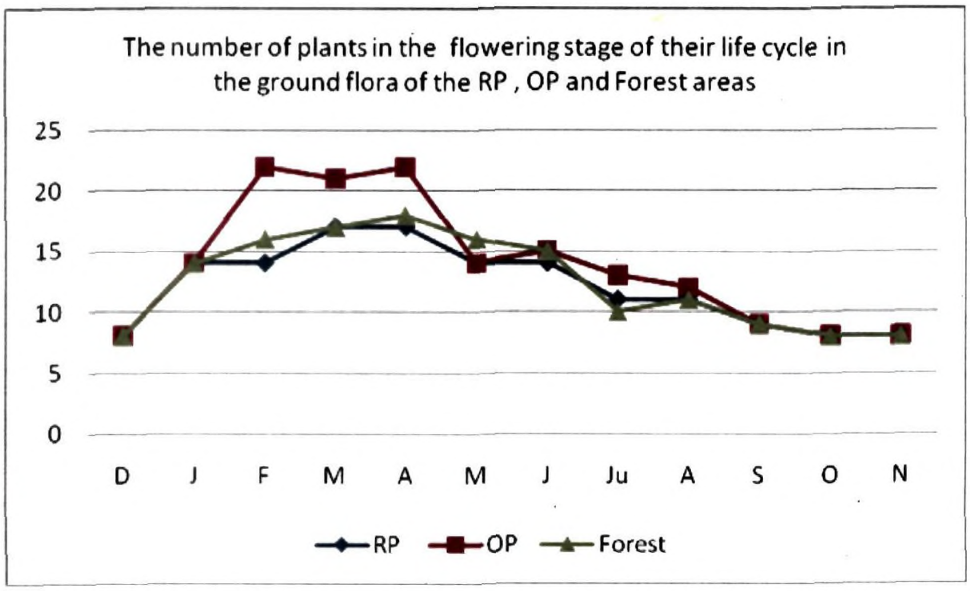
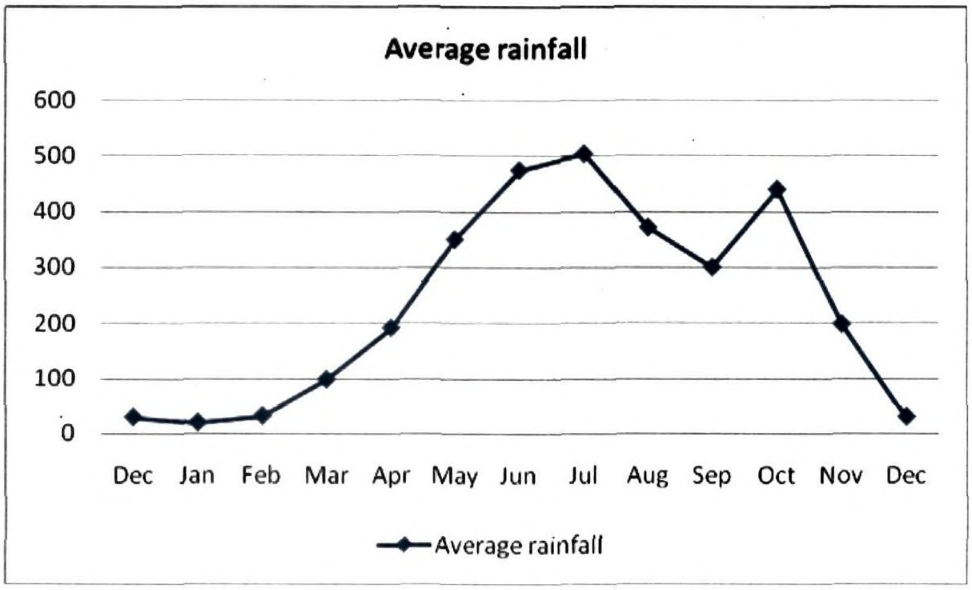


Figure 4.129- The average rainfall during the year (in mm).



The early flowering of plants in the OP areas as compared to the RP areas indicates that these plants are heliophilic in nature. Some plant species flower the year around indicating that these species have specific requirements and that the flowering is takes place according to their photoperiodic and dispersal requirements. Although a larger number of plants show preference to flowering during the period of the onset of monsoon, there is no direct statistical correlation between moisture and flowering (Figure 4.128 and 4.129).

The viability test of 19 commonly growing plants in the RP areas and compared it to the germination of rice seedlings (*Oryza sativa* var. *uma*) which has been used as a bioassay in the allelopathic tests. 20% plants show germination above 50 % in water (Figures 4.130 and 4.131).

Figure 4.130 & 4.131 Percent of germination of naturally growing plants found in the ground flora of Rubber plantations as compared to the germination of rice seeds (*Oryza sativa* var. Uma).

Figure 4.130

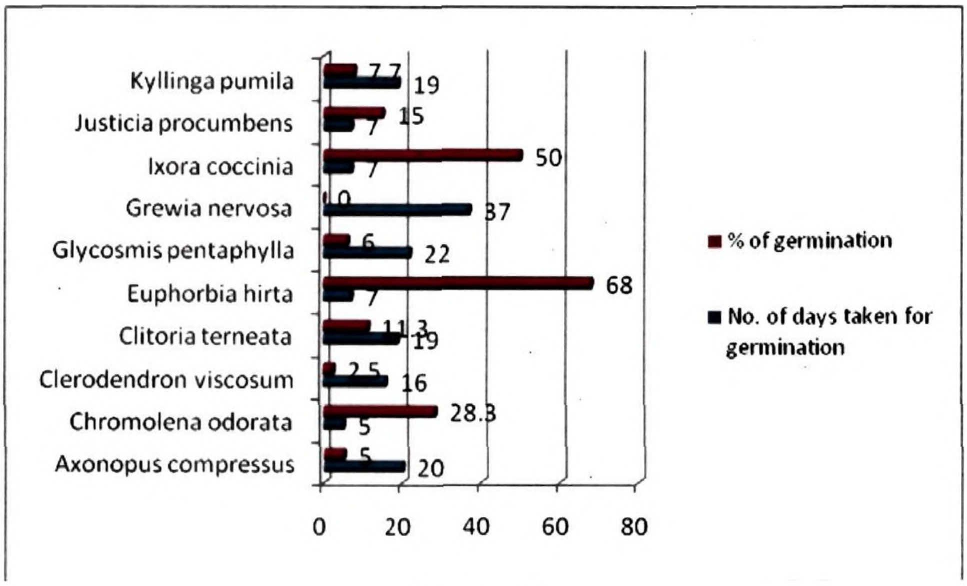
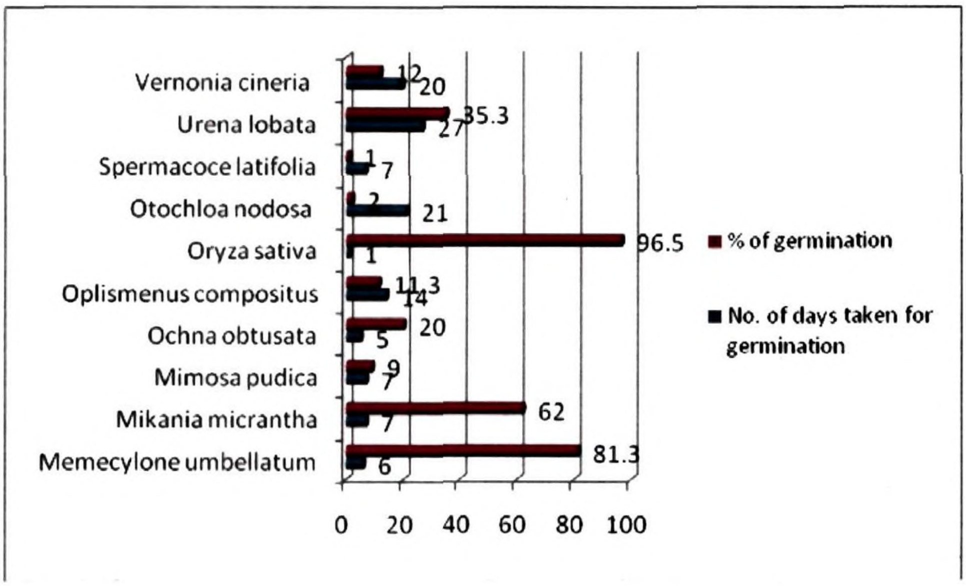


Figure 4.131



The ground flora of the unweeded plantations (Neezhoor and Puthupally) show the growth and emergence of plants like *Ixora brachiata* and *Memecylone umbellatum* which are zoochorous species eaten by animals. A list of plant species found in the rubber plantations and their mode of dispersal shows large number of plant species that are found in the natural flora of the RP areas are zoochorous and dispersed by animals (Table 4.28).

Table 4.28 Plant species that have been found in the ground flora vegetation of rubber plantation areas which are dispersed by animals. Some plant species are dispersed mechanically or by wind.

S.No.	Name of the plant	Vernacular name	Family	Habit	Types of areas in which the plant species is genrally found		Status	Mode of dispersal
1	*Aporosa lindleyana* (Wight) Baill.	Vetti	Euphorbiaceae	Medium tree	Ev. Gr for., Semi ev. Gr. For., Plains			Birds
2	*Ardisia pauciflora* Heyne ex Roxb.	Muttumaram	Myrsinaceae	Small tree	Ev gr. For., Shola for.			Birds
3	*Artocarpus hirsutus* Lam.	Anjili	Moraceae	Large tree	Semi ev gr,Moist decd.for,Plains		Endemic to South Western ghats	Monkeys
4	*Canthium augustifolium Roxb.*	Kattaramullu	Rubiaceae	Scandent shrub	Semi Ev.gr.for.			Birds
5	*Bombax cieba* L.	Elavu	Bombacaceae	Very large tree	Semi ev.gr. For.,Moist decd. For.			Monkeys(*Hanuman langur- Semnopithecus entellus*)
6	*Bridelia retusa* (L.) Spreng.	Mulluvenga	Euphorbiaceae	Medium tree	Semi ev. Gr. For.,Decd. For., Plains			Birds
8	*Careya arborea* Roxb.	Aalam	Lecythidaceae	Small tree	Moist & Dry decd. For., Plains			Mammals
9	*Cissus discolor* Blume	Njerinjampuli	Vitaceae	Shrub	Semi ev. Gr. For., Moist decd. For.			Birds
10	*Clerodendron viscosum* Vent.	Perivelum	Verbenaceae	Small tree	Degrd for., Plains			Birds
11	*Dalbergia latifolia* Roxb.	Eeti	Fabaceae	Large tree	Dry and Moist decd for.		Vulnerable IUCN 2000	Monkeys(*Hanuman langur- Semnopithecus entellus*)
12	*Desmodium triquetrum* (L.)DC.	Adakkapanal	Fabaceae	Shrub	Semi ev.gr.for,Moist decd.for.,Plains			Mechanical
13	*Diploclisia glaucescens* (Blume) Diels	Vattoli	Menispermaceae	Woody climber	Ev.gr.,Semi ev.gr.fro.,moist decd for.			Animal

14	*Elaeocarpus glandulosus Wall.*	Kara	Elaeocarpaceae	Medium tree	Ev gr. For, Semi ev. Gr. For., Shola for.			Monkeys(*Hanuman langur- Semnopithecus entellus*)
15	*Ficus hispida* L.f.	Thonditherakom	Moraceae	Small tree	Semi ev gr,Moist decd.for,Plains			Monkeys(*Hanuman langur- Semnopithecus entellus*)
16	*Glycosmis pentaphylla* (Retz.) DcC.	Panal	Rutaceae	Small tree	Semi ev gr,Moist decd.for,Plains			Monkeys(*Hanuman langur- Semnopithecus entellus*)
17	*Gmelina arborea* Roxb.	Kumbil	Verbenaceae	Medium tree	Moist & Dry decd. For., Plains			Monkeys(*Hanuman langur- Semnopithecus entellus*)
18	*Grewia nervosa* (Lour.) Panigrahi	Kottakka	Tiliaceae	Small tree	Semi ev. Gr. For.,Scrub jungles,Sacred groves			Rodents, Monkeys, Squirrels etc.
19	*Helectris isora* L.	Edampiri vallampiri	Sterculiaceae	Small tree	Decd. For., Plantation, Plains			Mechanical
20	*Hemidesmus indicus*(L.) R.Br.	,naruneendi	Periplocaceae	Shrub	Decd for,Plains,Plantations			Wind
21	*Ixora brachiata* Roxb.ex.DC.	Marachetti	Rubiaceae	Small tree	Semi ev.gr.for.		Endemic to Western ghats	Birds
22	*Jasminum brevilobum* A.DC..	Kattumulla	Oleaceae	Climbing shrub	Shola for.		Endemic to peninsular	Birds
23	*Lagerstroemia microcarpa* Wight	Venthekku	Lythraceae	Large tree	Moist decd. For., Plains		Endemic to western ghats	Monkeys(*Hanuman langur- Semnopithecus*
24	*Macaranga peltata* Roxb.) Muell. Arg.	Vatta	Euphorbiaceae	Medium tree	Moist decd. For, Secondary for.			Birds, Mammals
25	*Mallotus philippensis* (Lam.)Muell.- Arg.	Chenkoli	Euphorbiaceae	Small tree	Ev. Gr. For.,Semi ev. Gr. For., Moist decd. For., Plains			Birds, Animals, Monkeys
26	*Memecylone umbellatum* Burm.f.	Anakombi	Melastomaceae	Small tree	Semiev.gr.,moist decd for.,plains			Birds, squirrels, animals

27	*Olea dioica* Roxb.	Edala	Oleaceae	Medium tree	Semi ev gr,Moist decd.for,Plains			Birds , Mammals
28	*Pavetta indica* L. var. indica	Kamatta	Rubiaceae	Small tree	Banks of rivers,Rocky laterile slopes			Birds
29	*Pavetta tomentosa* Roxb.ex J.E. Smith		Rubiaceae	Small tree	Semi ev. Gr. For., Plains			Birds
30	*Persea macrantha* (Nees) Kosterm.	Kulamavu	Lauraceae	Large tree	Ev. Gr. For., Semi ev. Gr. For., Moist decd. For., Sacred groves			Birds
31	*Pothos scandens* L.	Anapparuva	Araceae	Climbing herb	Ev. Gr. For. ,Open areas, Sacred groves			Birds
32	*Smilax zeylanica* L.	Kareeelanchi	Smilacaeae	Climber	Semi ev. Gr. For.,Moist decd. For.,Plains			Birds
33	*Sterculia guttata* Roxb.ex DC.	Thondi	Sterculiaceae	Medium tree	Semi ev. Gr. For.,Moist decd. For.,Plains			Mechanical
34	*Syzygium hemisphericum* (Wight) Alston	Payinjaval	Myrtaceae	Medium tree	Ev. Gr. For., Shola for.			Monkeys(*Hanuman langur- Semnopithecus*
35	*Terminalia paniculata* Roth	Maruthu ,	Rhizophoraceae	Large tree	Moist and dry decd for., Plains			Wind
36	*Toona ciliata* Roem.	Vembu	Meliaceae	Large tree	Ev.gr. For.,Semi ev gr. For.			Wind
37	*Tylophora indica* (Burm.f.) Merr.	Vallipala	Asclepiadaceae	Slender climber	along bushes and thickets			Wind
38	*Zizyphus mauritiana* Lam.	Jujuba	Rhamnaceae	Small tree	Dry decd for.,Plains			Monkeys(*Hanuman langur- Semnopithecus*
39	*Zizyphus oenoplea* (L.) Mill.	Cheruthudali	Rhamnaceae	Climber	Moist &Dry decd for.,Plains			Monkeys(*Hanuman langur- Semnopithecus entellus*)
40	*Zizyphus rugosa* ,Lam.	Thodali	Rhamnaceae	Scandent shrub	Decd.for,Grasslands,Plains			Monkeys(*Hanuman langur- Semnopithecus entellus*)

Chapter 5

Discussion

Qualitative assessment

Floristic composition

Qualitative and quantitative assessments made over a period of three years of the 'Rubber plantation', 'Open areas' and the 'Forest areas' revealed the presence of a large number of species. The Qualitative assessment revealed the presence of 517 angiosperm species, 1 gymnosperm and 21 pteridophytes in all (Table 4.3 appendix). Such a large number of species has seldom been reported in surveys made (Yirdaw 2001, Wang *et al.* 2004). Muthukumar *et al.* 2006 reported the presence of 312 species belonging to 103 families (144 tree species, 60 lianas 108 understory plants species) in the tropical rain forest fragments of the Western Ghats in India, which is also considered a mega biodiversity center of the world. However, information available on vegetation structure and the flora in the plantations of *Hevea brasiliensis* (rubber plantations) is scanty. A report of a survey made by Abraham and Abraham (2000) of weed flora associated with a few rubber plantations in Kerala enumerated 72 dicots, 16 monocots which included 12 grasses 2 sedges and 2 ferns.

Out of the 517 species recorded in this survey, 420 species were found in the rubber plantation areas (RP areas) whereas 115 species were recorded in the Open areas (OP areas) and 187 species were found in the Forest areas. The least number of species were recorded in the Open areas (Table 4.4 and Figure 4.1). The RP areas have a higher disturbance score compared to the OP areas (Table 4.2).

Edge effect can be seen in the forest sampled.

The Forest areas sampled showed a low disturbance score. Oliviera *et al.* (2004) made a detailed study on the edge effect of Forests. A similar edge effect was also observed in the Mundakayam forests sampled in this study. Thenmala and Mundakayam forest were sampled along the edge of the forest, adjacent to the RP areas. The Ranni forest in the district of Pathanamthitta is represented by the forest in Chetheckal in this study. This is a secondary forest adjacent to the RP areas in Chetheckal and has a low level of disturbance (Table 4.2). According to Laurance (1991) the edge effects penetrated 300 m into the forest fragments. The present study penetrated 100 meters into the forest fragment. The presence of several grass species and pioneer species such as *Cyperus rotundus, Cynodon dactylon, Mitrocarpus villosus, Biophytum reinwartii ,Bracharia ramosa, Chromolena odorata, Cyathula prostrata* and small seeded trees like *Abrus precatorius, Ficus exasperata, Glycosmis pentaphylla* and *Helectris isora* are due to the edge effect of the fragmented forest and due to the secondary nature of the forest sampled (Table 4.3, 4.7 appendix). Growth of opportunistic species is reported in native eucalypt forests and at the edge of rainforests (Bean 1994, Wang 1995, Wang *et al.* 2004).

Studies on the species assemblages of forests by Oliviera *et al.* (2004) provides evidence that forest fragmentation leads to the establishment of two assemblages of tree species. The forest interior holds a rich assemblage of tree species consisting mostly of shade-tolerant canopy and emergent species. Exclusive large-seeded tree species are found in the interiors of the forest. These plants are naturally rare at the local and regional levels. The forest edge, on the other hand, has an impoverished assemblage of tree species in which, species adapted to disturbance prevail. Forest edge had twice as many pioneer species as the forest interior (83% vs. 37%), and only one third of the emergent species found in forest interior (Oliviera *et al.* 2004). Vertebrate-dispersed species were predominant in the interiors of the forest (Oliviera *et al.* 2004). Similar observations of the edge effect and more in this study, such as reduction in seedling recruitment due to habitat desiccation, and higher rates of adult mortality due to uprooting and breakage caused by wind turbulence is in conformity with the reports of Tabarelli *et al.* (2004). The species assemblage of the Forest areas also included small seeded trees along with deep forest species such as, *Actinodaphne bourdillonii, Bombax cieba, Careya arborea* to name a few (Table 4.3). Melo (2004) accumulated evidence suggesting that alterations in allocthonous seed rain (i.e. seeds from other habitats) may reduce the frequency and abundance of large-seeded tree species at the forest edge and thus drastically alter tree species composition in this habitat. The vast areas of adjacent RP could provide such an allocthonous seed rain and directly affecting the recruitment and establishment of large seeded tree species in the forest edge sampled. Very few tree species that are found in the interiors of the forest are found in the edge of the forest (Melo 2004). This is because they are shade-tolerant trees like the members of Sapotaceae (Pennington 1990, Jesus 2001) that disperse their seeds with the help of arboreal mammals, scatter-hoarding rodents and occasionally by bats and large birds (Spironello 1999). The species assemblage of the forest sampled showed the edge effect. They were sites chosen adjacent to extensive rubber plantations, and were, along the edge of the fragmented forest sampled.

<u>Relative diversity indicates a slow and gradual vegetation change.</u>

The families having the highest relative diversity index (RDI) in the RP areas are Fabaceae, Euphorbiaceae,Poaceae, Asteraceae and Acanthaceae (Figure 4.3).

The top ten families form 40% of the species composition. In the Forest areas the highest RDI are of the family *Fabaceae ,Rubiaceae* and *Apocyanaceae* (Figure 4.5) and form 35% of the species composition. The families Poaceae, Asteraceae, Acanthaceae, Commelinaceae and Convolvulaceae have the highest RDI values in the OP areas and form 61% of the species composition (Figure 4.4). There is a significantly a larger representation of a few families in the OP areas as compared to the RP and Forest areas (Figure 4.3, 4.4 and 4.5). Thus the RP area species and genera composition indicates a changing trend with a higher representation of Poaceae and Asteraceae members.

Several studies have been made comparing plantations to forests and of the study of the forest fragmentation and its repercussions on vegetation (Yirdaw 2001, Wang *et al.* 2004 and Cremene *et al.* 2005). Very few studies have emphasized on inventorying and identifying the complete vegetation, including all the habit forms (Trees, shrubs, herbs, lianas etc.). None of the studies include detailed qualitative floristic identification and listing of species. Hence relative diversity has not been included in those studies.

The families having the higher RDI values in the Forests sampled are Fabaceae, Rubiaceae, Apocynaceae, Malvaceae and Poaceae (Figure 4.5). Morley (2000) reported Euphorbiaceae, Fabaceae, Lauraceae and Rubiaceae are among the most dominant rain forest families world-wide. Comparison of the understory vegetation of plantations and adjacent natural forests in the Ethiopian highlands have shown that although the number of understory species in the natural forests is not significantly different from the plantations, despite a four times larger plot size, a much higher percentage of plants found in the natural forests were native species while on the other hand the plantations harbored more widespread weed species (Michelsen *et al.* 1996).

The changing vegetation of the RP areas show the invasion of wide spread weed species. The high RDI of Poaceae in the RP areas is indicative of such a change (Figure 4.3). The understory of the RP plantations, showed a higher RDI for the families Fabaceae and Euphorbiaceae. This is similar to the findings of Yirdaw's (2001) where he found a larger presence of the family Rubiaceae in the understory of the plantations. A higher RDI index value means a higher representation of the family in the region. The RP area has a higher representation of families with a RDI value less than 1 (Figure 4.6). This means there is considerably larger number of families represented by a single genera and a single species.

Disturbance and non-disturbance can result in increase species richness.

The individual sites samples showed a wide range of variation in their history and number of species (Figure 4.2). The sites have different histories and were evaluated for their level of disturbance (Table 4.2). Neezhoor and Puthupally plantations are unweeded for the past seven years. The other four sites viz. Pampadi, Chetheckal, Mundakayam and Thenmala were mechanically weeded plantations. Pearsons correlation using QED version 1.1 (Henderson and Seaby 2007) showed that there was no significant correlation between disturbance and the number of species in these rubber plantations ($r = 0.35$, $t = 0.74$, $DF = 4$, $P = >0.05$). The highest number of species was found in Chethekal with 180 species, followed by Neezhoor plantations with 179 species (Table 4.8). The histories of the management of these plantations differ. The Chetheckal plantations are weeded plantations while the Neezhoor plantations are unweeded plantations (Table 4.2). Puthupally which is also an unweeded site is also species rich, with the presence of

156 species (Table 4.8). Comparison made in a similar manner between cleared grazing land and plantations by Wang *et al.* (2004) showed that geographical spread of the site and preplanting management history confounds the comparison.

The high species richness (number of species) in the Chetheckal plantations can be an outcome of its topography and disturbance. Chetheckal are weeded plantations situated on a higher elevation than the rest of the plantations sampled (Table 3.2). Several studies have supported the view that disturbance encourages the growth of more species (Gough *et al.* 1994, Lewis *et al.* 1988, Kammer and Möhl 2002). Toumisto and Poulsen (2000) are of the view that while species composition and distribution patterns can be readily explained by topography, differences in the species compositions among the sites must depend on more local factors. The "more individuals" hypothesis suggests that species richness is positively correlated with the number of individuals, which in turn varies with energy availability (Currie and Paquin 1987, Currie 1991, Gaston 2000). Availability of both energy and nutrient resources are drastically different across developmental stages in forests. The number of individuals and species richness should be greater in recently disturbed forest habitat (Toky and Ramakrishnan 1983). The presence of higher species number in Neezhoor however cannot be explained by disturbance as these are unweeded areas. A similar high species number is also found in Puthupally. Here a lack of disturbance must be increasing heterogeneity in the habitat and thereby increasing species richness of the area to its pre-disturbance levels. Historical or random effects could also play a role (Ricklefs 1987). In studies of the Amazonian forest by Loya and Jules (2008) showed that the initiation plots were the most species rich, while Old-growth plots were the least rich. The differences in the species richness of these areas can be correlated to the availability of energy and nutrient resources.

Each habitat may have idiosyncratic dynamics; within-stage sampling efficacy may differ across habitats. A large number of species is found in the sites sampled in the RP areas, in both the disturbed and undisturbed sites. Comparisons across forest stages amount to comparisons across habitats. In a study made by Loya and Jules (2008) of the forest understory species composition in Amazonian forests they found that the disturbance regime creates a patchwork of forest blocks, each at various stages of stand development and, therefore, a mosaic of habitats variously suitable for forest understory species. Insufficient sample size can be ruled out because the species-area curves at all sites, level off well before the full sample size. The species area curves of each sampled site in this study (data not included) validates the adequacy of the sample size. It seems unlikely that the floristic results would change even if the sample areas would be significantly increased.

Weeded plantaions VS unweeded plantations

<u>Unweeded areas regenerate a large number of pioneer tree species</u>

The rubber plantations of Puthupally and Neezhoor were kept unweeded for a period of 7 years to see if the vegetation can be restored to its pre- disturbance levels. In principle this should allow more growth of natural and native species. A comparison of the species composition of weeded sites (Chetheckal, Mundakayam, Pampadi, and Thenmala) and the unweeded sites (Neezhoor and Puthupally) has shown that the weeded sites and the unweeded sites have both 61 species each, which are(in all the six locations) exclusively found in these areas, whereas 92 species are found common to both the areas. The species composition of the unweeded areas shows the presence of some tree species such as *Ficus hispida, Olea dioica, Ochna obtusa, Salacia oblonga, Salacia fruticosa, Strychnos nuxvomica, Syzygium caryophyllatum,* and some rare species such as *Memecylone randerianum, Glochidion zeylanicum, Glochidion ellipticum,* and *Dalbergia horrida* (Table 4.3 appendix).The species composition of the weeded sites showed the prevalence of more herb species especially the pioneer species. There are very few tree species in these sites.

Disturbance in the form of the preparation of the land by felling the timber, plouging the land will have its effect on the vegetation of these plantations. Ploughing leads to the complete destruction of top soil morphology and lays bare the underlying mineral soil. The following processes have the character of secondary succession, which will not necessarily lead to the restoration of the destroyed communities (Bobeic 1998). The forestry management may be a factor underlying, the site homogenization. The destruction of humus horizons caused by land preparation could contribute to disappearance of specific microsites, responsible for the community mosaic character (Aleinikrova *et al.* 1979, Kolasa and Biesiadka 1984, Palmer 1994). The re-growth of several tree species and rare species in the unweeded sites is an indication of change in species composition of the vegetation. A change in species composition precedes any change in the overall structure of the plant community (Codit *et al.* 1996). Late colonizing species (such as tree species in this study) and the gradual expansion of remnant populations have accounted for these changes is also supported by similar studies made by Halpern (1989). Studies in the forest plantations in the Afromontane region of Ethiopia facilitate the colonization and establishment of native woody species and eventually the restoration of diverse forests (Yirdaw 2001). Because some species may recover slowly after disturbance (Moola and Vasseur 2004, Donohue *et al.* 2000), their persistence across the landscape, will be dependent on several key factors, including rate of population increase, propagule abundance and dispersal mode. Species-specific differences in recovery are influenced by many factors, including habitat suitability (Gustafson and Gardner 1996, Vandermeer and Ricardo 2001, Bruno 2002), dispersal limitations (Matlack 1994, Clark *et al.* 1998; Sillett *et al.* 2000, Jacquemyn *et al.* 2001, Honnay *et al.* 2002), germination limitations (Primack and Maio 1992, Jules and Rathcke 1999, Dalling *et al.* 1998, 2002), and interactions among these factors (Verheyen and Hermy 2001). Investigations of distribution, colonization and extinction of plant species along the Rhine in the Netherlands have shown that for some species both colonization and extinction are affected by distance between localities (Ouborg 1993). Studies on the effect of logging on Redwood forests (Loya and Jules 2008) have shown that the recovery of some species is slow in managed forests. There is some evidence that at least ectomycorrhizal fungal communities are able to recover rapidly after logging, though composition is altered (Jones 2003). Long-term regeneration processes take more than one year to occur (Ben'ıtez-Malvido *et al.* 2001, Ben'ıtez-Malvido and Mart'mez-Ramos 2003).

The abandonment of vegetation in the RP areas leads to a species compositional change which indicates restoration towards a pre-disturbance level. This also leads to higher species richness. Whether this change can restore the vegetation to the pre-disturbance levels needs to be investigated further. The differences of these past findings may result in part because community recovery is system specific and influenced by numerous biotic and abiotic factors (Halpern 1989, Roberts and Gilliam 1995, Roberts 2004).

Isolation of Thenmala rubber plantations has led to lower species richness

Thenmala plantations are 8 km well within the forest. Table 4.8 shows that Thenmala RP has the lowest number of species (63 plant species) as compared to the other RP areas sampled. The species composition of this area shows that there are several pioneer species such as *Achyranthus aspera, Axonopus compressus, Centella asiatica, Commelina attenuata, Cyathula prostrata, Cytococcum oxyphyllum, Justicia procumbens, Spermacoce latifolia, Urena lobata* etc which are also reported in all the other plantations. When compared to the adjacent Thenmala Forest samples, there are only 12 common species viz. *Bracharia ramosa, Centrosema pubescens, Chromolena odorata, Cynodon dactylon, Cyclea peltata, Cyperus rotundus, Desmodium, gangeticum, Desmodium triangulare, Mitracarpus villosus, Oplismenus compositus, Selaginella delicatula* and *Smilax zeylanicum.* A majority of these species are pioneer species characteristic of a successional vegetation and are not deep forest species. As the plantation is situated well within the forest one would expect more deep seated forest species in these plantations. Instead the species composition resembles a disturbed habitat. The few species that are common to the Thenmala RP and the Forest area are also typically, those of the edge effect of a forest.

Pioneers colonize an area only because small (< 10 mg) seeds are present in immense numbers (Graza and Howe 2003). This can explain the presence of a large number of pioneers in Thenmala RP areas and their invasion into the surrounding forest within which the plantations are situated creating an effect similar to the edge effect in the forest. The experimental removal of palms, herbs, and ferns can result in an increase of light-demanding tree seedling species and a decreased recruitment of shade-tolerant, large-seeded tree species (Beńıtez-Malvido and Mart́ınez-Ramos 2003). Furthermore, small lianas have been observed to climb tree seedlings affecting their vigor (Vleut and P′erez-Salicrup 2005). Understory vegetation may affect plant density independent of species or may differentially influence emergence and survival of certain type of species, thereby influencing the composition and spatial structure of the "seedling" bank (Denslow *et al.* 1991, George and Bazzaz 1999, Svenning 2001). The pioneer species may interfere with tree seedling establishment through resource competition (*i.e.*, space, nutrients, water, or light) and environmental modification (Denslow *et al.* 1991, George and Bazzaz 1999, Svenning 2001, Harms *et al.* 2004).

The low number of species in the Thenmala plantations (Figure 4.22) could be attributed to the low availability of diaspores which can establish themselves in these plantations The limited dispersal of large-seeded as compared to small-seeded plant species suggests that many restoration sites will result in retarded or even arrested development, in which sites are overwhelmingly composed of small-seeded pioneer species (Wunderle 1997). In older plantations the shade provided by tree plantations protects the tender seedlings from excessive exposure to sunlight and high ground temperature and therefore reduces the mortality of the seedlings due to moisture stress. This does not happen when plantations are young as found in the Thenmala plantations. Liberman and Li (1992) also reported that in the dry forests of Ghana, sheltered and well-shaded sites had consistently high seedling densities, while exposed sites had low densities. Parrotta (1995) has found a significant negative correlation between understory species richness, seedling density and litter depth, especially for orinthochorous species. Litter accumulation acts as a progressively severe barrier to the regeneration of small-seeded tree and shrub species. Large seeds are more likely to be dispersed over shorter distances than small seeds and are therefore expected to have a lower rate or likelihood of colonizing sites (Yirdaw 2001). Jones *et al.* (2003) provided evidence that high impact of soil disturbances associated with logging may distort community development dynamics in ways that prevent recovery of pre-logging forest conditions. In a similar study by Yirdaw (2001) in the plantations of *Pinus patula, Cupressus lusitanica, Grevillea robusta,* and *Juniperus procera,* and in surrounding natural forests in Wondo Genet, Ethiopia, the primary canopy species were poorly represented or absent, while the pioneer and secondary sub-canopy species dominated in the undergrowth (Yirdaw2001).

When resource levels are low, competitive response ability, i.e. an ability to avoid or withstand interactions with other species or individuals becomes more important (Aarssen 1983, Goldberg and Landa 1991). A reduction in species richness in the Thenmala RP areas reflects a comparatively larger pool of species possessing strong competitive response ability. This is in agreement with similar studies reported (Hodgson 1987, Zobel 1992, Eriksson 1993). Plant traits such as plant height and seed size are correlated with competitive abilities in turn creating competitive hierarchies (Gaudet and Keddy 1988). All the above attributes of the vegetation dynamics explain the low number of species found in the Thenmala RP areas.

Presence of several growth forms and the vertical stratification in rubber plantations indicates their ability to regenerate forests.

Forestry management can lead to the disappearance of a highly structural character in natural forest communities (Bobeic 1998). RP areas show 218 herbs, 104 shrubs, 95 trees and 3 epiphytes (Table 4.9). The vertical stratification shows all four growth forms present in the understory of the RP areas sampled viz. ground layer, shrub layer, understory layer and canopy layer. Figure 4.7 shows that this vertical stratification is present in similar proportions all the three types of areas sampled (RP, OP, and Forest). There are 22 species of climbers in the RP areas, 11 climbers in the Forest areas and 6 climbers found in the OP areas sampled (Table 4.11).

Presence of a large number of herbs and climbers in the RP areas as compared to the OP and Forest areas (Figure 4.7) is a vegetation response to disturbance. Several studies ecological studies on climbers have been made. The abundance and ecological characteristics of climbers can be used to distinguish different intensities of disturbance in the rain forest (Garrigues 1999). In undisturbed thickets, the number of climbers increased with the area of the undisturbed thickets, but climbers were poorly represented in disturbed thicket (Puyrvaud *et al.* 2003). Also under severely disturbed conditions, the age class distribution of colonizers may be narrow, while individuals of diverse ages are found where disturbance is less severe (Kunwar and Sharma 2004). Presence of larger number of young climbers of a similar age class is an indication that the disturbance is severe.

The number of herbs is higher than the shrubs and the trees in the RP and OP areas whereas the forest areas show a larger number of trees and a comparatively smaller number of herbs (Figure4.7). Disturbance in the form of weeding, pre-planting procedures of land preparation, fertilization and mechanical stress due to pathways in the plantations led to the invasion of species with large ecological amplitude in these plantations. Notwithstanding a disturbed species composition the vertical stratification of the RP areas indicates a potentiality for regeneration of a diversity of plants and life forms. The presence of 51 tree species as compared to 6 tree species found in the OP areas and 44 understory species as compared to 12 in the OP areas (Table 4.10) is a strong evidence for its regeneration ability. The understory of tropical rain forests is characterized by a high diversity of plant species and growth forms such as tree seedlings, palms, shrubs, lianas, and herbs (Gentry and Dodson 1987, Benitez-Malvido 2006). Forest plots thus harbor more species at both local and regional scales (Gotelli and Ellison 2002). Studies on the harboring of species by plants that belong naturally to a habitat versus exotic plantations have shown that a larger amount of native flora diversity was found in Hardwood plantations as compared to the exotic Pine plantations (Gill and Williams 1996). Similarly Old plantations and native eucalyptus forests also support a large amount of native flora diversity. Although *Hevea brasiliensis* is an exotic tree species introduced in India the presence of several native floras and their diversity in growth forms and vertical stratification indicate that these plantations have the ability to regenerate forests.

Similar to earlier findings by Toky and Ramakrishnan 1983, Currie and Paquin 1987, Currie 1991 and Gaston 2000 the growth of several tree saplings and several growth forms in RP could be supported by the high nutrient levels in the soil and shade conditions which protects growing saplings from excessive exposure to sunlight. A mature rubber plantation is an excellent repository for mineral nutrients which is comparable to that of native forests (Akhurst 1933, Shorrocks 1965, Samarapuli 1996, Morris and Lau 1990, Krishnakumar *et al.* 1991). However the closing of rubber canopy results in the death of these saplings over a period of time. Several studies have found that trees influence the lower vegetation through over shading (Beatty 1984, Tyler 1989, Økland 1990, Piro˙znikow 1991, Bobiec 1994) and a supply of differentiated litter (Aleinikova *et al.* 1979, Riha *et al.* 1986, Pallant and Riha 1990, Peterson and Facelli 1992 and Peterson and Campbell 1993) influence on chemical properties of stem flow and canopy through fall

(Boerner and Koslowsky 1989, Koch and Matzner 1993) as well as the water regime modification (Sokołowski 1966).

Among the growth forms sampled the number of epiphytes was low in all the three areas (Table 4.9). The forest areas were along the periphery of the forest adjacent to the RP areas sampled. The edge effect could be the reason for the small numbers of epiphytes sampled in them. Also the presence of large number of trees on which the epiphytes grew was inaccessible and hence could not be sampled.

Quantitative studies

Sampling grain and Sampling intensity

A lack of uniformity was found in the areas sampled as the areas (RP, OP and Forest) were varied in size and nature. The RP areas are much vaster than the OP areas. The areas of the OP were ill defined and the size ambiguous (Table 4.2). Sampling scale has been a significant problem in the assessment of the effects of habitat modification on rainforest biota (Hamer and Hill 2000).

In this study quadrats were repeated over a temporal and spatial scale over the area chosen. Samplings were taken at regular intervals of time and space. The effect of habitat modification recorded at a single spatial scale is not representative of all scales (Gardner 1998). The quadrat size was determined by the species area curve for herbs, shrubs and trees (Table 4.1). Too large a quadrat gives little information about within-community variation, because it averages over many microsites. It cannot indicate the consistency of species ranks. Neither can a large quadrat examine the community structure at the spatial scale on which species interaction takes place (Watkins and Wilson 1994). In order to make a regional comparison of sites far apart, it is better to sample the local variation at each site as completely as possible (Tuomisto and Poulsen 2000).

The forests sampled had a vegetation structure which included a large number of trees. The dispersion patterns of the three areas shows that a large number of species show an aggregate dispersion pattern in all the three areas (Figure 4.21).

The RP areas have been sampled extensively at a landscape level, in order to reach the asymptotes for the species accumulation curve. To make comparisons feasible a single sampling grain was chosen for the herb, shrub and tree quadrats for all the sites (Table 4.1.). Species accumulation curves were used to reiterate the adequacy of the sampling effort. The all sample index of the RP, OP and Forest areas are 216, 160 and 168 respectively (Figure 4.23, 4.24. 4.25). The larger number of species obtained in the RP areas can be explained by the species area relationship. Species-area relationship is one of the most robust generalizations in ecology (Holt *et al.* 1999). That the number of species increases with sampling area has long been considered a "genuine law" of ecology (Schoener 1976). Additional sampling effort can yield an increase in numbers of species (Stohlgren *et al.* 1997, Gimaret-Carpentier 1998).

Sampling intensity required to depict floral communities realistically is an important concern of environmental protection and impact analysis (Stele *et al.* 1984, Miller and White 1986). The three year intensive survey takes into account both temporal and spatial scale of sampling and reinforces the adequacy of sampling. Summerville and Crist (2005) concluded from a 3-year survey of an old-growth deciduous forest that increased sampling effort among seasons, yielded greater accumulation of new species, than did additional years.

Quantitative assessment of the RP areas shows an all sample index of 216 (Figure 4.23). This is much lower than the number of plant species observed in the qualitative assessment (420 species in the RP areas alone Table 4.4). This is an indication of a large number of plants in the rubber plantations are with very low abundance. This could be the reason for which they could not be included in the samples. Based on empirical observations it is also widely recognized that species richness decreases with the increase of species dominance in a given area i.e. with increase in unevenness in species abundances (Bazzaz 1975, Huston 1979, Armesto and Pickett 1985, Crawley 1997). Further species richness in an area greatly depends on the distributional patterns of species (Williams 1943, Janzen 1970, Connell 1971, Crawley 1997, Ney-Nifle and Mangel 1999). He and Legendre (2002) found species richness higher if the species were randomly distributed and lower if there was spatial aggregation of species. The lower number of species encountered cannot be due to the aggregate pattern of dispersion found in RP areas, where 68% of the plant species show an aggregate dispersion pattern (Figure 4.21). The OP areas and the Forest areas sampled have also shown a high aggregation of 71% and 64% respectively (Figure 4.21). The quantitative sampling of the OP areas has yielded an all sample index of 160 species (Figure 4.24) while the qualitative assessment shows a lower number of 115 species (Table 4.4) and thus less than the quantitative sampling. The Forest areas show an all sample index of 168 (Figure 4.25) whereas the qualitative assessment reveals 187 species (Table 4.4). These discrepancies cannot be due to sampling error and lack of detectibility of the species in the survey as the sampling has been spatially and temporally extensive and the adequacy of the sampling has been supported by further statistical analysis.

Relative abundance and Rank on Abundance

Rank on abundance plots indicates high species richness and low evenness and suggests a log normal distribution in RP areas

The graphical output of the species number index of the three areas (Figures4.23 - 4.26) indicates a wide variation in the number of species found in the samplings of RP, OP and Forest areas. The presence of only two species in the quadrat samplings of the RP areas (Figure 4.23) show, the very low abundances of plants found in these areas. A large number of species were found in the quadrat samplings of Ranni (Chetheckal) secondary forest (Figure 4.26). The mature tropical forest area did not show much variation in the number of species found per sample indicating a more even distribution of plant species in the Forests (Figure 4.26). A maximum of 35 species were recorded in all the RP, OP and Forest areas (Figures 4.26). Species richness alone cannot be a measure of diversity. The relative abundance of species is a basic aspect of a community structure (Watkins and Wilson 1994). Measures of species diversity based on relative abundance, as well as richness, is necessary to capture the full complexity of diversity in conservation studies and in experiments of biodiversity and ecosystem functioning (Wilsey *et al.* 2005). Tuomisto and Poulsen (2000) have shown that differences related to drainage and other environmental factors observed at a local spatial scale are more reflected in the relative abundances of the pteridophyte species than in their presence or absence.

The first step toward a plant diversity analysis is the plotting of the rank on abundance plot (RA plot. The RA plot gives an insight into the structure of the community. The shape of the RA plot of the RP areas suggests that, there is high dominance of a few species and a low evenness as compared to the OP and the

Forest areas (Figure 4.27). There are a large number of plant species that are rare (lower in abundance). In the RA plot of all the subsamples, the RP areas lies well above those of The OP and Forest areas, indicating higher dominance of certain species but low evenness(Figures not included).The RA plots of all the RP subsamples are similar with the exception of Thenmala which shows a low species richness and evenness. The RA plots of these unweeded RP areas (Puthupally and Neezhoor) indicate vegetation change with more evenness and lower dominance of a few species (Figure 4.28 and 4.29). The Chetheckal RP areas also show a lower dominance of species and more evenness. These areas are first generation plantations found adjacent to the Ranni Chetheckal forest. Presence of a larger number of forest species can be seen in the species composition of this area. Plants like *Chasalia curviflora, Rauwolfia serpentina, Geophylla repens ,Stercularia guttata, Naragamia alata* (endemic), *Psychotria niligiriensis* (endemic),*Terminalia paniculata,* and *Tiliacora acuminata* are indicative of a species composition which was once characteristic of the area and which are now remnants (Table 4.2, 4.3(appendix)).

Species richness

Species accumulation curve and extrapolations based on it indicate sampling adequacy, low habitat heterogeneity of RP areas and quantifies accumulation patterns of species assemblages in the RP, OP and Forest areas.

Species accumulation of the RP areas (Figure 4.31) is slow as compared to the OP and the Forest areas (Figure 4.32, 4.33). A S_{max} of 216 species accumulated with 92 samplings (Figure 4.31) whereas the S_{max} of 168 species accumulated in the Forest areas with 35 samplings (Figure 4.33) and S_{max} of 160 species were accumulated in the OP areas with 27 samplings (Figure 4.32). The number of species or the species richness in a species assemblage is a significant measure of biodiversity at the habitat level (Bunge and Fitzpatrick 1993, Colwell and Coddington 1994, Mao and Colwell 2005).

The species accumulation curve of the areas quantifies the accumulation pattern of each of these areas and facilitates comparison of the three areas which are unequal in size .The different accumulation patterns is because of the difference in the environments due to different anthropogenic disturbance leading to different rates of species increment. Sanders (1968) observed that different environments tend to have characteristic rates of species increment. Quantifying accumulation patterns would facilitate comparison of species assemblages in different regions (Kilburn 1966, Buys *et al.* 1994, Sanders 1968, Colwell and Coddington 1994 and Gotelli and Colwell 2001) or in landscapes subject to different levels of natural or anthropogenic disturbance (McNaughton and Wolf 1970, Aspinall 1988).

The species accumulation curve without randomizations is not smooth and appears to level off at various levels (Figure 4.34). They smoothen with just 10 randomization tests (Figure 4.31). Randomization tests explicitly factor sample abundance into the test (Crist *et al.* 2003). This indicates that the RP areas are patchy and hence the slow acquisition of species but they are less heterogenous and hence curves are easily smoothened with a few randomizations. As sampling sites were added the species accumulation curve of the RP areas increased slowly but steadily. Ugland *et al.* (2005) opined that analysis of large communities should be done by a successive addition of predefined subsets of samples. Plotting the resulting accumulation curves in a common diagram usually will reveal heterogeneity between subsamples. According to them, this is a general feature of a counting process (over space or time), that keeps record of new objects being generated by an unobservable process. Discontinuities in the accumulation curves can be explained by changes in habitat heterogeneity. The species accumulation curve of the RP areas (Figure 4.34) has shown discontinuity which can be explained by habitat heterogeneity. A few randomizations also smoothens the curve indicating low heterogeneity in these areas (Figure 4.34). Studies on the pteridophyte diversity and species composition in four Amazonian rain forests have shown that differences in species richness include the physicochemical characteristics of the soils and the degree of spatial heterogeneity in soils and vegetation, both within the transects and in their vicinity (Shmida and Wilson 1985, Toumisto and Poulsen 2000). The larger coverage of area along with some habitat heterogeneity and patchiness of the habitat is the reason why larger number of species are found in the RP areas sampled as compared to OP and the Forest areas.

The nature of the accumulation curve of the three areas in this study also shows that there are differences in the underlying abundances of the species, habitat heterogeneity and spatial aggregation. Several studies have shown that the performance of species accumulation curve also varies with the underlying relative abundance distributions (Keating and Quinn 1998), spatial aggregation of species (Baltana's 1992) and habitat heterogeneity (Colwell and Coddington 1994, Lande *et al.*2000).

The species accumulation curves based on the area sampled (each sub-sample) did not stabilize well in each subset with approximately 15 quadrat samplings The curves approach near asymptotes in each stage, after which the species acquisition was very slow hence the sampling was suspended for that region. Comparisons of observed counts and estimated species richness as a function of sampling effort showed that the count data had a lower intercept and a steeper slope than the estimated richness (Cam *et al.* 2002). Sampling was continued till an asymptote was reached in the RP areas. Thus 92 samplings covered RP areas at a landscape level. A general observation that a species accumulation curve is used to estimate the expected number of new species to be detected, given a level of additional sampling effort, can lead to efficient planning and sampling protocols (Soberon and Llorente 1993, Colwell and Coddington 1994, Moreno and Halffter 2000, Shen *et al.* 2003). Relative sizes of α, ß, γ components of diversity between different landscapes or regions require rarefaction to standardize data to an equal sample size (Gotelli and Colwell 2001). Although species accumulation curves are routinely used statistical treatments are sparse (Mingoti and Meeden 1992, Ugland *et al.* 2003).

Species richness estimations

Non-parametric species richness estimations established adequacy of sampling and the low abundance of a large number of plant species in rubber plantations.

Non parametric species richness estimates were made and their values tabulated (Table 4.22). The asymptotes of the species richness curves indicate sampling adequacy on one hand, but it has been observed that these estimates (S_{max}) are much lower than the number of species obtained in the qualitative assessments in RP area where the S_{true} is 420 plant species (Table 4.4). In spite of an intensive spatial and temporal sampling covering an extensive area at the landscape level this discrepancy must have arisen due to the low abundance of rare species found in the RP areas. The very low abundances of the rare species (in this case rare in numbers, referred to as, singletons and doubletons by species richness estimators) must have resulted in their non-sampling in the RP areas. Such discrepancies are not found with regard to the non parametric species richness estimations of Forests and the OP areas in which case the S_{max} and S_{obs} is higher than the S_{true} (as in OP areas) and nearly equal to in the Forest areas.

Use of richness estimators can improve our evaluation of how disturbance impacts biological diversity and will be a standard component of future studies (Loya and Jules 2008). While density is influenced by various factors, including elevation, soil type, dominant and associated species and human activities (Shrestha 1998), climatic factors, environmental stability, land use and area and habitat heterogeneity are the factors often are found determinants of variability in species richness (Spies and Turner 1999, Kunwar and Sharma 2004). Loya and Jules (2008) have shown that the use of species richness estimators improves evaluation of understory plant response to logging.

Rarefaction

Rarefactions show that species richness is significantly lower in rubber plantations than in Open areas and Forest areas and that unweeded RP are undergoing a change in species composition.

In rubber plantations the number of species that can be expected from a randomly chosen subset is significantly lower than that of the Open areas and the Forest areas because a subset of 30 individuals yields 5.75 species in the RP whereas one can expect 19 species and 17 species from a similar subsets in the OP and Forest areas respectively (Figure 4.66, 4.67 and 4.68).

Richness estimates used to compare communities should be derived from effort-independent estimator curves. Richness estimates in sampled communities may differ due to differences in abundance of individuals. Hence standard statistical techniques for comparing species richness may be misleading (Colwell and Coddington 1994, Chazdon *et al.* 1998). One community may be more or less thoroughly sampled as compared to another using the same number of plots in each community if the number of individuals affects estimates of richness. A good estimator is one that becomes independent of sampling effort relatively early, remains stable, and is little affected by species patchiness or sample order (Gotelli and Colwell 2001). Rarefaction techniques scale species richness estimates by individual abundance levels (Colwell and Coddington 1994, Gotelli and Colwell 2001).

Rarefied species richness is the expected number of species for a given number of randomly sampled individuals (McCabe and Gotelli 2000) and facilitates comparison of areas in which densities may differ. Rarefaction curve is the only diversity measure that is sensitive to rare species and unbiased by sample size (Smith and Grassle 1977). Rarefaction re-scales the x-axis to the number of individuals based on the average number of individuals per sample. It is based on the hyper geometric distribution, sampling without replacement from the observed collection. Unlike species–area relationships, samples need not be area-based because rarefaction explicitly controls for differences in the numbers of individuals among samples (Brewer and Williamson 1994, Gotelli and Colwell 2001).

216 species were found in the RP areas when 7268 individuals were sampled (Figure 4.63). In OP areas 168 species were obtained from 2265 individuals (Figure 4.64) whereas 168 species were found when 1575 individuals were sampled (Figure 4.65). The sample based rarefactions show that from a subset of 30 randomly chosen individuals 5.75 species can be expected in a RP area (Figure 4.66). That the species richness of the RP areas is less as compared to the OP and the Forest areas is evident from the pooled rarefaction and sample based rarefaction. The sample based rarefaction of OP areas show that 19 species can be

expected in a subset of 30 randomly chosen individuals (Figure 4.67) whereas in the Forest areas 17 species can be expected from a subset of 30 randomly chosen individuals (Figure 4.68). The pooled rarefactions (Figures 4.64 and 4.65) show that the Forest area more species rich than the OP areas because the ratio of the number of species to the number of individuals is higher in the Forest areas than the OP areas (168 species: 1575 individuals sampled in the Forest VS 160 species: 2265 individuals sampled in the OP areas).

Disturbance is known to have a strong effect on abundance so it is important to disentangle the effects of disturbance on species richness by rarefying (McCabe and Gotelli 2000). In the graphical presentation of both pooled and single sample rarefactions (Figures 4.63-4.68), curves are plotted using the accumulated number of individuals, and not the accumulated number of samples, as suggested by Gotelli and Colwell (2001). This also removes the false perception of higher species richness due to high stem densities even when comparisons are based on standardized methods and identical sampling protocols (Cannon *et al.* 1998, Gottelli and Colwell 2001).

A similar parallel can be seen in the results of the weeded and unweeded areas 154 species were found when 2628 species were sampled in the unweeded RP plantations (Figure 4.70), whereas the same number of species (154 species) was obtained only when 4704 individuals were sampled in the weeded areas of the RP (Figure 4.69 and 4.70). Thus in the weeded areas there is the false perception of richness due to more number of individuals which in turn could be a direct outcome of disturbance withstood by these areas (OP area and weeded RP area). This also explains the species richness observed earlier in the qualitative assessments in the weeded and unweeded areas. It is evident that the species richness apparent in the weeded areas is more due to the higher number of individuals. This apparent richness can be explained by the 'more individual' hypothesis which suggests that species richness is correlated with the number of individuals (Currie and Paquin 1987, Currie1991, Gaston 2000).

Dominance diversity relation (Species abundance distribution curves)

DD curves indicate adequate sampling size and sampling adequacy and a log series distribution in the RP areas

The goodness of fit tests shows that the vegetation of the RP areas fit a log series distribution as well as lognormal distribution pattern (Figure 4.73). The RP areas have been extensively sampled and this has resulted in the inclusion of several rare species which fell below the veil line. The dominance of grass species such as *Axonopus compressus, Cytococcum patens, Cyrtococcum oxyphyllum, Oplismenus compositusans, Cynodon dactylon* and *Scleria corybosa* is a result of the availability of suitability of niche and resource apportionment. The very low abundances of the rare species (21.5 species behind the veil line Table 4.24) are resulting in a change in the composition of the species. This change has been brought about by disturbance. Elimination of several species and invasion of several species with high abundance value has resulted in a species composition that is dominated by a very abundant species. This has resulted in low evenness and comparatively high dominance of a few species ecologically and numerically. SAD curves are resource-apportioning models based on ecological theory (Wilson 1991, Kunwar and Sharma 2004). The resource-apportioning models can be seen as applying over ecological time or evolutionary time (Pielou 1975). In ecological-time models, the abundances are seen as a result of competition and other ecological interactions. In evolutionary-time models the abundances are seen as innate properties of the species, a result of co-evolution (Wilson 1991).The RP vegetation can be viewed as undergoing change in ecological time. The dominance of grasses and pioneer species is a result of competition and low availability of resources and other ecological interactions such as lack of habitat heterogeneity, poor seedling bank, thick leaf litter, allelopathy etc.

The species richness and density of the ground flora is indicative of changing environment with a top down control. On one side elimination of species is taking place and on the other side invasion of species that are more abundant and with higher ecological amplitude is taking place. This is resulting is homogenization of the vegetation and lack of heterogeneity of the habitat on one hand and succession with a natural tendency to a lognormal distribution on the other. Dominance-diversity relationship change along gradients has been studied by ecologists (Whittaker 1965, Bazzaz 1975, Gosselink and Turner 1978, May 1981). However the pattern of evenness and relative abundance varying along gradients has not been studied (Weiher Keddy 1999). All the individual sampled sites (the sub sampling) show a log normal distribution (Figure 4.76 - 4.89).The Mundakayam forest data fits both lognormal distribution and Broken stick model indicating high evenness in the vegetation.

The diversity distribution curves also show the adequacy of the sampling size. Evenness declines with species richness (Wieher and Keddy 1999). Increasing quadrat size will increase the total biomass and the relative abundance of the most minor species will tend to decline because most of the added biomass will come from more dominant species. Therefore evenness is scale dependent (Weiher and Keddy 1999). The relationship between topography and patterns in the diversity and abundance of trees has been studied in a large rain forest plot in Borneo, and there topography was found to explain the variation only to a low degree (He *et al.* 1996). In general, species richness and the density of individuals were not nearly as readily explained by topography as were species composition and distribution patterns. Many species showed similar distribution patterns in relation to topography (Tuomisto and Poulsen 2000).

Logmormal distribution on one hand has been described as almost ubiquitous for communities at stable equilibrium (May 1975, Hughes 1986, Gray 1987), especially in communities of high species diversity (Whittaker 1965, Huges 1986) and on the other hand, Lambshead and Platt (1985) stated that lognormal has never been found in undisturbed ecological samples. Geometric fits where species richness is low (Whittaker 1965, 1972, Pielou 1975, Gray 1987). The pooled samples of the OP and the Forest areas show a lognormal distribution whereas the RP areas fit a log series distribution as well as lognormal distribution indication disturbance and change in its vegetation composition. Chetheckal , Mundakayam, Pampadi and Thenmala also fit the log series distribution sub samplings. These are weeded areas and undergo high disturbance. All the subsamples of the OP areas also fit the log series .The OP areas of Thenmala, Mundakaym and Puthupally also fit the geometric series indicating lack of evenness and succession.

The abundance measure used in this study include counts and included all plant species because as reiterated by Wilson (1991) extreme points are particularly important for the fitting of several of the models. Although these models do not support any theory , their importance is lies in that fact that all ecological studies that strive for generality are part of a search for repeated, recognizable and explicable (Pielou 1975). To do science is to search for repeated patterns (Mac Arthur 1972). The dominance diversity relation differs with spatial scale but ecological processes will be different at large scales (Wilson 1991). The ideal would be to replicate a small scale to be a mean of several curves (Wilson 1991) as done in this study.

Diversity profiles

Diversity indices have given mixed verdicts on the diversity of the RO,OP and Forest areas but the diversity profiles have given a clear verdict that the RP areas are the least diverse among the three type of areas sampled.

Diversity assessments are useful tools in ecological evaluations (Lewis *et al.* 1988).The alpha diversity indices and evenness measures (Table 4.25) for the RP, OP and Forest areas show variations and make it difficult to summarize the data. This is because these indices combine information on occurrence and relative abundance for all species in an assemblage into a single number. Species diversity indices have commonly been used to summarize species occurrence and abundance data (Flather 1996). Species count, Shannon's index and the Simpson's index are used for comparing diversity and to determine trends following disturbance (Lewis *et al.* 1988). The Shannon index of the RP areas is 4.002, of the OP areas is 4.295 and for the Forest areas is 4.48 (Table 4.25).Randomization tests of Solow (1993) have shown these differences to be significantly different at the 5% level. The values of the Simpson's index are 27.85 for the RP areas, 42.88 for the OP areas and 55.86 for the Forest areas. The species count (All sample indexes) for the three areas are 216 for the RP areas, 160 for the OP areas and 168 for the Forest areas (Table 4.25). Shannon's index adequately includes both species count and evenness and is thus especially useful for describing ecological trends. However, they have been difficult to interpret (Peet 1975). Consequently, the potential for diversity indices to provide useful resource conservation and management insights have been questioned (Magurran 1988). Discontent with such composite indices of community structure has led to the examination of a family of measures that are based more directly on empirical species-abundance relations (Hurlbert 1971).

The Rényi Family diversity profiles (RF) and the Right Tailed sum diversity profile (RTS) of the RP, OP and Forest areas (Figure 4.101 and 4.103 respectively) have shown clear verdict that the rubber plantations are lower in diversity then the Open and Forest areas. The RTS profile (Figure 4.103) shows that the Forest areas are more diverse than the OP areas and the RP areas. The RTS diversity profiles do not intersect each other and hence tend to be ranked similarly by different diversity indices as seen in Table 4.25. The different diversity indices also show a consistent lower diversity index value for the RP areas than the OP and Forest areas. The slope also descends steeply in the RP and OP areas whereas it descends slowly in the Forest areas (Figure 4.103). This shows that the RP and the OP areas are dominated by a large number of few species that are abundant (Figure 4.101 and 4.103) The Forest areas are more even in that respect and that the species have similar abundances. Diversity profiles are even more useful for investigating ecological conditions because they not only illustrate intrinsic diversity ordering, they also illustrate other important information about community structure such as the relative contribution of abundant and rare species and the succession trends of a community over time as affected by abundant and rare species (Lewis *et. al.* 1998). All these diversity assessments possess qualities which make them useful as measures of diversity to be used for forest management. They are unaffected by the size (area) of the community, size of the plant, species name, number and equitability of proportional abundance (Lewis *et. al.*1998). The right tails of the diversity profiles are important because they present information on the rare species of the community which is important for conservation (Lewis *et. al.* 1998). Although they are unaffected by plant names graphical methods for examining individual species responses to disturbance can also be made (Moore *et al.* 1982a, 1982b).

The RTS diversity profiles of the weeded and unweeded areas as compared to the nearby Forest and the OP areas (Figure 4.110) has shown that the unweeded areas and unweeded areas are similar in diversity and their lines tend to intersect with each other. This indicates that different diversity indices will tend to rank them differently. The slope of the diversity profile of the unweeded area lies above that of the weeded area and falls more gradually indicating that these areas are more even than the weeded areas and that the plant species have similar abundances. The diversity profiles of the subsamples of the RP areas alone (Figure 4.102 and 4.104) show that the profiles of each area intersect each other and that they will tend to be ranked differently by different indices. However the Neezhoor RP areas have the lowest diversity while the Puthpally and Chetheckal RP areas have the highest diversity. This can be also seen in the tabulations of the various alpha diversity indices measured for each of these areas (Table 4.25) and their graphical output (Figures 4.97-4.100).The higher diversity in the weeded areas (e.g. Chetheckal , Mundakayam, Pamapdi and Thenmala) and the lower diversity in the unweeded areas (Figure 4.110) could be because these vegetations are in the process of returning to their pre-treatment levels. Lewis *et al.* (1998) have shown the influence of disturbance either by burning or by harvesting and site preparation in pine-wiregrass vegetation diversity increased for the next 2-4 years and returned to pretreatment levels. Scarce herbaceous species increased rapidly following disturbance but changes in the number of abundant species was limited. By six years after disturbance all components were moving towards pretreatment conditions. Results show that disturbance can help maintain species diversity. The low diversity of the Neezhoor rubber plantations as compared to all other plantations(Figure 4.102 and 4.104) in spite of being an unweeded area is probably because of the lack of diaspores or poor seed banks to establish themselves in these plantations. Thenmala rubber plantations also show the lowest diversity profile compared to other RP sites (Figure 4.102 and 4.104). Situated within the forest lack of diaspore availability does not explain its poor diversity. Abundance of grass species such as *Axonopus compressus* , *Kyllinga pumila, Cyperus rotundusand Bracharia ramosa* other pioneer species such as *Spermacoce latifolia, Urena lobata, Achyranthes aspera, Cyathula prostrate, Mukia madraspatana, Mikania macrantha* (exotic weed),*Centella asiatica, Hyptis saveolens, Eclipta prostrate, Hedyotis auricularis* , *Commelina attenuate, Chromolena odorata* are some species that may act as deterrents for the establishment of forest species. These plant species could either modify the microsites in which seeds germinate and plants establish themselves or they may influence the emergence and survival of certain forest species thus influencing the composition and spatial structure of the seed bank. Several studies have found that the abundance of a particular growth form or species may affect the presence and recruitment of other growth forms and species because different plants can modify the conditions of forest microsites (V'azquez-Yanes 1990, Facelli and Pickett 1991a, b, Ganade and Brown 2002, Montgomery 2004) in which seeds germinate and young plants establish (Clark and Clark 1989, Ben´ıtez-Malvido and Kossmann-Ferraz 1999, Farris-L´opez *et al.* 2004, Harms *et al.* 2004). Studies have also shown that understory vegetation may affect plant density independent of species or may differentially influence emergence and survival of certain type of species, thereby influencing the composition and spatial structure of the "seedling" bank (Denslow et *al.* 1991, George and Bazzaz 1999, Svenning 2001).

SHE analysis

SHE analysis of RP areas shows that the evenness of the vegetation floras decreases as sampling effort increases. The OP areas are ecotones undergoing successional change but have the potentiality to regenerate forests.

The equitability varied in the three areas. It decreases with more sampling effort in the RP and OP areas whereas it remains fairly constant in the Forest areas (Figures 4.111, 4.112 and 4.113) respectively). As the sampled area increased along with the number of samplings the diversity increased and the evenness decreased. There is a rapid accumulation of species in the initial samples, with a gradual addition of more and more species as the sampled area increases. This increase in species richness is not reflected well in the diversity which remains relatively constant owing to the sharp decrease in evenness (Figure 4.111). SHE analysis examines the relationship between S (species richness), H (information – the Shannon-Wiener diversity index) and E (evenness as measured using the Shannon-Wiener evenness index, otherwise known as Pielou J) in the samples. It is therefore an approach to look at the contribution of species number and equitability to changes in diversity. SHE analysis follows the way these parameters change with increasing sampling effort.

The analysis of the subsets of weeded and unweeded areas of Rubber plantations show that diversity is lower in the unweeded areas compared to the weeded areas. Evenness is lower in the weeded areas and is constantly low over the spatial scales (Figure 4.114). In the unweeded areas evenness is higher and there is a gradual decline over the spatial scale (Figure 4.115). Cumulative ln*(E)*/ln*(S)* remained relatively constant in all the plots, indicating that each sample community was best fit by log normal species abundance distribution (Figure 4.73-4.75).

Diversity H' is comparatively high in the Forest and OP (4.488, 4.295) areas but lower in the RP areas (3.493) over similar spatial scales. With a small sampling effort a high diversity (H') is observed in the OP areas. But after an initial increase, H' only shows a marginal increase in OP compared to the Forest areas (Figure 4.112 and 4.113). The evenness decreases as sampling effort increases (Figure 4.112). The diversity does not increase in spite of increase in species richness due to the low evenness. The SHE analysis of the OP and Forest areas shows that the two components of diversity, species richness and evenness are maintained in these areas as sampling increases. The OP areas which are undergoing succession with respect to their vegetation composition, as seen from their D-D curves can be considered ecotones (The OP areas conform to log normal and log series distribution). They resemble thickets of the forest which are natural assemblages found in the edge of the forest which are capable of regenerating forests. SHE analysis is useful for identifying ecotones (Hayek and Buzas 1997). It is also thought to be a useful method for testing whether the data conform most closely to a log-normal, log-series or MacArthur's broken stick model. It is probably the most effective practical method for testing for 'goodness-of-fit' to these models.

Ordinations

Similarity tests

The RP, OP and Forest areas are distinct natural assemblages of plants with distinct species assemblages. Various species of grasses are the main vectors responsible for the change in the species composition of the RP and the OP areas.

The similarity tests (ANOSIM and SIMPER Table 4.26) reveal that the three areas chosen for this study viz. RP, OP and the Forest areas are natural assemblages of species (vegetation) which have evolved over ecological time. There are distinct differences between the three groups chosen *a priori* with respect to their species composition. The invasion of several species of grass and several other pioneer species are the main components which are bringing about a change in the diversity of these areas. Plant species like *Axonopus compressus, Ottochloa nodosa, Mitracarpus villosus, Mikania macrantha* are abundant in the OP areas while species like *Cyrtococcum patens, Oplismenus composites, Cyathula prostrate* and *Axonopus compressus* characterize RP areas. The species composition more abundant and prevalent in the Forest sites is *Strychnos colubrina, Xylia xylocarpa, Michelia nilagirica, Helectris isora.*

The consequence of disturbance on the diversity of Rubber plantations

The two unweeded sites (Neezhoor and Puthupally) show more dissimilarity with an ANOSIM R value 0.28. The SIMPER between tests show that the two unweeded sites are also dissimilar from each other value 80.06 (Table 4.26).The SIMPER within (Figure 4.116) tests show that the average similarity within the quadrats of the Puthupally (unweeded) site is low (19.72) compared to the other sub samples. This indicates that the lack of disturbance favors the growth of a vegetation of a different type and a habitat that is heterogenous. Similar studies have shown that lack of disturbance may be another potentially important factor affecting community structure in the Old-growth plots study. In some systems, vascular plant diversity may rebound quickly from logging (Gilliam 2002, Gilliam *et al.* 1995, Peet and Christensen 1988; Roberts 2002) while in others Old-growth communities may take long periods of time to recover (Peterken and Game 1984, Whitney and Foster 1988, Dzwonko and Loster 1989) or may not recover at all (Duffy and Meier 1992).

The SIMPER within tests has found the Puthupally and Chetheckal sites are more heterogenous while Neezhoor, Pampadi, Mundakayam and Thenmala were more homogenous (Figure 4.116). Various grass species have been found to be responsible for the change in the vegetation of the different RP areas. The prevalence of various types of grass species in RP areas is an indication of succession and changing vegetation. The comparatively higher similarity of Mundakayam and Pampadi and Chetheckal and Mundakayam plantation (average dissimilarity 79.2) ground flora also corresponds with their higher disturbance scores (Table 4.2), indicating a response of the flora composition to be a response to disturbance. There are several evidences that disturbance promotes species richness. Although the RP areas are more mechanically disturbed than by the use of chemical fertilizers the low abundance of plant species found in these areas is a consequence of the changing habitat of the RP environment. The invasion of several grass species in succession changes the habitat to a more homogenous one.

The homogenous vegetation and the resultant homogenous habitat can have grave consequences. The low diversity and evenness in the RP areas are a consequence of low abundances of plants that are able to survive in these plantations. The lack of heterogeneity of the environment retards diversity. This has far reaching consequences on the farming ecosystem. Several studies have stressed upon the importance of diversity. Heterogeneous environments are considered to promote diversity of species when compared to homogeneous environments (Heck and Orth 1980, Irlandi and Crawford 1997 and Eggleston *et al.* 1999).Several studies have shown the various advantages of promoting diversity. In more diverse communities differences between species may allow complementary use of resources and cause greater space filling above and below ground (Naeem *et al.* 1994, Hector 1998).

Species diversity mediates community functional stability through compensating interactions to environmental fluctuations among co-occuring species (McNaughton 1977). Greater plant species diversity leads to greater stability of plant community biomass after a perturbation (McNaughton 1977, Leps *et al.* 1982, Frank and Mc Naughton 1991). Diversity stabilizes community and ecosystem properties (Tilman 1996). Higher plant diversity is also weakly associated with lower stability of abundances of individual plant species (May 1973). These two seemingly different results is unified by the mechanism of interspecific competition which in turn can magnify the effect of a perturbation on the abundances of individual species because a change in the abundance of individual species will impact the abundances of many other in the competitive network (Tilman 1996). Increased species diversity, which leads to stability of an ecosystem, is related to food web components (Pimm 1982, DeAngelis *et al.* 1989, Berryman *et al.* 1995). With increasing species richness and a constant level of connectance, simple food web models become less prone to further species loss following the deletion of one species (Pimm 1982). Diversity also influences the reliability (Naeem 1998), stability (Doak et. al. 1998, Tilman *et al.* 1998) and productivity (Huston 1997, Tilman *et al.* 1997) of an ecosystem. Diversity increase leads to certain physiological mechanisms that can influence ecological processes (Nijs and Impens 2000). In Mediterranean grass lands plant diversity determines the microbial biomass, hyphal length and enzyme activity (Chapin *et al.*1988). Below ground diversity of arbuscular mycorrhizal fungi in European calcareous grasslands contribute to nutrient capture and productivity (van der Heijden *et al.* 1998). Tropical leaves tend to have a higher incidence and concentration of toxic compounds for protection against herbivory (Coley 1983, Covich 1988). Thus competition also constrains community biomass, and the competitive release experienced by disturbance-resistant species. This helps in stabilizing community biomass in species rich community (Tilman 1996). The importance of leaf heterogeneity to habitat and resource patchiness and consequently to trophic processes, especially in the tropics is an important component contributing to diversity of organisms (Bastian *et al.* 2007).

PCA ordination plots

A vegetational change brings about homogenization of the environment and further invasion of several grass species. The consequential changes of succession change the habitat further away from the forest ecologically.

The PCA ordination plots (Figure 4.118) show that the vectors that are responsible for more than 30% of the variance are *Ishaemum indicum, Oplismenus compositus, Cyathula prostrata* and *Cyrtococcum patens.* A distinct deviation from the species composition of the Forest in both the RP and OP areas is brought about by these vectors. It also re- emphasizes that the RP areas are more similar to the OP areas. The PCA plot clearly indicates an overlapping of species composition between Forest and RP areas and between Forest and the OP areas (Figure 4.117). A trend of successional change in the vegetation structure on the RP and OP areas due to these vectors and other possible environmental variables such as disturbance and factors such as soil, light and temperature etc is clearly indicated. The manner in which the RP areas and the OP areas respond to the environmental variables they encounter need to be further investigated. It is however clearly evident that the two areas are under stress and undergoing a successional change in vegetation.

Figure 4.123 shows that the Thenmala, Chetheckal, Mundakayam and Pampadi (weeded) sites overlap each other while the Neezhoor and Puthupally (unweeded) sites appear to be more distinctive in their species composition. The SIMPER within have shown the ground flora plant species which characterize the vegetation in these plantations are *Oplismenus compositus* in Chetheckal, *Cyrtococcum paten* in Mundakayam, *Ishaemum indicum* in Neezhoor, *Axonopus compressus* in Pampadi, *Ishaemum indicum* in Puthupally and *Cynodon dactylon* in Thenmala. The unweeded areas Puthupally and Neezhoor show the dominance of *Ischaemum indicum* which is a sciophytic (shade loving) grass species, whereas the weeded areas show the prevalence of more heliophytic grass species. The difference in the species composition of the more abundantly found grass species characteristic of the individual areas can be an outcome of successional change and a response to changing environment. The possibility of a response of the vegetation to immediate disturbance cannot be ruled out as these areas are mechanically weeded.

The Thenmala RP areas form a distinct but overlapping group in the PCA ordination (Figure 4.123). There is a presence and high abundance of pioneer vegetation in the isolated plantations of Thenmala. These plantations are 8 km well within the forest and hence isolated from the diaspores of pioneers. This indicates that the forest diaspores do not establish themselves easily in the Thenmala plantations. These plantation habitats are more suited to the establishment of pioneer species which are lighter and produced in larger numbers. They reach far off places as they are dispersed by wind. The RP areas provide a homogenized habitat more suitable for the growth of pioneer species due to the initial preparation of the land during planting. Garza and Howe (2003) opined that far from a forest edge, even pioneer arrival may be very slow. However this study has shown that pioneers arrive in the RP areas within the forest and their establishment within the Thenmala areas is more successful than that of the surrounding forest species. 'Marginal-specialist' are the species that dominate the most productive areas also have the broadest range. Other species are superior in a more restricted range of less productive sites (Bell *et al.* 2000). Pioneer species can be considered similar to the 'marginal- specialist' species. Less effect of habitat diversity will be seen at either larger scales or at smaller scales where immigration may overwhelm competition (Bell *et al.* 2000). In a very careful study of plant communities of 0.1-ha plots in North Carolina forests, Palmer (1991) found that species diversity was related to the mean value of soil nutrients such as magnesium but not to their variance within plots.

The forest floor is structured, i.e. that the variance among sites increases with separation from 1 to about 50 m (Bell *et al.* 2000). This makes Forests a distinct group in the PCA ordination (Figure 4.117). The specific correlation of performance falls as general environmental variance increases, and that species diversity increases with environmental heterogeneity (MacArthur 1958, 1964, Recher 1969, Anderson 1978, Murdoch *et al.* 1972, Strong and Levin 1979, Moran 1980, Tonn and Magnuson 1982, Pianka 1967, Pringle 1990, Hewatt 1935, Kohn 1967, Harman 1972, Haila 1983, Kerr and Packer 1997, White and Miller 1988, Vivian-Smith 1997 and Silvertown and Wilkin 1983). It has been shown that the forest floor is not a simple mosaic of discrete habitats to which species become differently adapted. Instead, species responded differently to continuous variation in environmental quality (Bell *et al.* 2000).

Non metric multidimensional scaling

Rubber plantations are more similar to Open areas in their vegetational characteristics.

The rubber plantations resemble Forests to some extent as they foster several tree species that are found in Evergreen forests.

The plot of nMDS (Figure 4.119) shows the species composition of the RP and OP areas. Two areas overlap and many plant species found abundantly in the Open areas have invaded the rubber plantations. The similarity between RP and OP areas is in the species composition of the grasses is mainly responsible for this similarity. The slight overlapping of the RP and the Forest areas also indicate that the RP areas foster some plant species found in the Forest areas. This is supported by the observation that 88 tree species belonging to the Evergreen tropical forest have been found in the RP areas during the qualitative survey. A trend of succession is evident in the rubber plantations which is changing its vegetation towards a composition similar to the Open areas.

Medicinal plants

RP, OP and Forest areas harbor the growth of several medicinal plants.

A higher number of plant species found in the Forest areas (48.7%) are of medicinal importance (Figure 4.16) .The percentage of medicinal plants found in the RP, and OP areas are comparable (Figure 4.14 and 4.15). This indicates the RP and the OP areas also are capable of harboring species. These areas must be thus providing a habitat and suitable conditions for such plant species to survive similar to thickets found in the edge of forests which favor the growth of forest species (Puyrvaud *et al.* 2003). No endemic medicinal plants were found in the OP areas (Table 4.15 and Figure 4.15) whereas 4.4 % and 6.6% of the plant species found in the RP areas and Forest areas respectively were endemic medicinal plants. Thus RP areas provide a habitat that is suitable for the growth of several medicinal plants as well as endemic medicinal plants.

Endemic plants

Rubber plantations harbor the growth of a few endemic plants and are suitable habitats for the initial germination and seedling growth of endemic plants.

No endemic medicinal plants were found in the open areas (Figure 4.15). This could be because of the harsh environment these endemics have to withstand in the OP areas and the severe competition for sunlight and nutrients. Endemics are plants with specific geographic and habitat condition. They survive better if the initial protection of a habitat suitable for growth is provided along with its very specific environmental requirements provided by its habitat niche. Rubber plantations protect plants from an excessive exposure to sunlight and provide a nutrient rich soil which will harbor and favor the growth of these endemics. Endemic plants are plants with specific niche requirements. The study has revealed that 11.4% (48 species) of the plant species sampled in the RP areas are endemic plants (Table 4.16). Only 4.4 % (5 species) of the plant species of the OP areas were endemic (Table 4.16). These endemic species could be lost over a period of time. The gradual succession and homogenization of vegetation in the rubber plantations could eliminate these niches and brings about a further decrease in the growth of endemic plants. These plantations protect the seedlings from exposure to sunlight and provide a suitable substratum for their germination and initial growth. Plants like *Naragamia alata* and *Rauwolfia serpintina, Geophylla repens* are found to survive, flower and fruit in the RP areas.

Species that becomes 'rarer' may do so by a uniform reduction in abundance or by expressing a more clumped occurrence pattern scenarios that have varying susceptibilities to local extinction (Flather 1996). In a quantitative study Gaston (1994), considered a species rare if they fell below the first quartile of the frequency distribution of abundance. Above the first quartile of the frequency distribution, species were considered abundant. Korning *et al.* (1994) found that local variation in soil chemistry corresponded to local variation in the occurrence of different tree species, and suggested that this may be a factor that increases local species diversity. The distribution of several ground herb species within 1-ha plots have been related to topography both in Amazonia (Poulsen and Balslev 1991, Poulsen and Nielsen 1995) and in Borneo (Poulsen 1996). Studies using continuous transects have shown that spatial changes in species composition of pteridophytes and Melastomataceae correspond to variation in the texture or drainage of soils (Tuomisto and Ruokolainen 1994, Tuomisto *et al.* 1995).

Phenology

RP areas favor the growth of sciophytes and zoochorous species.

Most of the plants species found in the natural ground flora of the rubber plantations are heliophilic (light loving). *Hedyotis auricularis, Cyrtococcum patens* and *Axonopus compressus* have prolonged flowering periods (Table 4.27). This is because of these plants are pioneers and are highly competitive in nature of the plant. Such plant species have a high resource allocation to flowering and fruiting to ensure their survival (Gaudet and Keddy 1988, Goldberg and Landa 1991). Studies have shown that gap formation in forests accompanied by soil disturbance and the removal or destruction of understory vegetation increases light availability and reduces below ground competition (Gerhardt and Fredriksson 1995, Veenendaal *et al.* 1996, Fredericksen 1998, Cahill and Casper 2002, Makana and Thomas 2005). A reduction in species richness reflects a comparatively larger pool of species possessing strong competitive response ability (Hodgson 1987, Zobel 1992, Eriksson 1993). Associated with this competitive ability are plant traits such as plant height and seed size which in turn create competitive hierarchies (Gaudet and Keddy 1988).

Studies in the tropical forests by Tabarelli and Mantovani (2000) have shown that several lower-layer species are light-intolerant. Our studies have shown that RP areas foster the growth of more heliophilic plants with a competitive edge in response to the prevelance of disturbance. The understory of the unweeded areas showed an increase in zoochorous species such as *Ixora coccinia, Memecylone umbellatum*. The fruits of these plants are eaten by rodents and hence are dispersed by animals. The flowering of these plants corresponds with the rainy season (May to August) and also peak in January. This has also been reported in the studies on the phenology of littoral forest of SouthEastern Madagascar by Bollen and Donati (2005). Several studies in tropical forests (dry and moist) and savannas have shown a positive association between fleshy fruits and lower-layer species of animals (Morellato and Leita˜o-Filho 1992, Tabarelli and Mantovani 1999, Wilkander 1984), and between fleshy fruits and fruiting in the rainy season (Bullock 1995, Gottsberger and Silberbauer-Gottsberger 1983, Janzen 1966, Lieberman 1982, Machado *et al.* 1997, Mantovani and Martins 1988, Medina 1995, Morellato *et al.* 1989, Oliveira 1998, Rathcke and Lacey 1985).

This study shows no correlation between the rainfall and flowering phenophase(Figure 4.128 and 4.129). Studies by Bollen and Donati (2005) on the phenology of littoral forests in Madagascar also show that rainfall has little influence on the phenophases of the plants. However a strong correlation was found between the phenophases and the duration of light hours. The plants found in the OP areas show earlier flowering and more prolonged periods of flowering than in the RP and Forest areas. The RP areas do not provide habitats suitable for heliophilic plants as these areas cut off light to a large extent. This could result in reduced intensities of light and affect the light and temperature regimes affecting the response of the plants to flowering. Flowering has a close relationship with life history strategy and is affected by various factors including climatic conditions, habitat environments, and interactions with other organisms (Rathcke and Lacey 1985, Kawarasaky and Hori 2001, Bjerkevedt *et al.* 2003). Plants like *Oplismenus compositus* show a more prolonged flowering in the RP and Forest areas as compared to the OP areas. Personal observations have shown that this endemic grass species and plant species like *Naragamia alata* are found in more shady habitats. Hence they thrive well in the RP and Forest areas. Lack of disturbance in the RP areas promotes the growth of plants like *Ixora coccinea* and *Memecylone umbellatum* as seen in the floristic composition of the unweeded areas such as Puthupally and Neezhoor RP. These plants are zoochorous. The RP areas are thus more suitable for sciophytes (shade loving plants) and for the growth of zoochorous species (Table 4.28). The high prevalence of heliophytes in RP areas is not a natural plant association. It is more of a response to disturbance and exposure of the ground flora to more light.

Allelopathy

Aqueous leaf leachates of *Hevea brasiliensis* (Rubber) cause allelochemical stress to seed germination and growth of young seedlings.

Studies of the leaf leachates of *Hevea brasiliensis* on the seed germination and seedling growth of the test seeds *Oryza sativa* and on the seeds of the naturally growing plant species *Chromolena odorata* have shown an allelopathic effect on germination and seedling growth of both the species (Figure 4.125, 4.126 & 4.127). There is a significant retardation of germination and reduction of seedling growth of *Oryza sativa* by the leaf leachate of *Hevea brasiliensis* under laboratory conditions (Figure 4.125, 4.126 & 4.127). In the case of *Chromolena odorata* there was significant inhibition of germination (Figure 4.126). In a similar study the aqueous leachate of *Sicyos deppei* caused a strong allelochemical stress on *Lycopersicon esculentum* growth (Romero-Romero *et al.* 2005). No effect was seen on the rate of germination of L. *esculentum* (Lara- Nunez *et al.* 2006). Biochemical studies have shown an imbalance in the oxidative status in the ungerminated seed and the primary roots of *Lycopersicon esculentum* in these studies.

Allelopathic interactions are mediated by secondary metabolites (allelochemicals) released from donor plants to the environment, and have an influence on growth and development in both natural and agro- ecosystems(Inderjit and Duke 2003). These allelochemicals belong to a diverse chemical group and have different sites and modes of biochemical action. In general, when the effect of these allelochemicals decreases growth on the receiver plant, it is considered a biotic stress called 'allelochemical stress' (Cruz-Ortega *et al.* 2002, Reigosa 2002, Romero-Romero *et al.* 2002). This environmental stress factor can act as a mechanism of interference and can influence the pattern of vegetation, weed growth and crop productivity (Dakshini *et al.* 1999, Weir *et al.* 2004). Inderjit in 1996 reviewed the role of plant phenolics in allelopathy and found overwhelming evidence of their significant role. Weidenhamer *et al.* in 1993 showed through their studies on water solubility of 31 biologically active monoterpenes that these compounds are often biologically active at concentrations below their aqueous solubility. Putnam and Tang (1986) claim that, all cases of alleged allelopathy appear to involve a complex of chemicals.

In nature the ground flora has to face a mixture of these compounds. In the fields the stem and leaves get dry on the soil and whenever it rains the phytotoxic allelochemicals are released thus affecting the growth and development of other plants. A large number of the naturally growing plants found in the RP areas have seeds that germinate but show low viability (Figure 4.130 & 4.131). Seeds that germinate, normally take 5 to7 days to germinate when soaked in water. Seeds with low viability take a longer period of time to germinate. (14 to 22 days). This could add to the allelochemical stress undergone by these seeds to germinate in the plantations. Abundant rain in Kerala could form low concentrations of allelochemical leachates which could mitigate the stress situation.

This study contributes to the growing body of literature on plant allelopathic studies. More studies are needed on the allelopathic effect of *Hevea brasiliensis* on different plant species. This may include studies in different agro climatic conditions with different rainfall precipitations.

Conservation

Low abundances of plant species in rubber plantations is a cause of conservation concern.

Low abundance and elimination of plant species can have other consequential effects on the ecosystem.

Rubber farming ecosystems can be used as conservation links in a matrix of Tropical forest and farming ecosystems for the conservation and restoration of endemic and threatened species.

The study on the floristic diversity and abundance of the ground flora of rubber plantations have shown that there is a substantial reduction in the abundance of the ground flora and a consequent reduction in the diversity of the rubber plantations when compared to an Open area or the Forest areas. The study has provided sufficient evidence of sampling efficacy using species richness and through explicit evaluations on the effect of the abundance of the species. These inventories and statistical data clearly support the unauthenticated verdict that the rubber plantations do not support the growth of several plant species. These low abundances are due to invasion of pioneer species into the arena of rubber plantations replacing several abundant species. This invasion by pioneer species is due to pre-planting agricultural practices (termed disturbance in this study).The plants which survive the invasion of more fast growing plants, which are more efficient in resource usage, are further reduced in numbers (abundance) due to natural death as a result of canopy closure and the consequential low light availability (also included as disturbance in this study). This multipronged attack i.e. mechanical elimination of existing vegetation by ploughing and weeding, invasion by weeds and consequential competition for space and resources and the top down control due to poor light availability brings down the numbers of these plants and results in the observed low abundances of these plant species in the plantations. The growth, phenology and the vegetation dynamics of these plants are also impaired. Even though understory community recovery is universally recognized as important to forest conservation, and though species richness is almost universally used to investigate recovery rates, explicit evaluation of the effects of abundance and sampling efficacy on diversity metrics is not widely used in ecological studies(Loya and Jules 2008). Differences in species composition between Forest, OP and Mature RP areas in this study suggest slow changes. If these processes operate over the entire landscape, community structure and local extinction may be predicted, at least in part. The vast areas of land under rubber cultivation only compound these effects and will have further consequential effects on the remaining conserved forest areas. Studies in the steppe-like grasslands in Eastern Europe have shown that agricultural intensification and abandonment have resulted in their critical reduction of plant species thus posing it to be a threat to the regional biodiversity (Cremene *et al.* 2005). Replacing them with *Pinus* plantations have changed habitat quality and has a devastating effect on the unique indigenous diversity of the steppe- like grassland as soon as the canopy closes (Cremene *et al.* 2005). Several studies have suggested that information on tropical plant species in all growth forms as provided in this study, is needed because of its potential usefulness in understanding the relative extent of plant biodiversity across natural and human-disturbed habitats and its implication for conservation and management (Gentry and Dodson 1987, Gentry 1991, Annaselvan and Parthsarathy 2001, Van Andel 2001).

The quantitative analytical methods of species richness, D-D curves, diversity profiles , similarity indices, PCA and nMDS scaling used in this study have shown conclusively that there is a floristic species composition change in the RP areas which is distinctly different from the Forest areas and makes the RP areas more similar to the Open areas (Figure 4.119). These differences among the type of plants species found in the RP areas can have consequential effects as seen in other similar studies. Studies made by Chapin *et al.* 1998 on differences in the plant species composition has shown that differences among the types of plants that are present have an effect on primary productivity, nutrient losses and microbial nitrogen retention. Soil inorganic nitrogen pools are the lowest in more diverse plots because of the early seasonal annuals which is a highly competitive functional group (Chapin *et al.* 1998). Johnson *et al.* in 1996 have shown declining productivity with increasing diversity. Plant species richness has a strong impact on soil biological activity (microbial biomass, hyphal length and enzyme activity) by enhancing organic matter decomposition and by reducing nitrogen leaching (Chapin *et al.* 1998).

Several plants (approximately 50% of the plants that have been observed in the qualitative assessment) were below the threshold limit of being sampled in a quantitative assessment. This is because the abundance of these plants was so low, that they could not be sampled in spite of an intensive sampling at a landscape level. Statistical analysis of parametric and non parametric estimates has established the adequacy of the sampling. Stochastic extinction probability theory (Soulé 1987, Simberloff 1988) predicts that a minimum population size is required to prevent extinction, which is in turn coupled to a minimum area. On statistical grounds, rare species would therefore *per se* have higher extinction probabilities (Nijs and Impens 2000). Extinction can also be deterministic, if the disappearance of one keystone species prompts an outburst of secondary extinctions in highly connected species within the food web. In such a case common species would also be susceptible to extinction (Nijs and Impens 2000). Bond in 1994 devised a protocol to identify such species, but concluded that criteria to distinguish vulnerable ones is lacking. Statistical phenomena have been identified before with respect to the influence of diversity on ecosystem function (Naeem 1998, Doak *et al.* 1998, Tilman *et al.* 1997, 1998, Huston 1997). Thus the strong relationship between statistical components, diversity and extinction cannot be ignored.

Importance of maintaining genetic diversity in rubber plantations

Rubber farming ecosystems are vast expanses of land with monocultures of *Hevea brasiliensis*. This study has indicated that these areas are homogenous with respect to species diversity. The RP areas show the lowest diversity profile (Figures

4.101 & 4.103). Human-aided invasion of new species is most likely to occur in low-diversity managed landscapes (Chapin *et al.* 1998). This is possible in RP areas due to their low diversity profile. High species diversity reduces the probability of large changes in the ecosystem processes in response to the invasion of pathogen and species. The validation of this hypothesis confirms the advantage of maintaining genetic diversity in crop monocultures and the use and expansion of multi-cropping systems in agriculture (Vandermeer and Scultze 1990). Rubber plantations have since 1960s been intercropped and multi layered with grain, oil crops like rice peanut, sweet potato, creeping legumes, perennial cash crops such as tea, black pepper, pineapple so that farming can be sustainable (Zhiwei and Yide 1999). A more recent study by I'ma *et al.* in 2005 have evaluated the growth of medicinal plants in rubber plantations. Teak and other timber yielding species like Mahogany and Rosewood are also grown along the periphery of the plantations by several farmers. Recommended cover crops like *Cassia sp, Desmodium gyroides, Phaseolus angularis, Desmodium ovalifolium.* Creepers *Pueraria phaseoloides, Centrosema pubescens, Calopogonium caeruleum, Psophocarpus palustris, Calopogonium mucunoides, Phaseolus calcaratus.* Shrubs *Flemingia congesta Tephrosia candida Crotolaria anagyroides.* Ferns *Gleichenia linearis* are also grown with Rubber plantations. The growth of a single cover crop like *Mucuna pruriens* or *Pueraria phseoloides* conserves soil but the assessment with respect to conservation of the diversity of species has not been studied. Observations have shown that these plants further suppress the growth of natural flora and affect the diversity of plants. Although several attempts have been made to intercrop rubber with other commercial and non-commercial crops, this is the first study made on the effect of maintaining the natural flora of the plantations and thereby maintaining its genetic diversity. Maintaining or conserving biodiversity might be helpful in reducing the pathogenic attack and other species on rubber. It is well known principle that monoculture s has the possibility of attacks from diseases and pathogens. The rubber trees in the native habitat of the Amazonian forests are not attacked by the South American leaf blight (SALB) caused by the fungus *Micrococcus uli.,* whereas commercial cultivation in South America is prevented by the diseases because of the severe attack in the monoculture. Hence a conscious effort to increase the biodiversity in the RP areas can indirectly protect the Ecosystem to some extent from invasion by pathogens and invading species. Inter cropping of pineapple and banana is widely practiced in the mature phase. Attempts to intercrop other economic plants in the immature phase have met with only partial success. Intercropping of edible plants in the mature rubber plantations is not successful.

Restoration of biodiversity using rubber plantations and Open areas

Plantations can play an important role in restoring the productivity, ecosystem stability, and biological diversity in degraded tropical lands (Parrotta 1992). Rubber plantations can also play a similar role. Almost any vegetation adds organic matter and nutrients, and retains water; to a greater extent than barren land. Continuous growing of rubber in India for the past one century has not resulted in any reduction in the productivity of the soil unlike several other agricultural systems *Hevea brasiliensis* cultivation has actually improved and sustained soil productivity. These plantations aid the conservation of soil and water (Krishnakumar *et al.* 1991, Krishnakumar and Potty 1992). Rubber plantations are a self sustainable ecosystem and could maintain a fair degree of biodiversity if properly managed (Sethuraj and Jacob 1997).The present study provides evidence to support the view that RP areas have a low diversity profile and that several species show low abundances. If properly managed, it can be used to restore biodiversity at the local level and help in the sustenance of biodiversity at a landscape level. 20% (88 species) of the plant species composition of the RP areas are also plant species that are found are naturally found in Evergreen forests. 22% (99 species) plant species that are found in the RP also grow naturally in Semi evergreen forests and approximately 50% (219 species) plant species are those that grow naturally in the Moist deciduous forests (Table 4.20, Figure 4.20). They also show the presence of 160 medicinal plants and some endemic plants species. However these plants have low abundances and may not be able to sustain their numbers with the present methods of cultivation and rate of destruction. The conservation of these plants and their habitat will be a way to conserve biodiversity in rubber plantations. The term restoration should refer to an ecosystem (or to a soil). Chapin *et al.* in 1998 have shown that both species diversity and landscape diversity have important ecosystem consequences. According to them landscape diversity will influence the conservation of future species diversity also landscape heterogeneity most strongly influences those processes that depend on multiple patch types and are controlled by the flow of organisms. There have been few studies to make generalizations. Given the rate at which natural biotic diversity is changing it is imperative that a more predictive understanding of the ecosystem and consequences of these changes in both natural and managed ecosystem must be developed. The presence of a large number of medicinal plants and endemic plants in the RP areas can conserve these plants at a landscape level. This, however, requires planning at a local and landscape level and proper management of the rubber farming ecosystems.

One taxonomic group is a poor indicator for the overall diversity (Baur *et al.* 1996, Niemel¨a and Baur 1998). Preliminary studies have shown that the unweeded areas of the rubber farming ecosystems showed an increase in the diversity of plants and the presence of a larger number of life forms. Personal observations also showed the presence of a larger number of insects, rodents and birds in the rubber farming ecosystems as a response to the growing ground flora. Butterflies are realistic and practical indicators of species change. They indicate a decline in plants, insects, and birds because of their rapid response to habitat change (Thomas 2004). Kapoor in 2008 has shown that spider species composition shows significant changes in relation to habitat alteration. Inventories are potentially of great value for informing conservation decisions, since land-use decisions are usually made at a local scale where insects and other arthropods can provide a rich source of data on environmental change (Kremen *et al.* 1993). Cremene *et al.* in 2005 found that the proportions of red-listed species in plants and nocturnal Lepidoptera were correlated. Several studies have shown that certain rare and threatened butterfly species benefit from grassland abandonment (Erhardt 1985*a*, 1985*b*, Thomas 1991, Balmer and Erhardt 2000). Cremene *et al.* in 2005 advocated a shopping-basket approach to the measurement of diversity and to conservation evaluation (i.e., measuring species richness and abundance of several taxonomic groups instead of just one which was also supported by others earlier(Launer and Murphy 1994, Oliver and Beattie 1996). A similar study in the diversity of rubber farming ecosystems and an inventory of the plant and animal diversity in the rubber farming ecosystems could be of immense conservation value to the diversity studies in Kerala because this state conserves a large number of endemic species found in the Western Ghats.

Loss of species and extinction from forest fragments

Forest fragments in Kerala are surrounded by a matrix of plantations and agrecosystems that are less representative of a forest. Studies on the retention of species by forest fragments in Kerala are negligible. The Mundakayam RP areas and the Chetheckal RP areas are adjacent to reserve forests. On the other hand the Thenmala RP areas are within the forest. These plantations are believed to represent the forest matrix to some extent owing to their nature. This study has shown that there is little similarity between the RP and Forest areas sampled. Hence they cannot be considered to be representative of the forest. The RP area adjacent to the forest has shown distinct vegetation which is more similar to the OP areas in spite of their proximity to the forest. This indicates that the vegetation of the RP areas does not allow the retention ad establishment of late successional species. The matrix of the OP and the RP areas influences rates of accumulation of organic matter and nutrients. As opined by Lugo in 1997 and Vandermeer and Carvajal 2001, it could also affects the population and community dynamics of species in the remnants that surrounds the matrix.

Forest fragments excised from continuous forest and embedded in alien matrices lose many species of animals and plants over 20–100 years (Turner 1996). The dominance of several grass species in the RP areas and the presence of a few tree and shrub species that are mechanically or wind dispersed will not stem the loss of species from the remnant fragmented forests. As suggested by Finegan in 1996, loss of species from remnants may not be stemmed if land is quickly occupied by one or a few early successional species, followed by what we call the 'pioneer desert' of early and late pioneers that retards the influx of disperser-limited deep-forest trees for a century or more (Finegan 1996). If intensive land, use imposes a 'time tax' of soil degradation (Lugo 1988), the 100+ year pioneer matrix imposes another 'time tax' of species loss from remnants, a lost opportunity cost that may be irredeemable. Loss of mutualists and herbivores may accelerate plant extinctions in forest fragments. A disproportionate number of tropical trees require insects, bats or birds for pollination, and bats, birds, terrestrial or arboreal mammals for seed dissemination (Howe and Westley 1997), and the diversity of recruiting cohorts of seedlings is maintained by thinning by ground foraging mammals (Dirzo and Miranda 1991).

The Mundakayam forest shows the invasion of several species that are found in the OP and RP areas. These plant species such as *Mitracarpus villosus, Bracharia ramosa, Clerodendron viscosum, Cyathula prostrata, Cyperus rotundus and Ficus exasperata* are pioneer plants typical of a successional community. The edge effect seen in this forest is a result of the quality of the surrounding matrix and the vulnerability of these areas to invasion by such plants. The proximity of fragments to sources of dispersal agents, influence which species are vulnerable to local extinction in remnants. The source landscape and the quality of surrounding matrices, will probably determine which species are most vulnerable in a given area. Very low densities of most species make tropical forest fragments particularly vulnerable to high rates of local extinction (Maina and Howe 2000). Species number is positively associated with size of habitat patches, while population densities of all but the dominants are inversely correlated with richness (Preston 1948, MacArthur 1972). Recent studies have shown that seedlings and juveniles of many rain forest species suffer declines in fragments (Cordeiro and Howe 2001, Githiru *et al.* 2002) and some island communities show dramatic losses through older juvenile and sapling stages (Leigh *et al.* 1993). With adult tropical trees dying at a rate of roughly

1% per year in mature forest (Brokaw 1985, Sukumar *et al.* 1998), the less representative the matrix is of mature forest, the more rapidly small populations of dispersal agents and trees with reduced recruitment will be lost from remnants. Maina and Howe in 2000 argued that tree species most vulnerable to local extinction from small forest remnants are those at the moderately abundant to rare end of the species abundance distribution. These species lose pollinators or dispersal agents in small fragments, while those most likely to persist are highly vagile weeds, augmented by successional pioneer deserts, and 'always rare' species that function as successful metapopulations. The forests fragments sampled in the present study are also susceptible to such losses and local extinctions if the surrounding RP matrix does not support its flora and fauna.

Rubber plantations as link to forest

Forest plantations established on degraded sites long devoid of a native tree cover can act as successional catalysts, facilitating the recolonisation of native flora through their influence on understory microclimate and soil fertility, suppression of dominant grasses and provision of habitats for seed dispersing animals (Parrotta 1995).

Production of fleshy fruits is known to require a lot of water (Lieberman 1982) and is therefore associated with soil water availability (Bullock 1995, Gentry 1995, Medina 1995). Several species in the rubber plantations produce fleshy fruits (Table 4.5 appendix). Personal observations have also confirmed that undisturbed plantations (Puthupally, Neezhoor) where natural ground vegetation was allowed to flourish resulted in the growth of several plant species which produced fleshy fruits which are animal dispersed (Table 4.28). Plants like *Olea dioica, Memecylone umbellatum, Mallotus philippensis, Macranga peltata, Lagerstromia microcarpa, Grewia nervosa, Glycosmis* *pentaphylla, Ficus hispida, Eleocarpus glandulosus, Canthium augustifolium, Artocarpus hirsutus* are some species that thrive in the RP areas. The vertebrate population which fed on it and were the likely dispersal agents also increased in numbers considerably. Several butterflies were also seen during the flowering season of these plants.

Recent research on tropical forest plantations indicate that plantations may enhance the recruitment, establishment and succession of native woody species by functioning as foster ecosystems (Parrotta 1992, 1995, Lugo *et al.* 1993, Geldenhuys 1997, Otsamo 2000, Viisteensaari 2000). Rubber plantations in Kerala with its vast expanse and proximity to Tropical rain forest offers such a means to restore ecosystem functioning and the advantage of a cash crop. Their composition of the OP areas shows the presence of 23%, 32% and 11% of plant species belonging to the natural habitats of Tropical evergreen, Semi evergreen and moist deciduous forests (Table 4.20, Figure 4.20). The OP areas also form the matrix of the vegetation between forest remnants. Puyrvaud *et al.* in 2003 argued that in restoration of biological diversity between forest remnants, the vegetation matrix matters. Thus the OP areas are also a valuable resource and are comparable to the 'vegetation thickets' found along the edge of the forest, which in has great potential to restore and link fragmented forests (Puyrvaud *et al.* 2006). The natural ground flora of the RP areas shows the presence of several forest species that are found naturally in the Evergreen forest, Semi evergreen, Moist deciduous and Dry deciduous forests (Figure 4.20, Table 4.20). The study also reveals a tendency for the rubber plantations to favor the growth of plant species that naturally grow in the moist deciduous forests (Table 4.20). Rubber plantations adjacent to reserve forests and those that form the matrix within forest fragments can be used as foster ecosystems to enhance the recruitment, establishment and succession of native species. Garza and Howe in 2003 put forward the view that variations on passive succession of exotic or native trees, may offer a means of restoring ecosystem function, but they do not avoid the equivalent of the pioneer desert forest remnants remaining surrounded by low-diversity matrix. In general, in forest regeneration of large areas of abandoned agricultural land or pasture, passive succession cannot stem the loss of species from forest remnants. Isolated trees attract dispersal agents, and artificially positioned perches likewise increase the seed rain of animal-dispersed species (Guevara 1991, Miriti 1998), but recruitment is slow and remains unrepresentative of mature forest (Holl 1999).

Initially natural forest stands near a restoration site can provide baseline data that can be utilized in the evaluation of the extent and rate of plant species recruitment and establishment in plantations. We must consciously promote the growth either by allowing naturally growing plants or by planting late successional and deep-forested animal dispersed species in the rubber plantations. Table 4.28 gives a list of plants that have been found naturally growing in the rubber plantations and their modes of dispersal. The plants with mechanical and wind dispersed seeds can be considered the pioneer species which are more characteristic of the edge of the forest. Plants such as *Careya arborea, Helectris isora* and Hemidesmus *indicus* come under this category. Plants such as *Artocarpus hirsutus, Ixora brachiata, Jasminum brevilobum, Lagerstroemia microcarpa* are endemic species dispersed by birds and animals. Hence they come under the category of deep forested species which can be consciously planted in RP areas as a conservation measure. Some late succssional species such as those found in the Forest areas may also be planted to beat the time tax on biodiversity as suggested by Garza and Howe in 2003. A large number of deep forested plants species can be planted in RP areas to conserve biodiversity. Of these the plants that are found in the forest areas that are endemic to the Western Ghats or of medicinal importance can be prioritized (Table 4.7 appendix, Table 4.14). To name a few plants that are of medicinal importance that can be cultivated in RP areas are trees like *Adenanthera pavonina, Antidesma acidum, Aporosa lindleyana, Artocarpus hirsutus, Salacia oblonga, Azadirachta indica, Bixa orellana, Naringi crenulata, Tabernaemontana heyneana, Xylia xylocarpa* and shrubs like *Anamirta cocculus* (woody climber), *Piper nigrum,, Piper longum, Ricinus communis, Zizyphus rugosus.* Table 4.12, 4.13 & 4.14 (appendix) provides a list of medicinal plants that can be intercropped with rubber plantations. Table 4.16 shows that 48 endemic plants have been found in the RP areas. A detailed list of these endemic plants is found in Table 4.17. A variation on passive succession of these plants would permit a cash crop and cost little. Whether such a method would create unintended consequences, be a superior strategy to enrichment of early and late pioneer stands, or simply be the only option in regions used for plantation crops, should be a matter of debate. Garza and Howe in 2003 suggested that beating the time tax on biodiversity is possible if the natural succession of pioneers is actively enriched with plantings of late-successional and deep-forest animal-dispersed tree species. Lugo in 1997 pointed out that plantation monocultures of some short-lived exotics cast enough shade to suppress pioneers, but admit invasion by deep-forest species. The lack of quantifiable practical standards for biodiversity makes the setting of goals by managers and the monitoring of results difficult (Spellerberg and Sawyer 1996, Yirdaw 2001). However forest plantation managers should make biodiversity management one of the main components of their task (Yirdaw 2001). Thus trees such as *Artocarpus hirsutus, Meiogyne pannosa, Memecylone randerianaum, Psychotria nilgiriensis, Meiogyne ramarowii , Glochidion zeylanicum, Turpinia malabarica, Xanthophyllum arnottianum, Knema attenuata, Lagerstromia microcarpa, Myristica malabarica, Tabernaemontana heyneana, Actinodaphne* *malabarica, Actinodaphne bourdilonii, Michelia nilgirica,Cinnamomum sulphuratum, Polyalthia fragrans* shrubs such as *Salacia beddomei, Dalbergia horrida, Salacia fruticosa, Derris brviceps, Rauvolfia micrantha, Piper barberi, Strychnos lenticellata* and herbs such as *Cyrtococcum longipes, Theriophonum infaustum, Stachyphyrnium spicatum Acrotrema arnottianaum, Pteris scabripes, Polystichium moluccense* can be passively allowed to grow or planted intentionally in the RP areas. Several of these endemic plant species are deep forested species that can be conserved to beat the time tax by cultivating them in the foster ecosystems of rubber plantations.

The feasibility of using plantations of exotic monocultures to promote late successional indigenous species depends on the species used and the location. In Brazil, *Leucaena leucocephala*(Lam.) De Wit (Fabaceae) plantations admitted more native forest species than *Casuarina* plantations (Parrotta 1995). In Hawaii plantations of *Eucalyptus saligna* Sm. (Myrtaceae) and *Flindersia brayleyana* F. V. Muell. (Rutaceae) from Australia and *Fraxinus uhdei* (Wenzig) Lingelsh (Oleaceae) from Mexico established in the 1950s and 1960s fostered very different regeneration pathways (Harrington and Ewel 1997). *Eucalyptus saligna* strongly favoured exotics and *Flindersia braylenana* replaced itself, while *Fraxinus uhdei* favoured two dominants of surrounding mature forest, *Cibotium glaucum* (Sm.) Hook. & Arnott (Dicksoniaceae) and *Metrosideros polymorpha* Gaud.(Myrtaceae). In the Congo, Eucalypt plantations admit a number of native forest species, especially close (< 50 m) to the forest edge, with strong representation of wind-dispersed species that show especially rapid regrowth after clear-cutting of the plantation crop (Loumeto and Huttel 1997). This study has shown that the RP areas support the growth of Evergreen, Semi evergreen and Moist deciduous species. Table 4.20 shows that several tree saplings grow in the RP areas and are in fact protected from elimination due to the shade and a protected environment. These plant species found in the RP areas that come under the category of 'forest pioneers' are *Trema orientalis* (Ulmaceae, and *Ficus hispida, Ficus exasperata* (Moraceae). These plants are found more towards the edge of the forest and are not found deep inside the forest. These pioneer tree species have smaller seeds while the deep forest species are large seeded which need the help of vertebrates to disperse them. Plantations of exotic trees can help to start a succession (Janzen 2000, Feyera *et al.* 2002).

One management strategy is planting buffers, corridors and stepping-stone stands around and between remnant forests (Janzen 1988, Lamb *et al.* 1997, Tewksbury *et al.* 2002). Rubber farming ecosystem with the vast expanse of land they occupy between forests can be used in a similar manner to form foster ecosystems. Buffers, corridors and stepping stone stands can be ear marked and conservation implemented at a landscape level. Another method of restoring matrix diversity after release from intensive agriculture is to upgrade or eliminate the 100-year pioneer tree species by encouraging late-successional trees long before they would passively arrive of their own accord. Several late successional species, medicinal species and endemic species can be planted along with the existing plantations along the periphery of the plantations or in the gaps of the rubber plantations. This in turn should attract vertebrate dispersal agents that accelerate the process of seed dispersal into and out of forest fragments. Restoring matrix diversity encourages natural processes of immigration and integration among nuclei of forest remnants. Pioneer trees will arrive of their own accord near forest edges (Martínez-Garza and González-Montagut 1999, 2002, Ingle 2003) but animal-dispersed pioneers such as *Cecropia, Cordia, Ficus* and *Trema* could usefully be planted far (> 100 m) from source forests edges to secure soil, provide shade and initiate the process of frugivore assembly. Tucker & Murphy in 1997 demonstrated that planting late-successional species accelerate succession to complex forests and is an important facet of enrichment planting.

Rubber plantations affect the seed bank at the local and regional level

In rubber plantations when abandoned primary successional tree species grow but late successional species may not grow. Preliminary seed bank studies have shown that the soil in the RP areas also does not have the deep forested species. Preliminary studies (data not included) that the rubber plantations and Open areas have poor seed banks as compared to the forest areas. Plant species found in the seedbank of the RP areas are species of the primary succession such as *Axonopus compressus, Oplismenus composites, Cyrtococcum patens, Justicia procumbens, Hedyotis auricularis, Spermacoce latifolia, Cyathula prostrate* etc. No tree species emerged in these prelimnary studies. In the tropics, abandoned croplands and pastures do not have seed banks of forest species, nor are there seedling or sapling cohorts waiting to respond to opportunity. Low rates of colonization and emergence, and high mortality of seeds and seedlings, result in low densities and diversities of tree juveniles and saplings (Uhl *et al.* 1988, Nepstad *et al.* 1996, Zimmerman *et al.* 2000). Under such conditions dispersal becomes a limiting factor in the rate of forest regeneration (Quintana-Ascencio *et al.* 1996, Holl 1999, Miller 1999) and the size and distribution of remnant sources of forest seeds becomes an important determinant of seed dispersal and seedling recruitment.

Many reasons can be attributed to the poor seed banks found in RP and OP areas. Sites which are frequently disturbed by clearance for cultivation favors establishment of species that are fast growing and can reach reproductive maturity at a young age (< 5 y). Repeated occupancy of pioneers at a site maintains a high density of their seed in the soil (Saulei and Swaine 1988). Another explanation is that accumulated litter might delay or prevent seeds reaching the soil giving more chance for predation (Cintra 1997). Litter fall in RP areas may create a similar situation. Although fast growth rate and abundant seed bank are characteristic of tropical pioneer species (Swaine and Whitmore 1988), mega seed bank and high growth rate are consider to be the two vital attributes (Drury aqnd Nisbet 1973). Also the ability to resprout once damaged, is a trait that would favor persistence in disturbance-prone environments where the vegetation is not completely removed (Rogers and Hartemink 2000).

Seed dispersal is a fundamental process in biodiversity restoration of a degraded site (Yirdaw 2001). The forest soil seed bank is typically smaller than that of fallow soils (Thompson1992). The large variations may be attributed to non-uniform dispersal of seeds in the soil, non-uniform incorporation of seed into the top 0.05 m of soil, or the influence on germination of spatial variation of the soils at each site (Thompson 1992). Frequency and scale of disturbance, and litter layer can also influence seed bank size (Rogers and Hartemink 2000).

In succession habitats like the plantation the abundance of a particular growth form or species may affect the presence and recruitment of other growth forms and species because different plants can modify the conditions of forest microsites (V´azquez-Yanes 1990, Facelli and Pickett 1991 a, b, Ganade and Brown 2002, Montgomery 2004) in which seeds germinate and young plants establish (Clark and Clark 1989, Ben´ıtez-Malvido and Kossmann-Ferraz 1999, Farris-L´opez 2004, Harms *et al.* 2004). Understory vegetation may affect plant density independent of species or may differentially influence emergence and survival of certain type of species, thereby influencing the composition and spatial structure of the "seedling" bank (Denslow 1991, George and Bazzaz 1999, Svenning 2001, Benitez-Malvido 2006).

Thus we must consciously promote the growth either by allowing naturally growing plants or by planting late successional and deep forested animal dispersed species in the rubber plantation.

Conclusions

The following inferences have been made from this study.

1. The qualitative assessments made on an intensive spatial and temporal scale of the rubber plantations, Open areas and the Forest areas of the Kottayam, Kollam and Pathanamthitta districts show that these areas are species rich. They show the presence of 420 species in the rubber plantation areas (RP areas), 115 species in the Open areas (OP areas) and 187 species the Forest areas sampled.
2. Comparison of the vegetation in the Forest, RP and OP areas using the Relative diversity Index (RDI) shows that there is a gradual change in vegetation. The RP area species and genera composition indicates a changing trend with a higher representation of Poaceae and Asteraceae members.
3. The vegetation of the unweeded RP areas over, a period of time, leads to a species compositional change which indicates restoration towards a pre-disturbance level. This also leads to higher species richness and a large number of pioneer tree species typical of a forest succession.
4. The understory of rubber plantations sampled in Thenmala which were within the Forest areas did not reflect the vegetation of the forest. Instead they showed comparatively low species richness and a vegetation composition typical of a successional change with a large number of pioneer species. The surrounding forest matrix also gets invade by these pioneer species.
5. Presence of several growth forms and the vertical stratification in rubber plantations indicates an ability to regenerate forests.

6. Quantitative assessment of the RP areas shows an all sample index of 216. This is the number of species observed in the quantitative sampling (S_{obs}). This is much lower than the number of plant species observed in the qualitative assessment (S_{true}). This is an indication of a large number of plants in the rubber plantations are with very low abundance because of which they could not be sampled. This discrepancy was not found in the qualitative and quantitative assessment of the OP and Forest areas.
7. Rank on abundance plots of the rubber plantations areas have indicated a high species richness and low evenness. It also suggests a lognormal distribution in the RP areas.
8. Comparisons of the rank on abundance plots of the rubber plantation subsamples have indicated that the evenness has increased in the unweeded RP areas as compared to the weeded RP areas.
9. There is a slow acquisition of species in the RP areas. Species accumulation of the RP areas showed that S_{max} was reached with 92 samplings with an accumulation of 216 species. In the OP areas S_{max} was reached with 27 samplings and an accumulation of 168 species. In the Forest areas the same was reached with 35 samplings and an accumulation of 168 species.
10. The species accumulation curve of the RP areas smoothen with just 10 randomizations. This indicates that these regions are less heterogeneous.
11. The parametric and non parametric species richness estimators chosen, used to estimate the species richness to the S_{obs} levels of the quantitative assessments showed that the S_{obs} of the quantitative assessment and the S_{max} estimated by the parametric and non parametric species richness estimators are nearly the same. This reinforces the adequacy of the samplings.

12. Rarefactions richness estimates which are used to compare communities are an effort-independent estimator curves and distangles the effect of disturbance on species richness. 216 species were found in the RP areas when 7268 individuals were sampled. In OP areas 168 species were obtained from 2265 individuals whereas 168 species were found when 1575 individuals were sampled in the Forest areas. Single sample rarefactions have shown that in rubber plantations the number of species that can be expected from a randomly chosen subset is significantly lower than that of the Open areas and the Forest areas because a subset of 30 individuals yields 5.75 species in the RP whereas one can expect 19 species and 17 species from a similar subsets in the OP and Forest areas respectively.
13. Rarefactions have shown 154 species were found when 2628 species were sampled in the unweeded RP plantations, whereas the same number of species (154 species) was obtained only when 4704 individuals were sampled in the weeded areas of the RP.
14. The SAD curves of the pooled samples of the OP and the Forest areas show a lognormal distribution, whereas the RP areas fit a log series distribution as well as lognormal distribution indicating disturbance and change in its vegetation composition.
15. The RP areas have been extensively sampled and this has resulted in the inclusion of several rare species which fell below the veil line. The dominance of grass species such as *Axonopus compressus, Cyrtococcum patens, Cyrtococcum oxyphyllum, Oplismenus compositus, Cynodon dactylon* and *Scleria corybosa* is a result of the availability of suitable niche and resource apportionment. The very low abundances of the rare species (21.5 species

behind the veil line) are resulting in a change in the composition of the species. This change has been brought about by disturbance. Elimination of several species and invasion of several species with high abundance value has resulted in a species composition that is dominated by a very abundant species. This has resulted in low evenness and comparatively high dominance of a few species ecologically and numerically.

16. The Shannon index of the RP areas is 4.002, of the OP areas is 4.295 and for the Forest areas is 4.48. Randomization tests of Solow (1994) have shown these differences to be significantly at the 5% level.
17. The Renyi Family diversity profiles (RF) and the Right Tailed sum diversity profile (RTS) of the RP, OP and Forest areas have shown that the rubber plantations are lower in diversity then the Open and Forest areas.
18. The low diversity profile of the Thenmala RP areas which are situated within the Forest is due to the non establishment of diaspores from the surrounding forest.
19. SHE analysis has shown that the equitability varied in the RP, OP and Forest areas. It decreased with more sampling effort in the RP areas which showed a sharp decline in evenness although it showed an increase in species richness. This increase in species richness is not reflected well in the diversity which remains relatively constant owing to the sharp decrease in evenness. The equitability also decreased with more sampling effort in the OP areas whereas it remains fairly constant in the Forest areas.
20. Thus SHE analysis and the SAD curves suggest that the OP areas are like ecotones and resemble forest thickets which are natural assemblages found in the edge of the forest which is capable of regenerating forests.

21. The PCA ordination plots show that the vectors that are responsible for more than 30% of the variance are *Ishaemum indicum, Oplismenus compositus, Cyathula prostrata* and *Cyrtococcum patens.* A distinct deviation from the species composition of the Forest in both the RP and OP areas is brought about by these vectors. It is evident that the two areas are under stress and undergoing a successional change in vegetation.
22. The nMDS ordinations show that there is a similarity in the species composition of the RP and OP ecosystems. The RP ecosystems are distinctly different from the Forest ecosystems. A trend of succession is evident in the rubber plantations which is changing its vegetation towards a composition similar to the Open areas.
23. The RP areas have 160 medicinal plants belonging to 58 families. No endemic medicinal plants were found in the OP areas. RP areas provide a habitat that is suitable for the growth of several medicinal plants as well as endemic medicinal plants.
24. The study has revealed the presence of 48 endemic species (11.4%) in the rubber plantations. The gradual succession and homogenization of vegetation in the rubber plantations could eliminate the niches in the habitat where these plants survive and jeopardize the growth of endemic plants. The numbers of endemics that survive in the OP areas are low as these habitats are harsh and the endemics have to face fierce competition to survive.
25. Phenological studies have shown that the RP areas are more suitable for sciophytes (shade loving plants) and for the growth of zoochorous species such as *Ixora brachiata* and *Memecylone umbellatum.* The high prevalence of

heliophytes in RP areas is not a natural plant association. It is more of a response to disturbance and exposure of the ground flora to more sunlight.

26. There is a significant retardation of germination and reduction of seedling growth of *Oryza sativa* and *Chromolena odorata* by the leaf leachate of *Hevea brasiliensis* under laboratory conditions.
27. A large number of the naturally growing plants found in the RP areas have seeds that germinate but show low viability. This could add to the allelochemical stress undergone by these seeds to germinate in the plantations. Abundant rain in Kerala could form low concentrations of allelochemical leachates which could mitigate the stress situation.
28. Low abundances of plant species in rubber plantations is a cause of conservation concern.
29. Differences in species composition between Forest, OP and Mature RP ecosystems in this study suggest such slow changes. If these processes operate over the entire landscape, community structure and local extinction may be predicted, at least in part. The vast areas of land under rubber cultivation only compound these effects and will have further consequential effects on the remaining conserved forest areas.
30. Rubber farming ecosystems can be used as conservation links in a matrix of Tropical forests and farming ecosystems for the conservation and restoration of endemic and threatened species
31. The presence of a large number of medicinal plants and endemic plants in the RP areas can conserve these plants at a landscape level. This however requires planning at a local and landscape level and proper management of the rubber farming ecosystems.

32. Rubber plantations in Kerala with its vast expanse and proximity to Tropical rain forest offers a means to restore ecosystem functioning and the advantage of a cash crop.
33. Rubber plantations adjacent to reserve forests and those that form the matrix within forest fragments can be used as foster ecosystems to enhance the recruitment, establishment and succession of native species.
34. We must consciously promote the growth either by allowing naturally growing plants or by planting late successional and deep -forested animal dispersed species in the rubber plantations.
35. To name a few plants that are of conservation and medicinal importance that can be cultivated in RP areas are trees like *Adenanthera pavonina, Antidesma acidum, Aporusa lindleyana, Artocarpus hirsutus, Salacia oblonga, Azadirachta indica, Bixa orellana, Naringi crenulata, Tabernaemontana heyneana, Xylia xylocarpa* and shrubs like *Anamirta cocculus* (woody climber), *Piper nigrum,, Piper longum, Ricinus communis, Zizyphus rugosus.*
36. Preliminary seed bank studies have shown that the soil in the RP areas also does not have the deep forested species.

In conclusion it can be said that conservation studies should go beyond using species richness as the sole indicator of diversity. To attain a more complete understanding of diversity, quantitative studies such as the measure of relative abundance should be used to conserve and determine the status of threatened plant species.

Summary

The qualitative assessments made on an intensive spatial and temporal scale of the RP, OP and forest areas show that these areas are species rich. They show the presence of 420 species in the rubber plantation areas (RP areas), 115 species in the Open areas (OP areas) and 187 species in the Forest areas. The number of species observed in the qualitative assessment is considered S_{true} and considered to be the actual number of species present in the sampled area. The RP areas have 160 medicinal plants belonging to 58 families. Seven medicinal plants in the RP areas are endemic. The study has revealed the presence of 48 endemic species (11.4%) in the rubber plantations.

Quantitative assessment of the RP areas shows an all sample index of 216. This is the number of species observed in the quantitative sampling (S_{obs}). This is much lower than the number of plant species observed in the qualitative assessment S_{true}(420 species in the RP areas alone). This is an indication of a large number of plants in the rubber plantations with very low abundance value because of which they could not be sampled. There is a slow acquisition of species in the RP areas. Species accumulation of the RP areas showed that S_{max} was reached with 92 samplings with an accumulation of 216 species. In the OP areas S_{max} was reached with 27 samplings and an accumulation of 160 species. The Forest areas the same was reached with 35 samplings and an accumulation of 168 species. The species accumulation curve of the RP areas smoothen with just 10 randomizations. This indicates that these regions are less heterogeneous. The asymptotes of the species accumulation curve and the rarefaction curves suggest adequate sampling.

Parametric and non parametric species richness estimators showed that the S_{obs} of the quantitative assessment and the S_{max} estimated by the parametric and non parametric species richness estimators are nearly the same. This reinforces the adequacy of the samplings. Single sample rarefactions have shown that in rubber plantations the number of species that can be expected from a randomly chosen subset is significantly lower than that of the Open areas and the Forest areas.

The Rank on abundance plots of the rubber plantations areas have indicated high species richness and low evenness and that evenness increases in the unweeded areas. The Species abundance distribution curves (SAD curves) of the pooled sample of the OP and the Forest areas show a lognormal distribution whereas the RP areas fit a log series distribution as well as lognormal distribution indicating disturbance and change in its vegetation composition. . The dominance of grass species such as *Axonopus compressus, Cyrtococcum patens, Cyrtococcum oxyphyllum, Oplismenus compositusans, Cynodon dactylon* and *Scleria corybosa* is a result of the availability of suitability of niche and resource apportionment. The very low abundances of the rare species (21.5 species behind the veil line) are resulting in a change in the composition of the species. This change has been brought about by disturbance. Elimination of several species and invasion of several species with high abundance value has resulted in a species composition that is dominated by a very abundant species. SHE analysis has shown that the equitability varied in the RP, OP and Forest areas. It decreased with more sampling effort in the RP areas which showed a sharp decline in evenness although it showed an increase in species richness. The SHE analysis and the SAD curves suggest that the OP areas are like ecotones and resemble forest thickets which are natural assemblages found in the edge of the forest which is capable of regenerating forests.

The Shannon index of the RP areas is 4.002, of the OP areas is 4.295 and for the Forest areas is 4.48. Randomization tests of Solow (1994) have shown these differences to be significantly different at the 5% level. The Renyi Family diversity profiles (RF) and the Right Tailed sum diversity profile (RTS) of the RP, OP and Forest areas have shown clear verdict that the rubber plantations are lower in diversity then the Open and Forest ecosystems.

The low diversity profile of the Thenmala RP areas which are situated within the Forest is due to the non establishment of diaspores from the surrounding forest. The abundance of pioneer species could either modify the microsites in which seeds germinate and plants establish themselves or they may influence the emergence and survival of certain forest species thus influencing the composition and spatial structure of the seed bank. Various grass species have been found to be responsible for the change in the vegetation of the different RP areas. The prevalence of various types of grass species in RP areas is an indication of succession and changing vegetation. The homogenous vegetation and the resultant homogenous habitat can have grave consequences as this result in a decrease in plant and consequently animal diversity. Single sample rarefactions of weeded and unweeded areas have shown that heterogeneity increases when the rubber plantations are left unweeded. The PCA ordination plots show that the vectors that are responsible for more than 30% of the variance are *Ishaemum indicum, Oplismenus compositus, Cyathula prostrata* and *Cyrtococcum patens.* A distinct deviation from the species composition of the Forest in both the RP and OP areas is brought about by these vectors. The nMDS ordinations show that there is a similarity between RP and OP areas in the species composition of the grasses. A trend of succession is evident in the rubber plantations which is changing its vegetation towards a composition similar to the Open areas.

The gradual succession and homogenization of vegetation in the rubber plantations could eliminate the niches in the habitat where these plants survive and jeopardize the growth of endemic plants. Phenological studies have shown that the RP areas are more suitable for sciophytes (shade loving plants) and for the growth of zoochorous species. Allelopathic studies have shown that there is a significant retardation of germination and reduction of seedling growth of *Oryza sativa* and *Chromolena odorata* by the leaf leachate of *Hevea brasiliensis* under laboratory conditions.

Low abundances of plant species in rubber plantations is a cause of conservation concern. Low abundance and elimination of plant species can have other consequential effects on the ecosystem. Differences in species composition between Forest, OP and Mature RP areas in this study suggest such slow changes. If these processes operate over the entire landscape, community structure and local extinction may be predicted, at least in part. The vast areas of land under rubber cultivation only compound these effects and will have further consequential effects on the remaining conserved forest areas. There is a strong relationship between statistical components, diversity and extinction which cannot be ignored. The study also reveals a tendency for the rubber plantations to favor the growth of plant species that naturally grow in the Moist deciduous forests. Presence of several growth forms and the vertical stratification in rubber plantations indicates an ability to regenerate forests. The vegetation of the unweeded RP areas over a period of time leads to a species compositional change which indicates restoration towards a pre-disturbance level. This also leads to higher species evenness and a large number of pioneer tree species typical of a forest succession.

Rubber plantations adjacent to reserve forests and those that form the matrix within forest fragments can be used as foster ecosystems to enhance the recruitment, establishment and succession of native species. Initially natural forest stands near a restoration site can provide baseline data that can be utilized in the evaluation of the extent and rate of plant species recruitment and establishment in plantations. We must consciously promote the growth either by allowing naturally growing plants or by planting late successional and deep-forested animal dispersed species in the rubber plantations. To name a few plants that are of medicinal importance that can be cultivated in RP areas are trees like *Adenanthera pavonina, Antidesma acidum, Aporusa lindleyana, Artocarpus hirsutus, Salacia oblonga, Azadirachta indica, Bixa orellana, Naringi crenulata, Tabernaemontana heyneana, Xylia xylocarpa* and shrubs like *Anamirta cocculus* (woody climber), *Piper nigrum, , Piper longum, Ricinus communis, Zizyphus rugosus.* Preliminary seed bank studies have shown that the soil in the RP areas also does not have the deep forested species.

In conclusion rubber plant diversity analysis has shown that rubber farming ecosystems have a low diversity profile. These areas are species rich but show a low evenness because the vegetation in rubber plantations is dominated by a few abundant successional pioneer species. As a consequence of this several species have become rare and have low abundances. The study emphasizes the importance of measures of species diversity based on relative abundance as well as richness in order to capture the full complexity of diversity in conservation studies. Rubber farming ecosystems show the presence of several medicinal and endemic plant species but their survival can be jeopardized by the successional change as result of the present methods of weeding and cultivation. Rubber farming ecosystems have the ability to regenerate forests. It has the ability to nurture the growth of several plant species when left undisturbed. In the present scenario the vast expanses of rubber plantations can be utilized to conserve the existing forest fragments by planting late successional species, medicinal plants and plants which are in the verge of extinction in these plantations.

References

Aarssen, L. W. 1983. Ecological combining ability and competitive combining ability in plants: towards a general evolutionary theory of coexistence in systems of competition. *American Naturalist* **122**: 707-731.

Abraham, M. and Abraham C. T. 2000. Weed flora of rubber plantations in Kerala. *Indian Journal of Natural Rubber Research* **13** (1&2): 86-91.

Adamson D. A. and Fox, M. D. 1982. Change in Australasian vegetation since European settlement. *In:* Smith, J. M. B. (ed.) *A History of Australasian Vegetation*. McGraw-Hill, Sydney. Pp. 109–151.

Akhurst, C. G. 1932. The carbon and nitrogen contensts of some natural covers. *Journal of the Rubber research institute of Malaya* **4**(2): 131-139.

Alados, C. L., Pueyo, Y., Giner, M. L., Navarro, T., Escos, J., Barroso, F., Cabezudo, B. and Emlen, J. M. 2003. Quantitative characterization of the regressive ecological succession by fractal analysis of plant spatial patterns. *Ecological Modeling* **163**: 1-17.

Alcantara, F. A., de Buurman, P., Furtini Neto, A. E., Curi, N., Roscoe, R., 2004. Conversion of grassy cerrado into riparian forest and its impact on soil organic matter dynamics in an oxisol from south east Brazil. *Geoderma* **123** (3/4): 305-317.

Aleinikova, M. M., Porfiriev, V. C. and Utrobina, N. M. 1979. *The mosaic structure of Spruce-broad-leaf forests in the East of European part of USSR* (Volzhosko-kamskii Reserve). Nauka,Moscow (in Russian).

Alsaadawi, I. S., Arif, M. B. and Alrubeaa, A. A. 1985. Allelopathic effects of *Citrus aurantium* L. isolation, characterization and biological activities of phytotoxins. *Journal of Chemical Ecology* **11:** 1527.

Altesor, A., Dilandro, E., May, H. and Ezeurra, E. 1998. Long-term species change in a Uruguayan grassland. *Journal of Vegetation Science* **9**: 173-180.

Andelman, S. J., and Willig, M. R. 2003. Present patterns and future prospects for biodiversity in the Western Hemisphere. *Ecology Letters* **6**: 1-7.

Andelman, S. J., and Willig, M. R. 2003. Present patterns and future prospects for biodiversity in the Western Hemisphere. *Ecology Letters* **6**: 1-7.

Anderson, M. and Halpin, N. 1998. Private Forestry Plantation - Joint Venture Scheme. *Managing and Growing Trees - Farm Forestry and Vegetation Management* (Conference Proceedings 19–21 October 1998), pp. 413–416. Queensland Government and Greening Australia.

Anderson, J. M. 1978. Inter and intra-habitat relationships between woodland *Cryptostigmata* species diversity and the diversity of soil and litter microhabitats. *Oecologia* **323**, 341-348.

Andreae, B. 1981. *Farming Development and Space: A World Agricultural Goegraphy* (translated from German by H.F. Gregor) de Gruyter, Berlin.

Annaselvan, J., and Parthasarathy, N. 2001. Diversity and distribution of herbaceous vascular epiphytes in a tropical evergreen forest at Varagalair, Western Ghats, India. *Biodiversity Conser*vation **10**: 317–329.

Anon. 1871. Rules regarding grant of land for cultivation of coffee. Memorandum of 8 March 1862; Rules for the sale of wasteland on the travancore Hills, 24 April 1865. *Travancore Almanac* pp 123-136.

Anonymous (1987-88, 89-90, 1991-92, 1992-93, 1994-95) *Annual Review of the Rubber Research Institute of India.*

Anonymous 1990. *National Strategy for Conservation and Sustainable Development,* Report of the Core Committee, Ministry of Environment and Forest, Government of India.

Armesto, J. J. and Pickett, S. T. A. 1985. Experiments on disturbance in old-field plant communities: impact on species richness and abundance. *Ecology* **66**: 230-240.

Ashton, P. S. 1977. A contribution of rain forest research to evolutionary theory. *Annals* of *Missouri Botanical Garden* **64**: 694-705.

Aspinall, R. 1988. Use of species-area relationships for analysis of biological atlas data. *Area* **2**: 347-351.

Aweto, A. O. 2001. Impact of single species tree plantations on nutrient cycling in West Africa. *International Journal of Sustainable Development and World Ecology* **8** (4): 365-368.

Baur, B., Joshi, J., Schmid, B., Hänggi, A., Borcard, D., Stary, J., Pedroli-Christen, A.,Thommen, G. H., Luka, H., Rusterholz, H. P., Oggier, P., Ledergerber, S. and Erhardt, A. 1996. Variation in species richness of plants and diverse groups of invertebrates in three calcareous grasslands of the Swiss Jura mountains. *Rev. Suisse Zool.* 103: 1-33.

Baur, B., Joshi, J., Schmid, B., Hänggi, A., Borcard, D., Stary, J., Pedroli-Christen, A., Thommen, G. H., Luka, H., Rusterholz, H. P., Oggier, P., Ledergerber, S. and Erhardt, A. 1996. Variation in species richness of plants and diverse groups of invertebrates in three calcareous grasslands of the Swiss Jura mountains. *Rev. Suisse Zool.* 103: 1-33.

Bazzaz, F. A. 1975. Plant species diversity in old-field successional ecosystems in southern Illinois. *Ecology* **56**: 485-488.

Bazzaz, F. A. 1975. Plant species diversity in old-field successional ecosystems in southern Illinois. *Ecology* **56**: 485-488.

Bean, A. R. 1994. *Ricinocarpos Speciosus* — a disappearing species. Society for Growing Australian Plants .*Queensland Region Bulletin* 37–38.

Beatty, S. W. 1984. Influence of microtopography and canopy species on spatial patterns of forest understory plants. *Ecology* **65:** 1406-1419.

Beckon, W. N. 1993. The effect of insularity on the diversity of land birds in the Fiji islands: implication for refuge design. *Oecologia* **94**: 318-329.

Bell, G., Lechowicz, M. J. and Waterway, M. J. 2000. Environmental heterogeneity and species diversity of forest sedges. *Journal of Ecology* **88:** 67- 87.

Ben´itez-Malvido, J. and Kossmann-Ferraz. I. D. K. 1999. Litter cover variability affects seedling performance and herbivory. *Biotropica* **31**: 598–606.

Ben´itez-Malvido, J., and. Kossmann-Ferraz, I. D. K, and Ceccon, E. 2001. Seed rain vs. seed bank, and the effect of vegetation cover on the recruitment of tree seedlings in tropical successional vegetation. *In*: J. Cramer y S. Lied (eds.) *Life*

Forms and Dynamics in Tropical Forests. "Dissertationes Botanicae" series **346:** pp 185-203.

Benitez- Malvido, J. 1998. Impact of forest fragmentation on seedling abundance in a tropical rain forest. *Conservation Bioogy* **12:** 380- 389.

Benitez- Malvido, J., and Mart́inez-Ramos, M. 2003. Impact of forest fragmentation on understory plant species richness in Amazonia. *Conservation Biology* **17:** 389–400.

Benitez-Malvido, J. 2006. Effect of low vegetation on the recruitment of plants in successional habitat Types. *Biotropica* **38** (2): 171–182.

Berryman, A. A., Michalski, J., Gutierrez, A. P. and Arditi, R. 1995. Logistic theory of food web dynamics. *Ecology* **76:** 336-343.

Bhagwat, S. A., Kushalappa, C. G., Williams, P. H. and Brown, N. D. 2005. A Landscape Approach to Biodiversity Conservation of Sacred Groves in the Western Ghats of India. *Conservation Biology* 1853–1862

Bhat, D. M., Naik, M. B., Patagar, S. G., Hegde, G. T. , Kanade, Y. G. , Hagde, G. N., Shastri, C. M., Shetti D. M. and Furtadio, R. M. 2000. Forest dynamics in tropical rain forests of Uttara Kannada district in Western Ghats, India. *Current Science* **79**(7): 975-985.

Bian Huaxin 1981. Plant covers of rubber plantations and their management. *Science and Technology of tropical crops* **5**: 33.

Bierregard Jr., R. O., Laurance, W. F., Gascon, C., Benitez-Malvido, J., Fearnside, P. M., Fonseca, C. R., Ganade, G., Malcolm, J. R., Martins, M. B., Mori, S., Oliveira, M., Rankin-de Mérona, J., Scariot, A., Spironello, W. and Willianson, B. 2001. Principles of forest fragmentation and conservation in the Amazon. *In* : Bierregaard, R. O.Jr., Gascon, C., Lovejoy, T. E. and Mesquita, R. C. G. (eds.). *Lessons from Amazonia: The Ecology and Conservation of A Fragmented Fores t.* Yale University Press, New Haven, USA. Pp. 371–385.

Billiet, F. 2004. Phenology of tropical and subtropical plants in greenhouses in the National Botanic Garden of Belgium. *Scripta Bot. Belg.* **29**: 39-54.

Bjervekevedt, D., Odlandt, A., Naujalis, J., Laztuka, J. 2003. The growth and phenology patterns of herb Paris (*Paris quadrifolia* L. Trilliaceae): relation to soil and air temperatures. *Ekologija* **1:** 74-79.

Blasco, F. 1970. Aspects of flora and ecology of the savannas of the South Indian Hills. *J. Bombay nat. Hist. Soc.* 67: 522-534.

Bobiec A. 1998. The mosaic diversity of field layer vegetation in the natural and exploited forests of Białowie˙za. *Plant Ecology* **136:** 175–187.

Bobiec, A. 1994. The micromosaic structure of the ground layer vegetation in thirty-four chosen plots of Białowie˙ za Forest in north-eastern Poland. *Fragm. Flor. Geobot.* **39**: 619–638.

Boerner, R. E. J. and Koslowsky, S. D. 1989. Microsite variations in soil chemistry and nitrogen mineralization in a beech-maple forest. *Soil Biology and Biochemistry* **21:** 795–801.

Bolker, B. M., Pacala, S. W., Bazzaz, F. A., Canham, C. D. and Levin, S. A. 1995. Species diversity of ecosystem response to carbon dioxide fertilization: Conclusions from a temperate forest model. *Global change biology* **1**:373-381.

Bollen, A. and Donati, G. 2005. Phenology of the littoral forest of Sainte Luce, Southeastern Madagascar. *Biotropica* **37**(1): 32-43.

Bond, W. J. 1994. Keystone species. *In* Schulze, E. D. and Mooney, H. A. (eds.) *Biodiversity and ecosystem function.* Springer- Verlag, Berlin. pp. 237-253.

Boyle, T. J. B. and Boyle Ch. E. B. 1994. (Eds.). *Biodiversity, temperate ecosystems and global change.* Berlin et. al. Springer-Verlag. Pp. 256.

Bradstock, R. A., Auld T. D., Keith D. A., Kingsford R. T., Lunney D. and Sivertsen D. P. (eds.). 1995. *Conserving Biodiversity: Threats and Solutions.* Surrey Beatty and Sons, Sydney.

Braun-Blanquet, J. 1932. Plant Sociology: The Study of Plant Communities. McGraw-Hill, New York, NY, USA. (1965 English translation).

Brewer, A. and Williamson, M. 1994. A new relationship for rarefaction. *Biodiversity Conservation,* **3**, 373–379.

Bridson, D. and Forman, L. 1992. *The Herbarium Handbook*, Kew, Royal Botanic Gardens, UK.

Brigham, S. D., Johnston, C. A., Pastor, J., Updegraff, K. 1995. Potential feedbacks of northern wetlands on climate change. *Biosciences* **45**: 262-274.

Brokaw, N. V. L. 1985. Gap-phase regeneration in a tropical forest. *Ecology* **66**: 682-687.

Bronson, K. F. and Moiser, A. R. 1993. Nitrous oxide emissions and methane consumption in wheat and corn cropped systems. *In*: Harper, L.A., Moiser, A. R., Duxbury, J. M. and Rolston, D. E., (eds.) *Agricultural Ecosystem Effects on Trace Gases and Global Change*. Madison (WI): American Society of Agronomy. Pp. 133-144.

Brose, U., Martinez, N. D. and William, R. J. 2003. Estimating species richeness: sensitivity to sample coverage and insensitivity to spatial patterns. *Ecology* **84**(9): 2364-2377.

Brown, J. H. 1995. Macroecology. University of Chicago Press, Chicago, Illinois, USA.

Brunig, C. F. 1983. In: *Tropical Rain Forest Ecosystems: Structure and Function* (ed. Golley, F.B.), Elselvier Scientific Publishing Company, Amsterdam, The Netherlands. pp. 49-75.

Bruno, J. F. 2002. Causes of landscape-scale rarity in cobble beach plant communities. *Ecology* **83**: 2304–2314.

Bullock, S. H. 1995. Plant reproduction in neotropical dry forests. *In*: Bullock, S. H., Mooney, H. A. & Medina, E. (eds.). *Seasonally dry tropical forests*. Cambridge University Press, Cambridge. pp. 277–303.

Bulmer, M. G. 1974. On fitting the Poisson log normal distribution to species abundance data. *Biometrics* **30**: 101-110.

Bunge, J. and Fitzpatrick, M. 1993. Estimating the number of species: A review. *Journal of the American statistical Association* **88**: 364-373.

Burnham, K. P. and Overton, W. S. 1979 Robust estimation of population size when capture probabilities vary among animals. *Ecology* **60**, 927-936.

Buys, M. H., Maritz, J. S, Boucher, C. and VanDer Walt, J. J. A. 1994. A model for species-area relationships in plant communities. *Journal of Vegetation Science* **5**, 63-66.

Buzas M. A. and Gibson T. G. 1969. Species diversity: benthonic foraminifera in western North Atlantic. *Science* **163**: 72–75.

Buzas, M. A., and Hayek, L. C. 1996. Biodiversity resolution: an integrated approach. *Biodiversity Letters* **3**: 40-43.

Cahill, J. F., Jr., and Casper, B. B. 2002. Canopy gaps are sites of reduced below ground plant competition in a productive old field. *Plant Ecology* **165**: 207-215.

Cam, E., Nichols, J. D., Hines, J. E., Sauer, J. R., Alpizar-Jara, R. and Flather, C. T. 2002. Disentangling sampling and ecological explanations underlying species–area relationships. *Ecology* **83**: 1118–1130.

Camargo, J. A. 1993. Must dominance increase with the number of subordinate species in competitive interactions? *Journal of Theoretical Biology* **161**: 537-542.

Cannon, C. H., Peart, D. R. and Leighton, M. 1998. Tree species diversity of commercially logged Bornean rainforest. *Science* **281**: 1366-1368.

Castro, I., Sterling, A. and Galiano, E. F. 1986. Multi- species pattern analysis of Mediterranean pastures in three stages of ecological succession. *Vegetatio* **68**: 37-42.

Chakraborty, N. K., Pal, T. K., Dey, S. K. and Varghese, Y. A., 2002. Flora of Rubber and other plantations in Tripura. *Indian Journal of Natural Rubber research*, **15**(1): 103-106.

Chalcraft, D. R., and W. J. Resetarits, Jr. 2003. Predator identity and ecological impacts: functional redundancy or functional diversity? *Ecology* **84**: 2407-2418.

Chan, H. Y., Yew, F. K. and Pushparajah, E. 1984. Approaches towards land evaluation systems for *Hevea brasiliensis* cultivation in Peninsular Malaysia. *Proceedings International Rubber Conference* Colombo. pp. 545-562.

Chao, A. and Lee, S M. 1992 Estimating the number of classes via sample coverage. *Journal of American Statistical Association* **87**: 210–217.

Chao, A. 1984. Non-parametric estimation of the number of classes in a population. *Scandinavian Journal of Statistics* **11**: 265-270.

Chao, A. 1987. Estimating the population size for capture-recapture data with unequal matchability. *Biometrics* **43**: 783-791.

Chapin III, F.S., Sala, O. E., Burke, I. C., Grime, J. P., Hooper, D. U., Lauenroth, W. K., Lombard, A., Mooney, H. A., Mosier, A. R., Naeem, S., Pacala, S., Roy, J., Steffen, W. L. and Tilman, D. 1998. Ecosystem consequences of declining biodiversity. Experimental evidence and a research agenda for the future. *Bioscience* **48**: 45-52.

Chapin, F.S., III, Zavaleta, E. S., Eviners, V.T., Naylor, R. L., Vitousek, P.M., Reynolds, H.L., Hooper, D. U., Lavorel, S., Sala, O.E., Hobbie, S.E., Mack, M.C. and Diaz, S. 2000. Consequence of changing biodiversity. *Nature* **405**: 234-242.

Chazdon, R. L., Colwell, R. K., Denslow, J. S., Guariguata, M. R. 1998. Statistical methods for estimating species richness of woody regeneration in primary and secondary rain forests of NE Costa Rica. *In:* Dallmeier F, Comiskey JA (eds) *Forest biodiversity research, monitoring and modeling: conceptual background and Old World case studies.* Parthenon Publishing, Paris. pp 285–309.

Cintra, R. 1997. Leaf litter effects on seed and seedling predation of the palm *Astrocaryum murumuru* and the legume tree *Dipteryx micrantha* in Amazonian forest. *Journal of Tropical Ecology* **13**: 709-725.

Clark, D. B., and Clark. D. A., 1989. The role of physical damage in the seedling mortality regime of a Neotropical rain forest. *Oikos* **55**: 225–230.

Clark, J. S., Maklin, E. and Wood, L. 1998. Stages and spatial scales of recruitment limitation in southern Appalachian forests. *Ecol Monog* **68**: 213–235.

Clarke, K. R. 1988. *Detecting change in benthic community structure.* Pages 131-142 in R. Oger (ed.) *Proceedings of invited papers, fourteenth international Biometric conference.* Namur, Belgium. Société Adolphe Quéelet Gembloux, Belgium [560, 561, 562, 563],

Clarke, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. *Australia Journal Ecology* **18**, 117-143.

Clench, H. 1979. How to make regional lists of butterflies: Some thoughts. *Journal Lepidopterist's Society* **33**: 216-231.

Codit, R., Hubell, S. P., Foster, R. B. 1996. Assessing the response to plant functional types to climatic change in Tropical forests. *Journal of Vegetation Science* **7**(3(): 405-416.

Cohn, L. 1995. The myths and realities of industrial timber plantations. *Forest Perspectives* **5**: 5–8.

Coleman, B. D. 1981. On random placement and species-area relations. *Mathematical Biosciences* **54**, 191-215.

Coleman, M. D., Mares, M. D., Willig, M. R. and Hsieh, Y. H. 1982. Randomness, area and species richness. *Ecology* **63**, 1121-1133.

Coley, P. D. 1983. Herbivory and defensive characteristics of tree species in a lowland tropical forest. *Ecological Monographs* **53**: 209–233.

Collins, S. L. 1990. Patterns of community structure during succession in tallgrass prairie. *Bulletin of the Torrey Botanical Club* **117**: 397-408.

Colwell, R. K., Mao C. X., and Chang J. 2004. Interpolating, extrapolating, and comparing incidence-based species accumulation curves. *Ecology* **85**: 2717-2727.

Colwell, R. K. 2004 *Biota2: the biodiversity database manager.* Sinauer Associates, Inc. Sunderland, MA.

Colwell, R. K. 2000. EstimateS: Statistical estimation of species richness and shared species from samples (Software and User's Guide), Version 6. http://www.viceroy.eeb.uconn.edu/estimates.

Colwell, R. K. and Coddington, J. A. 1994. Estimating terrestrial biodiversity through extrapolation. *Philosophical Transaction of the Royal Society: Biological Science* **345**, 101-118.

Community Analysis Package (CAP) Version 4.0, 2007. Pisces Conservation Ltd. Lymington, UK (www.pisces-conservation.com).

Condit, R., Hubbell, S., Lafrankie, J.V., Sukumar, R., Manokaran, N., Foster, R. and Ashton, P. 1996. Species-area and species-individual relationships for tropical trees: a comparison of three 50-ha plots. *Journal of Ecology* **84**: 549-562.

Connell, J. H. 1971. On the role of natural enemies in preventing competitive exclusion in some marine animals and in rain forest trees. *in* den Boer, P. J. and Gradwell, G. R. editors. Dynamics of populations. Proceedings of the Advanced Study Institute, Centre for agricultural Publishing and Documentation, Pudoc, Wageningen, The Netherlands. Pp. 298-312.

Cordeiro, N. and Howe, H. F. 2001. Low recruitment of trees dispersed by animals in African forest fragments. *Conservation Biology* **15**: 1733–1741.

Costa, F. and Magnusson, W. 2002. Selective logging effects on abundance, diversity, and composition of tropical understory herbs. *Ecological Applications* **12**: 807–819.

Covich, A. P. 1988. Geographical and historical comparisons of neotropical streams: biotic diversity and detrital processing in highly variable habitats. *Journal of the North American Benthological Society* **7**: 361–386.

Crawley, M. J. 1997. The structure of plant communities.*In* M.J. Crawley (ed.), *Plant ecology*, Second edition, Blackwell, Oxford, London, UK. Pp. 475-531.

Crawley, M. J. and Harral, J. E. 2001. Scale dependence in plant biodiversity. *Science* **345**: 101–118.

Cremene, C., Groza, G., Rakosy, L., Schileyko, A., Baur, A., Erhardt, A. and. Baur, B. 2005. Alterations of Steppe-Like Grasslands in Eastern Europe: A Threat to Regional Biodiversity Hotspots. *Conservation Biology* **19** (5): 1606-1618.

Crist, T. O., Veech, J. A., Gering, J. C. and Summerville, K. S. 2003. Partitioning species diversity across landscapes and regions: a hierarchical analysis of a, b, and c-diversity.*American Naturalist* **162:** 734–743.

Cruz-Ortega R., Ayala-Cordero G. and Anaya A.L. 2002. Allelochemical stress produced by the aqueous leach ate of *Callicarpa acuminate*: effects on the roots of bean, maize and tomato. *Physiologia Plantarum* **116**: 20-27.

Curran, L. M., Trigg, S. N., McDonald, A. K., Astiani, D., Hardiono, Y. M., Siregar, P., Caniago, I. and Kasischke, E. 2004. Lowland Forest Loss in Protected Areas of Indonesian Borneo. *Science* **303** (5660): 1000-1003.

Currie, D. J. 1991. Energy and large-scale patterns of animal and plant species richness. *American Naturalist* **137**: 27–49.

Currie, D. J. and Paquin, V. 1987. Large-scale biogeographical patterns of species richness of trees. *Nature* **329**: 326–327.

D'eath, G., and K. E. Fabricius. 2000. Classification and regression trees: a powerful yet simple technique for ecological data analysis. *Ecology* **81:** 3178–3192.

Dakshini K. M. M., Foy C. L. and Inderjit. 1999. Allelopathy: one component in a multifaceted approach to ecology. *In* Inderjit, K.M.M. Dakshini and C.L. Foy (eds.), *Principles and Procedures in Plant Ecology : Allelochemical Interactions,* CRC Press, New York, NY, USA. pp. 3-14.

Dalling, J. W., Hubbell, S. P. and Silvera, K. 1998. Seed dispersal, seedling establishment and gap partitioning among tropical pioneer trees *Journal of Ecology* **86**: 674–689.

Dalling, J. W., Muller-Landau, H. C., Wright, S. J. and Hubbell, S. P. 2002. Role of dispersal in the recruitment limitation of neotropical pioneer species. *Journal of Ecology* **90**: 714–727.

De Jong, K. 1975. *An analysis of the behaviour of a class of genetic adaptive systems.* PhD thesis, University of Michigan.

Dean, W. 1987. *Brazil and the struggle for rubber: A study in environmental history.* Cambridge University Press, Cambridge. pp 234.

DeAngelis, D. L., Bartell, S. M. and Brenkert, A. L. 1989. Effect of nutrient cycling and food chain length on resilience. *The American Naturalist* **134**: 778-805.

DeAngelis, D. L., Bartell, S. M. and Brenkert, A. L. 1989. Effect of nutrient cycling and food chain length on resilience. *The American Naturalist* **134**:778-805.

DeBenedictis, P. A. 1973. On the correlations between certain diversity indices. *American Naturalist* **107**: 295-302.

Denslow, J. S., Newell, E. and Ellison, E. M. 1991. The effect of understory palms and cyclanths on the growth and survival of Inga seedlings. *Biotropica* **23**: 225–234.

Digby, P. G. N., and Kempton, R. A. 1987. Population and Community Biology Series: Multivariate Analysis of Ecological Communities. Chapman and Hall, London.

Dignan, P., Bren, L. 2003. A study of the effect of logging on the understory light environment in riparian buffer strips in a south-east Australian forest. *Forest Ecology and Management* **172**: 161–172.

Dirzo, R. and Miranda, A. 1991. Altered patterns of herbivory and diversity in the forest understorey: a case study of the possible consequences of contemporary defaunation. *In* Price, P., Lewingston, T., Fernandes, G. and Benson, W. (eds.), *Plant-Animal Interactions: Evolutionary Ecology in Tropical and Temperate Regions.* John Wiley & Sons, New York, NY. Pp. 273–287.

Doak, D. F., Bigger, D., Harding-Smith, E., Marvier, M. A., O'Malley R. and Thomson, D. 1998. The statistical inevitability of stability-diversity relationships in community ecology. *The American Naturalist* **151**: 264-276.

Domoroes, M. 1984. The 'Rubber Climate' of Sri Lanka: Observations on an agro climatic land classification for rubber cultivation in Sri Lanka. *Proceedings of International Rubb. Conf.*, Colombo, pp. 381-387.

Donohue K., Foster D. R. and Motzkin G. 2000. Effects of the past and present on species distribution: land-use history and demography of wintergreen. *Journal of Ecology 88*: 303–316.

Dorazio R. M., Royle, J. A., Oderstrom S. and Glimskar, A. 2006. Estimating species richness and accumulation by modeling species occurrence and detectability. *Ecology* **87**: 842-854.

Drabble, J. H. 1973. *Rubber in Malaya* 1876-1922: Oxford University Press, Kuala Lumpur. pp. 1-13.

Drakare, S., Lennon, J. J. and Hillebrand, H. 2006. The imprint of geographical, evolutionary and ecological context on species- area relationships. *Ecology Letters*, **9**: 215–227.

Drury, W. H. and Nisbet, I. T .C. 1973. Succession. *Journal of the Arnold Arboretum* **54**: 331-368.

Duckham, A. N. and Masefield, G. B. 1970. *Farming systems of the world.* Chatto anfd Windus, London.

Duffy, D. C. and Meier, A. J. 1992. Do Appalachian herbaceous understories ever recover from clear-cutting? *Conservation Biology* **6**:196–201.

Dupre, C. and Ehrlen, J. 2002. Habitat configuration, species traits and plant distributions. *Journal of Ecology* **90**: 796-805.

Dyrness, C. T. 1973. Early stages of plant succession following logging and burning in the western cascades of Oregon. *Ecology* **54**: 57–69.

Dzwonko, Z. and Loster, S. 1989. Distribution of vascular plant species in small woodlands on the western Carpathian foothills. *Oikos* **56**: 77–86.

Eggleston, D. B., Elis, W. E., Etherington, L. L., Dahlgren, C. P. and Posey, M. H. 1999. Organism response to habitat fragmentation and diversity: Habitat colonization by estuarine macrofauna. *Journal of Experimental Marine Biology and Ecology* **236**: 107- 132.

Ehrlich, P. R. and Wilson, E. O. 1991. Biodiversity studies: science and policy. *Science* **253**: 758–761.

Ehrlich, P. R. and Mooney H. A. 1983. Extinction, substitution, and ecosystem services. *BioScience* **33**: 284-254.

Environment Protection Authority (EPA) and Ministry of Economic Development and Cooperation (MEDAC) 1997. *The Conservation Strategy of Ethiopia. Volume I. The Resource Base, its Utilization and Planning for Sustainability.* Addis Ababa, Ethiopia.

Erhardt, A. 1985a. Diurnal Lepidoptera: sensitive indicators of cultivated and abandoned grassland. *Journal of Applied Ecology* **22**: 849–861.

Erhardt, A. 1985b. Wiesen und Brachland als Lebensraum f'ur Schmetterlinge. Eine Feldstudie im Tavetsch (GR). *Denkschriften der Schweizerischen Naturforschenden Gesellschaft* **98**: 1–154 (in German).

Eriksson, O. 1993. The species- pool hypothesis and plant community diversity. *Oikos* **68**: 371- 374.

Flather, C. H. 1996. Fitting species-accumulation functions and assessing regional land use impacts on avian diversity.*Journal or Biogeography* **23:** 155- 168

Facelli, J. M., and Pickett, S. T. A. 1991b. Plant litter: Light interception and effects on an old-field plant community. *Ecology* **72:** 1024–1031.

Facelli, J. M., and. Pickett, S. T. A. 1991a. Plant litter: Its dynamics and effects on plant community structure. *Botanical Review* **57:** 1–32.

FAO. 1981. Forest Genetic resources Information. No. 10 Rome, Italy: Food and Agriculture Organization.

FAO. 2001. Global Forest Resources Assessment. Main report. FAO Forestry paper. 140, Food and Agriculture Organization of the United Nations, Rome, 2001.

http://www.fao.org/forestry/fo/fra/index.jsp

Farm guide 2001. Farm information Bureau. Trivandrum, Kerala.

Farris-L'opez, K., Denslow, J. S., Moser, B., and Passmore. H. 2004. Influence of a common palm, *Oenocarpus mapora*, on seedling establishment in a tropical moist forest in Panama.*Journal of Tropical Ecology* **20**: 429–438.

Ferreira, L. V., and W. F. Laurance. 1997. Effects of forest fragmentation on mortality and damage of selected trees in central Amazonia. *Conservation Biology* 11: 797-801.

Ferreira, L. V. 1997. Effects of the duration of flooding on species richness and floristic composition in three hectare in the Jaú National Park in floodplain forests in central Amazonia. *Biodiversity Conservation* **6**: 1353-1363.

Feyera, S., Beck, E. and Lu¨ ttge, U. 2002. Exotic trees as nurse trees for the regeneration of natural tropical forests. *Trees* **16:** 245–249.

Finegan, B. 1996. Pattern and process in neotropical secondary rain forests: the first 100 years of succession. *Trends in Ecology and Evolution* **11**: 119–124.

Fisher, R. A., Cobert, A. S. and Williams, C. B. 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. *Journal of Animal Ecology* **12:** 42-58.

Forest Statistics India. 2003. Indian Council of Forestry Research and Education, New Forest, Dehradun.pp 1-118.

Forest Statistics. 2003. Forests and Wildlife Department, Kerala (KFD, 2003). pp 10-38.

Foster, B. L., Smith, V. H., Dickson, T. L. and Hildebrand. T. 2002. Invasibility and compositional stability in a grassland community: relationships to diversity and extrinsic factors. *Oikos* **99**: 300-307.

Frank, D. A. and McNaughton, S. J. 1991. Stability increases with diversity in plant communities: empirical evidence from the 1988 Yellowstone drought. *Oikos* **62**: 360-362.

Franklin, J. F. 1982. Old-growth forests in the Pacific Northwest: an ecological view. *In: Old-growth forests: a balanced perspective.* University of Oregon, Bureau of Governmental Research and Service, Eugene, Oregon, USA. Pp 5 to 27.

Franklin, J. F., Spies, T. A., Van Pelt, R., Carey, A. B., Thornburgh, D. A., Berg, D. R., Lendenmayer, D. B., Harmon, M. E., Keeton, W. S., Shaw, D. C., Bible, K., Chen, J. 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. *Forest Ecology and Management* **155**: 399–423.

Fredericksen, T. S. 1998. Limitations of low- intensity selection and selective logging for sustainable forestry. *Commonwealth Forest Review* **77**: 261-266.

Frost, E. J. 1992. *The effect of forest-clearcut edges on the structure and composition of old-growth mixed conifer stands in the western Klamath Mountains.* Masters of Arts thesis presented to Humboldt State University, California, USA.

Gadgil, M. and Meher-Homji, V. M. 1990. Ecological diversity *In*: J.C. Daniel and J.S Serrao (eds.) Conservation in Developing Countries: Problems and Prospects. *Proceedings of the Centenary Seminar of the Bombay Natural History Society,* Bombay Natural History Society and Oxford University Press, Bombay, India. Pp 175-198.

Gadgil, M. 1992. Biodiversity: Time for bold steps. *The Hindu Survey of Environment.* pp. 21-23.

Gadgil, M. 1996. Documenting diversity: An experiment. *Current Science* **70**: 36-44.

Gadgil, M. and Guha, R. 1992. *This fissured land: An ecological history of India.* Oxford University Press.

Galiano, E. F. 1982. Pattern detection in plant population through the analysis of plant- to- all plant distances. *Vegetatio* **49**: 39-43.

Gamble, J. S. and Fischer C. E. C. 1915-1935. *Flora of Presidency of Madras*, vol. 1-3. Botanical Survey of India (reprint Ed. 1957).

Gamble, J. S., 1935. Flora of Presidency of Madras, vol. 1-3. Adlard and son Ltd. London.

Ganade, G., and Brown, V. K. 2002. Succession in old pastures of Central Amazonia: Role of soil fertility and plant litter. *Ecology* **83**: 743–754.

Gardner, R. H. 1998. Patterns, process, and the analysis of spatial scales. *In*: Petersen, D. L. and Parker, V.T. (eds.), *Ecological scale: theory and applications.* Columbia University presss, New York. Pp. 17-34.

Garrigues, J. P. 1999. *Action anthropique sur la dynamique des formations ve´ge´tales au sud de l'Inde (Gha^ts occidentaux, Etat du Karnataka, District de Shimoga).* PhD Thesis, University Claude Bernard, Lyon 1.

Garza, C. M., and Howe, H. F. 2003. Restoring tropical diversity: beating the time tax on species loss *Journal of Applied Ecology* **40**: 423–429.

Gascon, C., Willianson, B. and Fonseca, G. A. B. 2000. Receding forest edges and vanishing reserves. *Science* **288**: 1356–1358.

Gaston, K. J. 1998. Species richness: measure and measurement. *In*: K.J. Gaston and J.I. Spicer(eds.), *Biodiversity: an introduction.* Blackwell science, Oxford, UK. Pp. 77-113.

Gaston, K. J. 2000. Global patterns in biodiversity. *Nature* **405**: 220–227.

Gaston, K. J., Spicer, J. I.2004. *Biodiversity: An introduction.* Blackwell Publishing, Oxford.

Gaston, K .J. 1994. *Rarity.* Chapman & Hall, London.

Gauch, H. G., Jr. 1982. *Multivariate Analysis in Community Structure.* Cambridge University Press, Cambridge.

Gaudet, C. L. and Keddy, P. A. 1988. A comparative approach to predicting competitive ability from plant traits. *Nature* **334**: 242-243.

Geldenhuys, C. J. 1997. Native forest regeneration in pine and eucalypt plantations in Northern Province, South Africa. *Forest Ecology and Management* **99**: 101–115.

Gentry, A. H. 1991. The distribution and evolution of climbing plants. *In*: F.E. Putz and H. A. mooney (eds.), *The biology of vines.* Cambridge university press, New York. Pp 3-52.

Gentry, A. H. 1995. Diversity and floristic composition of neotropical dry forests. *In*: Bullock, S. H., Mooney, H. A. & Medina, E. (eds). *Seasonally dry tropical forests.* Cambridge University Press, Cambridge. Pp. 146–193.

Gentry, A. H. and Dodson, H. C. 1987. Contribution of non-trees to species richness of tropical rain forest. *Biotropica,* **19**: 149-156.

Gentry, A. H. 1988. Changes in the plant community diversity and floristic composition on environmental and geographic gradients. *Annals of Missouri Botanical garden* **75**:1-34.

George, L. O., and Bazzaz, F. A. 1999. The fern understory as an ecological filter: Emergence and establishment of canopy tree seedlings. *Ecology* **80**: 833–845.

Gerhardt, K., and Fredriksson, D. 1995. Biomass allocation of broad-leaf mahogany seedlings *Swietena macrophylla* King. in abandoned pasture and secondary dry forest in Gaunacaste, Costa Rica. *Biotropica* **27**: 174-182.

Ghate, U., Joshi, N. V. and Gadgil, M. 1998. On the patterns of tree diversity in the Western Ghats of India. *Current Science* **75**: 594-604.

Gill, A. M., Williams, J. E. 1996. Fire regimes and biodiversity: the effects of fragmentation of southeastern Australian eucalypt forests by urbanization, agriculture and pine plantations. *Forest Ecology and Management* **85**: 261-278.

Gilliam, F. S., Turrill, N., Adams, M. B.1995. Herbaceous-layer and overstory species in clear-cut and mature central Appalachian hardwood forests. *Ecological Applications* **5**: 947–955.

Gilliam, F. S. 2002. Effects of harvesting on herbaceous layer diversity of a central Appalachian hardwood forest in West Virginia, USA. *Forest Ecology and Management* **155**: 33–43.

Gimaret-Carpentier, C., Pe'lissier, R., Pascal, J. P. and Houllier, F. 1998. Sampling strategies for the assessment of tree species diversity. *Journal of Vegetation Science* **9:** 161–172.

Gini, C. 1912. *Variabilit'a e mutabilit'a: contributo allo studio delle distribuzioni e delle relazioni statistiche,* in Studi Economico-giuridici della Regia Facolt'a Giurisprudenza, anno III, parte II, Cuppini, Bologna.

Githiru, M., Bennun, L. and Lens, L. 2002. Regeneration patterns among bird-dispersed plants in a fragmented Afrotropical forest, south-east Kenya. *Journal of Tropical Ecology* **18:** 143–149.

Goldberg, D. E. and Landa, K. 1991. Competitive effect and response: hierarchies and correlated traits in the early stages of competition. *Journal of Ecology* **79:** 1013-1030.

Goldberg, D. E. and Estabrook, G.F. 1998. Separating the effects of number of individuals sampled and competition on species diversity: an experimental and analytic approach. *Journal of Ecology* **86**: 983–988.

Goldsmith, E. R., Allen, M., Allaby, J. D. and Sam, L. 1972. *A Blueprint for Survival.* Middlesex: Penguin.

Goldthorpe, C. C. and Tan, L. I. 1996. A review of environmental issues in natural rubber production. *The Planter,* **72**(840): 123-139.

González-Bernádez, F. 1981. *Ecología y Paisaje.* Blume, Madrid.

González-Bernáldez, F. and Díaz-Pineda, F. 1980. Bases para la tipificación integrada de pastizales de dehesa. *Pastos* **10**(1): 20-43.

Gooselink, J. G. and Turner, R.E. 1978. The role of hydrology and fresh wetland ecosystems. *In*: Good,R.E. Whigham, D.F. and Simpson, R.L. (eds.), *Freshwater wetlands-Ecological processes and management potential.* Academic Press, New York. Pp. 63-78.

Gorresen, P. M., and Willig, M. R. 2004. Landscape-scale responses of bats to habitat fragmentation in Atalantic rainforest of Paraguay. *Journal of Mammalogy* **85:** 688-697.

Gotelli, N. J. and Ellison, A. M. 2002. Biogeography at a Regional Scale: Determinants of Ant Species Density in New England Bogs and Forests *Ecology* **83** (6): 1604-1609.

Gotelli, N. J. and Colwell, R. K. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. *Ecology Letters* **4**, 379–391.

Gottsberger, G. and Silberbauer-Gottsberger, I. 1983. Dispersal and distribution in the vegetation of Brazil. Sonderbaende des Naturwissenschaftlichen Vereins in Hamburg **7**: 315–352.

Gough, L., Grace, J. B. and Taylor, L. 1994. The relationship between species richness and community biomass: the importance of environmental variables. *Oikos*, **70**: 271-279.

Grassle, J. F. and Maciolek, N. J. 1992 Deep-sea species richness: regional and local diversity estimates from quantitative bottom samples. *American Naturalist* **139,** 313-341.

Gray, J. S. 1987. Species abundance patterns. *In*: Gee, J. H. R. and Giller, P. S. (eds), *Organization of communities,past and present.* Blackwell, Oxford. Pp 53-67.

Greenberg, C. H. Neary, D. G., Haris, L. D., Linda, S. P. 1995. Vegetation recovery following high intensity fire and silviculture treatments in sand pine scrub. *American Midland Naturalist* **133**: 149–163.

Grigg, D. B. 1974. *The Agricultural Systems of the World: An evolutionary approach.* Cambridge University press, London.

Grigg, D. B. 1970. *The Harsh Lands.* Mac Milan, London.

Guevara, S., Meave del Castillo, J., Moreno-Casasola, P. and Laborde, J. 1991. Floristic composition and structure of vegetation under isolated trees in neotropical pastures. *Journal of Vegetation Science* **3**: 655–664.

Gurudev, S. and Subramanian, K. N. 1991. Endemic plants of kerala and need for its conservation. *In* C.K. Karunakaran *et al.* (ed.) *Proceedings of Symposium on Rare and Endangered plants of the Western Ghats.* Forest department, Kerala. Trivandrum. Pp. 314-330.

Gustafson, E. J. and Gardner, R. H. 1996. The effect of landscape heterogeneity on the probability of patch colonization. *Ecology* **77**: 94–107.

Haila, Y. 1983. Land birds on northern islands: a sampling metaphor for insular colonization. *Oikos* **41**: 334-351.

Haines, W. B., 1929. Some considerations on soil pitting. *Quarterly Journal of Rubber Research Institute of Malaya*, **30**: 211.

Haines, W. B. and Pillay, K. S. 1933. Note on the activity of raw humus in relation to natural covers. *Journal of the rubber Research Institute of Malaya*, **5**(1): 14-21.

Halpern, C. B, Spies, T. A. 1995. Plant species diversity in natural and managed forests of the Pacific Northwest. *Ecological Applications* **5**: 913–934.

Halpern, C. B. 1989. Early successional patterns of forest species interactions of life history traits and disturbance. *Ecology* **70**: 704–720.

Hamer, K. C. and Hill, J. K. 2000. Scale-Dependent Effects of Habitat Disturbance on Species Richness in Tropical Forests *Conservation Biology* **14**(5): 1435-1440.

Hannerz, M. K. and Ha´nell, B. 1997. Effects on the flora in Norway spruce forests following clear cutting and shelter wood cutting. *Forest Ecology and Management* **90**: 29–49.

Harman, W. N. 1972. Benthic substrates: their effect on freshwater mollusca. *Ecology* **53**: 271- 277.

Harms, K. E., Powers, J. S. and Montgomery, R. A. 2004. Variation in small sapling density, understory over, and resource availability in four Neotropical forests. *Biotropica* **38**: 40–51.

Harrington, R. A. and Ewel, J. J. 1997. Invasibility of tree plantations by native and non-native indigenous plant species in Hawaii. *Forest Ecology and Management* **99**: 153–162.

Harris, L. D., Maser, C., McKee, A. 1982. Patterns of old-growth harvest and implications for Cascades wildlife. *Trans North Am Wildlife Natural Resource Conference* .**47**: 374–392.

Hayek, L. A. C., and Buzas, M. A. 1997. Surveying natural populations. Columbia University Press, New York.

Hayek, L. C., and Buzas, M. A. 1998. SHE analysis: an integrated approach to The analysis of forest biodiversity. *In*: Dallmeier, F., and Comiskey, J. (eds.) *Forest biodiversity research, monitoring and modeling.* UNESCO and Parthenon Publishing Group, Paris. Pp.311-321.

He F. and Legendre P. 2002. Species Diversity Patterns Derived from Species-Area Models. *Ecology* **83**(5): 1185-1198.

He, F., Legendre, P. and LaFrankie, J. V. 1996. Spatial pattern of diversity in a tropical rain forest in Malaysia. *J. Biogeogr.* **23**: 57-74.

Heck ,K. L. Jr, van Belle, G., Simberloff, D. 1975. Explicit calculation of the rarefaction diversity measurement and the determination of sufficient sample size. *Ecology* **56**: 1459- 1461.

Heck, K. L. Jr. and Orth. R. J. 1980. Structural components of eelgrass (Zostera marina) meadows in the lower Chesapeke Bay-decapod crustaceans. *Estuaries* **3**: 289-295.

Hector, A. 1998. The Effect of Diversity on Productivity: Detecting the Role of Species Complementarity *Oikos*, **82**(3): 597-599.

Heip, C. 1974. A new index measuring evenness. *J. Mar. Biol. Ass. UK.*, **54**, 555-557.

Heltshe, J. and Forrester, N. E. 1983. Estimating species richness using the jackknife procedure. *Biometrics* **39**: 1-11.

Henderson, P. A. and Seaby R. H. M. 2007. QED Statistics 1.1, Pisces Conservation Ltd, Lymington, England. www.piscesconservation.com

Henderson, P. A. and Seaby, R. M. H. 2007. Community Analysis Package (CAP) 4.0 Pisces Conservation Ltd., Lymington, England. www.piscesconservation.com

Hendon , D. and Charman, D. J. 2004. High resolution peat land water- table changes for the past 200 years: the influence of climate and implications for management. *Holocene* **14** (1): 125-134.

Hewatt, W. G. 1935. Ecological succession in the *Mytilus californianus* habitat as observed in Monterrey Bay, California. *Ecology* **16**: 244-253.

Heywood, V. H. 1995. *Global biodiversity assessment,* Cambridge University Press, Cambridge.

Hill, J. L. and Curran, P. J. 2001. Species composition in fragmented forests: conservation implications of changing forest area. *Applied Geography* **21**(2): 157-174.

Hill, M. O. 1973. Diversity and evenness: a unifying notation and its consequences. *Ecology* **54**: 427-432.

Hodgson, J. G. 1987. Why do so few plant species exploit productive habitats? An investigation into cytology, plant strategies and abundance within a local flora. *Functional ecology* 1: 243-250.

Holl, K. H. 1999. Factors limiting tropical rain forest regeneration in abandoned pastures: seed rain, seed germination, microclimate and soil. *Biotropica* **31**, 229–242.

Holt, R. D., Lawton, J. H., Polis, G. A. and Martinez, N. D. 1999. Tropical rank and the species-area relationship. *Ecology* **80**: 1495-1504.

Honnay, O., Verheyen, K., Butaye, J., Jaquemyn, H., Bossuyt, B., Hermy ,M. 2002. Possible effects of habitat fragmentation and climate change on the range of forest plant species. *Ecology Letters* **5**: 525–530.

Hooker, J. D. 1907. Sketch of the flora of British India. *Imperial Gazetteer of India* 3(1&4): 157-211.

Hooper, D. U. and Vitousek, P. M. 1997. The effects of plant composition and diversity on ecosystem processes. *Science* **277** (5330): 1302-1305.

Howe, H. F. and Westley, L.C. 1997. Ecology of pollination and seed dispersal. *In* M.J. Crawley (ed.) *Plant Ecology*, 2nd edn. Blackwell Science, London, UK. Pp. 262-283.

Huges, R. G. 1986. Theories and models of species abundance. *American Naturalist* **128**: 879-899.

Hulbert, S. H. 1971. The non-concept of species diversity: a critique and alternative parameters. *Ecology* **52**: 577-586.

Huston, J. 1997. Hidden treatments in biological experiments: re-evaluating the ecosystem function of biodiversity. *Oecologia* **110**:449-460.

Huston, M. 1979. A general hypothesis of species diversity. *American Naturalist* 113:81-101.

I'ma, N., Vijayakumar, K. R. and Sethuraj, M. R. 2005. Intercropping of medicinal plants in rubber plantations- light requirements and mechanism of shade adaptation. *International Natural Rubber Conference*. Pp. 205-209.

Inderjit. and Dakshini, K. M. M. 1990. The nature of interference potential of the weed *Pluchea lanceolata* (DC) C.B. Clark (Asteraceae). *Plant Soil* **122**: 298.

Inderjit. and Dakshini, K. M. M. 1992. interference potential of the weed *Pluchea lanceolata* (Asteraceae): growth and physiological responses of asparagus bean, *Vigna unguiculata* var. *sesquipedalis, American Journal of Botany* **79**: 977.

Inderjit and Duke S. O. 2003. Ecophysiological aspects of allelopathy. *Planta* **217**: 529-539.

Inderjit. 1996. Plant phenolics in allelopathy. *Botanical Review* **62**: 186-202.

Indian Rubber Statistics (2008) published by The Rubber Board of India , Kottayam, India.Pp. 1-10.

Ingle, N.R. 2003. Seed dispersal by wind, birds and bats between Philippine montane rainforest and successional vegetation. *Oecologia* **134**: 251–261.

Investigation Group of Multi- layer Farming in Rubber Plantations of Hainan State Farms, Guangdong State Farms Bureau. 1988. An investigation report of multilayer farming in rubber plantations in Hainan state farms. *Research on Tropical Crops* **2**: 1.

Irlandi, E. A., Crawford, M.K. 1997. Habitat linkages: the effect of intertidal saltmarshes and adjacent subtidal habitats on abundance, movement, and growth of an estuarine fish. *Oecologia* **110:** 222-230.

IUCN red data book of Indian plants. 2002. M.P. Nayar and A.R. K. Shastri (eds.), publ. Botanical survey of India, Govt. of India.

Jacob, J, Chaudhuri, D, Thaliyal, A. P., Mondal, D., Singh, R. P., Met, S., Dekka, H. K., and Devakumar, A. S. 2002. Ecological impact of natural rubber, teak and Jarul plantations. *In*: Rethinam, R., Khan, H.H., Reddy, V.M., Mandal, P. K. and

Suresh, K. (Eds.). *Plantation Crops Research and development in the New Millenium*. Coconut Development Board, India. Pp 365-369.

Jacquemyn, H., Butaye, J. and Hermy, M. 2001. Forest plant species richness in small fragmented mixed deciduous forest patches: the role of area, time and dispersal limitation. *Journal of Biogeography* **28**: 801–812.

Jacquemyn, H., J. Butaye and M. Hermy. 2003. Influence of environmental and spatial variables on regional distribution of forest plant species in a fragmented and changing landscape. *Ecography* **26**: 768-776.

Jain, S. K. and De Fillipps R. A. 1991. *Medicinal Plants of India* (Vol1&2). Reference publication INC. Algonac, Michigan.

Janzen, D. H. 1966. Synchronization of sexual reproduction of trees within the dry season in Central America. *Evolution* **21**: 620–637.

Janzen, D. H. 1988. Management of habitat fragments in a tropical dry forest: growth. *Annals of the Missouri Botanic Garden* **75**: 105–116.

Janzen, D. H. 2000. Costa Rica's Area de Conservacio´n Guanacaste: a long march to survival through non-damaging biodevelopment. *Biodiversity* **1**: 7–20.

Jesus, R. M. 2001. *Manejo florestal: impactos ecológicos de diferentes níveis de remoção e os impactos de sua sustentabilidade.* PhD thesis, Universidade de Campinas, Campinas, Brazil.

Johnson, K. G., Vogt, K. A., Clark, H. J., Schmitz, O. J. and Vogt, D. J. 1996. Biodiversity and the productivity and stability of ecosystems. *Trends Ecol. Evol.* **11**, 372–377.

Jones, K. P. 1994. Natural rubber as a green commodity: Part II. *Rubber Developments*, **47**(3): 37-41.

Jones, K. P. and Allen, P. W. 1992. Historical development of the world rubber industry. *In*: Sethuraj, M. R. and Mathew, N. M. (Eds.), *Natural Rubber: Biology, Cultivation and technology* Elsevier, Amsterdam, Netherland. Pp.1-25.

Jones, M. D., Durall, D. M. and Cairney, J. W. G. 2003. Ectomycorrhizal fungal communityes in young forest stands regenerating after clear-cut logging. *New Phytol* **157**: 399–422.

Jordan, C. 1983. Productivity of tropical rain forest ecosystems and the implications for their use as future wood and energy sources. *In*: Golley, F. (Ed) *Tropical rain forest ecosystems: structure and function.* Elsevier, Amsterdam. Pp. 117-135.

Joseph, K. T. 1991. Soil conservation *In*: R. Kiew (ed). *The state of Nature Conservation in Malaysia.* Malayan Nature Society, Kuala Lumpur, Malaysia. Pp. 209-221.

Jules E. S. 1998. Habitat fragmentation and demographic change for a common plant: Trillium in old-growth forest. *Ecology* **79**: 1645–1656.

Jules, E. S. and Rathcke, B. J. 1999. Mechanisms of reduced trillium recruitment along edges of old-growth forest fragments. *Conservation Biology.* **13**: 784–793.

Kammer, P. M., and Möhl, A. 2002. Controlling species richness in Alpine plant communities: An assessment of the importance of stress and disturbance. *Artic, Antartic and Alpine Research* **34**(4): 398-407.

Kapoor, V. 2008. Effects of rainforest fragmentation and shade-coffee plantations on spider communities in the Western Ghats, India. *Journal of Insect Conservation* **12**: 53–68.

Kareiva, P. M., Kingsolver, J. G. and Huey, R. G. 1993. (ed.) *Biotic Interactions and Global Change* Sinauer Associates Inc., Sunderland, MA.

Kawarasaky S. and Y. Hori. 2001. Flowering phenology of understory herbaceaous species in a cool temperate deciduous forest in Ogawa forest reserve, Central Japan. *Journal of Plant Research* **114**: 19-23.

Keating, K. A. and Quinn, J. F. 1998. Estimating species richness: the Michaelis-Menten model revisited. *Oikos* **81**: 411-416.

Keel, S., Gentry, A. H. and Lucio S. 1993. Using Vegetation Analysis to Facilitate the Selection of Conservation Sites in Eastern Paraguay. *Conservation Biology* 7(1): 66-75.

Keenan R., Lamb, D., Woldring, O., Irvine T. and Jensen R. 1997. Restoration of plant biodiversity beneath tropical tree plantations in Northern Australia. *Forestry Ecology and Management* **99**: 117–131.

Kempton, R. A. 1979. The structure of species abundance and measurement of diversity. *Biometrics* **35**: 307-321.

Kempton, R. A. and Taylor, L. R. 1976. Models and statistics for species diversity. *Nature* **262**: 818-820.

Kendall, D. G. 1948. On some modes of population growth leading to Fisher, R.A. logarithmic series distribution. *Biometrika* **35**: 6–15.

Kent, M. and Coker, P. 1992. *Vegetation description and analysis: A practical approach.* John Wiley and Sons, Chichester, 363 pp.

Kerala State Land Use Board (KSLUB) 1997. *Land Resources of Kerala State.* Vikas Bhavan, Thiruvananthapuram. pp.209

Kerr, J. T. and Packer, L. 1997. Habitat heterogeneity as a determinant of mammal species richness in high-energy regions. *Nature* **385**: 252-254.

Kilburn, P. D. 1966. Analysis of the species-area relation. *Ecology*, **47**, 831- 843.

King, A. W., and Pimm, S. L. 1983. Complexity, diversity, and stability: a reconciliation of theoretical and empirical results. *American Naturalist* **122**: 229-239.

Koch, A. S. and Matzner, E. 1993. Heterogeneity of soil and soil solution chemistry under Norway spruce (Picea abies Karst.) and European beech (Fagus silvatica L.) as influenced by distance from the stem basis. *Plant Soil* **151**: 227–237.

Kohn, A. J. 1967. Environmental complexity and species diversity in the gastropod genus *Conus* on Indo-West Pacifc reef platforms. *American Naturalist* **101**: 251- 260.

Kolasa, J. and Biesiadka, E. 1984. Diversity cocept in ecology. *Acta Biotheor* **33**: 145–162.

Korning, J., Thomsen, K., Dalsgaard, K. and Nørnberg, P. 1994. Characters of three Udults and their relevance to the composition and structure of virgin rain forest of Amazonian Ecuador. *Geoderma* **63**: 154-164.

Kothandaraman, R., Jacob M., Krishnakumar, A. K., Kochuthresiamma, J., Jayarathnam, K. and Sethuraj,M. R. 1989. Comparative efficiency of *Mucuna bracteata* DC and *Pueraria phaseoloides* Benth on soil nutrient enrichment, microbial population and growth of *Hevea*. *Indian Journal of natural Rubber Research,* **2**(2): 147-150.

Krebs, C. J. 1989. *Ecological Methodology*. Harper Collins, New York.

Kremen, C., Colwell, R. K., Erwin, T. L., Murphy, D. D., Noss, R.F. and Sanjayan, M.A. 1993. Terrestrial arthropod assemblages: their use in conservation planning. *Conservation Biology* **7:** 796-808.

Krishnakumar, A. K., Gupta, C., Sinha , R. R., Sethuraj, M. R., Potty, S. N, Eappen, T. and Das, K. 1991. Ecological impact of rubber (*Hevea brasiliensis*) plantations in North East India: 2.Soil properties and biomass recycling. *Indian Journal of Natural Rubber Research* **4**(2): 134-141.

Krishnakumar, A. K. and Potty, S. N. 1992. Nutrition of *Hevea*. *In*: Sethuraj, M. R. and Mathew, N. M. (eds).*Natural Rubber: Biology Cultivation and Technology,* Elsevier, Amsterdam. Pp. 239-262.

Kruscal, J. B. and Wish, M. 1977. *Mulidimensional Scaling*. Sage Publications. Beverly Hills. CA.

Kruscal, J. B. 1964. Nonmetric multidimensional scaling: a numerical method. *Psychometrika* **29**: 115-129.

Kunwar, R. P. and Sharma, S. P. 2004. Quantitative analysis of tree species in two community forests of Dolpa district, mid-west Nepal. *Himalayan Journal of Sciences* **2** (3): 23-28.

Lamb D. 1998. Large-scale ecological restoration of degraded tropical forest lands: The potential role of timber plantations. *Restoration Ecology* **6**, 271–279.

Lamb, D., Parrotta, J., Keenan, R. and Tucker, N. 1997. Rejoining habitat remnants restoring degraded rainforest land. *In*: Laurance, W.F. and Bierregaard, R.O. Jr (eds), *Tropical Forest Remnants*. University of Chicago Press, Chicago, IL. Pp. 366–385.

Lambshead, P. J. D. and Platt, H. M. 1985. Structural patterns of marine benthic assemblages and their relationship with empirical statistical models. *In* Gibbs, P.E. (ed.), *Proc. 19th European Marine Biology Symposium* Cambridge univ. Press, Cambridge, UK. Pp. 371-380.

Lande, R. 1996. Statistics and partitioning of species diversity, and similarity among multiple communities. *Oikos* **76**: 5–13.

Lande, R., P. J. DeVries, and Walla, T. R. 2000. When species accumulation curves intersect: implications for ranking diversity using small samples. *Oikos* **89**:601–605.

Lara- Nunez, A. , Romero- Romero, T. , Ventura, J. L., Blancas, V., Anaya , A. L. and Cruz- Ortega, R. 2006. Allelochemical stress causes inhibition of growth and oxidative damage in *Lycopersicon esulentum* Mill. *Plant Cell and Environment* **29**: 2009-2016.

Launer, A. E., and Murphy, D. D. 1994. Umbrella species and the conservation of habitat fragments: a case of a threatened butterfly and a vanishing grassland ecosystem. *Biological Conservation* ***69*:** 145- 153.

Laurance, W. F. 1998. Effect of forest fragmentationon recruitment patterns in Amazonion tree communities. *Conservation Biology* **12**: 460-464.

Laurance, W. F., and. Bierregaard, R. O. (Eds.). 1997. Tropical forest remnants: Ecology, management and conservation of fragmented communities. University of Chicago Press, Chicago.

Laurance, W. F. 1991. Edge effects in tropical forest fragments: application of a model for the design of nature reserves. *Biological Conservation* **57**: 205–219.

Laurance, W. F. 2001. Fragmentation and plant communities: synthesis and implications for landscape management. *In*: R.O. Bierregaard Jr., C. Gascon, T.E. Lovejoy & R.C.G. Mesquita (eds), *Lessons from Amazonia: The Ecology and Conservation of a Fragmented Forest.* Yale University Press, New Haven, USA. Pp. 158–168.

Laurance, W. F., Delaminica, P., Laurance, S. G., Vasconcelos ,H. L. and Lovejoy,T. E. 2000. Rainforest fragmentation kills big trees. *Nature* **404**: 836.

Laurance, W. F., Laurance, S. G., Ferreira, L. V., Rankin-de Merona, J. M., Gascon, C. and Lovejoy, T. E. 1997 . Biomass collapse in Amazonian forest fragments. *Science* **278**: 1117-1118.

Laurance, W. F., Ferreira,L. V., Rankin-de Merona, J. M. and Laurance, S. G, Hutchings, R. W. and Lovejoy, T. E. 1998a. Effects of forest fragmentation on recruitment patterns in Amazonian tree communities. *Conservation Biology* **12**, 460-464.

Laurance, W. F., Ferreira, L. V.,Rankin-de Merona, J. M. and Laurance, S. G. 1998b. Rain forest fragmentation and the dynamics of Amazonian tree communities. *Ecology* **79**, 2032-2040.

Lee, S. M. and Chao, A. *1994.* Estimating population size via sample coverage for closed capture–recapture models. *Biometrics* **50**, 88–97.

Legendre, L. and Legendre, P. 1983. *Numerical Ecology.* Elsevier Scientific Publishing Company, Amsterdam, 419 pp.

Legendre, P. and Legendre, L. 1998. *Numerical Ecology.* Elsevier Science, Amsterdam, 2nd edition.

Leigh, E. G. Jr, Wright, S. J., Herre, E. A. and Putz, F. E. 1993. The decline of tree diversity on newly isolated Tropical Island: a test of a null hypothesis and some implications. *Evolutionary Ecology* **7**: 76–102.

Leps, J., Osbornová-Kosinová, J. and Rejmánek, M. 1982. Community stability, complexity and species life history strategies. *Vegetatio* **50**: 53-63.

Levassor, C., Diaz- Pineda, F. and Gonzälez-Bernädez, F. 1981. Tipología de pastizales en relación con el relieve. *Pastos* **11**(3):45-68.

Lewis, C. E., Swindel, B. F. and Tanner, G. W. 1988. Species Diversity and Diversity Profiles: Concept, Measurement, and Application to Timber and Range Management.*Journal of Range Management.* **41**(6): 466-469.

Liberman, D. and Li, M. 1992. Seedling recruitment patterns in a tropical dry forest in Ghana.*Journal of Vegetation Science* **3**: 375–382.

Lieberman, D. 1982. Seasonality and phenology in a dry tropical forest in Ghana. *Journal of Ecology* **70**: 791–806.

Lieberman, M., Lieberman, D., Hartshorn, G. S. and Peralta, R. 1985. Small-scale altitudinal variation in lowland wet tropical forest vegetation. *Journal of Ecology* **73**: 505-516.

Liu, C., Whittaker, R. J., Ma, K. and Malcolm, J. R. 2007. Unifying and distinguishing diversity ordering methods for comparing communities. *Population Ecology* **49**(2): 89-100.

Lomolino, M. V. 2000. Ecology's most general, yet protean pattern: the species–area relationship. *Journal of Biogeogaphy* **27**: 17–26.

Longino, J. T., Coddington, J. and Colwell, R. K. 2002. The ant fauna of a tropical rain forest: estimating species richness three different ways. *Ecology* **83**: 689–702.

Loumeto, J., J. and Huttel, C. 1997. Understorey vegetation in fast-growing tree plantations on savanna soils in Congo. *Forest Ecology and Management* **99**: 65–81.

Lovejoy, T. E., Bierregaard, R. O., Rylands, A.B., Malcolm, J. R.,. Quintela, C. E, Harper, L.H., Brown, K. S., Powell, A. H., Powell, G. V. N., Schubart, H. O. R. and Hays. M. B. 1986. Edge and other effects of isolation on Amazon forest fragments. *In*: Soule, M. E. (Ed). *Conservation biology: The science of scarcity and diversity.* Sinauer, Sunderland, Massachusetts. Pp. 257-285.

Loya, D. T. and Jules, E. S. 2008. Use of species richness estimators improves evaluation of understory plant response to logging: a study of redwood forests. *Plant Ecology* **194**: 179–194.

Lubchenco, J., and 15 other authors. 1991. The sustainable biosphere initiative: an ecological research agenda. *Ecology* **72**(2): 371-412.

Ludwig, J. A., and Reynolds, J. F. 1988. Statistical ecology: a primer on methods and computing. John Wiley and Sons, New York, NY, USA.

Lugo A. E. 1992. Tree plantations for rehabilitating damaged forest lands in the tropics. *In:* Wali, M. K. (ed.). *Ecosystem Rehabilitation*, Vol. 2. *Ecosystem Analysis and Synthesis*, Academic Publishing, The Hague. Pp. 247–255.

Lugo, A. E., Parotta, J. A. and Brown, S. 1993. Loss in species caused by tropical deforestation and their recovery through management. *Ambio* **22:** 106–109.

Lugo, A. E. 1988. The future of the forest: ecosystem rehabilitation in the tropics. *Environment* **30**(7): 41–45.

Lugo, A. E. 1997. The apparent paradox of establishing species richness on degraded lands with tree monocultures. *Forest Ecology and Management* **99**, 9–19.

Lugo, A. E. and Brown, S. 1992.The tropical forests as sinks of atmospheric carbon. *Forest. Ecology and Management* **54**, 239-255.

MacArthur, R. 1972. Geographical Ecology. Princeton University Press, Princeton, New Jersey.

MacArthur, R. H. 1957. On the relative abundance of birds species. *Proceeding of the National Academy of Science* **43**: 293-295.

MacArthur, R. H. 1958. Population ecology of some warblers of Northeastern coniferous forests. *Ecology* **39**: 599-619.

MacArthur, R. H. 1964. Environmental factors affecting bird species diversity. *American Naturalist* **98**: 387-397.

MacArthur, R. H. and Wilson, E. O. 1967. The theory of island biogeography. Princeton Univ. Press, New York.

Machado, I. C. S., Barros, L. M. and Sampaio, E. V. S. B. 1997. Phenology of caatinga species at Serra Talhada, PE, Northeastern Brazil. *Biotropica* **29**: 57–68.

Magurran, A. E. 1988. *Ecological diversity and its measurement.* Princeton University Press, Princeton, New Jersey, USA.

Magurran, A. E. 2004 Measuring Ecological Diversity. Blackwell Publishing, Oxford. p. 256.

Magurran, A. E. and Henderson, P. A. 2003. Explaining the excess of rare species in natural species abundance distributions. *Nature* 422: 714-716.

Maina, G. and Howe, H. F. 2000. Inherent rarity in community restoration. *Conservation Biology,* **14**, 1335–1340.

Makana, J. R. and Thomas, S. C. 2005. Effects of light gaps and litter removal on the seedling performance of six African timber species. *Biotropica* **37**(2): 227-237.

Mantovani, W. and Martins, F. R. 1988. Variac,o˜es fenolo´gicas das espe´cies do cerrado da Reserva Biolo´gica de Moji Guac,u, Estado de Sa˜o Paulo. *Revista Brasileira de Bota˘nica* **11**: 101–112.

Mao, C. X. and Colwell, R. K. 2005. Estimation of species richness: mixture models, the role of rare species, and inferential challenges. *Ecology* **86**: 1143-1153.

Mao, C. X., Colwell, R. K. and Chang, J. 2005. Estimating the Species Accumulation Curve Using Mixtures *Biometrics* **61**: 433-441.

Markham, C. R. 1876. The cultivation of Caoutchouc yielding trees in British India. *Journal of the Society of Art.* Pp. 475-482.

Marquet, P. A., Keymer, J. E. and Cofre, H. 2003. Breaking the stick in space: of niche models, metacommunities and patterns in the relative abundance of species. *In* Blackburn, T. M. and Gaston, K. J. (ed.) *Macroecology: Concepts and Consequences.* Cambridge: Cambridge University Press. Pp. 64-84.

Martinez, N. D., Hawkins, B. A., Dawah, H. A. and Feifarek, B. P. 1999. Effects of sampling effort on characterization of food-web structure. *Ecology* **80**:1044–1055.

Martínez-Garza, C. and González-Montagut, R. 1999. Seed rain from forest fragment into tropical pastures in Los Tuxtlas, Mexico. *Plant Ecology* **145**: 655–665.

Martínez-Garza, C. and González-Montagut, R. 2002. Seed rain of fleshy-fruited species in tropical pastures in Los Tuxtlas, Mexico. *Journal of Tropical Ecology* **18**: 457- 462.

Mathew, G. Rugmini, P. and Sudheendrakumar, V. V., 2004. Effect of plantation programmes on insect species diversity- a study in Parambikulam forest, Kerala, India. *Entomon* **29** (4): 361-372.

Matlack, G. R. 1994. Plant species migration in a mixed-history forest landscape in eastern North America. *Ecology* **75**: 1491–1502.

Maury-Lechon, G. 1993. Biological characters and plasticity of juvenile tree stages to restore degraded tropical forests: a systems framework for site analysis and restoration research. *In*: H. Lieth & M. Lohmann (eds.), *Restoration of Tropical Forest Ecosystems*. Kluwer Academic Publishers, Dordrecht, the Netherlands. Pp. 37–46.

May, R. M. 1973. *Stability and complexity in model ecosystems*. Princeton University Press, Princeton, New Jersey, USA.

May, R. M. 1975. Patterns of species abundance and diversity. *In* Cody, M. L. and Diamond, J. M. (eds.), *Ecology and evolution of communities*. Harvard Univ. Press, Cambridge, MA, pp. 81-120.

May, R. M. 1981. Models for two interacting populations. *In*: May, R. M. (ed.), *Theoretical ecology- Principles and applications*. Sinauer, Sunderland, MA. Pp. 78-104.

May, R. M. 1975. Patterns of species abundance and diversity. *In*: Cody, M.L. & Diamond, J.M. (eds). *Ecology and Evolution of Communities*. Belknap Press of Harvard University Press, Cambridge MA. Pp. 81–120.

McCabe, D. J. and Gotelli, N . J. 2003. Caddisfly diapause aggregations facilitate benthic invertebrate colonization. *Journal of Animal Ecology* 72: 1015-1026.

McCarthy, B. C.,. Small, C. J and Rubino, D. L. 2001. Composition, structure, and dynamics of Dysart Woods, an old-growth mixed mesophytic forest of southeastern Ohio. *Forest Ecology and Management* **140**: 193-213.

McGill, B. J. Etienne, R. S., Gray, J. S., Alonso, D., Anderson, M. J., Benecha, H. K., Dornelas, M., Enquist, B. J., Green, J. L., He, F., Hurlbert, A. H., Magurran, A. E. Marquet,, P.A., Maurer, B. A., Ostling, A., Soykan, C. U., Ugland, K. I., and White E. P. 2007. Species abundance distributions: moving beyond single prediction theories to integration within an ecological framework. *Ecology Letters* **10:** 995–1015.

McGill, B. J., Etienne, R.S., Gray, J. S., Alonso, D., Anderson, M. J., Benecha, H. K., Dornelas, M., Enquist, B. J., Green, J. L., He, F., Hurlbert, A. H., Magurran, A. E., Marquet, Maurer, B. A., Ostling, A, Soykan, C. U., Ugland, K.I and White, E. P. 2007. Species abundance distributions: moving beyond single prediction theories to integration within an ecological framework. *Ecology Letters* **10**: 995–1015.

McIntosh, R. P. 1967. An index of diversity and the relation of certain concepts to diversity. *Ecology* **48**: 392–402.

McNaughton, S. J. 1977. Diversity and stability of ecological communities: a comment on the role of empiricism in ecology. *Americal Naturalist* **111**: 525-525.

McNaughton, S. J. and Wolf, L. L. 1970. Dominance and the niche in ecological systems. *Science*, **167**, 131-139.

McNeely, J. A., Miller, K. R., Reid, W. V., Mittermeier, R. A. and Werner, T. B. 1990. *Conserving the World's Biological Diversity*. Gland, Switzerland: IUCN-The World Conservation Union and Washington, DC, USA: the World Resources Institute, Conservation International, World Wide Fund for Nature and The World Bank.

Medina, E. 1995. Diversity of life forms of higher plants in neotropical dry forests. *in* Bullock, Mooney, S. H., and Mooney, H. A. and Medina, E. (eds). *Seasonally dry tropical forests*. Cambridge University Press, Cambridge. Pp. 221–242.

Meier, A. J., Brantton, S. P., and Duffy, D. C. 1995. Possible ecological mechanisms for loss of vernal-herb diversity in logged eastern deciduous forests. *Ecological Applications* **5**: 935–946.

Melo, F. P. L. 2004. Efeito de Borda, Chuva de Sementes e o Recrutamento de Plântulas: o Caso das Grandes Sementes. MSc thesis, Universidade Federal de Pernambuco, Recife, Brazil.

Menon, A. R. R. 1987. Forest Flora and Conservation. Biology and Utility of Wild Plants. South Gujarat University: 146-159.

Menon, S. and K. S. Bawa. 1997. Applications of Geographic Information Systems (GIS), remote-sensing, and a landscape ecology approach to biodiversity conservation in the Western Ghats. *Current Science* **73**(2): 134-145.

Michelsen, A., Lisanework, N., Friis, I. and Holst, N. 1996. Comparisons of understorey vegetation and soil fertility in plantations and adjacent natural forests in the Ethiopian highlands. *The Journal of Applied Ecology* **33**(3): 627-642.

Miller, P. M. 1999. Effects of deforestation on seed banks in a tropical deciduous forest of eastern Mexico. *Journal of Tropical Ecology* **15**: 179–188.

Miller, R. I. and White, P. S. 1986. Considerations for preserve design based on the distribution of rare plants in Great Smoky Mountains national Park, U.S.A. *Journal of Environmental Management* **10**: 119-124.

Miller, R. I. and Wiegert, R. G. 1989. Documenting completeness, species-area relations, and the species- abundance distribution of a regional flora. *Ecology* **70**: 16-22.

Mingoti, S. A. and Meeden, G. 1992. Estimating the total number of distinct species using presence and absense data. *Biometric*, **48**: 863-75.

Miriti, M. N. 1998. Regeneracao florestal em pastagens abandonadas na Amazonia Central: competicao, predação, e dispersao de sementes. Floresta Amazonica: Dinamica, Regeneracao E Manejo (eds.) C. Nacional de Pesquisa da Amazonia, Manaus, Brazil. Pp. 179–191.

Montgomery, R. A. 2004. Effects of understory foliage on patterns of light attenuation near the forest floor. *Biotropica* **36**: 33–39.

Moola, F. M. and Vasseur, L. 2004. Recovery of late-seral vascular plants in a chronosequence of post-clear cut forest stands in coastal Nova Scotia, Canada. *Plant Ecology* **172**: 183–197.

Mooney, H. A., Cushrnan ,J. H., Medlna, E., Sala, O. E. and Schulze, E. D. (eds.). 1996. *Functional Roles of Biodiversity: A Global Perspective.* John Wiley and Sons, Chichester.

Moore, A. 1938. Rubber growing: Elementary principles and practice. Rubber Research Institute of Malaya,*Planting Manual*, 7.

Moore, W. H, Swindel, B. F. and Terry, W. S. 1982a. Vegetation response to clearcutting and chopping in a north Florida flatwoods forest. *Journal of Range Manage.* **35**: 214-218.

Moore,W. H., Swindel, B. F. and Terry, W. S. 1982b. Vegetative response to prescribed fire in a north Florida flatwoods forest. *Journal of Range Manage.* **35**: 386-389.

Moran, V. C. 1980. Interactions between phytophagous insects and their Opuntia hosts. *Ecological Monographs* **50**: 153-164.

Morellato, L. P. C. and Leita˜o-Filho, H. F. 1992. Padro˜es de frutificac¸a˜o e dispersa˜o na Serra do Japi. *In*: Morellato, L. P. C. (ed.). *Histo´ria natural da Serra do Japi.* Editora da UNICAMP, Campinas. Pp. 112–139.

Morellato, L. P. C., Rodrigues, R. R., Leita˜o-Filho, H. F. and Joly, C. A. A. 1989. Estudo comparativo da fenologia de espe´cies arbo´reas de floresta de altitude e floresta meso´fila semideciı´duana Serra do Japi, Jundiaı´, Sa˜o Paulo. *Revista Brasileira de Bota^nica* **12**: 85–98.

Moreno, C. E. and Halffter, G. 2000. Assessing the completeness of bat biodiversity inventories using species accumulation curves. *Journal of Applied Ecology* **37**, 149-158.

Morley, R. J. 2000. Origin and evolution of tropical rain forests. John Wiley & Sons, Chichester.

Morris, S. and Lau, C. H. 1990. Soil fertility changes following land clearing and rubber culltivation. *International Soil Science Congress*, Koyoto, Japan. Pp. 22-27.

Motomura, I. 1932. A statistical treatment of associations. *Japanese Journal of Zoology* **44**: 379-383.

Murdoch, W. W., Evans, F.C. and Peterson, C.H. 1972. Diversity and pattern in plants and insects. *Ecology*, **53**: 819-829.

Muthuramkumar, S., Ayyappan, N. and Parthasarthy, N. 2006. Plant Community Structure in Tropical Rain forest Fragments of the Western Ghats, India. *Biotropica* **38**(2): 143-160.

Myers, N. 1988. Threatened biotas: "hot spots" in tropical forests. *The Environmentalist* **8**: 1-20.

Myers, N. 1990. The biodiversity challenge: expanded hot-spots analysis. *The Environmentalist* **10**: 273-256.

Naeem, S., Thompson, L. I., Lawler, S. P., Lawton, J. H. and Woodfin, R. M. 1994. Declining biodiversity can alter the performance of ecosystems. *Nature* **368**: 734-737.

Naeem, S. 1998. Species redundancy and ecosystem reliability. *Conservation Biology* **12**: 39-45.

Nair, K. K. N. and Basha, S. C. 1995. Centers in Kerala rich in endemic angiosperms as potential sites for biodiversity preservation. *J.Econ. Tax. Bot.* **19**(3): 719-733.

Nair, N. C. and Daniel, P. 1986. The flora of the Western Ghats: A review. *Proceedings of the Indian Academy of Science* (Suppl.). pp. 127-163.

Narendra Prasad, S. 1998. Conservation planning for the Western Ghats of Kerala: II. Assessment of habitat loss and degradation. *Current Science* **75**: 228–235.

National Strategy for Conservation and Sustainable Development. 1990. Govt of India.

Nayar, M. P. 1996. *Hot Spots of Endemic plants of India, Nepal and Bhutan*. Tropical Botanic Garden and Research Institute, Trivandrum, S.B Press.

Nayar, T. S. 1994. A concise review of the forest flora of Kerala. *Journal of the Bombay Natural History Society*, 91(1): 212-219.

Nepstad, D., Pereira, C. A. and.Cardoso da SIlva. J. M. 1996. A comparative study of tree establishment in abandoned pasture and mature forest of eastern Amazonia. *Oikos* **76**: 25–39.

Ney-Nifle, M., and M. Mangel. 1999. Species-area curves based on geographical range and occupancy. *Journal of theoretical Biology* **196:** 327-342.

Ng, K. F., Stur, W. W. and Shelton, H. M. 1997. New forage species for integration of sheep in rubber plantations. *Journal of Agricultural sciences*, **128**(3): 347-355.

Niemel¨a, J., and Baur, B. 1998. Threatened species in a vanishing habitat: plants and invertebrates in calcareous grasslands in the Swiss Jura mountains. *Biodiversity and Conservation* **7**: 1407–1416.

Nijs, I., and Roy, J. 2000. How important are species richness, species evenness and interspecific differences to productivity? A mathematical model. *Oikos* **88**: 57-66.

Nijs; I., Impens, I. 2000. Biological Diversity and Probability of Local Extinction of Ecosystems *Functional Ecology* **14**(1): 46-54.

Nøhr, H., and Jørgensen. A. F. 1997. Mapping of biological diversity in Sahel by means of satellite image analyses and ornithological surveys. *Biodiversity and Conservation* **6**: 545-566.

Noss, R. F., and Cooperrider. A. Y. 1994. *Saving nature's legacy.* Island Press, Washington, D.C.

Økland, T. 1990. Vegetational and ecological monitoring of boreal forests in Norway. I. Rausjomarka in Akershus county, SE Norway. *Sommerfeltia* **10**: 1–52.

Oliveira , M. A., Grillo, A. S. and Tabarelli, M. 2004. Forest edge in the Brazilian Atlantic forest: drastic changes in tree species assemblages *Oryx* **38** (4): 389-394.

Oliveira, P. E. 1998. Fenologia e biologia reprodutiva de espe´cies de Cerrado. In: Sano, S. M. and Almeida, S. P. (eds.). *Cerrado: flora e ambiente.* Embrapa-CPAC, Planaltina, DF. Pp. 169–192.

Oliveira-Filho A. T., Marcio de Mello J. and Scolforo J.R.S. 1997. Effects of past disturbance and edges on tree community structure and dynamics within a fragment of tropical semideciduous forest in south-eastern Brazil over a five-year period (1987-1992). *Plant Ecology* **131**: 45-66.

Oliver, C. D. and Larson, B. C. 1996. *Forest Stand Dynamics.* Update Edition. John Wiley and Sons, New York. pp. 521.

Oliver, J., and Beattie, A. J. 1996. Designing a cost-effective invertebrate survey: a test of methods for rapid assessment of biodiversity. *Ecological Applications* **6:** 594–607.

Otsamo, R. 2000. Secondary forest regeneration under fast growing forest plantations on degraded *Imperata cylinderica* grasslands. *New Forests* **19:** 69–93.

Ouborg, N. J. 1993. Isolation, population size and extinction: the classical and metapopulation approaches applied to vascular plants along the Dutch Rhine-system. *Oikos* **66**: 298-308.

Paijmans, K. 1970. An analysis of four tropical rain forest sites in New Guinea. *The Journal of Ecology*, **58** (1), 77-101.

Pallant, E. and Riha, S. J. 1990. Surface soil acidification under Red Pine and Norway spruce. *Soil Science Society of America Journal* **54**: 1124–1130.

Palmer, M. W. 1990. The estimation of species richness by extrapolation. *Ecology* **71:** 1195-1198.

Palmer, M. W. 1994. Variation in species richness: towards a unification of hypotheses. In: Zobel, M., Palmer, M. W., Kull, K. & Herben, T. (eds.), *Vegetation structure and species coexistence*. Proceedings of the Symposium held in Tartu, Estonia, 3–7 September 1992. Opulus Press, Uppsala. Pp. 85–101.

Palmer, M. W. 1991. Patterns of species richness among North Carolina hardwood forests: tests of two hypotheses. *Journal of Vegetation Science* **2**: 361-366.

Parrotta J. A. 1993. Secondary forest regeneration on degraded tropical lands: the role of plantations as 'foster ecosystems'. *In:* Lieth, H. and Lohmann, M. (eds.). *Restoration of Tropical Forest Ecosystems*, Kluwer, Dordrecht. Pp. 63–73.

Parrotta, J. A. 1992. The role of plantation forests in rehabilitating degraded tropical ecosystems. *Agriculture Ecosysemt and Environment* **41**: 115–133.

Parrotta, J. A. 1995. Influence of overstory composition on understory colonisation by native species in plantations on a degraded tropical site. *Journal of Vegetation Science* **6**: 627–636.

Parthasarthy, N. and Karthikeyan, R. 1997. Plant biodiversity inventory and conservation of two tropical dry evergreen forests on the Coromandel Coast, South India. *Biodiversity Conservation* **6:** 1063-1083.

Patil, G. P. and Taillie, C.1979. An overview of diversity. *In* Grassle, J.F., G.P. Patil, W. Smith and C. Taillie (eds.) *Ecological diversity in theory and practice.* Inter. Coop. Publish. House, Fairland, Maryland. Pp. 3-27.

Peet, R. K. 1974. The measurement of species diversity. *Annual review of ecology and Systematics* **5**: 284-307.

Peet, R. K. 1975. Relative diversity indices. *Ecology* **56:** 496-498.

Peet, R. K., Christensen, N. L. 1988. Changes in species diversity during secondary forest succession on the North Carolina Piedmont. In: During HJ, Werner MJ (eds) *Diversity and pattern in plant communities.* SPB Academic Publishing, The Hague. Pp. 233–245.

Pennington, T. D. 1990. *Sapotaceae.* Flora Neotropica, Monograph 52. The New York Botanical Garden, New York, USA.

Peres, C. A. 2001. Paving the way to the future of Amazonia. *Trends in Ecology and Evolution,* **16**: 216–219.

Petch , T. 1914. Notes on the history of plantation rubber industry in the east. *Annals of the Royal Botanic Gardens, Peradeniya.* **5**: 440-487.

Peter-john, W. T., Correll, D. L. 1984. Nutrient dynamics in an agricultural watershed: Observations on the role of a riparian forest. *Ecology* **65**: 1466-1474.

Peterken, G. F. and Game, M .1984. Historical factors affecting the number and distribution of vascular plant species in the woodlands of central Lincolnshire. *Journal of Ecology* **72**: 155–182.

Peters, R. L. And Lovejoy, T. E. 1992. *Global Warming and Biological Diversity.* Yale Univ Press, New Haven, CT.

Peterson, C. J. and Campbell, J. E. 1993. Microsite differences and temporal change in plant communities of treefall pits and mounds in an old-growth forest. *Bulletin of Torrey Botanical Club* **120**: 451–460.

Peterson, C. J. and Facelli, J. M. 1992. Contrasting germination and seedling growth of *Betula alleghaniensis* and *Rhus typhina* subjected to various amounts and types of plant litter. *American Journal of Botany* **79:** 1209–1216.

Pianka, E. R. 1967. On lizard species diversity: North American flatland deserts. *Ecology* **48**: 333-351.

Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology.* **13**, 131-144.

Pielou, E. C. 1984. *The interpretation of ecological data.*John Wiley, New York.

Pileou, E. C. 1975. *Ecological Diversity,* John Wiley, New York, USA. 165 p.

Pimm, S. L. 1982. *Food Webs.* Chapman & Hall, London. pp 219.

Pimm, S. L. and Raven, P. 2000. Extinction by numbers. *Nature* 403: 843-845.

Pimm, S. L., Russell, G. J., Gittleman, J. L. and Brooks, T. M. 1995. The future of biodiversity. *Science* 269: 347-350.

Pineda, F. D., Casado, M. A., De Miguel, J. M. and Montalvo, J.(eds.) 1991. *Diversidad Biológica/ Biological diversity.* F. Areces, SCOPE, Adena- WWF, Madrid.

Piper, J. K. 1995. Composition of prairie plant communities on productive versus unproductive sites in wet and dry years. *Canadian Journal of Botany* **73**: 1635-1644.

Piro˙znikow, E. 1991. Plant population structure of herb layer in stable forest community (*Tilio carpinetum)* in the Białowie˙za National Park. Phytocoenosis 3: 127–139 (in Polish with English summary).

Pither, R and Kellman, M. 2002 Tree species diversity in small, tropical riparian forest fragments in Belize, Central America. *Biodiversity and Conservation* **11**: 1623-1636.

Poulsen, A. D. 1996. Species richness and density of ground herbs within a 1-ha plot of lowland rain forest in northwest Borneo. *Journal of Tropical Ecology* **12**: 177-190.

Poulsen, A. D. and Balslev, H. 1991. Abundance and cover of ground herbs in an Amazonian rain forest. *Journal of Vegetation Science 2*: 315-322.

Poulsen, A. D. and Balslev, H. 1991. Abundance and cover of ground herbs in an Amazonian rain forest. *Journal of Vegetation Science* **2:** 315-322.

Poulsen, A. D. and Nielsen, I. H. 1995. How many ferns are there in one hectare of tropical rain forest? *American Fern Journal* **85**: 29-35.

Pramod, P., Daniels, R., Joshi, N. V., and Gadgil, M. 1997. Evaluating bird communities of Western Ghats to plan for a biodiversity friendly development C*urrent Science* **73**(2), 156--162.

Preston, F. W. 1948. The commonness and rarity of species. *Ecology* **29**: 254–283.

Preston, F. W. 1962a. The canonical distribution of commonness and rarity. I. *Ecology* **43**: 185-215.

Preston, F. W. 1962b. The canonical distribution of commonness and rarity. I. *Ecology* **43**: 410-432.

Primack, R. B. and Maio, S .L. 1992. Dispersal can limit local plant distribution. *Conservation Biology* **6**: 513–519.

Pringle, C. M. 1990. Nutrient spatial heterogeneity. Effects on community structure, physiognomy and diversity of stream algae. *Ecology* **71**: 905-920.

Purvis, A., and Hector, A. 2000. Getting the measure of biodiversity. *Nature* **405**: 212-219.

Putnam, A. R. and Tang, C. S. 1986. Allelopathy: state of science. *In* Putnam,A.R. and Tang, C.S., (eds). *The Science of Allelopathy*. John Wiley & Sons. New York. Pp. 1.

Putz F. E., Blate, G. M., Redford, K. H., Fimbel, R., Robinson, J. 2001.Tropical Forest Management and Conservation of Biodiversity: An Overview. *Conservation Biology*, **15**(1): 7-20.

Puyravaud J. P., Dufour, C. and Aravajy ,S., 2003. Rain forest expansion mediated by successional processes in vegetation thickets in the Western Ghats of India. *Biogeography*, **30**, 1067–1080.

Puyravaud, J. P. and Garrigues, J. P. 2002. L'agriculteur ou la fore^t? Syste`mes agraires, pre´le`vements et conse´quences e´cologiquessous la cre^te des Gha^ ts (district de Shimoga). L'homme et la fore^t en Inde du sud. Modes de gestion et symbolisme de la fore^t dans les Gha^ts occidentaux (ed. By J. Pouchepadass and J.-Ph. Puyravaud), pp. 167–234. French Institute of Pondicherry and Karthala.

Puyravaud, J. P., Davidar, P., Pascal, J. P., and Ramesh, B. R. 2004. Analysis of threatened endemic trees of the Western Ghats of India sheds new light on the red Data Book of Indian plants. Biodiversity and conservation 12(10): 2091-2106.

QED Statistics, Version 1.1, 2007, Pisces Conservation Ltd. Lymington, UK (www.pisces-conservation.com)

Quinn, J. F. and Harrison S. P. 1988. Effects of habitat fragmentation and isolation on species richness: evidence from biogeographic patterns. *Oecologia* **75**: 132-140.

Quintana-Ascencio, P. F., Gonzales-Espinoza, M., Ramírez- Marcial, N., Dominguez-Vázquez, G. and Martínez-Icó, M. 1996. Soil seed banks and regeneration of tropical rainforest from milpa fields at the Selva Lacandona, Chiapas,Mexico. *Biotropica* **28**: 192–209.

Raaijmakers, J. G. W. 1987 Statistical analysis of the Michaelis-Menten equation. *Biometrics* **43**: 793-803.

Ramakrishna, K. 1992. "Interest Articulation and Law-Making in Climate Change Negotiations: Perspectives from Developing Countries", *Transnational Law and Contemporary Problems*, Volume 2 (1992), pp: 153-172.

Ramesh, B. R., P ascal, J. P. and De Franceschi, D. 1993. Distribution of endemic, arborescent evergreen species in the Western Ghats. *Proceedings of the rare, endangered and endemic plants of the Western Ghats*, pp. 20–29. Kerala Forest Department, Kerala.

Rathcke, B. and Lacey, E. P. 1985 Phenological patterns of terrestrial plants. *Annual Review of Ecology and Systematics* **16**: 179–214.

Raunkiaer, C. 1934. The Life Forms of Plants and Statistical Plant Geography. Clarendon Press, Oxford.

Raven, P. H. 1977. Perspectives in Tropical Botany: Concluding remarks. *Annals of Missouri Botanical Garden* **64**: 746-748.

Recher, H. F. 1969. Bird species diversity and habitat diversity in Australia and North America. *American Naturalist* **103**: 75-80.

Reigosa J. M., Pedrol N., Sanchez- Moreiras A. M. and Gonzalez L. 2002. Stress and allelopathy. *In*: Reigosa, M. and Pedrol, N. (eds.} *Allelopathy From Molecules to Ecosystems.* OCED.Science Publishers, Inc., Enfield, NH, USA. Pp. 231-256.

Rennolls, K. and Laumonier. Y. 2000. Species Diversity Structure Analysis at Two Sites in the Tropical Rain Forest of Sumatra. *Journal of Tropical Ecology* **16**(2): 253-270.

Rényi, A. 1961. On measures of entropy and information. *In*: Neyman, J. (ed.), 4th*Berkeley Symposium on Mathematical Statistics and Probability.*Berkeley. pp. 547-561.

Ricklefs, R. E. 1987. Community diversity: relative roles of local and regional processes. *Science* **235**: 167-171.

Riha, S. J., Senesac, G. and Pallant, E. 1986. Effects of forest vegetation on spatial variability of surface mineral soil pH, soluble aluminium and carbon. *Water Air Soil Pollution* **31**: 929–940.

Roberts, M. R. and Zhu, L. 2002. Early response of the herbaceous layer to harvesting in a mixed coniferous-deciduous forest in New Brunswick, Canada. *Forest Ecology Management* **155**: 17–31.

Roberts, M. R. 2002. Effects of forest plantation management on herbaceous-layer composition and diversity. *Canadian Journal of Botany* **80**: 378–389.

Roberts, M. R. 2004. Response of the herbaceous layer to natural disturbance in North American forests. *Canadian Journal Botany* **82**: 1273–1283.

Roberts, M. R.and Gilliam, F. S. 1995. Patterns and mechanisms of plant diversity in forested ecosystems: implications for forest management. *Ecological Applications* 5: 969–977.

Rogers, H. M. and Hartemink, A. E. 2000. Soil seed bank and growth rates of an invasive species, *Piper aduncum*, in the lowlands of Papua New Guinea *Journal of Tropical Ecology* **16**: 243-251.

Romero- Romero, T., Anaya, A. L. and Cruz- Ortega, R. 2002. Screening for effects of phytochemical variability on cytoplasmic protein synthesis pattern of crop plants. *Journal of Chemical ecology* **28**: 617-629.

Rosenzweig, M. L. 1995. Species diversity in space and time. Cambridge University Press, Cambridge, UK.

Ruokolainen, K., A. Linna, and Tuomisto. H. 1997. Use of Melastomaceae and Pteridophytes for revealing phytogeographical patterns in Amazonian rain forests. *Journal of tropical Ecology* **13**: 243- 256.

Samarappuli, L. 1996. The contribution of rubber plantations towards a better environment. *Bulletin of the Rubber Research Institute of Sri Lanka* **33**: 45-54.

Sanders, H. 1968. Marine benthic diversity: a comparative study. *American Nauralistt* **102**: 243–282.

Sasidharan, N. 2004. *Biodiversity documentation for Kerala Part 6: Flowering Plants.* KFRI Library Cataloguing- in-Publication Data.Publ.by Kerla Forest Research Institute, Peechi, Kerala.

Saulei, S. M. and Swaine, M. D. 1988. Rain forest seed dynamics during succession at Gogol, Papua New Guinea.*Journal of Ecology* **76**: 1133-1152.

Scariot, A. 1999. Forest fragmentation effects on palm diversity in central Amazonia. *Journal of Ecology* **87**: 66-76.

Scheiner, S. M. 2003. Six types of species–area curves. *Global Ecol. Biogeogr.* **12**: 441–447.

Schelhas, J. and Greenberg, R. (eds.) 1996. Forest Patches in Tropical Landscapes. Washington, DC: Island Press.

Schluter, D. and Ricklefs, R. E. 1993. Species diversity: an introduction to the problem. *In*: Ricklefs, R.E. and D. Schluter, (eds.) *Species diversity in ecological communities.* University of Chicago Press, Chicago, Illinois, USA. Pages 1-10.

Schmitz, O. J. 2003. Top predator control of plant biodiversity and productivity in an old field. *Ecology Letters* 6: 156-163.

Schoener, T. W. 1976. The species-area relation within archpelagos: models and evidence from island land birds. *In*: H.J. Frith and J. H. Calaby (eds.) *Proceedings of the 16th International Ornithological conference.* Australian Academy of Science, Canberra, Australia. Pp 629-642.

Schultes, R. E. 1977. The odyssey of the cultivated rubber tree. *Endeavor* **1**(3&4): 135-137.

Schulze, E. D. and Mooney, H. A. (eds.) 1993. *Biodiversity and Ecosystem Function.* Berlin: Springer- Verlag.

Seaby, R. M. H. and Henderson, P. A. 2006. *Species Diversity and Richness* (SDR)Version 4. Pisces Conservation Ltd., Lymington, Hampshire, England. (www.pisces-conservation.com).

Sethuraj, M. R. and Jacob, J. 1997. *Rubber and the environment.* Second Meeting of the Expert Group, Project on Promotion of Natural Rubber as an Environment Friendly Raw-material and a renewable resource, 1997, Cochin India.

Sethuraj, M. R. and Jacob, J. 1997. *Rubber and the environment.* Second Meeting of the Expert Group, Project on Promotion of Natural Rubber as an Environment Friendly Raw-material and a renewable resource, 1997, Cochin India.

Shafer, C. L. 1995. Values and shortcomings of small reserves. *Bioscience* 45: 80-88.

Sharma, R. A. 1993. The socioeconomical evaluation of social forestry in India. *Ambio* **22**: 219–224.

Shen, T. J., A. Chao and Lin, C. F. 2003. Predicting the number of new species in further taxonomic sampling. *Ecology* **84**: 798-804.

Shmida, A. and Wilson, M. V. 1985. Biological determinants of species diversity. *Journal of Biogeography* **12**: 1-20.

Shmida, A. and Wilson, M. V. 1985. Biological determinants of species diversity. *Journal of Biogeography* **12**: 1-20.

Shorrocks, M. 1965. Mineral nutrition, growth and nutrient cycle of *Hevea brasiliensis*: 1. Growth and nutrient content. *Journal of Rubber Research Institute of Malaya*, **19**(1): 32-47.

Shrestha, S., Jha, P. K. and Shrestha. K. K. 1998. Vegetation of degraded, regenerating and natural forests in Riyale, Kavre, Nepal. *Pakistan Journal of Plant Science* **4**(1): 13-28.

Sillett, S. C., McCune, B., Peck, J. E., Rambo, T. R. and Ruchty, A. 2000. Dispersal limitations of epiphytic lichens result in species dependent on old-growth forests. *Ecological Application* **10**: 789–799.

Silvertown, J. and Wilkin, F. R. 1983. An experimental test of the role of micro-spatial heterogeneity in the coexistence of congeneric plants. *Biological Journal of the Linnean Society* **19**: 1- 8.

Simberloff, D. 1988. The contribution of population and community biology to conservation science. *Annual Review Ecology and Systematic* **19:** 473-511.

Simpson, E. H. 1949. Measurement of diversity. *Nature* (London) **163:** 688.

Sivanadyan, K. and Moris, N. 1992. Consequence of transforming tropical rain forests to *Hevea* plantations. *The Planter*, **68** (800): 547-567.

Sivanadyan, K., Gandhimathi, H. and Haridas, G., 1995. *Rubber a unique crop: The mature Hevea stands as a nutritionally self – sustaining ecosystem in relation to latex yield.* Rubber Research Institute of Malaysia, Kuala Lumpur.

Small, C. J. and McCarthy B. C. 2002. Spatial and temporal variability of herbaceous vegetation in an eastern deciduous forest. *Plant Ecology* **164**: 37-48.

Smith, B., and Wilson, J. B. 1996. A consumer's guide to evenness indices. *Oikos* **76**: 70-82.

Smith, E. P. and van Belle, G. 1984. Non parametric estimation of species richness. *Biometrics* **40**, 119–129.

Smith, M. D. and Knapp, A. K. 2003. Dominant species maintain ecosystem function with non-random species loss. *Ecology Letters* **6**: 509-517.

Smith, M. D., Wilcox, J. C., Kelly, T. and Knapp, A. K. 2004. Dominance not richness determines invisibility of tallgrass prarie. *Oikos* **106**: 253-262.

Smith, R. L. and Smith, T. M. 2006. *Elements of ecology*. Publ.Benjamin Cummings.

Smith, W., and Grassle, J. F. 1977. Sampling properties of a family of diversity measures. *Biometrics* **33**: 283-292.

Sobe´ron, J. M. and Llorente, J. B. 1993. The use of species accumulation functions for the prediction of species richness. *Conservation Biology* **7**, 480-488.

Sohmer, S. 1994. *in* Peng, C. I. and Chou, C. H. (eds.). *Biodiversity and Terrestrial Ecosystems,Monograph Series* Vol. 14. Institute of Botany, Academia Sinica, Taipei. Pp. 43–51.

Sokołowski, A. W. 1966. Influence of spruce upon pH value of soil in the aggregation of fresh coniferous forest. *Sylwan* **3**: 57–64 (in Polish with English summary).

Solbrig, O. T. (ed.) 1991. *From genes to ecosystems: a research agenda, for biodiversity.* International Union of Biological Sciences, Paris, France.

Solow A. R. 1994. On the Bayesian estimation of the number of species in a community. *Ecology* **75**: 2139-2142.

Solow, A. R. 1993. A simple test for change in community structure. *Journal of Animal Ecology* **62**(1), 191-193.

Solow, A. R. and Smith, W. 1991. Detecting cluster in a heterogeneous community sampled by quadrats. *Biometrics* **47**: 311-317.

Sonwa, D. J., Nkongmeneck, B. A., Weise, S., Tchatat, F. M, Adesina, A. A., Janssens, M. J. J. 2007. Diversity of plants in cocoa agroforests in the humid forest zone of Southern Cameroon. *Biodiversity Conservation* **16**: 2385–2400.

Soulé, M. E. (ed.) 1987. *Viable populations for conservation.* Cambridge University Press, Cambridge.

Soulé, M. E. 1991. Conservation: tactics for a constant crisis. *Science* **253**: 744-750.

Southwood, T. R. E. and Henderson, P. A. 2000. *Ecological Methods* 3rd Edition. Blackwell Science. pp 575.

Spellerberg, I. F. and Sawyer, J. W. D. 1996. Standards for biodiversity: a proposal based on biodiversity standards for forest plantations. *Biodiversity and Conservation* 5: 447–459.

Spies T. A. and Turner, M. G. 1999. Dynamics forest mosaics. In: Hunter ML Jr. (ed.). *Maintaining biodiversity in forest ecosystems.* Cambridge: Cambridge University Press. Pp 95-160.

Spironello, W. 1999. The Sapotaceae community ecology in a central Amazonian forest: effects of seed dispersal and seed predation. PhD thesis, University of Cambridge, Cambridge, UK.

State Biodiversity Strategy and Action Plan (SBSAP). 2005. for Kerala. Prepared under, The National Biodiversity Strategy & Action Plan (NBSAP), India, Kerala forest research Institute, Peechi. KFRI, Library Cataloguing-in-publishing Data.

Steadman, D.W. 1995. Prehistoric extinction of Pacific Island Birds: Biodiversity meets zooarcheology. *Science* **267:** 1123-1131.

Stele, B. B., Bayn, R.L. Jr., and Val Grant. C. 1984. Environmental monitoring using populations of birds and small mammals: analyses of sampling effort. *Biological conservation* **30**: 157-172.

Stevens, R.D., and Willig, M. R. 2002. Geographical ecology at the community level: perspectives on the diversity of New World bats. *Ecology* **83:** 545-560.

Stirling, G., and Wilsey, B. 2001. Empirical relationships between species richness, evenness, and proportional diversity. *American Naturalist* 158: 286-299.

Stohlgren, T. J., Chong, G. W., Kalkhan, M. A. and Schell, L. D. 1997. Multiscale sampling of plant diversity: effects of minimum mapping unit size. *Ecological Appications* **7**: 1064–1074.

Strong, D. R. and Levin, D. A. 1979. Species richness of plant parasites and growth form of their hosts. *American Naturalist* **114**: 1-22.

Strong, W. L. 2002. Assessing species abundance unevenness within and between plant communities. *Community Ecology* **3**, 237-246.

Sugihara, G. 1980. Minimal community structure: an explanation of species abundance patterns. *The American Naturalist* **116**: 770-787.

Sukumar, R., Suresh, S., Dattaraja, H. S. and Joshi, N. V. 1998. Dynamics of a tropical deciduous forest: population changes (1988 through 1993) in a 50-ha plot at Mudumalai, southern India. Forest Biodiversity, Research Monitoring and Modelling. In Dallmeier, F. and Comiskey, J. (eds.). *Man and Biosphere Series,* V. 20. UNESCO and the Parthenon Publishing Group, NY, USA. Pp. 495- 506.

Sullivan, T. P., Sullivan, D. S., Lindgren, P. M. F. 2001. Influence of variable return harvest on forest ecosystems I. Diversity and stand structure. *Journal of Applied Ecology* **38**: 1221–1233.

Summerville, K. S. and Crist, T. O. 2005. Temporal scaling of species accumulation in forest Lepidoptera. *Biodiversity Conservation* **14**: 3393- 3406.

Svenning, J. C. 2001. On the role of microenvironmental heterogeneity in the ecology and diversification of Neotropical rain-forest palms (Arecaceae). *Botanical Review* **67**: 1–53.

Swaine, M. D. and Whitmore, T. C. 1988. On the definition of ecological species groups in tropical rain forests. *Vegetatio* **75**: 81-86.

Tabarelli, M. and MantovanI, W. 1999. A regenerac,a˜o de uma floresta tropical montana apo´s cortee queima (Sa˜o Paulo-Brasil). *Revista Brasileira de Biologia* **59**: 239–250.

Tabarelli, M. and Mantovani, W. 2000. Gap-phase regeneration in a tropical montane forest: the effects of gap structure and bamboo species. *Plant Ecology* **148**: 149–155.

Tabarelli, M., Silva, J. M. C. and Gascon, C. 2004. Forest fragmentation, synergisms and the impoverishment of neotropical forests. *Biodiversity and Conservation* **13**: 1419–1425.

Tabarelli, M., Mantovani, W. and Peres, C. A. 1999. Effects of habitat fragmentation and plant guild structure in the montane Atlantic forest of southeastern Brazil. *Biological Conservation* **91**: 119–127.

Taylor, L. R. 1978. Bates, Williams, Hutchinson- a variety of diversities. *In*: L. A. Mound & N. Warloff (ed.), *Diversity in insect faunas: 9th symposium of the Royal Entomological Society,* Oxford, Blackwell. pp. 1-18.

Tempelton, J. K. 1968. Partition of assimilates. *Journal of Rubber Research Institute of Malaya* **21**: 259-263.

ter Steege, H., Jetten, V. G., Polak, A. M. & Werger, M. J. A. 1993. Tropical rain forest types and soil factors in a watershed area in Guyana. *Journal of Vegetation Science* 4: 705-716.

Tewksbury, J. J., Levey, D. J., Haddad, N. M., Sargent, S., Orrock, J. L., Weldon, A., Danielson, B. J., Brinkerhoff, J., Damschen, E. I. and Townsend, P. 2002. Corridors affect plants, animals, and their interactions in fragmented landscapes. *Proceedings of the National Academy of Sciences*, USA **99**: 12923–12926.

Thomas, J. A. 1991. Rare species conservation: case studies of European butterflies. *in* I. F. Spellerberg, F. B. Goldsmith, and M. G. Morris, (eds.) *The scientific management of temperate communities for conservation.* Blackwell Science, Oxford, United Kingdom. Pp. 149–197.

Thomas, S. C. 2004. Ecological correlates of tree species persistence in tropical forest fragments. *In* E. C. Losos and E. G. Leigh. (Eds.). *Forest diversity and dynamism: Findings from a large scale plot network,* University of Chicago press, Chicago, Illinois. Pp. 279- 313.

Thompson, K. 1992. The functional ecology of seed banks. Pp. 231-258 *In* : Fenner, M. (ed.). *Seeds the ecology of regeneration in plant communities.* CAB International, Wallingford. Pp.373.

Tilman, D. 1996. Biodiversity: Population versus Ecosystem Stability. *Ecology* **77**(2): 350-363.

Tilman, D. and Lehman, C. 2002. The functional consequence of biodiversity. *In* Kinzig, A., Pacala, S. and Tilman, D. (eds.). *The functional consequence of biodiversity.* Princeton Monographs in Population biology 33. Princeton university Press, Princeton, new jersey, USA. Pp. 9-42.

Tilman, D., Lehman, C. L. and Bristow, C. E. 1998. Diversity – stability relationships: statistical inevitability or ecological consequence? *The American Naturalist* **151**: 277-282.

Tilman, D., Lehman, C. L., Thomson, K.T. 1997. Plant diversity and ecosystem productivity: theoretical considerations. *Proceedings of the National Academy of Sciences U.S.A.* **94**: 1857-1861.

Tilman, D., Wedin, D. and Knops, J. 1996. Productivity and sustainability influenced by biodiversity in grassland ecosystems. *Nature* **379**: 718-720.

Tilman, D. 1997. Community invasibility, recruitment limitation, and grassland biodiversity. *Ecology* **78** (1): 81-92.

Tokeshi, M. 1996. Power fraction: a new explanation of relative abundance patterns in species-rich assemblages. *Oikos* **75**: 543–550.

Tokeshi, R. 1993. Species abundance patterns and community structure. *Advances in Ecological Research* **24**: 111-195.

Toky, O. P., Ramakrishnan, P. S. 1983. Secondary succession following slash and burn agriculture in north-eastern India: nutrient cycling. *Journal of Ecology* **71**: 747–757.

Tonn, W. M. and Magnuson, J. J. 1982. Patterns in the species composition and richness of fish assemblages in northern Wisconsin lakes. *Ecology* **63**: 1149 - 1166.

Tóthmérész, B. 1995. Comparison of different methods for diversity ordering. *Journal of Vegetation Science* **6**: 283-290.

Tucker, N. I. J. and Murphy, T. M. 1997. The effects of ecological rehabilitation on vegetation recruitment: some observations from the wet tropics of North Queensland. *Forest Ecology and Management* **99**: 133–152.

Tuomisto, H. and Ruokolainen, K. 1994. Distribution of Pteridophyta and Melastomataceae along an edaphic gradient in an Amazonian rain forest. *Journal of Vegetation Science* **5**: 25-34.

Tuomisto, H. and Poulsen, A. D. 2000. Pteridophyte diversity and species composition in four Amazonian rain forests *Journal of Vegetation Science* **11**: 383-396.

Tuomisto, H. and Poulsen, A. D. 1996. Influence of edaphic specialization on pteridophyte distribution in neotropical rain forests. *Journal of Biogeography.* **23**: 283-293.

Tuomisto, H., Ruokolainen, K., Kalliola, R., Linna, A., Danjoy, W. and Rodriguez, Z. 1995. Dissecting Amazonian biodiversity. *Science* **269**: 63-66.

Turil, W. B. 1964. Plant Taxonomy, Phytogeography and Plant ecology. *Vistas in Botany* **4**: 187-224.

Turner, I. M. 1996. Species loss in fragments of tropical rain forest: a review of the evidence. *Journal of Applied Ecology* **33**: 200–209.

Turner, I. M. and Corlett, R. T. 1996. The conservation value of small, isolated fragments of lowland tropical rain forest. *Trends in Ecology and Evolution* **11**(8): 330-333.

Tyler, G. 1989. Interacting effects of soil acidity and canopy cover on the species composition of field-layer vegetation in oak/hornbeam forests. *Forest Ecology and Management* **28**: 101–114.

Ugland, K. I., Gray, J. S. and Lambshead P. J. D 2005. Species accumulation curves analysed by a class of null models discovered by Arrhenius. *Oikos* **108**: 263-274.

Ugland, K. I., Gray, J. S. and Ellingsen, K. E. 2003. The species- accumulation curve and estimation of species richness. *Journal of Animal Ecology* **72**: 888–897.

Uhl, C., Buschbacher, R. and Serrao, E.A.S. 1988. Abandoned pastures in Eastern Amazonia. I. Patterns of plant succession. *Journal of Ecology* **76**: 663–681.

UNEP-CBD, 1991.*Convention on Biological Diversity*, (CBD) Secretariat on CBD, United Nations Environment Programme , Montreal, Canada.

United Nations Environment Programme 1992. Convention on Biological Diversity, UNEP Na. 92-7807, Nairobi.

V'azquez-Yanes, C., Orozco-Segovia, A., Rinc 'on, E., S'anchezcoronado, M. E., Huante, P., Toledo, J. R. and Barradas, V. L. 1990. Light beneath the litter in a tropical forest: Effect on seed germination. *Ecology* **71**: 1952–1958.

Van Andel, T. 2001. Floristic composition and diversity of mixed primary forest and secondary forests in northwest Guyana. *Biodiversity Conservation* **10**: 1645–1682.

van der Heijden, H. G. A., Klironomos, J. N., Ursic, M., Moutoglis, P., Streitwolf-Engel, R., Boller, T., Wiemken A. and Sanders, I. R. 1998. Mycorrhizal fungal diversity determines plant biodiversity, ecosystem variability and productivity. *Nature* **369:** 69-72.

Vandermeer, J. and Carvajal, R. 2001. Metapopulation dynamics and the quality of the matrix. *American Naturalist*, **158**, 211–220.

Vandermeer, J., Ricardo, C. 2001. Metapopulation dynamics and the quality of the matrix. *American Naturalist* **158**: 211–220.

Vandermeer, J., Schultz, B. 1990. Variability, stability, and risk in intercropping: Some theoretical explorations. *In* Gliessman, S.R., (ed.) Agroecology: *Research in the ecological basis for sustainable agiculture.* New York: Springer-Verlag. Pp. 205-229.

Veenendaal, E. M., Swaine, M. D., Lecha, R. T., Walsh, M. F., Abebrese, I. K. and Owusu-Afriyie, K. 1996. Response of West African Forest tree seedlings to irradiance and soil fertility. *Functional Ecology* **10**: 501-511.

Verheyen, K. and Hermy, M. 2001. The relative importance of dispersal limitation of vascular plants in secondary forest succession in Muizen Forest, Belgium. *Journal of Ecology* **89**: 829–840.

Verheyen, K. Guntenspergen, G. R. and Biesbrouck, B. 2003. An integrated analysis of the effects of past land use on forest herb colonization at the landscape scale. *Journal of Ecology* **91**:731- 742.

Viana, V. M., Tabanez, A. A. and Batista. J. 1997. Dynamics and restoration of forest fragments in the Brazilian Atlantic moist forest. *In*: W. F. Laurance and R. O. Bierregaard (Eds.). *Tropical forest remnants: Ecology, management and conservation of fragmented communities*, University of Chicago Press, Chicago. Pp. 351-365.

Viisteensaari, J., Johansson, S., Kaarakka, V. and Luukkanen, O. 2000. Is the alien tree species *Maesopsis eminii* Engl. (Rhamnaceae) a threat to tropical forest conservation in the East Usambaras, Tanzania? *Environmental Conservation* **27**(1): 76–81.

Vijayakumar, K, R., Sanjeeva Rao, P. and Sethuraj, 1 M. R. 1989. Natural Rubber- A commercially important forest species. *Rubber Board Bulletin* **24** (3).

Vijayakumar, K. R., Sanjeeva Rao, P. 1992. Climatic requirements in Natural Rubber: Biology, cultivation and technology.*In* Sethuraj, M.R. and Mathew, N.M. (eds.). *Development in crop science*, 1992 Elsevier Science Publishers.Pp 200-219.

Vijayakumar, K. R., Chandrashekhar, T. and Philip, V. 2000. Agroclimate. *In*: P. J. George and C. Kuruvilla J. (Eds.). *Natural Rubber: Agromanagement and crop processing*. Anaswara printing and publishing company.Pp 97-116.

Vitousek, P. M. 1994. Beyond global warming: Ecology and global change. *Ecology* **75**:1861-1876.

Vitousek, P. M. 1997. Human domination of Earth's ecosystems. *Science* **278** (5335): 21-21.

Vivian-Smith, G. 1997. Microtopographic heterogeneity and foristic diversity in experimental wetland communities. *Journal of Ecology* **85**: 71- 82.

Vleut, I., and P′erez-salicrup, D. R. 2005. Lianas and their supporting plants in the understory of Los Tuxtlas, Mexico. *Journal of Tropical Ecology* **21**: 577- 580.

Wan, A. R. and Abu, A. 2002. Natural Rubber: An ecofriendly material. *In*: *C.* Kuruvilla Jacob (Ed.). *Global competitiveness of Indian Rubber plantation industry.*

Rubber planters Conference, Rubber Research institute of india, Kottayam, Kerala. Pp. 237-244.

Wang, J. (1995) Ricinocarpus speciosus. In: *Flora and Fauna Information System — Species Management Manual*, Vol. 3. Queensland Department of Natural Resources, Brisbane.

Wang J., Borsboom, A. C. and Smith, G. C. 2004. Flora diversity of farm forestry plantations in Southeast Queensland. *Ecological Management & Restoration* 5(1), 43-51.

Watkins, A. J. and Wilson J. B. 1994. Plant Community Structure, and Its Relation to the Vertical Complexity of Communities: Dominance/Diversity and Spatial Rank Consistency *Oikos*, 70 (1): 91-98.

Watson, G. A. 1963. Cover plants and tree growth: 1. The effect of leguminous and non- leguminous cover plants on the period of immaturity. *Planter's bulletin*, 68: 123-129.

Weidenhamer, J. D., Macais, F. A., Fischer, N. H. and Williamson, G. B. 1993. Just how insoluble are monoterpenes? *Journal of Chemical Ecology* 19: 1799-1993.

Weiher, E. and Keddy, P. A. 1999. Relative Abundance and Evenness Patterns along Diversity and Biomass Gradients. *Oikos* 87(2): 355-361.

Weiher, E. and Keddy, P. A. 1999. Relative Abundance and Evenness Patterns along Diversity and Biomass Gradients. *Oikos* 87(2): 355-361.

Weir T.L., Park S. W. and Vivanco J. M. 2004. Biochemical and physiological mechanisms mediated by allelochemicals. *Current Opinion in Plant Biology 7*: 472-479.

Wesenbeeck, B. K., van, Mourik, T., van Duivenvoorden, J. F. and Cleef, A. M.,2003. Strong effects of a plantation with *Pinus patula* on Andean subpuramo vegetation ; a case study from Columbia. *Biological Conservation* 114 (2): 207-218.

White, P. S. and Miller, R. I. 1988. Topographic models of vascular plant richness in the southern Appalachian high peaks. *Journal of Ecology* 76: 192-199.

Whitmore, T. C. 1975. Tropical rainforestry of the Far East. Claredon Press. Oxford, London. (1984, 2nd ed.).

Whitmore, T. C. 1984. *Tropical Rain Forests of the Far East*.Clarendon, Oxford.

Whitmore, T. C. and Sayer, J. A., 1992. Deforestation and species extinction in tropical moist forests. *In*: T.C. Whitmore and J.A. Sayer (Eds.) *Tropical deforestation and species extinction*, Chapman and Hall, London. Pp. 1-14.

Whitmore, T. C. 1997. Tropical forest disturbance, disappearance, and species loss. *In*: Laurence W.F. and Bierregaard, Jr., R.O. (Eds.), *Tropical forest remnants*. The University of Chicago Press,Chicago. Pp. 2-28.

Whitney, G. C., Foster, D. R. 1988. Overstory competition and age as determinants of the understory flora of woods in central New England. *Journal of Ecology* **76**: 867–876.

Whittaker, R. H. 1965. Dominance and diversity in land plant communities. *Science* 147: 250-260.

Whittaker, R. H. 1977. Evolution of species diversity in land communities. *In*: M.K. Hecht, W.C. Steere and B. Wallace (eds.) *Evolutionary Biology*, Vol. 10, Plenum, NY. Pp. 1-67.

Whittaker, R. H. 1972. Evolution and measurement of species diversity. *Taxon* **21**: 213-251.

Wilkander, T. 1984. Mecanismos de dispersion de diasporas de una selva decidua en Venezuela. *Biotropica* **16**: 276–283.

Williams, C. B. 1964. *Patterns in the balance of nature*. Academic Press, New York.

Williams, C. N. and Joseph, K.T. 1973. *Climate, Soil and crop Production in the Humid Tropics*. Oxford University Press, Kuala Lumpur.

Williams, C. B. 1943. Area and number of species. *Nature* **152**:264-267.

Williams-Linera, G. 2002. Tree species richness complementarity, disturbance and fragmentation in a Mexican tropical Montane cloud forest. *Biodiversity Conservation* **11**, 1825-1845.

Willig, M. R. 2003. Challenges to understanding dynamics of biodiversity in time and space. *Paleobiology* 29: 30-33.

Wilsey, B. J., and Polley, H. W. 2004. Realistically low species evenness does not alter grassland species richness-productivity relationships. *Ecology* **85**: 2693-2701.

Wilsey, B. J., and Polley, H. W. 2002. Reductions in grassland species evenness increase dicot seedling invasion and spittle bug infestation. *Ecology Letters* **5**: 676-684.

Wilsey, B. J., and Polley, H. W. 2003. Effect of seed additions and grazing history on diversity and above ground productivity of sub-humid grasslands. *Ecology* **84**: 920-931.

Wilsey, B. J., and Potvin, C. 2000. Biodiversity and ecosystem functioning: importance of species evenness in an old field. *Ecology* **81**: 887-893.

Wilsey, B. J., Chalcraft, D. R, Bowles, C. M. and Willig, M. R. 2005. Relationships among indices suggest that richness Is an incomplete surrogate for grassland biodiversity. *Ecology* **86**(5): 1178-1184.

Wilson, E. O. 1988. *Biodiversity.* National Academy Press, Washington, D.C. 521 pp.

Wilson, J. B. 1991. Methods for fitting dominance/diversity curves. *Journal of Vegetation Science.* **2**: 35-46.

Wunderle, J. M. 1997. The role of animal seed dispersal in accelerating native forest regeneration on degraded tropical lands. *Forest Ecology and Management* **99**: 223–235.

Wycherley, P. R. 1968. Introduction of *Hevea* to the Orient. *The Planter* **44**: 127-137.

Yang J. C., Huang, J. H., Pan Q. M., Tang J. W., Han X. G. 2004. Long term impact of land use change on dynamics of tropical soil carbon and nitrogen pools. *Journal of Environmental science(China)*, **16** (2): 256-261.

Yew, F. K. 1982. *Contribution towards the development of a land evaluation system for Hevea brasiliensis* Muell. Arg. *Cultivation in Peninsular Malaysia.* Doctoral thesis, State University of Ghent, Belgium.

Yirdaw, E. 2001. Diversity of naturally-regenerated native woody species in forest plantations in the Ethiopian highlands. *New Forests* **22**: 159–177.

Zhiwei, F. and Yide, S. 1999. Weed management in China's rubber plantations. *Proceedings of IRRDB Symposium:Cultivation and Farming Systems* pp 173-175.

Zhu, H., Xu, Z. F., Wang, H. and Li, B. G. 2004. Tropical rain forest fragmentation and its ecological and species diversity changes in southern Yunnan. Biodiversity and conservation 13(7): 1355-1372.

Zimmerman, J. K., Pascarella, J. B. and Aide, T. M. 2000. Barriers to forest regeneration in an abandoned pasture in Puerto Rico. *Restoration Ecology* **8**: 350–360.

Zobel, M. 1992. Plant species coexistence – the role of historical evolutionary and ecological factors. *Oikos* **65**: 314- 320.

Zuidema, P. A., Sayer, J. A. and Dikman, W. 1996. Forest fragmentation and biodiversity: the case for intermediated-sized conservation areas. *Environmental Conservation*, **23**: 290–297.

Appendix

Table 4.3 Qualitative floristic survey of the three major ecosystems in different locations viz. Rubber plantations, Open areas and Forest areas and the individual site locations (subsets) with the area under Kottayam, Patanamthitta and Kollam districts (Neez- Neezhoor,Puthu- Puthupally,Pamp- Pampadi,Then- Thenmala and Chet- Chetheckal).

S.No.	Name of the plant	Site location														
		Rubber Plantations						Open areas						Forest		
		Neez	Puthu	Pamp	Mund	Then	Chet	Neez	Puthu	Pamp	Mund	Then	Chet	Chet	Mund	Then
	Angiosperms															
1	*Abrus precatorius* L.		√												√	√
2	*Abrus pulchellus* Wall. Ex Thw.		√				√									
3	*Abutilon ramosum*(Cav.) Guill. & Perr.	√														
4	*Acacia catechu (L.f.) Wild.*														√	
5	*Acacia pennata*(L.)Wild.	√					√	√						√		
6	*Acacia sinuata* (Lour.)Merr.	√														
7	*Acalypha indica* L.					√		√								
8	*Acalypha racemosa* Heyne ex Baill.						√									
9	*Achyranthes aspera* L.				√	√						√				
10	*Acrocarpus fraxinifolius* Wight& Arn.														√	
11	*Acrotrema arnottianum* Wight					√									√	√
12	*Actephila excelsa* (Dalz.) Muell. Arg.															
13	*Actinodaphne bourdillonii* Gamble														√	√
14	*Actinodaphne malabarica Balakr.*															√
15	*Adenanthera pavonina L.*														√	√
16	*Adenostemma lavenia*(L.) O. Ktze.	√		√	√			√								
17	*Aeginetia indica* L.		√					√								
18	*Aerva lanata* (L.) Juss.ex Schult.			√	√											
19	*Aganope thyrsiflora* (Benth.)		√	√										√		
20	*Ageratum conizoides* L.	√	√	√	√		√	√								
21	*Ageratum haustonianum* Mill.						√									
22	*Agnosma cymosa* (Roxb.) G. Don		√				√									√
23	*Agrostistachys indica* Dalz.		√													
24	*Ailanthus triphysa*(Dennst.) Alston			√												
25	*Albizzia amara* (Roxb.) Boivin	√														
26	*Albizia lebbeck*(L) Willd.						√				√					
27	*Albizia odoratissima* (L.f.) Benth.						√									
28	*Allmania nodiflora* L.) R.Br. Ex Wight var. nodiflora															
29	*Allophylus cobbe (L.)* Raeusch.	√	√		√		√	√	√		√		√			

30	*Allopteris cinicina* (L.)Stapf	√					√	√					√			
31	*Alocasia fornicata* (Roxb.) Schott								√							
32	*Alstonia scholaris(L.) R.Br.*			√										√	√	√
33	*Alternanthera pungens*Kunth				√		√		√							
34	*Alternanthera sessilis*(L.) R.Br.	√		√	√		√						√			
35	*Alternanthera tenella*Moq.															
36	*Amaranthus spinosus*L.															
37	*Anamirta cocculus* (L.) Wight & Arn.						√									
38	*Andrographis atropurpurea*(Dennst)Alston.	√					√	√								
39	*Andrographis lineata* Wall.ex.Nees						√									
40	*Andrographis paniculata*(Burm.f.)Wall.ex Nees						√									√
41	*Aneilemma montana*(Wight) Clarke			√			√				√					√
42	*Aneilemma scaberrimum*(Blume) Kunth						√									√
43	*Anisochilus carnosus (L.f.) Wall. Ex Benth.*	√		√	√											
44	*Antidesma acidum* Retz.	√	√				√				√			√	√	√
45	*Antidesma alexiteria* L.		√													
46	*Antidesma montanum*Blume	√	√		√											
47	*Antistrophe serratifolia*(Bedd.) Hook.f.				√											
48	*Antigonon leptopus* Hook. & Arn.															
49	*Apluda mutica*(L.)				√											
50	*Apodytes dimidiata* Meyer ex Arn															√
51	*Aporusa acuminata* Thw.				√											
52	*Aporosa lindleyana* (Wight) Baill.			√			√								√	√
53	*Ardisia pauciflora* Heyne ex Roxb.		√													√
54	*Argyreia hirsuta* Wight & Arn.						√									
55	*Aristolochia tagala* Cham.			√												
56	*Artocarpus heterophyllum*Lam.			√			√									
57	*Artocarpus hirsutus* Lam.		√													√
58	*Arundinella purpurea* Hochst								√							
59	*Asystacia gangetica*(L.) Anders.var. gangetica			√	√		√						√			
60	*Asystacia gangetica*(L.) Anders var. mendeliana												√			
61	*Asystasia dalzelliana* Sant.	√	√	√	√		√							√	√	
62	*Atalantia monophylla*(L.) DC.															√
63	*Atalantia racemosa* Wight *var racemosa*												√			
64	*Axonopus compressus*(Sw.) P.Beauv.	√	√	√	√	√	√	√	√	√	√		√			
65	*Azadirachta indica* A. Juss.	√														√
66	*Bambusa bambos*(L.)Voss			√												
67	*Barleria cristata* L.	√					√									
68	*Barleria buxifolia* L.						√	√								
69	*Bauhinia malabarica* Roxb.						√									

70	*Bidens pilosa* L.				√									√		
71	*Bidens sulphurea* (Cav.) Sch- Bip.															
72	*Biophytum reinwardti* (Zucc.) Klotzsch.var*rein*	√													√	
73	*Biophytum sensitivum*(L.) DC. Var sensitivum	√	√		√						√				√	
74	*Biophytum sensitivum*(L.) DC. Var *candolleanu*	√		√			√				√					√
75	*Bixa orellana* L.														√	
76	Blainvillea acmella (L.) Philip				√											
77	*Blepharistemma serratum*(Dennst.)		√													
78	*Blumea lacera*(Burm.f.) DC.	√														
79	*Blumea mollis*(D.Don) Merr.	√	√	√						√						
80	*Blumea oxydonta* DC.	√														
81	*Boehmaria macrophylla* Hornem. Var. macrophylla		√													
82	*Boerhaavia diffusa* L.						√									
83	*Boesenbergia pulcherrima*(Wall.)O.Ktze					√										
84	*Bombax cieba* L.														√	√
85	*Bombax scophulorum* Dunn					√										
86	*Bracharia ramosa* (L.) Stapf				√						√				√	
87	*Bridelia retusa* (L.) Spreng.	√	√	√			√									
88	*Bridelia scandens* (Roxb.) Willd.															√
89	*Bulbostylis densa*(Wall.exRoxb.)Hand-Mazz.		√													
90	*Caesalpinia bonduci* (L.) Roxb.															√
91	*Caesalpinia mimosoides* Lam.	√		√			√									
92	*Caladium bicolor* (Ait.ex Dryand.)Vent.	√		√				√								
93	*Calamus thwaitesii* Becc.& Hook.f.															√
94	*Calophyllum polyanthum* Wall.														√	
95	*Calycopteris floribunda* Lam.	√					√						√			√
96	*Canthium augustifolium Roxb.*	√	√	√			√		√					√		
97	*Canthium coromandelicum* Burm.f.Alston		√	√			√									
98	*Cardiospermum halicacabum* L.		√			√										√
99	*Careya arborea* Roxb.		√	√			√								√	
100	*Caryota eurens* L.		√													
101	*Cassia fistula* L.														√	
102	*Cassia javanica*		√		√	√										
103	*Cayratia pedata* (Lam.) A. Juss. Ex Gafnexp.															
104	*Centella asiatica (L.)*	√	√	√	√	√	√					√				
105	*Centrosema pubescens* Benth.	√	√	√	√	√	√		√			√		√	√	√
106	*Ceropegia maculata* Bedd.															√
107	*Chamaecrista mimosoides*(L.)Greene.			√												
108	*Chassalia curviflora* Wall.ex Kurzz Thw. Var op	√			√		√									√
109	*Chionanthus mala-elengi*(Dennst.) P.S Green	1													√	√

Table 4.3

110	*Chromolaena odorata* (L.) King & Robins.	√	√	√	√	√	√	√	√				√	√	√	
111	*Chrysophyllum cainito* L.															
112	*Chrysopogon aciculatus*(Retz.)Trin.	√														
113	*Chukrasia tabularis* A. Juss.			√												
114	*Cinnamomum malabatrum*(Burm.f.) Blume.		√													
115	*Cinnamomum sulphuratum Nees*															√
116	*Cissampelose pareira* L. Var.hirsuta				√		√				√		√	√	√	
117	*Cissus discolor* Blume		√													
118	*Cissus repens* Lam.						√									
119	*Citrus maxima* (Burm. F.) Merr.															√
120	*Cleome monophylla* L.			√				√								
121	*Cleome rutidosperma* DC.	√	√													
122	*Clerodendron paniculatumm*L.	√			√	√										
123	*Clerodendron viscosum* Vent.	√	√	√	√		√		√	√				√	√	
124	*Clidemia hirta* (L.) D. Don				√											
125	*Clitoria ternatea* L.			√	√	√	√									
126	*Coffea arabica* L.															
127	*Combretum albidum* G. Dons		√				√									
128	*Commelina attenuata*KoenigexVahl	√	√	√	√		√		√							
129	*Commelina benghalensis* L.	√			√		√				√					
130	*Commelina ensifolia* R.Br.		√	√				√								
131	*Commelina maculata* Edgew	√	√	√			√	√	√							√
132	*Conyza bonariensis* (L.) Cronq.													√		
133	*Corchorus aestuans* L.															
134	*Costus speciosus* (Koenig) J.E.Smith	√														√
135	*Crinium latifolium* L.			√												
136	*Crotalaria evovuloides* Wight ex Wight & Arn.												√	√		
137	*Crotalaria humifusa* Graham ex Benth.			√												
138	*Cucurligo orchiodes* Gaertn				√						√					√
139	*Cucurma neilgherrensis* Wight	√														√
140	*Cucurma pseudomontana*Graham	√			√		√									
141	*Cucurma zedoaria* (Christm.) Rosc.	√														
142	*Cyanotis cristata* (L.) D. Don				√		√									
143	*Cyanotis tuberosa*(Roxb.) Schult.f.cristata(L.)D.Don			√			√									
144	*Cyanotis villosa* (Spreng.)Schult.f.				√		√									
145	*Cyathula prostrata*(L.) Blume	√	√	√	√	√	√	√							√	√
146	*Cyclea peltata* (Lam.)Hook.f.Thoms.	√	√				√		√						√	
147	*Cymbopogon flexosus* (Nees ex Steud.) Wats.													√		
148	*Cynanchum alatum*Wight & Arn.	√														
149	*Cynodon dactylon (L.) Pers*				√							√				√

Table 4.3

150	*Cyperus diffusus* Vahlssp monostachyus					√										
151	*Cyperus rotundus L.*														√	
152	*Cyperus zollingeri* Steud.		√						√							
153	*Cyrtococcum longipes*(Wight&Arn.exHook.f.)A.Camus					√										
154	*Cyrtococcum oxyphyllum*(Steud.) Stapf	√		√		√	√									
155	*Cyrtococcum patens*(L.) A. Camus	√	√	√	√	√	√	√		√			√	√		
156	*Cyrtococcum trigonum*(Retz.) A. Camus						√									
157	*Dalbergia horrida* (Dennst.) Mabb.		√	√												
158	*Dalbergia lanceolaria* L.f. ssp. Paniculata						√									
159	*Dalbergia lanceolaria* L.f. ssp lanceolaria					√										
160	*Dalbergia latifolia* Roxb.						√									
161	*Dalbergia volubilis* Roxb.	√	√													
162	*Dendrocnide sinuata* (Blume)Chew		√		√											
163	*Derris brevipes* (Benth.) Baker	√	√													
164	*Desmodium alysicarpoides* van Meeuwen	√														
165	*Desmodium ferrugineum* Wall.ex Thw.			√												
166	*Desmodium gangeticum*(L.) DC		√													√
167	*Desmodium heterocarpon*(L.)DC.															
168	*Desmodium heterophyllum*(Wild) DC.	√		√	√											
169	*Desmodium microphyllum*(Thunb.)DC.	√														
170	*Desmodium pulchellum*(L.) Benth.						√						√			
171	*Desmodium triflorum*(L.)DC.	√		√												
172	*Desmodium triangulare*(Retz.)Mers.															√
173	*Desmodium triquetrum*(L.)DC.	√					√							√		
174	*Desmodium zonatum* Miq.				√						√					
175	*Digitaria ciliaris* (Retz.)koeler	√	√				√						√			
176	*Digitaria longiflora* (Retz.)Pers.						√						√	√		
177	*Dioscorea bulbifera* L.		√	√			√	√						√		
178	*Dioscorea pentaphylla* L.						√							√		
179	*Dioscorea tomentosa* Koenig ex Spreng.						√									
180	*Diospyros buxifolia* (Blume) Hiertn															√
181	*Diploclisia glaucescens* (Blume) Diels				√		√				√		√	√	√	
182	*Dipteracanthus prostratus*(Poi.)Nees	√	√				√	√								
183	*Drypetes venusta* (Wight) Pax & Hoffm.		√													
184	*Eclipta prostrata (L.) L.*					√						√				
185	*Elaeocarpus glandulosus Wall.*		√						√						√	√
186	*Elastostemma lineolatum* Wight	√					√									
187	*Elephantopus scaber* L.	√		√	√			√			√					
188	*Elettaria cardamomum*(L.)					√										
189	*Eleusine indica (L.)* Gaertn.								√				√			

190	*Eleutheranthera ruderalis*(SW) Sch.Bip.	√		√				√		√						
191	*Emilia sonchifolia* (L.) DC.	√		√			√						√			
192	*Euphorbia heterophylla*L.															
193	*Euphorbia hirta*L.	√		√	√											
194	*Eurya nitida* Korth.															
195	*Ficus benghalensis* **L**.															√
196	*Ficus exasperata* Vahl	√		√			√						√		√	√
197	*Ficus heterophylla* L.F.															√
198	*Ficus hispida* L.f.		√													
199	*Fimbristylis dichotoma*(L.)Vahl ssp dichotoma	√			√											
200	*Flacourtia montana* Graham															
201	*Flemingia strobilifera* (L.) R.Br. Ex Ait.f.				√											
202	*Flemingia wallichi* Wight & Arn.		√													
203	*Flueggea virosa* (Roxb.ex Willd.) Baill.	√	√		√			√								√
204	*Geophylla repens* (L.) Johnst.				√		√									
205	*Globba marattina*L.					√										
206	*Glochidion ellipticum* Wight	√		√												
207	*Glochidion zeylanicum* (Gaertn.) A Juss.	√														
208	*Gloriosa superba* L.	√		√			√									
209	*Glycosmis pentaphylla* (Retz.) DC.	√	√	√	√		√									√
210	*Gmelina arborea* Roxb.		√													
211	*Gomphandra coriaceae* Wight															
212	*Gomphandra tetrandra*(Wall) Sleumer															√
213	*Gomphostemma eriocarpa*Benth.				√											
214	*Gomphrena celasioides* Mart.						√									
215	*Gomphrena globosa* L.															
216	*Grewia glabra* Blume															√
217	*Grewia nervosa*(Lour.) Panigrahi	√	√		√		√		√							
218	*Grewia tillifolia* Vahl.															√
219	*Gymnostachyum febrifugum*Benth.															
220	*Gynandropsis gynandra* (L.)Briq.	√														
221	*Gynura aurantiaca* (Blume) DC.				√		√									
222	*Hedyotis auricularia* L.	√	√	√	√	√	√									
223	*Hedyotis brachiata*(Wight)	√		√	√			√			√					
224	*Hedyotis corymbosa*(L.) Lam.				√											
225	*Hedyotis puberula* (G.Don) R.Br. Ex Arn.							√								
226	*Helectris isora* L.	√	√	√			√							√	√	√
227	*Heliotropium indicum* L.	√														
228	*Hemidesmus indicus*(L.) R.Br.	√	√	√	√	√	√							√	√	√
229	*Hevea braziliensis* (Willd. Ex A Juss.)		√	√												

230	*Hibiscus hispidissimus* Griff.		√	√	√		√		√					√		
231	*Hibiscus lunarifolius* Wild.	√					√									
232	*Hibiscus surattensis L.*	√														
233	*Holarrhena pubescens* (Buch-Ham.) Wall. Ex G.Don					√	√							√		√
234	*Hugonia mystax* L.		√													
235	*Hydnocarpus pentandra* (Buch.-Ham.) Oken															√
236	*Hygrophila ringens* (L.) Steud.		√	√	√											
237	*Hyptis capitata* Jacq.	√	√	√												
238	*Hyptis sauveolens*(L.) Poit	√														
239	*Ichnocarpus frutiscens*(L)R.Br.	√	√	√	√		√							√		
240	*Impatiens flaccida* Arn.				√											
241	*Indigofera linnaei* Ali.				√											
242	*Ipomea alba L.*	√							√							
243	*Ipomea barlerioides* (Choisy) Benth. Ex Clarke.												√	√		
244	*Ipomea cairica*(L.)Sweet				√			√								
245	*Ipomea marginata*(Desr.) Verdec.				√											
246	*Ipomea obscura*(L.)Ker-Gawl.	√						√								
247	*Ipomea pes-caprae*(L.)R.Br.				√											
248	*Ipomea quamoclit*L.															
249	*Ipomea triloba*(L.)															
250	*Ischaemum indicum*(Houtt.)Merr.	√		√			√									
251	*Ischaemum timorense*Kunth	√	√	√	√		√	√		√						
252	*Ixora brachiata* Roxb.ex.DC.						√									
253	*Ixora coccinea* L.	√	√	√	√											
254	*Ixora finlaysoniana* Wall. Ex Don															
255	*Ixora johnsonii* Hook.f.				√		√								√	
256	*Ixora malabarica*(Dennst.) Mabb.		√		√											
257	*Ixora nigricans* R.Br. Ex Wight & Arn.															√
258	*Jasminum azoricum*L. var azoricum															√
259	*Jasminum brevilobum* A.DC. .	√	√			√	√									√
260	*Jasminum rottlerianum*Wall.ex A. DC. Var.rottle	√	√			√	√						√			√
261	*Julostylis augustifolia*						√						√			
262	*Justicia betonica* L.				√	√										
263	*Justicia japonica* Thunb.			√												
264	*Justicia procumbens* L.	√	√	√	√		√	√	√		√					
265	*Kammetia caryophyllata*(Roxb.)Nicols.Suresh			√												
266	*Knema attenuata*(Hook. F. & Thoms.) Warb.														√	√
267	*Knoxia mollis* Wight& Arn.						√									
268	*Kyllinga brevifolia* Rottb.var.brevifolia	√		√												
269	*Kyllinga pumila* Michaux	√				√										

270	*Lagerstroemia indica* L.															√
271	*Lagerstroemia microcarpa*Wight						√								√	
272	*Lagerstroemia speciosa*(L.) Pers.				√									√	√	√
273	*Lannea coromandelica* (Houtt.) Merr.															√
274	*Lantana camara* L.						√							√		
275	*Lantana camara* L. var.aculeata (L.) Moldenke	√	√	√			√	√						√		
276	*Lawsonia inermis* L.							√								
277	*Leea indica* (Burm.f.) Merr.Philipp.															√
278	*Lepidagathis incurva* Buch.Ham	√		√			√									
279	*Leucaena leucocephala* (Lam.) de Wit															
280	*Leucas aspera* (Willd.)Spreng.	√		√												
281	*Leucas indica* (L.)R.Br.ex Vatke			√												
282	*Limnophila aquatica* (Roxb.) Alston															
283	*Limnophylla repens* (Benth.) Bent. In DC.															
284	*Litsea laevigata* (Nees) Gamble						√									
285	*Lobelia alsinoides* Lam.							√								
286	*Lophatherum gracile*Brogn.		√	√			√									
287	*Ludwigia perennis*L.				√											
288	*Macaranga indica* Wight	√	√	√							√					
289	*Macaranga peltata* Roxb.) Muell.- Arg.						√									
290	*Maesa indica* (Roxb.) DC.				√											
291	*Mallotus philippensis* (Lam.)Muell.- Arg.					√										
292	*Mallotus tetracoccus (Roxb.) Kurz*						√									
293	*Malvastrum coromandelianum*(L.) Garcke													√		
294	*Mangifera indica*L.															√
295	*Manihot glaziovii* Muell.- Arg.						√									
296	*Maranta arundinaceae L.*															√
297	*Meineckia longipes* (Wight) Webster		√													
298	*Meiogyne pannosa* (Dalz.) Sinclair						√									
299	*Meiogyne ramarowii* (Dunn) Gandhi						√									
300	*Melastoma malabathricum*L.		√		√											
301	*Melicope lunu-ankenda* (Gaertn.) Hartley		√						√							
302	*Melochia corchorifolia* L.	√		√										√		
303	*Memecylone randerianum*SM&MR Almeida		√													
304	*Memecylone umbellatum*Burm.f.		√													
305	*Merremia umbellata*(L.)Hall.f.				√		√							√		
306	*Merremia vitifolia*(Burm.f.)Hall.f.	√	√				√	√					√	√		
307	*Mesua ferrea L.*					√										
308	*Michelia nilagirica* Zenk.														√	
309	*Microstegium ciliatum*(Trin.)A.Camus			√												

310	*Mikania macrantha* Kunth	√	√	√		√	√	√	√			√	√			
311	*Mimosa diplotricha* C.Wight&Sanvalle	√	√	√	√				√							
312	*Mimosa pudica* L.	√		√	√	√	√			√	√					
313	*Mitragyna parvifolia* (Roxb.) Korth.															√
314	*Mitracarpus villosus* (S w) DC..	√	√	√	√		√	√			√	√	√		√	
315	*Mollinaria trichocarpa* (Wight)Balakr.			√		√										
316	*Mollugo pentaphylla* L.	√														
317	*Monochoria vaginalis* (Burm.f.)				√											√
318	*Morinda citrifolia* L.				√											
319	*Morus alba* L.															
320	*Mucuna pruriens* (L.) DC.		√				√									
321	*Mukia maderaspatana* (L.) Roem.				√					√		√				
322	*Murdannia japonica* (Thunb.) Faden						√		√							
323	*Murdannia pauciflora* (Wight)Brueck.			√												
324	*Mussaenda bellila* Buch- Ham.	√					√									
325	*Myristica malabarica Lam.*															√
326	*Myxopyrum smilacifolium* (Wall.)Blume					√	√									
327	*Naragamia alata* Wight&Arn.	√	√		√		√							√	√	√
328	*Naravelia zeylanica* (L.) DC.	√	√	√	√											
329	*Naringi crenulata* (Roxb.) Nicols														√	
330	*Neanotis monosperma* (Wall ex Wight & Arn.)		√				√									
331	*Neolamarckia cadamba* (Roxb.) Bosser															√
332	*Nothopegia colebrookeana* (Wight) Blume															
333	*Nothapodytes nimmoniana* (Graham) Mabb.															√
334	*Ochna obtusata* DC.		√													
335	*Ocimum gratissimum* L.				√											
336	*Ocimum tenuiflorum* L.	√														
337	*Olea dioica* Roxb.	√	√				√		√							√
338	*Ophiorrhiza mungos* L.				√											
339	*Oplismenus burmanii* (Retz.) P. Beauv.															
340	*Oplismenus compositus* (L.) P.Beauv.	√	√	√		√	√			√						
341	*Oróxylum indicum* (L.) Benth. Ex Kurz			√												
342	*Oryza sativa* L.	√														
343	*Osbeckia octandra* (L.) DC.	√														
344	*Ottochloa nodosa* (Kunth) Dandy	√		√	√					√	√					
345	*Oxalis corniculata L.*	√				√						√				
346	*Pajanelia longifolia (Willd.) K. Schum.*			√											√	
347	*Panicum brevifolium* L.		√		√	√	√		√					√		
348	*Panicum gardeneri* Thw.								√							
349	*Panicum notatum* Retz.						√									

350	*Panicum repens* L.	√														
351	*Paspalidium flavidum*(Retz.) A.Camus				√								√			
352	*Paspalum canarae*(Steud.)Veldk.			√												
353	*Passiflora edulis* Sims.			√												
354	*Passiflora foetida* L. var. foetida		√											√		
355	*Pavetta indica* L. var. indica	√														
356	*Pavetta tomentosa*Roxb.ex J.E. Smith						√									
357	*Pennisetum polystachyon*(L.) Schult.					√			√				√			
358	*Peperomia pellucida*(L.)Kunth	√	√	√	√	√	√				√					
359	*Perotis indica* (L.)O.Ktze												√			
360	*Persea macrantha* (Nees) Kosterm.			√												√
361	*Phaulopsis imbricata*(Forssk.) Sweet.	√	√						√							
362	*Phyla nodiflora* (L.) Greeene															√
363	*Phyllanthus amarus*Schum.& Thonn.	√	√	√	√	√	√				√					
364	*Phyllanthus embelica* L.														√	√
365	*Phyllanthus gardnerianus*(Wight) Baill.			√												
366	*Phyllanthus myrtifolius*Moon			√												
367	*Phyllanthus reticulatus*Poir.		√	√		√	√									
368	*Phyllanthus urinaria* L.		√		√		√									
369	*Pilea kingii* Fischer														√	
370	*Pilea microphylla (L.) Liebm.*	√	√	√	√	√	√			√	√					
371	*Piper barberi* Gamble															√
372	*Piper longum* L.				√		√		√					√	√	√
373	*Piper nigrum* L.		√	√	√		√							√		√
374	*Plumbago zeylanica* L.	√				√										√
375	*Pogostemon purpurascens*Dalz.	√		√										√		
376	*Polyalthia coffeoides* (Thw.ex Hook. F. & Thoms.)													√		√
377	*Polyalthia fragrans* (Dalz.) Bedd.															√
378	*Pongamia pinnata*(L.) Pierre		√													
379	*Porana* volubilis Burm.f.		√													
380	*Pothos scandens* L.	√	√				√									
381	*Pouzolzia zeylanica*(L.) Bennett	√	√													
382	*Protsasparagus racemosus*(Willd.) Oberm.					√										
383	*Pseudarthria viscida* (L.) wight & Arn.					√										√
384	*Psuedoraphis spinescens* (R. Br.) Vickery															
385	*Psychotria nilgiriensis* Deb & Gangop.						√									
386	*Psydrax dicoccus* Gaertn.															√
387	*Pterocarpus marsupium Roxb.*			√										√		
388	*Pterospermum reticulatum*Wight& Arn.		√	√												
389	*Pueraria phaseoloides* (Roxb.) Benth.	√	√	√	√		√									

390	*Pycnospora lutescens* (Poir.) Schind.	√	√				√									
391	*Pycreus pumilus*(L.0Nees	√														
392	*Quisqualis indica* .															
393	*Rauvolfia micrantha* Hook.f.															√
394	*Rauvolfia serpentina* (L.)0 Benth.		√				√							√		
395	*Richardia scabra* L.															
396	*Rhyncosia cana* (Wild.) DC.						√									
397	*Ricinus communis* L.															√
398	*Rourea minor* (Gaertn.) Marr.		√													
399	*Rungia apiculata* Bedd.		√				√									
400	*Rungia parviflora*(Retz.) Nees	√	√	√	√		√	√								
401	*Rungia pectinata*(L.) Nees	√					√									
402	*Sageratia hamosa* Brongn.		√													
403	*Salacia beddomei* Gamble		√													
404	*Salacia fruticosa* Heyne ex Lawson	√	√				√									
405	*Salacia oblonga* Wall. Ex Wight & Arn.		√						√							
406	*Salvia leucantha* Cav.			√												
407	*Salvia splendens* Sellow ex Roem. Schult.				√											
408	*Samanea samans* (Jacq.) Merr.															
409	*Sapindus trifoliata* L.															√
410	*Saprosoma foetens*(Wight)K.Schum						√									
411	*Sauropus androgynous*(L.) Merr.	√		√												
412	*Sauropus bacciformis* (L.) Airy Shaw,	√					√									
413	*Schleichera oleosa (Lour.) Oken*															√
414	*Schumannianthus variqatus*(Roxb.) Rolfe						√									
415	*Scleria corymbosa* Roxb.		√	√												
416	*Scleria terrestris*(L.) Fassett		√		√	√										√
417	*Scoparia dulcis* L.	√	√	√	√		√	√				√		√		
418	*Sebastiana chamaelea*(L.) Muella.-Arg.	√		√												
419	*Senna alata* (L.)Roxb.															
420	*Senna siamea* (Lam.) Irwin & Barneby						√									
421	*Senna tora* L.		√													
422	*Sesamum orientale* L.															
423	*Setaria barbata*(Lam.) Kunth															√
424	*Setaria palmifolia*(Koenig)Stapf															
425	*Sida acuta* Burm.f.ssp acuta				√											
426	*Sida alnifolia* L.	√		√	√											
427	*Sida beddomei* Jacob	√		√												
428	*Sida cordata*(Burm.f.)Borss.	√		√			√							√		
429	*Sida cordifolia* L.				√											

430	*Sida fryxelli* Sivar.& Pradeep				√											
431	*Sida linifolia* Cav.				√		√									
432	*Sida mysorensis* Wight& Arn.															
433	*Sida rhombifolia* L.	√		√	√						√				√	
434	*Sida rhomboidea* Roxb.ex Fleming							√								
435	*Smilax zeylanica* L.	√	√	√	√		√									√
436	*Solanum americanum* Mill.					√										
437	*Solanum capsicoides* All.				√											
438	*Solanum torvum* Sw.					√										
439	*Solanum virginianum* L.				√											
440	*Solenocarpus indicus* Wight &Arn.		√			√										√
441	*Spermacoce articularis L.*			√												
442	*Spermacoce latifolia* Aubl.	√	√	√	√	√	√			√						
443	*Spermacoce ocymoides* burm.f.				√											
444	*Spilanthus calva* Dc.	√		√	√						√	√		√		
445	*Spilanthus paniculata* Wall.ex DC.															
446	*Spilanthus radicans* Jacq.	√														
447	*Spondias pinnata* (L.f.) Kurz.															√
448	*Sporobolus indicus*(L.) .Br. Var fertilis (Steud.)	√	√				√									
449	*Stachyphyrnium spicatum*(Roxb.) Schum.	√			√											√
450	*Stachytarpheta indica*(L.) Vahl.	√		√	√		√	√					√			
451	*Stachytarpheta jamaicensis*(L.) Vahl	√														
452	*Sterculia guttata* Roxb.ex DC.					√	√									√
453	*Streblus asper* Lour.															√
454	*Strobilanthus ciliatus* Nees.	√					√									√
455	*Strobilanthus heyneanus* Nees						√									
456	*Struchium sparganophorum(l.) O. Ktze*	√				√										
457	*Strychnos colubrina* L.		√		√		√								√	
458	*Strychnos minor* Dennst.		√													
459	*Strychnos nux- vomica* L.	√	√				√							√		√
460	*Strychnos lenticellata*															√
461	*Stylosanthes fruticosa*(retz.) Alston.		√													
462	*Suregada augustifolia* (Baill.exMuell.-Arg.)Airy Shaw		√						√							
463	*Swietenia mahogoni*(L.) jacq.	√														
464	*Symplocos cochin chinensis* (Lour.) Moore ssp laurind		√				√						√			
465	*Synedrella nodiflora* (L.) Gaertn.	√	√	√	√	√	√									
466	*Syzygium calophyllifolium* Walp.		√						√							
467	*Syzygium caryophyllatum*(L.) Alston		√													√
468	*Syzygium cumini*(L.) Skeels															√
469	*Syzygium hemisphericum*(Wight) Alston		√													

470	*Syzygium occidentalis*(Bourd.) Gandhi				√											
471	*Syzygium zeylanicum*(L.) DC.		√	√	√											
472	*Tabernaemontana divaricata*(L.) R.Br.	√	√	√			√	√						√		
473	*Tabernaemontana heyneana*Wall.														√	
474	*Tabernaemontana gamblei*Subram. & Henry		√													
475	*Tecomaria capensis* (Thunb.) Spach.		√													
476	*Tectona grandis* L.f.					√										√
477	*Tephrosia pumila* (Lam.) Pers.	√			√			√								
478	*Tephrosia purpurea* (L.) Pers.	√			√		√	√								
479	*Terminalia bellirica* (Gaertn.) Roxb.														√	√
480	*Terminalia chebula* Retz.															
481	*Terminalia elliptica* Willd.															√
482	*Terminalia catappa* L.						√									
483	*Terminalia paniculata* Roth		√		√		√							√		√
484	*Tetracera akara* (Burm.f.) Merr.		√													
485	*Tetrameles nudiflora* R.Br.															√
486	*Themeda triandra* Forssk		√	√												
487	*Thespesia lampas* (Cav.) Dalz.& Gibs.															√
488	*Theriophonum infaustum*N.E.Br.	√		√												
489	*Thottea siliquosa* (Lam.)Ding Hou				√											
490	*Tiliacora acuminata* (Poir.)n Miers ex Hook. f.& Thoms.						√								√	√
491	*Toona ciliata* Roem.			√												√
492	*Trema orientalis* (L.)		√						√						√	
493	*Trichosanthes nervifolia* L.				√											
494	*Tridax procumbens* L.			√												
495	*Triumphetta rhomboidea*Jacq.	√												√		
496	*Turpinia malabarica* Gamble						√									
497	*Tylophora indica*(Burm.f.) Merr.	√	√		√		√				√			√	√	
498	*Tylophora mollisma* Wight&Arn	√	√				√							√		
499	*Urena lobata* L.ssp lobata	√		√	√		√							√		
500	*Urena lobata* ssp *sinuata*(L.) Borss.	√					√	√	√			√		√		
501	*Utricularia stellaris* Lf.								√							
502	*Vernonia anthelmintica*(L.) Wild.		√													
503	*Vernonia cinerea*(L.) Less.	√	√	√	√	√	√	√	√					√		
504	*Vernonia elliptica* DC.	√						√								
505	*Vigna umbellata* (Thunb.) Ohwi & Ohashi		√													
506	*Waltheria indica* L.												√			
507	*Wedelia chinensis* (Osbeck) Merr.						√									
508	*Wedelia trilobata* (L.) A.S. Hitche.			√												
509	*Wrightia tinctoria* (Roxb.) R.Br.															

Table 4.3

510	*Xanthophyllum arnottianum* Wight		√		√	√	√									√
511	*Xenostegia tridentata* (L.) Austin&Staples	√					√	√						√		
512	*Xylia xylocarpa* (Roxb.) Taub.						√							√		
513	*Zanthozylum rhetsa* (Roxb.) DC.														√	√
514	*Zingiber zerumbet* (L.) J.E.Smith	√														
515	*Zizyphus mauritiana* Lam.		√	√			√									
516	*Zizyphus oenoplea* (L.) Mill.	√	√				√							√		√
517	*Zizyphus rugosa* Lam.			√	√	√	√							√		√
	Gymnosperms															
1	*Cycas circinalis L.*	√						√								
	Pteridophytes															
1	*Adiantum capillus-veneris* L.			√			√									
2	*Adiantum caudatum* L.		√	√												
3	*Adiantum lunulatum* Burm.f.	√				√		√	√		√		√			
4	*Bolbotis prolifera* (Bory) C.Chr.& Tardieu															√
5	*Ceratopteris thelictroides(L.)Brongn.*			√			√									
6	*Cheilianthes tenuifolia* (Burm.f.) Sw.	√														
7	*Christella parasitica* (L.) H. Lev.						√									
8	*Diplazium esculentum (Retz) Sw.*			√												
9	*Drynaria quercifolia* (L.) J.Sm.						√									√
10	*Lindsaea ensifolia Sw.*	√					√									
11	*Lygodium flexuosum* (L.) Sw.	√	√		√		√							√	√	
12	*Nephrolepis auriculata* (L.) Trimen	√	√		√	√	√							√		
13	*Nephrolepis delicatula* (Decne.) Pic.Serm		√			√		√	√		√		√			
14	*Parahemionites cordata* Roxb.ex Hook.& Grev. I	√		√												√
15	*Polystichum moluccense* (Blume) T. Moore				√											
16	*Pteridium revolutum* (Blume) Nakai			√												
17	*Pteris biaurita* L.	√		√			√									√
18	*Pteris confusa* T.G.Walker				√	√										
19	*Pteris scabripes* Wall.ex J. Agardh														√	√
20	*Pyrrosia heterophylla* (L.) M.G.Price	√	√		√			√	√		√		√	√		√
21	*Selaginella delicatula* (Desv.ex Poir.) Alston	√	√	√	√	√	√	√	√		√		√			

Rubber plantation areas

Open areas

Forest areas

Table 4.5 - Taxonomic , ecological description and conservation status of the plant species in the rubber plantations.

S.No.	Name of the plant	Vernacular name	Family	Habit	Types of areas in which the plant species is genrally found		Status
Angiosperms							
1	*Abrus precatorius* L.	Kunni	Fabaceae	Twining shrub			
2	*Abrus pulchellus* Wall. Ex Thw.		Fabaceae	Twining shrub	Semi ev.gr. For., Moist decd. For.		
3	*Abutilon ramosum* (Cav.) Guill. & Perr.		Malvaceae	Erect shrub	Degr. For.		
4	*Acacia pennata* (L.)Wild.	Karincha	Mimosaceae	Scandent shrub	Moist decd.for		
5	*Acacia sinuata* (Lour.)Merr.	Chenikka	Mimosaceae	Climbing shrub	Moist decd.for		
6	*Acalypha indica* L.	Kuppameni	Euphorbiaceae	Herb	Dry decd.for. ,Plains		
7	*Acalypha racemosa* Heyne ex Baill.	Valia kuppameni	Euphorbiaceae	Sub shrub	Semi ev. Gr. For., Dry decd for. Plains		
8	*Achyranthes aspera* L.	Kadaladi	Amaranthaceae	Herb	Degr. Decd. For., Plantations		
9	*Acrotrema arnottianum* Wight	Nilampunna	Dilleniaceae	Rhizomatous herb	Ev. Gr. For.		Endemic to S.Western ghats
10	*Adenostemma lavenia* (L.) O. Ktze.		Asteraceae	Erect herb	Ev. Gr. For., Semi ev. Gr. For.		
11	*Aeginetia indica* L.	Keripu	Orobanchaceae	Prostratre herb	Semi Ev. Gr. For., Moist decd. For.		
12	*Aerva lanata* (L.) Juss.ex Schult.	Cherula	Amaranthaceae	Herb	Decd. for., Open areas		
13	*Aganope thyrsiflora* (Benth.)		Fabaceae	Shrub	Semi ev.gr. For.,Plains		
14	*Ageratum conizoides* L.	Appa,Katappa	Asteraceae	Erect herb	weed in open areas		
15	*Ageratum haustonianum* Mill.		Asteraceae	Herb	degrd.for.,open areas		
16	*Agnosma cymosa* (Roxb.) G. Don		Apocynaceae	Climber	Semi ev.gr. For., Alongside streams		
17	*Agrostistachys indica* Dalz.		Euphorbiaceae	Small tree	Ev. Gr. For., Shola for.		Endemic to central and peninsular India
18	*Ailanthus triphysa (Dennst.) Alston*	Permaram	Simaroubaceae	Large tree	Semi ev. Gr. For., Plains		
19	*Albizia amara* (Roxb.) Boivin	Oonjal	Mimosaceae	Medium tree	Dry decd. for.		
20	*Albizia lebbeck* (L.) Willd.	Vaka	Mimosaceae	Large tree	Decd. for. ,Plains		
21	*Albizia odoratissima* (L.f.) Benth.	Kunni vagha	Mimosaceae	Large tree	Dr decd. for. ,plains		
22	*Allophylus cobbe* (L.) Raeusch.	Mukkannanpezhu	Sapindaceae	Small tree	Semi ev. Gr. For.,Moist decd for.,Sacred groves		

Table 4.5 Chapter 4: Results

23	*Allopteris cinicina* (L.)Stapf		Poaceae	herb	Moist&dry decdfor.,Openareas		
24	*Alstonia scholaris* (L.) R.Br.	Ezhilampala	Apocynaceae	Large tree	Moist decd for. ,Sacred groves,plains		
25	*Alternanthera pungens* Kunth		Amaranthaceae	Herb	Degr. Decd.for.,Open areas		
26	*Alternanthera sessilis* (L.) R.Br.	Kozhuppa	Amaranthaceae	Herb	Water courses, marshy areas		
27	*Anamirta cocculus* (L.) Wight & Arn.	Pollakai	Menispermaceae	Woody climber	Semi ev. Gr. For.,Moist decd. For.,Plains		
28	*Andrographis atropurpurea* (Dennst)Alston.		Acanthaceae	herb	Ev.gr.,semi ev.gr.for.		
29	*Andrographis lineata* Wall.ex.Nees		Acanthaceae	Sub shrub	Grasslands		Endemic to South Western ghats
30	*Andrographis paniculata* (Burm.f.)Wall.ex Nees	Nilavepu	Acanthaceae	Sub shrub	Scrub jungles,plains		
31	*Aneilemma montana* (Wight) Clarke		Commelinaceae	Herb	Ev gr. For., Semi ev. Gr. For.		Endemic to peninsular India
32	*Aneilemma scaberrimum* (Blume) Kunth		Commelinaceae	Herb	Ev gr. For., Semi ev. Gr. For.		
33	*Anisochilus carnosus (L.f.) Wall. Ex Benth.*	Kattukoorkka	Lamiaceae	Erect herb	Rocky areas		
34	*Antidesma acidum* Retz.	Areepazham	Euphorbiaceae	Small tree	Semi ev.gr. For.,Moist decd for.,Sacred groves		
35	*Antidesma alexiteria* L.	Thathalamaram	Euphorbiaceae	Small tree	Ev.gr. For.		
36	*Antidesma montanum* Blume	Putharaval	Euphorbiaceae	Small tree	Ev.Gr. For.,Shola for., Sacred groves		
37	*Antistrophe serratifolia* (Bedd.) Hook.f.		Myrsinaceae	Erect herb	Ev. Gr. For.		Endemic to south western ghats. Vulnerable (Nayar, 1997)
38	*Apluda mutica* (L.)		Poaceae	Herb	Moist decd.for. ,Open areas		
39	*Aporosa acuminata* Thw.	Neervetti	Euphorbiaceae	Small tree	Ev.gr. For.		
40	*Aporosa lindleyana* (Wight) Baill.	Vetti	Euphorbiaceae	Medium tree	Ev. Gr for., Semi ev. Gr. For., Plains		
41	*Ardisia pauciflora* Heyne ex Roxb.	Muttumaram	Myrsinaceae	Small tree	Ev gr. For., Shola for.		
42	*Argyreia hirsuta* Wight & Arn.	onapoo	Convolvulaceae	Climber	Decd. For., Plains		
43	*Aristolochia tagala* Cham.	Garuda kod	Aristolochiaceae	Climbing shrub	Ev. Gr. For., Semi ev. Gr. For., Moist decd for.		
44	*Artocarpus heterophyllum* Lam.	Plavu	Moraceae	Large tree	Cultivated		
45	*Artocarpus hirsutus* Lam.	Anjili	Moraceae	Large tree	Semi ev gr,Moist decd.for,Plains		Endemic to South Western ghats
46	*Asystacia gangetica* (L.) Andersvar. gangetica	Upputhali	Acanthaceae	Sub shrub	Degrd.for.Plains		
47	*Asystasia dalzelliana* Sant.		Acanthaceae	Herb	Ev gr.for.,Semi ev.gr. For.		

48	*Axonopus compressus*(Sw.) P.Beauv.		Poaceae	Herb	Moist&dry decd.for.,Open areas,paddyfields		
49	*Azadirachta indica* A. Juss.	Aariyaveppu	Meliaceae	Medium tree	Dry decd. For., Cultivated		
50	*Bambusa bambos*(L.)Voss	Mulla	Poaceae	Shrub	Ev.gr.for.,Dry decd.for.,Grasslands		
51	*Barleria buxifolia* L.		Acanthaceae	Small prickly shrub	Open areas		Endemic to peninsular India
52	*Barleria cristata* L.		Acanthaceae	Shrub	Moist decd. For. ,Plains		
53	*Bauhinia malabarica* Roxb.	Arampuli	Caesalpiniaceae	Small tree	Decd. for.		
54	*Bidens pilosa* L.		Asteraceae	Shrub	Open areas,a weed		
55	*Biophytum reinwardtii* (Zucc.) Klotzsch.var *reinwardtii*		Oxalidaceae	Erect herb	Moist decd. for. ,Plantations, Plains		
56	*Biophytum sensitivum*(L.) DC. Var sensitivum	Mukkutti	Oxalidaceae	Herb	Dry decd. for.,Grasslands		
57	*Biophytum sensitivum*(L.) DC. Var *candolleanum* (Wight) Edgew.&Hook.f.	Nilamthengu	Oxalidaceae	Herb	Dry decd. For. , Grasslands		
58	*Blainvillea acmella* (L.) Philip		Asteraceae	Herb	Dry decd. For., Plains		
59	*Blepharistemma serratum* (Dennst.)	Nirkurunda	Rhizophoraceae	Small tree	Semi ev. Gr. For.,Moist decd. For., Plains		
60	*Blumea lacera*(Burm.f.) DC.	Rakilla	Asteraceae	Erect herb	Dry decd. For., Plains		
61	*Blumea mollis* (D.Don) Merr.		Asteraceae	Erect herb	degr.decd for,grasslands		
62	*Blumea oxydonta* DC.		Asteraceae	Herb	along streams and open areas		
63	*Boehmaria macrophylla* Hornem. Var. macrophylla		Urticaceae	Shrub	Ev. Gr. For.		
64	*Boerhaaavia diffusa* L.	Thazhuthama	Nyctaginaceae	Prostrate herb	Moist & Dry decd. For., Plains		
65	*Boesenbergia pulcherrima* (Wall.)O.Ktze		Zingiberaceae	Annual herb	Evgr.for.,Semi ev.gr.for.		Threatened Nayar1997
66	*Bombax cieba* L.	Elavu	Bombacaceae	Very large tree	Semi ev.gr. For.,Moist decd. For.		
67	*Bracharia ramosa* (L.) Stapf		Poaceae	Herb	Grasslands,Moist decd forest,Open ares		

68	*Bridelia retusa* (L.) Spreng.	Mulluvenga	Euphorbiaceae	Medium tree	Semi ev. Gr. For.,Decd. For., Plains		
69	*Bulbostylis densa(* Wall.exRoxb.)Hand-Mazz.		Cyperaceae	Herb	Grasslands,Open areas		
70	*Caesalpinia mimosoides* Lam.	Theemullu	Caesalpiniaceae	Climbing shrub	Moist decd. for.,Degrd.for.,Plains		
71	*Caladium bicolor*(Ait.ex Dryand.)Vent.	Kaatu chembu	Araceae	Tuberous herb	Open areas		
72	*Calycopteris floribunda* Lam.	Pullanni	Combretaceae	Woody climber	Moist decd. For,., Plains		
73	*Canthium augustifolium Roxb.*	Kattaramullu	Rubiaceae	Scandent shrub	Semi Ev.gr.for.		
74	*Canthium coromandelicum* Burm.f.Alston	Karamullu	Rubiaceae	Shrub	dry decd. For.,sacred groves		
75	*Cardiospermum halicacabum* L.	Paluruvam	Sapindaceae	Climbing herb	Moist decd for., Scrub jungles		
76	*Careya arborea* Roxb.	Aalam	Lecythidaceae	Small tree	Moist & Dry decd. For., Plains		
77	*Caryota eurens* L.	Anapana	Arecaceae	Tree	Ev. Gr. For., Plains		
78	*Cassia javanica*		Caesalpiniaceae	Tree		Exotic	
79	*Centella asiatica* (L.)	Kudakkan	Apiaceae	Prostrate herb	Decd. For.,plains,Wet places		
80	*Centrosema pubescens* Benth.	Kattupayani	Fabaceae	Slender climber	Decd. For., Plantations, Plains		
81	*Chamaecrista mimosoides*(L.)Greene.	Ceruthakara	Caesalpiniaceae	erect herb	dryand moist decd.for.		
82	*Chasssalia curviflora* Wall.ex Kurzz Thw. Var *ophioxyloides* (Wall.) Deb & Krishna	Vellakurinji	Rubiaceae	Shrub	All types of forests, Plains		
83	*Chromolaena odorata* (L.) King & Robins.	Cummunist pacha	Asteraceae	Shrub	Open areas		
84	*Chrysopogon aciculatus*(Retz.)Trin.	Snehapullu	Poaceae	herb	Degr.dry&Moist decd.for.,plains		
85	*Chukrasia tabularis* A. Juss.	Karadi	Meliaceae	Large tree	Ev. Gr. For., Semi ev. Gr. For., Moist decd. For., Shola for.		
86	*Cinnamomum malabatrum* (Burm.f.) Blume.	Vayana	Lauraceae	Medium tree	Ev. Gr. For., Semi ev. Gr. For.		
87	*Cissampelose pareira* L. Var.hirsuta	Malathangi	Menispermaceae	Herbaceous climber	Decd. For., Plains		
88	*Cissus discolor* Blume	Njerinjampuli	Vitaceae	Shrub	Semi ev. Gr. For., Moist decd. For.		

89	*Cissus repens* Lam.	Mrigampuli	Vitaceae	Scandent shrub	All types of forest		
90	*Cleome monophylla* L.		Capparaceae	Erect herb	Dry decd for., Plain		
91	*Cleome rutidosperma* DC.	Neelavela	Capparaceae	Herb	Coastal areas		
92	*Clerodendron paniculatumm* L.	Krishnakireedam	Verbenaceae	Shrub	Cultivated		
93	*Clerodendron viscosum* Vent.	Perivelum	Verbenaceae	Small tree	Degrd for., Plains		
94	*Clidemia hirta* (L.) D. Don		Melastomaceae	Shrub	Degr. For. Areas		
95	*Clitoria ternatea* L.	Shankhapushpam	Fabaceae	Climber	Open areas, cultivated		
96	*Combretum albidum* G. Dons	Manjakody	Combretaceae	Woody climber	*Semi ev. Gr.* For., Alongside river banks		
97	*Commelina attenuata* KoenigexVahl		Commelinaceae	Herb	Grasslands,plains		
98	*Commelina benghalensis* L.	Kanavazhai	Commelinaceae	Herb	Decd.for.,Open areas		
99	*Commelina ensifolia* R.Br.		Commelinaceae	Slender herb	Grasslands,Sacredgrovews		
100	*Commelina maculata* Edgew		Commelinaceae	Erect herb	Ev.gr.for.		
101	*Costus speciosus*(Koenig) J.E.Smith	Channa	Zingiberaceae	Herb	Semiev.gr.,Moist decd.for.,Plains		
102	*Crinium latifolium* L.		Amaryllidaceae	Perennial herb	Grassland		
103	*Crotalaria humifusa* Graham ex Benth.		Fabaceae	Herb	Grasslands		
104	*Cucurligo orchiodes* Gaertn	Nilapana	Hypoxidaceae	Herb	Moist decd. For. Grasslands ,Plains		
105	*Cucurma neilgherrensis* Wight	Koova	Zingiberaceae	Rhizomatous herb	Grasslands		
106	*Cucurma pseudomontana* Graham		Zingiberaceae	Herb	Grassland,Open areas		Endemic to peninsular India
107	*Cucurma zedoaria* (Christm.) Rosc.	Manja koova,Kasthuri manjal	Zingiberaceae	Rhizomatous herb	Moist decd. For., Plains		
108	*Cyanotis cristata* (L.) D. Don		Commelinaceae	Erect herb	Grasslands,Degr.for.,Open areas		
109	*Cyanotis tuberosa*(Roxb.) Schult.f		Commelinaceae	Perennial herb	Grasslands,Wet rocks		Endemic to peninsular India
110	*Cyanotis villosa*(Spreng.)Schult.f.		Commelinaceae	Herb	Moist decd. For.		
111	*Cyathula prostrata*(L.) Blume	Cherukadaladi	Amaranthaceae	Herb	Semi ev.gr.for.,Moist decd.for.,plains		
112	*Cyclea peltata*(Lam.)Hook.f.Thoms.	Padathalli	Menispermaceae	Climber	Ev.gr.,Semiev.gr. For.		
113	*Cynanchum alatum* Wight & Arn.		Asclepiadaceae	Twining herb	Semi ev. Gr. For.		Endemic to south western ghats, Rare (Nayar,1997)
114	*Cynodon dactylon (L.) Pers*	Karuka	Poaceae	Herb	Paddy fields ,Open areas		
115	*Cyperus diffusus* Vahlssp monostachyus		Cyperaceae	Herb	along streams		

116	*Cyperus zollingeri* Steud.		Cyperaceae	Herb	Moist decd. For.		
117	*Cyrtococcum longipes*(Wight&Arn.exHook.f.)A.Camus		Poaceae	herb	Evgr.for.,Dry decd.for.,Grassland		Endemic to Western Ghats
118	*Cyrtococcum oxyphyllum*(Steud.) Stapf		Poaceae	herb	Moist decd.for.,Semi ev.gr.for,Evgr.for.		
119	*Cyrtococcum patens*(L.) A. Camus		Poaceae	herb	Moist decd.for.Plains		
120	*Cyrtococcum trigonum*(Retz.) A. Camus		Poaceae	herb	Damp places along seacoast Open areas, Forests		
121	*Dalbergia horrida* (Dennst.) Mabb.	Aanamullu	Fabaceae	Climbing shrub	Semi ev.gr. Fro.,Moist decd.for.,Sacred groves		Endemic to South Western ghats
122	*Dalbergia lanceolaria* L.f. ssp lanceolaria	Velleeti	Fabaceae	Medium tree	Dry and Moist decd for		
123	*Dalbergia lanceolaria* L.f. ssp. Paniculata	Pinekanni	Fabaceae	Medium tree	Dry and Moist decd for.		
124	*Dalbergia latifolia* Roxb.	Eeti	Fabaceae	Large tree	Dry and Moist decd for.		Vulnerable IUCN 2000
125	*Dalbergia volubilis* Roxb.		Fabaceae	Woody climber	Moist decd for.		
126	*Dendrocnide sinuata* (Blume)Chew	Anamayakki	Urticaceae	Small tree	Ev. Gr. For.		
127	*Derris brevipes* (Benth.) Baker		Fabaceae	Woody climber	Moist decd.for		Endemic to Western ghats
128	*Desmodium alysicarpoides* van Meeuwen		Fabaceae	Erect herb	Moist decd.for		
129	*Desmodium ferrugineum* Wall.ex Thw.		Fabaceae	Sub shrub	Decd. , Moist decd for., plantations		
130	*Desmodium gangeticum*(L.) DC	Orila	Fabaceae	Shrub	Moist decd.for.,plantations		
131	*Desmodium heterophyllum*(Willd) DC.		Fabaceae	Prostrate herb	Dergraded moist decd.for.		
132	*Desmodium microphyllum*(Thunb.)DC.		Fabaceae	Herb	Grassland,savannah		
133	*Desmodium pulchellum*(L.) Benth.	Cherupachotti	Fabaceae	sub shrub	Moist decd.for.		
134	*Desmodium triflorum* (L.)DC.	Cherupulladi	Fabaceae	Prostrate herb	Moist decd. for., Grasslands		
135	*Desmodium triquetrum*(L.)DC.	Adakkapanal	Fabaceae	Shrub	Semi ev.gr.for,Moist decd.for.,Plains		
136	*Desmodium zonatum* Miq.		Fabaceae	Erect herb	Semi ev.gr.for.,moist decd.for.		
137	*Digitaria ciliaris* (Retz.)koeler		Poaceae	Herb	Moist decd.for.,Grassland,Open areas		
138	*Digitaria longiflora* (Retz.)Pers.		Poaceae	Herb	Grasslands,Open areas		

139	*Dioscorea bulbifera* L.	Kattu kaachil	Dioscoreaceae	Climbing shrub	Moist decd.for.,Plains		
140	*Dioscorea pentaphylla* L.	Noorakizhangu	Dioscoreaceae	Climbing shrub	Degraded decd for.		
141	*Dioscorea tomentosa* Koenig ex Spreng.	Kavala	Dioscoreaceae	Climbing shrub	Semi ev. Gr. For., Shola for.		
142	*Diploclisia glaucescens*(Blume) Diels	Vattoli	Menispermaceae	Woody climber	Ev.gr.,Semi ev.gr.fro.,moist decd for.		
143	*Dipteracanthus prostratus*(Poi.)Nees		Acanthaceae	Herb	Degr. For., Plains		
144	*Drypetes venusta* (Wight) Pax & Hoffm.	Konnamaram	Euphorbiaceae	Medium tree	Ev.gr. For., Sem ev. Gr. For.		Endemic to Western ghats
145	*Eclipta prostrata* (L.) L.	Kayyunni	Asteraceae	Herb	Paddy fields		
146	*Elaeocarpus glandulosus Wall.*	Kara	Elaeocarpaceae	Medium tree	Ev gr. For, Semi ev. Gr. For., Shola for.		
147	*Elastostemma lineolatum* Wight		Urticaceae	Herb	Ev.gr. For., Semi ev. Gr. For.		
148	*Elephantopus scaber* L.	Anachuvadi	Asteraceae	Herb	Moist decd.for., Plains		
149	*Elettaria cardamomum* (L.)	Elam	Zingiberaceae	Rhizomatous herb	Ev. Gr. For. Cultivated		
150	*Eleutheranthera ruderalis* (SW) Sch.Bip.		Asteraceae	herb	Degr.moist decd.for.,plains		
151	*Emilia sonchifolia* (L.) DC.	Muyalchevian	Asteraceae	Prostrate herb	Moist & Dry decd. For., Plains		
152	*Euphorbia hirta*L.	kuzhinagappala	Euphorbiaceae	Erect herb	degr.decd.for.,Plains.Plantations		
153	*Ficus exasperata* Vahl	Therakom	Moraceae	Small tree	Moist decd for., Plains		
154	*Ficus hispida* L.f.	Thonditherakom	Moraceae	Small tree	Semi ev gr,Moist decd.for,Plains		
155	*Fimbristylis dichotoma*(L.)Vahl ssp dichotoma		Cyperaceae	Herb	Degr. Decd. For.,Cultivated land,Riverbanks		
156	*Flemingia strobilifera* (L.) R.Br. Ex Ait.f.	Kumalu	Fabaceae	Shrub	Semi ev. Gr. For., Decd for.,Plains		
157	*Flemingia wallichi* Wight & Arn.		Fabaceae	Erect shrub	Ev.gr. For.		
158	*Fluggea virosa* (Roxb.ex Willd.) Baill.	Perimklavu	Euphorbiaceae	Small tree	Dry and Moist decd for.,Plains		
159	*Geophylla repens* (L.) Johnst.	Karimutthil	Rubiaceae	Prostrate herb	Semi ev. Gr. For. Moist decd. for.		
160	*Globba maratina*L.		Zingiberaceae	Rhizomatous herb	Moist decd.for.,Grassland,Openareas		
161	*Glochidion ellipticum* Wight	Njanjetti	Euphorbiaceae	small tree	Ev. Gr. For. ,Shola for		Endemic to Western ghats
162	*Glochidion zeylanicum* (Gaertn.) A.Juss.	Neervetti	Euphorbiaceae	small tree	Ev. Gr for., Semi ev. Gr. For., Plains		Endemic to Western ghats

163	*Gloriosa superba* L.	Menthonni	Liliaceae	Climbing herb	Semi ev.gr. for., Moist decd.&dry decd. for.,Sacred groves		
164	*Glycosmis pentaphylla* (Retz.) DcC.	Panal	Rutaceae	Small tree	Semi ev gr,Moist decd.for,Plains		
165	*Gmelina arborea* Roxb.	Kumbil	Verbenaceae	Medium tree	Moist & Dry decd. For., Plains		
166	*Gomphostemma eriocarpa* Benth.		Lamiaceae	Slender herb	Ev . Gr. For.		Endemic to south western ghats
167	*Gomphrena celasioides* Mart.		Amaranthaceae	Herb	Decd. For.,Plains		
168	*Grewia nervosa*(Lour.) Panigrahi	Kottakka	Tiliaceae	Small tree	Semi ev. Gr. For.,Scrub jungles,Sacred groves		
169	*Gynandropsis gynandra* (L.)Briq.	Karavela	Capparaceae	Erect herb	Decd. for. ,Plains		
170	*Gynura aurantiaca* (Blume) DC.		Asteraceae	Herb	cultivated		
171	*Hedyotis auricularia* L.	Erachiketti	Rubiaceae	Herb	Degr.for.,Plains		
172	*Hedyotis brachiata*(Wight)		Rubiaceae	Herb	Open areas		
173	*Hedyotis corymbosa*(L.) Lam.	Onathumba	Rubiaceae	Herb	Degrd.for,Plains		
174	*Helectris isora* L.	Edampiri vallampiri	Sterculiaceae	Small tree	Decd. For., Plantation, Plains		
175	*Heliotropium indicum L.*	Thelkkada	Boraginaceae	Herb	Lkaeshores ,Paddy fields		
176	*Hemidesmus indicus*(L.) R.Br.	,naruneendi	Periplocaceae	Shrub	Decd for,Plains,Plantations		
177	*Hevea braziliensis* (Willd. Ex A Juss.)	Rubber	Euphorbiaceae	Tree	cultivated		Introduced
178	*Hibiscus hispidissimus* Griff.	Mattipuli,Uppanacham	Malvaceae	Rambling shrub	Dry& Moist decd for., Plains		
179	*Hibiscus lunarifolius* Wild.	Mlamkuruparetthi	Malvaceae	shrub	Dry , Moist decd. For.		
180	*Hibiscus surattensis* L.	Kakkapoovu	Malvaceae	Scandent sub shrub	Moist decd. For., Plains		
181	*Holarrhena pubescens* (Buch-Ham.) Wall. Ex G.Don	Kadalapala	Apocynaceae	Small tree	Moist decd. For., Dry decd. For. ,Plains		
182	*Hugonia mystax* L.	Modirakanni	Linaceae	Climbing shrub	Moist decd. For., plains		
183	*Hygrophila ringens* (L.) Steud.		Acanthaceae	Shrub	all areas		
184	*Hyptis capitata* Jacq.		Lamiaceae	Shrub	Degr.for.,Open areas		
185	*Hyptis sauveolens*(L.) Poit		Lamiaceae	Sub shrub	Degr.decd.for.,Open areas		
186	*Ichnocarpus frutiscens*(L)R.Br.	Palvalli	Asclepiadaceae	climber	Moist dry decd.for.,plains		
187	*Impatiens flaccida* Arn.		Balsaminaceae	Herb	moist decd. For.		
188	*Indigofera linnaei* Ali.	Cherru-pulladi	Fabaceae	Prostrate herb	Grasslands ,Plains		
189	*Ipomea alba L.*	Mandavalli	Convolvulaceae	Climber	Moist decd. For., along sea coast		

190	*Ipomea cairica* (L.)Sweet	Kolambipoo	Convolvulaceae	Twiner	Moist & Dry decd. For., Plains		
191	*Ipomea marginata* (Desr.) Verdec.	Kolambi, Thiruthali	Convolvulaceae	Climber	Swampy areas		
192	*Ipomea obscura* (L.)Ker-Gawl.	Thiruthali	Convolvulaceae	Twiner	Degr. For., Plains		
193	*Ipomea pes-caprae* (L.)R.Br.	Adumbuvalli	Convolvulaceae	Creeping herb	Sandy coasts ,Railaway tracts		
194	*Ischaemum indicum* (Houtt.)Merr.		Poaceae	herb	Moist grasslands,Forest margins		
195	*Ischaemum timorense* Kunth		Poaceae	herb	Margins of backwaters,Grasslands		
196	*Ixora brachiata* Roxb.ex.DC.	Marachetti	Rubiaceae	Small tree	Semi ev.gr.for.		Endemic to Western ghats
197	*Ixora coccinea* L.	Chetti	Rubiaceae	Shrub	Plains		
198	*Ixora johnsonnii* Hook.f.		Rubiaceae	Shrub	Ev.gr.for.		
199	*Ixora malabarica* (Dennst.) Mabb.	Cherukaravu	Rubiaceae	Shrub	Semi ev.gr.for.,Moist decd.for,Sacred groves		Endemic to S.outh Western Ghats, Vulnerable
200	*Jasminum brevilobum* A.DC..	Kattumulla	Oleaceae	Climbing shrub	Shola for.		Endemic to peninsular India
201	*Jasminum rottlerianum* Wall.ex A. DC. Var.*rottlerianum*	Kattumulla	Oleaceae	Climbing shrub	Ev.gr. For.,moist decd.for., Shola for.		
202	*Julostylis augustifolia (Arn.) Thw.*		Malvaceae	Small tree	Semi ev. Gr. For., Moist decd. For.		
203	*Justicia betonica* L.	Vellakurunji	Acanthaceae	Shrub	Moist decd for.,Open areas		
204	*Justicia japonica* Thunb.		Acanthaceae	Herb	Grassland,Open areas		
205	*Justicia procumbens* L.		Acanthaceae	Herb	Moist decd.for.,Grasslands,Plains		
206	*Kammetia caryophyllata* (Roxb.)Nicols.Suresh		Apocynaceae	Climbing shrub	Ev gr. For. Semi ev. Gr. For. Sacred groves		
207	*Knoxia mollis* Wight& Arn.		Rubiaceae	Herb	Ev. Gr. For.,Moist decd. For.		
208	*Kyllinga brevifolia* Rottb.var. brevifolia		Cyperaceae	herb	Marshy areas,Openareas		
209	*Kyllinga pumila* Michaux		Cyperaceae	herb	Grasslands		
210	*Lagerstroemia microcarpa* Wight	Venthekku	Lythraceae	Large tree	Moist decd. For., Plains		Endemic to western ghats
211	*Lagerstroemia speciosa* (L.) Pers.	Poomarathu	Lythraceae	medium tree	Ev.gr.for.,Semi ev.gr.for.,Along banks of rivers,Cultivated		
212	*Lantana camara* L.	Poochedi, Konda	Verbenaceae	Shrub	Wid ,Cultivated		
213	*Lantana camara* L. var.aculeata (L.) Moldenke	Konda	Verbenaceae	Shrub	Cultivated		

214	*Lepidagathis incurva* Buch.Ham		Acanthaceae	Herb	Decd for.,Open areas		
215	*Leucas aspera* (Willd.)Spreng.	Thumba	Lamiaceae	Herb	Decd. for., Open areas		
216	*Leucas indica* (L.)R.Br.ex Vatke	Thumba	Lamiaceae	Erect herb	Moist & Dry decd. For., Plains, Rocky areas		
217	*Litsea laevigata* (Nees) Gamble		Lauraceae	medium tree	Semi ev.gr. For.		Endemic to South Western ghats
218	*Lophatherum gracile* Brogn.		Poaceae	Herb	Ev.gr.for.		
219	*Ludwigia perennis* L.	Neerkarayambu	Sonneratiaceae	herb	Waterlogged areas,Grasslands		
220	*Macaranga indica* Wight	Vatta	Euphorbiaceae	Medium tree	Degr. For.		
221	*Macaranga peltata* Roxb.) Muell.- Arg.	Vatta	Euphorbiaceae	Medium tree	Moist decd. For, Secondary for.		
222	*Maesa indica* (Roxb.) DC.	Kireethi	Myrsinaceae	Small tree	Ev.gr. For.,moist decd.for., Shola for.,Grasslands		
223	*Mallotus philippensis* (Lam.)Muell.- Arg.	Chenkoli	Euphorbiaceae	Small tree	Ev. Gr. For.,Semi ev. Gr. For., Moist decd. For., Plains		
224	*Mallotus tetracoccus* (Roxb.) Kurz	Vattakumbil	Euphorbiaceae	Medium tree	Ev. Gr. For., Semi ev. Gr. For., Shola for., plains		
225	*Manihot glaziovii* Muell.- Arg.	Kattu rubber	Euphorbiaceae	Medium tree	Cultivated		
226	*Meineckia longipes* (Wight) Webster		Euphorbiaceae	Shrub	Semi ev.gr. For.		
227	*Meiogyne pannosa* (Dalz.) Sinclair	Panthal maram	Annonaceae	Small tree	Ev. Gr. For.		Endemic to South Western ghats
228	*Meiogyne ramarowii* (Dunn) Gandhi		Annonaceae	Small tree	Ev.gr. For.		Endemic to South Western ghats
229	*Melastoma malabathricum* L.	Athirani,Kadali	Melastomaceae	Shrub	Stream banks,Marshy areas		
230	*Melicope lunu-ankenda* (Gaertn.) Hartley	Kattuchembakam	Rutaceae	Medium tree	Ev. Gr. For.,Semi ev. Gr. For., Moist decd. For., Plains		
231	*Melochia corchorifolia* L.		Sterculiaceae	Woody herb	Degr. Decd for., Open areas		
232	*Memecylone randerianum* SM&MR Almeida	Kasavu	Melastomaceae	Small tree	Semi ev.gr. For.		Endemic to South Western ghats
233	*Memecylone umbellatum* Burm.f.	Anakombi	Melastomaceae	Small tree	Semiev.gr.,moist decd for.,plains		
234	*Merremia umbellata* (L.)Hall.f.	Vayara	Convolvulaceae	Prostrate twining herb	All types of for.,Plains		

235	*Merremia vitifolia* (Burm.f.)Hall.f.	Manja kolambi	Convolvulaceae	Climber	Degraded for.,Plains		
236	*Mesua ferrea L.*	Churuli	Clusiaceae	large tree	Ev.gr. For.		
237	*Microstegium ciliatum* (Trin.)A.Camus		Poaceae	Herb	Banksofstreams, Margin of froests		
238	*Mikania macrantha* Kunth		Asteraceae	Scandent shrub	Plains,Plantations		
239	*Mimosa diplotricha* C.Wight&Sanvalle	Aanathotavadi	Mimosaceae	Climbing shrub	weed in degraded for.,plains		
240	*Mimosa pudica* L.	Thottavadi	Mimosaceae	herb	plains		
241	*Mitrcarpus villosus* (S w) DC..		Rubiaceae	Erect herb	Degr.moist decd.for.,Open areas,plains		
242	*Mollinaria trichocarpa* (Wight) Balakr.		Hypoxidaceae	Herb	Wet places of Decd.for.,Sandy coasts		
243	*Mollugo pentaphylla* L.	Parpadakapullu	Molluginaceae	Herb	Moist & Dry decd. For., Banks of streams		
244	*Monochoria vaginalis* (Burm.f.)	Karinmkovalum	Pontederiaceae	herb	Paddy fields,Low wetlands		
245	*Morinda citrifolia* L.	Cherumanjanathi	Rubiaceae	Small tree	Sea coast ,Open areas		
246	*Mucuna pruriens* (L.) DC.	chorivalli	Fabaceae	Slender climber	Secondary for, Plains		
247	*Mukia maderaspatana* (L.) Roem.	Mukkapeeram	Cucurbitaceae	Climber	Decd. For. Plains		
248	*Murdannia japonica* (Thunb.) Faden		Commelinaceae	Erect herb	Ev.gr.,Semi ev.gr.,Moistdecd .for.		
249	*Murdannia pauciflora* (Wight)Brueck.		Commelinaceae	Creeping herb	Grassland,Moist areas		
250	*Mussaenda bellila* Buch- Ham.	Parathole	Rubiaceae	Scandent shrub	Semi ev gr for.,Moist decd.for,Plains		Endemic to Western ghats
251	*Myxopyrum smilacifolium* (Wall.)Blume	Chathuravalli	Oleaceae	Climbing shrub	Ev.gr for.,Semi ev.gr.for.,Sacred groves		
252	*Naragamia alata* Wight&Arn.	Nilanaragam	Meliaceae	Herb	Moist decd for.,Plantation		
253	*Naravelia zeylanica* (L.) DC.	Vathamkodi	Ranunculaceae	Climbing shrub	Moist decd. For., Plains		
254	*Neanotis monosperma*(Wall ex Wight & Arn.)		Rubiaceae	Herb	Grasslands		Endemic to peninsular india
255	*Ochna obtusata* DC.		Ochnaceae	Small tree	Moist decd. For.		
256	*Ocimum gratissimum* L.	Kattuthrithavu	Lamiaceae	Sub shrub	Dry & Moist decd. For. ,Plains		
257	*Ocimum tenuiflorum* L.	Krishna thulasi	Lamiaceae	Sub shrub	Cultivated as sacred plant		
258	*Olea dioica* Roxb.	Edala	Oleaceae	Medium tree	Semi ev gr,Moist decd.for,Plains		
259	*Ophiorrhiza mungos* L.	Avilpori	Rubiaceae	Herb	Semi ev.gr. For.,Plains		
260	*Oplismenus compositus*(L.) P.Beauv.		Poaceae	Herb	Degr.decd.for.,Shady Open places		

261	*Oroxylum indicum* (L.) Benth. Ex Kurz	Palakapayyani	Bignoniaceae	Medium tree	Moist decd. For., Plains		
262	*Oryza sativa* L.	Nellu	Poaceae	Herb	Cultivated		
263	*Osbeckia octandra* (L.) DC.		Melastomaceae	Sub shrub	Ev. Gr. For.		
264	*Ottochloa nodosa* (Kunth) Dandy		Poaceae	Herb	Forest fringes,Banks of streams		
265	*Oxalis corniculata* L.	Puliyarila	Geraniaceae	Herb	Degr. For., plains		
266	*Pajanelia longifolia (Willd.) K. Schum.*	Payyani,Azhantha	Bignoniaceae	Medium tree	Semi ev. Gr. For., Moist decd. For., Plains		
267	*Panicum brevifolium* L.		Poaceae	Herb	Margins of forests,Backwaters,Open areas		
268	*Panicum notatum* Retz.		Poaceae	Herb	Moist decd.for.,Sacred groves		
269	*Panicum repens* L.		Poaceae	Herb	Wetlands ,MarshylandGrasslands,Openareas		
270	*Paspalidium flavidum* (Retz.) A.Camus		Poaceae	Herb	Paddy fields,Banks of backwatersand streams		
271	*Paspalum canarae* (Steud.) Veldk.		Poaceae	Herb	Grasslands		
272	*Passiflora edulis* Sims.	Passion fruit	Passifloraceae	Climbing shrub	Cultivated, Wild		
273	*Passiflora foetida* L. var. foetida	Chadayn	Passifloraceae	Climbing shrub	Degr. For.,Open areas		
274	*Pavetta indica* L. var. indica	Kamatta	Rubiaceae	Small tree	Banks of rivers,Rocky laterile slopes		
275	*Pavetta tomentosa* Roxb.ex J.E. Smith		Rubiaceae	Small tree	Semi ev. Gr. For., Plains		
276	*Pennisetum polystachyon* (L.) Schult.		Poaceae	Herb	Degr. Moist decd. For.,Open ares		
277	*Peperomia pellucida* (L.)Kunth	Mashipatcha	Piperaceae	Erect herb	Degr. For., Open areas		
278	*Persea macrantha* (Nees) Kosterm.	Kulamavu	Lauraceae	Large tree	Ev. Gr. For., Semi ev. Gr. For., Moist decd. For., Sacred groves		
279	*Phaulopsis imbricata* (Forssk.) Sweet.	Kallurukki	Acanthaceae	Herb	Semi ev.gr.for,Decd.for.,Plains		
280	*Phyllanthus amarus* Schum.& Thonn.	kizhukanelli	Euphorbiaceae	slender herb	Degr.moist.decd. for.		
281	*Phyllanthus gardnerianus* (Wight) Baill.		Euphorbiaceae	Herb	Semi ev. Gr. For., Moist decd for.,Grasslands		
282	*Phyllanthus myrtifolius* Moon		Euphorbiaceae	Shrub	ornamental		
283	*Phyllanthus reticulatus* Poir.	kattuniruri	Euphorbiaceae	Scandent shrub	Semi ev.gr.for.,Moist decd.for..Stream bank,lakeshores		

284	*Phyllanthus urinaria* L.	chuvanna keezharnelli	Euphorbiaceae	erect herb	Degr.decd.for.,Plains		
285	*Pilea microphylla (L.) Liebm.*		Urticaceae	Herb	Cultivated		
286	*Piper longum* L.	Kattuthipali	Piperaceae	Scandent shrub	Ev gr. For., Sem ev. Gr. For., Moist decd for., Open areas		
287	*Piper nigrum* L.	Karumulaku	Piperaceae	Climbing shrub	Ev. Gr. For., Semi ev. Gr. For., Cultivated		
288	*Plumbago zeylanica* L.	Tumbakoduveli	Ericaceae	Shrub	Decd. For., Plains		
289	*Pogostemon purpurascens* Dalz.	Choriyanthalli	Lamiaceae	Sub shrub	Semi ev. Gr. For., Moist decd for. Plains		
290	*Pongamia pinnata* (L.) Pierre	pongu	Fabaceae	Medium tree	Dry,Moist decd fro,Cultivated as avenue tree		
291	*Porana volubilis* Burm.f.		Convolvulaceae	Climber	Cultivated		
292	*Pothos scandens* L.	Anapparuva	Araceae	Climbing herb	Ev. Gr. For. ,Open areas, Sacred groves		
293	*Pouzolzia zeylanica* (L.) Bennett		Urticaceae	Herb	Open areas		
294	*Protsasparagus racemosus* (Willd.) Oberm.	Sathaveri	Liliaceae	Climbing shrub	All types of forest ,Plains		
295	*Pseudarthria viscida* (L.) wight & Arn.	Moovila	Fabaceae	Sub shrub	Moist decd. For., Plains		
296	*Psychotria nilgiriensis* Deb & Gangop.		Rubiaceae	Small tree	Ev. Gr. For.		Endemic to south western ghats
297	*Pterocarpus marsupium Roxb.*	Vega	Fabaceae	Large tree	Moist and Dry decd. For., Plains		
298	*Pterospermum reticulatum* Wight& Arn.	Malayuram	Sterculiaceae	Large tree	Ev.gr. For., Semi ev. Gr. For.		Vulnerable IUCN 2000
299	*Pueraria phaseoloides (9* Roxb.) Benth.	Thottapayar	Fabaceae	Climbing herb	Cultivated		
300	*Pycnospora lutescens* (Poir.) Schind.		Fabaceae	Trailing herb	Decd for., plains		
301	*Pycreus pumilus*(L.0Nees		Cyperaceae	herb	Marshyland,Wet land,paddyfields		
302	*Rauvolfia serpentina* (9 L.)0 Benth.	Amalpuri,Sarpa gandhi	Apocynaceae	Herb	Moist decd. For. ,Plains		
303	*Rhyncosia cana* (Wild.) DC.		Fabaceae	Shrub	Dry decd for.		
304	*Richardia scabra* L.		Rubiaceae	Herb	Degrd forest,Plains		
305	*Rourea minor* (Gaertn.) Marr.	Kuriel	Connaraceae	Woody climber	Sem ev. Gr. For., Sacred groves		
306	*Rungia apiculata* Bedd.		Acanthaceae	Erect herb	Shola for.		
307	*Rungia parviflora* (Retz.)		Acanthaceae	Herb	open areas		
308	*Rungia pectinata* (L.) Nees		Acanthaceae	Herb	Semi ev.gr.for.,open areas		
309	*Sageratia hamosa* Brongn.		Rhamnaceae	shrub	Ev.gr for.,Semi ev.gr.for.		
310	*Salcia beddomei* Gamble		Hippocrateaceae	Climbing shrub	Ev.gr.for.,Semi ev.gr. For.		Endemic to South Western ghats

311	*Salacia fruticosa* Heyne ex Lawson	Korandi	Hippocrateaceae	Climbing shrub	Ev.gr. For., Semi ev. Gr. For.,Sacred groves, Plains		Endemic to Western ghats
312	*Salacia oblonga* Wall. Ex Wight & Arn.	Ponkoranti	Hippocrateaceae	Climbing shrub	Ev.gr.for.,Semi ev.gr. For.		
313	*Salvia leucantha* Cav.		Lamiaceae	Diffused sub shrub	ornamental		
314	*Salvia splendens* Sellow ex Roem. Schult.		Lamiaceae	Herb	Cultivated		
315	*Saprosma foetens* (Wight) K. Schum.		Rubiaceae	Small tree	Ev. Gr. For.,Shola for.		
316	*Sauropus androgynous* (L.) Merr.		Euphorbiaceae	Shrub	Ev.gr. For., Semi ev. Gr. For., Secondary for.,Cultivated		
317	*Sauropus bacciformis* (L.) Airy Shaw,	Nilam thengu	Euphorbiaceae	Herb	Grassy areas near sea		
318	*Schumannianthus varigatus* (Roxb.) Rolfe	Kattukuppa	Zingiberaceae	Erect herb	Ev. Gr. For. ,Semi ev. Gr. For.,Decd for., Marshy areas		
319	*Scleria corymbosa* Roxb.		Cyperaceae	Herb	Ev. Gr .for.,		
320	*Scleria terrestris* (L.) Fassett		Cyperaceae	Herb	Semi ev.gr. For., Decd. For.		
321	*Scoparia dulcis* L.	Kallurukki	Scrophulariaceae	Erect herb	Open areas		
322	*Sebastiana chamaelea* (L.) Muella.-Arg.	kodiyarannakku	Euphorbiaceae	Herb	Moist& Dry decd for.,Grassland,plains		
323	*Senna siamea* (Lam.) Irwin & Barneby		Caesalpiniaceae	Tree	Cultivated		
324	*Senna tora* L.	Thakara	Caesalpiniaceae	shrub	moist decd.for.,plains		
325	*Sida acuta* Burm.f.ssp acuta	Malatanni	Malvaceae	Erect shrub	Dry , Moist decd. For.,Plains		
326	*Sida alnifolia* L.		Malvaceae	herb	Moist decd. For., Plains		
327	*Sida beddomei* Jacob		Malvaceae	herb	Semi ev.gr.,Moist decd. For.,Plains		Endemic to South Western ghats
328	*Sida cordata* (Burm.f.)B	Valli kurunthotti	Malvaceae	Trailing herb	All types of for.,Plains		
329	*Sida cordifolia* L.	Anakurunthoti	Malvaceae	Erect herb	Open areas		
330	*Sida fryxellii* Sivar.& Pradeep		Malvaceae	Sub shrub	Open ares.Plains		
331	*Sida linifolia* Cav.		Malvaceae	Sub shrub	Open areas		
332	*Sida rhombifolia* L.	Kurunthotti	Malvaceae	shrub	Degr. For., Open areas		
333	*Smilax zeylanica* L.	Kareeelanchi	Smilacaeae	Climber	Semi ev. Gr. For.,Moist decd. For.,Plains		
334	*Solanum americanum* Mill.	Manathakkali	Solanaceae	Herb	Degr. Moist decd for.,Riversides,Plains		

Table 4.5 Chapter 4: Results

335	*Solanum capsicoides* All.		Solanaceae	Shrub	Degrd. For., Open areas		
336	*Solanum torvum* Sw.	Anachunda	Solanaceae	Shrub	Degr. for. ,plains		
337	*Solanum virginianum* L.	Kandakarichunda	Solanaceae	Herb	Ev. Gr. for.		
338	*Solenocarpus indicus* Wight &Arn.	Kattambazham	Anacardiaceae	Small tree	Ev. Gr. For.,Rock formations		Endemic to south western ghats,Rare (Nayar 1997)
339	*Spermacoce articularis L.*	Tharthvel	Rubiaceae	Herb	Dry decd. For.,Grasslands, plains		
340	*Spermacoce latifolia* Aubl.	Vellatharavu	Rubiaceae	Erect herb	Moist dry decd.for.,wet places		
341	*Spermacoce ocymoides* burm.f.	Tharakeera	Rubiaceae	Procumbent herb	Open areas		
342	*Spilanthus calva* Dc.	Kuppamanjal	Asteraceae	Herb	wet marshy open areas		
343	*Spilanthus radicans* Jacq.	Venapacha	Asteraceae	Herb	Degrd moist decd for.,Plains		
344	*Sporobolus indicus* (L.) .Br. Var fertilis (Steud.) Jovet & Guedes		Cyperaceae	herb	Moist,Dry decd.for.		
345	*Stachyphyrnium spicatum* (Roxb.) Schum.		Marantaceae	Herb	Semi ev. Gr. For.,Moist decd. For.		Endemic to South India
346	*Stachytarpheta indica* (L.) Vahl.		Verbenaceae	Sub shrub	Open areas		
347	*Stachytarpheta jamaicensis* (L.) Vahl		Verbenaceae	Shrub	Dry and Moist decd for., Plains		
348	*Sterculia guttata* Roxb.ex DC.	Thondi	Sterculiaceae	Medium tree	Semi ev. Gr. For.,Moist decd. For.,Plains		
349	*Strobilanthus ciliatus* Nees.	Karimkurinji	Acanthaceae	Shrub	Ev. Gr. For.,Semi ev. Gr. for		Endemic to Peninsular India
350	*Strobilanthus heyneanus* Nees	Muttukurunji	Acanthaceae	Shrub	Ev.gr. For.		Endemic to south west India
351	*Struchium sparganophorum*(L.) O. Ktze		Asteraceae	Herb	Wet areas in grasslands		
352	*Strychnos colubrina* L.	Vallikanjiram	Loganiaceae	Climbing shrub	Ev.gr.for.,Semi ev.gr. For., Banks of streams		
353	*Strychnos minor* Dennst.	Cherukanjiram	Loganiaceae	Climbing shrub	Ev.gr. For.		
354	*Strychnos nux-vomica* L.	Kanjiram	Loganiaceae	Medium tree	Moist and Dry decd. For., Sacred groves		
355	*Stylosanthes fruticosa* (retz.) Alston.		Fabaceae	Sub shrub	Lake shores and river banks		
356	*Suregada augustifolia* (Baill.exMuell.-Arg.)Airy Shaw		Euphorbiaceae	Small tree	Ev gr. For.		Endemic to peninsular India
357	*Swietenia mahogoni* (L.) jacq.	Mahagony	Meliaceae	Medium tree	Cultivated		
358	*Symplocos cochin chinensis* (Lour.) Moore ssp laurind	Pachotti	Symplocaceae	Small tree	Ev. Gr. For., Semi ev. Gr. For., Shola for., Sacred groves		
359	*Synedrella nodiflora* (L.) Gaertn.	Mudianpacha	Asteraceae	Erect herb	Decd. for. ,Plains		

360	*Syzygium calophyllifolium* Walp.		Myrtaceae	Large tree	Ev gr. For		
361	*Syzygium caryophyllatum* (L.) Alston	Karinjara	Myrtaceae	Small tree	Ev.gr.for,Semi ev.gr. For.		
362	*Syzygium hemispherium*(Wight) Alston	Payinjaval	Myrtaceae	Medium tree	Ev. Gr. For., Shola for.		
363	*Syzygium occidentalis*(Bourd.) Gandhi	Attuchamba	Myrtaceae	Small tree	Ev gr. For., Banks of streams		Vulnerable IUCN 2000
364	*Syzygium zeylanicum* (L.) DC.	Poochapazham	Myrtaceae	medium tree	Ev gr. For., Banks of streams		
365	*Tabernaemontana divaricata* (L.) R.Br.	Nandiyarvattom	Apocynaceae	Shrub	Cultivated		
366	*Tabernaemontana gamblei* Subram. & Henry		Apocynaceae	Shrub	Ev. Gr. For.		Lower risk Conservation dependent IUCN 20000
367	*Tecomaria capensis* (Thunb.) Spach.		Bignoniaceae	Sub shrub	Cultivated		
368	*Tectona grandis* L.f.	Thekku	Verbenaceae	Large tree	Moist decd for., Cultivated		
369	*Tephrosia pumila* (Lam.) Pers.		Fabaceae	Slender herb	Wet rocky areas		
370	*Tephrosia purpurea* (L.) Pers.	Kodikozhingil, Kozhuva	Fabaceae	Shrub	Moist decd. for., Grasslands,plains		
371	*Terminalia catappa* L.	Kadappa	Rhizophoraceae	Large tree	Cultivated		
372	*Terminalia paniculata* Roth	Maruthu ,	Rhizophoraceae	Large tree	Moist and dry decd for., Plains		
373	*Tetracera akara* (Burm.f.) Merr.	Nennal valli	Dilleniaceae	Climbing shrub	Semi ev. Gr. For.		
374	*Themeda triandra* Forssk		Poaceae	Herb	Decd.for.,Grassland,Openareas		
375	*Theriophonum infaustum* N.E.Br.		Araceae	Herb	Moist decd. For., Marshy areas		Endemic to south western ghats
376	*Thottea siliquosa* (Lam.)Ding Hou	Alpam	Aristolochiaceae	Shrub	Ev. Gr. For., Semi ev. Gr. For.		
377	*Tiliacora acuminata* (Poir.)n Miers ex Hook. f.& Thoms.	Vallikanjiram	Menispermaceae	Climbing shrub	Moist decd. For.		
378	*Toona ciliata* Roem.	Vembu	Meliaceae	Large tree	Ev.gr. For.,Semi ev gr. For.		
379	*Trema orientalis* (L.)	Pottama	Ulmaceae	Small tree	Moist and dry decd. For.,Plains		
380	*Trichosanthes nervifolia* L.	Kattupadavalam	Cucurbitaceae	Slender climber	Semi ev. Gr. For. ,Plains		
381	*Tridax procumbens* L.	Odiyancheera	Asteraceae	Herb	Decd. for. ,plains		
382	*Triumphetta rhomboidea* Jacq.	Oorpam	Tiliaceae	Erect herb	Degr. Decd. For., Plains		
383	*Turpinia malabarica* Gamble	Kanakkapalam	Staphyleaceae	Large tree	Ev. Gr. For.		Endemic to South india & Sri Lanka
384	*Tylophora indica*(Burm.f.) Merr.	Vallipala	Asclepiadaceae	Slender climber	along bushes and thickets		
385	*Tylophora mollisma* Wight&Arn		Asclepiadaceae	herb	Shola for.		Endemic to South India

386	*Urena lobata* L.ssp lobata	Oorpan	Malvaceae	Shrub	Degr.for.,Plains		
387	*Urena lobata* ssp *sinuata*(L.) Borss.	Uram,Uthiram	Malvaceae	Sub shrub	Moist decd.for.,Plains		
388	*Vernonia anthelmintica* (L.) Wild.	Kattujeeragam	Asteraceae	Herb	Decd for.		
389	*Vernonia cinerea* (L.) Less.	Poovan kurunal	Asteraceae	Herb	Decd. for.,Plains		
390	*Vernonia elliptica* DC.	curtain chadi	Asteraceae	Shrub	cultivated		
391	*Vigna umbellata* (Thunb.) Ohwi & Ohashi		Fabaceae	Slender twiner	Semi ev. Gr. For., Moist decd for.		
392	*Wedelia chinensis* (Osbeck) Merr.	Manjakanjunni	Asteraceae	Herb	Marshy areas		
393	*Wedelia trilobata* (L.) A.S. Hitche.		Asteraceae	Herb	Wild , Cultivated		
394	*Xanthophyllum arnottianum* Wight	Madakka,mottal	Polygalaceae	Small tree	Ev.gr.for,Semi ev.gr. For.		Endemic to Western ghats
395	*Xenostegia tridentata* (L.)Austin&Staples	Cheruvayera,Prasaram	Convolvulaceae	prostrate herb	Decd. for.,Plains		
396	*Xylia xylocarpa* (Roxb.) Taub.	Irul,Irulpool	Mimosaceae	Large tree	Moist decd.for.,Plains		
397	*Zingiber zerumbet* (L.) J.E.Smith	Kattinchi	Zingiberaceae	Rhizomatous herb	Ev. Gr. For.		
398	*Zizyphus mauritiana* Lam.	Jujuba	Rhamnaceae	Small tree	Dry decd for.,Plains		
399	*Zizyphus oenoplea* (L.) Mill.	Cheruthudali	Rhamnaceae	Climber	Moist &Dry decd for.,Plains		
400	*Zizyphus rugosa* ,Lam.	Thodali	Rhamnaceae	Scandent shrub	Decd.for,Grasslands,Plains		
Gymnosperm							
1	*Cycas circinalis* L.	Eenth	Cycadaceae	Small palm	Moist decd. For., Open areas		common
Pteridophytes							
1	*Adiantum capillus-veneris* L.		Adiantaceae	terrestrial herb	rock crevices,Humid localities		rare
2	*Adiantum caudatum* L.		Adiantaceae	Small terrestrial herb	Open areas rock crevices		not common
3	*Adiantum lunulatum* Burm.f.		Adiantaceae	Small terrestrial herb	Open areas rock crevices,forests		very common
4	*Ceratopteris thelictroides(L.)* Brongn.		Parkeriaceae	Aquatic herb	Tropical and temperate regions		common
5	*Cheilianthes tenuifolia* (Burm.f.) Sw.		Actiniopteridaceae	Small terrestrial herb	rocky areas, plains		common
6	*Christella parasitica* (L.) H. Lev.		*Thelypteridaceae*	*terrestrial herb*	humid forest, *stream banks*		*common*
7	*Diplazium esculentum (Retz) Sw.*		Aspleniaceae	terrestrial herb	Open areas, Moist localities		common
8	*Drynaria quercifolia* (L.) J.Sm.		Polypodiaceae	A large gregarious epiphyte	Coastal plains , forests of western ghats		common
9	*Lindsaea ensifolia Sw.*		Lindsaeceae	Small terrestrial herb	Open ans well shded areas		common

10	*Lygodium flexuosum* (L.) Sw.		Schizaceae	Terrestrial climbing herb	Open areas, Plains, forest margins		common
11	*Nephrolepis auriculata (L.) Trimen*		Oleandraceae	Terrestrial herb	Open forest areas		common
12	*Nephrolepis delicatula (Decne.) Pic.Serm*		Oleandraceae	Terrestrial herb	Shaded rocky areas		common
13	*Parahemionites cordata* Roxb.ex Hook.& Grev. Fraser- Jenk		Hemionitidaceae	Small terrestrial herb	coastal plains,high altitude forest		not common
14	*Polystichum moluccense* (Blume) T. Moore		Aspleniaceae	Small terrestrial herb	Ev. Gr. For		Rare
15	*Pteridium revolutum* (Blume) Nakai		Dennstaedtiaceae	Epiphyte or lithophyte	Moist rocks and soils		common
16	*Pteris biaurita* L.		Pteridaceae	Terrestrial herb	Forests,stream banks		Not common
17	*Pteris confusa* T.G.Walker		Pteridaceae	Terrestrial herb	Forests,stream banks		Not common
18	*Pyrrosia heterophylla* (L.) M.G.Price		Polypodiaceae	Epiphytic	rocky areas,forests		common
19	*Selaginella delicatula* (Desv.ex Poir.) Alston		Lycopodiaceae	terrestrial herb	Forests, plains		common

Index of the plant species distibution. The areas are classified as per the flora (Sasidharan 2004)

Tropical evergreen forest -	Cultivated areas-
Tropical semievergreen forest-	Marshy and wet areas-
Moist & Dry decidous forest-	Grasslands-
Shola forest-	Sacred groves-
Open areas-	Rocky areas -
Plains-	Plantations-

Table 4.6 - Taxonomic , ecological description and conservation status of the plant species in the Open areas.

Sno.	Name of the plant	Vernacular name	Family	Habit	Distribution		Status
Angiosperms							
1	*Acacia pennata*(L.)Wild.	Karincha	Mimosaceae	scandent shrub	Moist decd.for		
2	*Acalypha indica* L.	Kuppameni	Euphorbiaceae	Herb	Dry decd.for. ,Plains		
3	*Adenostemma lavenia* (L.) O. Ktze.		Asteraceae	Erect herb	Ev. Gr. For., Semi ev. Gr. For.		
4	*Aeginetia indica* L.	Keripu	Orobanchaceae	Prostrate herb	Semi Ev. Gr. For., Moist decd. For.		
5	*Ageratum conizoides* L.	Appa,Katappa	Asteraceae	Erect herb	weed in open areas		
6	*Albizia lebbeck* (L) Willd.	Vaka	Mimosaceae	Large tree	Decd. For. ,Plains		
7	*Allophylus cobbe (L.)* Raeusch.	Mukkannanpezhu	Sapindaceae	Small tree	Semi ev. Gr. For.,Moist decd for.,Sacred groves		
8	*Allopteris cinicina* (L.)Stapf		Poaceae	herb	Moist&dry decdfor.,Openareas		
9	*Alocasia fornicata* (Roxb.) Schott		Araceae	Perennial herb	Ev gr. For.		
10	*Alternanthera pungens* Kunth		Amaranthaceae	Herb	Degr. Decd.for.,Open areas		
11	*Alternanthera sessilis* (L.) R.Br.	Kozhuppa	Amaranthaceae	Herb	Water courses, marshy areas		
12	*Andrographis atropurpurea*(Dennst)Alston.		Acanthaceae	herb	Ev.gr.,semi ev.gr.for.		
13	*Aneilemma montana*(Wight) Clarke		Commelinaceae	Herb	Ev gr. For., Semi ev. Gr. For.		Endemic to peninsular India
14	*Antidesma acidum* Retz.	Areepazham	Euphorbiaceae	Small tree	Semi ev.gr. For.,Moist decd for.,Sacred groves		
15	*Arundinella purpurea* Hochst		Poaceae	Herb	Grasslands		Endemic to south India
16	*Asystacia gangetica* (L.) Andersvar. gangetica	Upputhali	Acanthaceae	Sub shrub	Degrd.for.Plains		
17	*Asystacia gangetica* (L.) Anders var. mendeliana		Acanthaceae	Shrub	moist localities		
18	*Atalantia racemosa* Wight *var racemosa*	Kattunarakam	Rutaceae	Small tree	Ev. Gr. For., Sermi ev. Gr. For.,Dry decd. For.		
19	*Axonopus compressus* (Sw.) P.Beauv.		Poaceae	herb	Moist&dry decd.for.,Open areas,paddyfields		
20	*Barleria buxifolia* L.		Acanthaceae	Small prickly shrub	Open areas		Endemic to peninsular India
21	*Biophytum sensitivum* (L.) DC. Var sensitivum	Mukkutti	Oxalidaceae	Herb	Dry decd. for.,Grasslands		
22	*Biophytum sensitivum* (L.) DC. Var *candolleanum* (Wight) Edgew.&Hook.f.	Nilamthengu	Oxalidaceae	Herb	Dry decd. For. , Grasslands		

Table 4.6 Chapter 4: Results

23	*Bracharia ramosa* (L.) Stapf		Poaceae	Herb	Grasslands,Moist decd forest,Open ares		
24	*Caladium bicolor* (Ait.ex Dryand.)Vent.	Kaatu chembu	Araceae	Tuberous herb	Open areas		
25	*Canthium augustifolium Roxb.*	Kattaramullu	Rubiaceae	Scandent shrub	Semi Ev.gr.for.		
26	*Centrosema pubescens* Benth.	Kattupayani	Fabaceae	Slender climber	Decd. For., Plantations, Plains		
27	*Chromolaena odorata* (L.) King & Robins.	Cummunist pacha	Asteraceae	Shrub	Open areas		
28	*Cissampelose pareira* L. Var.hirsuta	Malathangi	Menispermaceae	Herbaceous climber	Decd. For., Plains		
29	*Cleome monophylla* L.		Capparaceae	Erect herb	Dry decd for., Plain		
30	*Clerodendron viscosum* Vent.	Perivelum	Verbenaceae	Small tree	Degrd for., Plains		
31	*Commelina attenuata* KoenigexVahl		Commelinaceae	Herb	Grasslands,plains		
32	*Commelina benghalensis* L.	Kanavazhai	Commelinaceae	Herb	Decd.for.,Open areas		
33	*Commelina ensifolia* R.Br.		Commelinaceae	Slender herb	Grasslands,Sacred groves		
34	*Commelina maculata* Edgew		Commelinaceae	Erect herb	Ev.gr.for.		
35	*Crotalaria evovuloides* Wight ex Wight & Arn.		Fabaceae	Herb	Moist decd for. Grasslands		
36	*Cucurligo orchiodes* Gaertn	Nilapana	Hypoxidaceae	Herb	Moist decd. For. Grasslands ,Plains		
37	*Cyathula prostrata* (L.) Blume	Cherukadaladi	Amaranthaceae	Herb	Semi ev.gr.for.,Moist decd.for.,plains		
38	*Cyclea peltata* (Lam.)Hook. f.Thoms.	Padathalli	Menispermaceae	Climber	Ev.gr.,Semiev.gr. For.		
39	*Cyperus zollingeri* Steud.		Cyperaceae	Herb	Moist decd. For.		
40	*Cyrtococcum patens* (L.) A. Camus		Poaceae	herb	Moist decd.for.Plains		
41	*Desmodium pulchellum* (L.) Benth.	Cherupachotti	Fabaceae	sub shrub	Moist decd.for.		
42	*Desmodium zonatum* Miq.		Fabaceae	Erect herb	Semi ev.gr.for.,moist decd.for.		
43	*Digitaria ciliaris* (Retz.)koeler		Poaceae	Herb	Moist decd.for.,Grassland,Open areas		
44	*Digitaria longiflora* (Retz.)Pers.		Poaceae	Herb	Grasslands,Open areas		
45	*Dioscorea bulbifera* L.	Kattu kaachil	Dioscoreaceae	Climbing shrub	Moist decd.for.,Plains		
46	*Diploclisia glaucescens* (Blume) Diels	Vattoli	Menispermaceae	Woody climber	Ev.gr.,Semi ev.gr.fro.,moist decd for.		
47	*Dipteracanthus prostratus* (Poi.)Nees		Acanthaceae	Herb	Degr. For., Plains		
48	*Elaeocarpus glandulosus Wall.*	Kara	Elaeocarpaceae	Medium tree	Ev gr. For, Semi ev. Gr. For., Shola for.		

49	*Elephantopus scaber* L.	Anachuvadi	Asteraceae	Herb	Moist decd.for., Plains		
50	*Eleusine indica (L.)* Gaertn.		Poaceae	Herb	Open areas		
51	*Eleutheranthera ruderalis* (SW) Sch.Bip.		Asteraceae	herb	Degr.moist decd.for.,plains		
52	*Emilia sonchifolia* (L.) DC.	Muyalchevian	Asteraceae	Prostrate herb	Moist & Dry decd. For., Plains		
53	*Ficus exasperata* Vahl	Therakom	Moraceae	Small tree	Moist decd for., Plains		
54	*Fluggea virosa* (Roxb.ex Willd.) Baill.	Perimklavu	Euphorbiaceae	Small tree	Dry and Moist decd for.,Plains		
55	*Grewia nervosa* (Lour.) Panigrahi	Kottakka	Tiliaceae	Small tree	Semi ev. Gr. For.,Scrub jungles,Sacred groves		
56	*Hedyotis brachiata* (Wight)		Rubiaceae	Herb	Open areas		
57	*Hedyotis puberula* (G.Don) R.Br. Ex Arn.	Kunthamanian	Rubiaceae	Shrub	Grassland,Open ares		Endemic to S.Western ghats
58	*Hibiscus hispidissimus* Griff.	Mattipuli,Uppanacham	Malvaceae	Rambling shrub	Dry& Moist decd for., Plains		
59	*Ipomea alba L.*	Mandavalli	Convolvulaceae	Climber	Moist decd. For., along sea coast		
60	*Ipomea barlerioides* (Choisy) Benth. Ex Clarke.		Convolvulaceae	Herb	Grasslands,Savannahs		
61	*Ipomea cairica* (L.)Sweet	Kolambipoo	Convolvulaceae	Twiner	Moist & Dry decd. For., Plains		
62	*Ipomea obscura* (L.)Ker-Gawl.	Thiruthali	Convolvulaceae	Twiner	Degr. For., Plains		
63	*Ischaemum timorense* Kunth		Poaceae	herb	Margins of backwaters,Grasslands		
64	*Jasminum rottlerianum* Wall.ex A. DC. Var.rottlerianum	Kattumulla	Oleaceae	Climbing shrub	Ev.gr. For.,moist decd.for., Shola for.		
65	*Julostylis augustifolia (Arn.) Thw.*		Malvaceae	Small tree	Semi ev. Gr. For., Moist decd. For.		
66	*Justicia procumbens* L.		Acanthaceae	Herb	Moist decd.for.,Grasslands,Plains		
67	*Lantana camara* L. var.aculeata (L.) Moldenke	Konda	Verbenaceae	Shrub	Cultivated		
68	*Lawsonia inermis* L.	Mailanchi	Melastomaceae	Shrub	Cultivated		
69	*Lobelia alsinoides* Lam.	Kakkapoovu	Lobeliaceae	Annual herb	Wet areas in grasslands		
70	*Macaranga indica* Wight	Vatta	Euphorbiaceae	Medium tree	Degr. For.		
71	*Melicope lunu-ankenda* (Gaertn.) Hartley	Kattuchembakam	Rutaceae	Medium tree	Ev. Gr. For.,Semi ev. Gr. For., Moist decd. For., Plains		
72	*Merremia vitifolia* (Burm.f.)Hall.f.	Manja kolambi	Convolvulaceae	Climber	Degraded for.,Plains		
73	*Mikania macrantha* Kunth		Asteraceae	Scandent shrub	Plains,Plantations		

74	*Mimosa diplotricha* C.Wight&Sanvalle	Aanathotavadi	Mimosaceae	Climbing shrub	weed in degraded for.,plains		
75	*Mimosa pudica* L.	Thottavadi	Mimosaceae	herb	plains		
76	*Mitrcarpus villosus* (S w) DC..		Rubiaceae	Erect herb	Degr.moist decd.for.,Open areas,plains		
77	*Murdannia japonica* (Thunb.) Faden		Commelinaceae	Erect herb	Ev.gr.,Semi ev.gr.,Moistdecd.for.		
78	*Olea dioica* Roxb.	Edala	Oleaceae	Medium tree	Semi ev gr,Moist decd.for,Plains		
79	*Ottochloa nodosa*(Kunth) Dandy		Poaceae	Herb	Forest fringes,Banks of streams		
80	*Panicum brevifolium* L.		Poaceae	Herb	Margins of forests,Backwaters,Open areas		
81	*Panicum gardeneri* Thw.		Poaceae	Herb	Semi ev. Gr. For., Shola for.		
82	*Paspalidium flavidum* (Retz.) A.Camus		Poaceae	Herb	Paddy fields,Banks of backwatersand streams		
83	*Pennisetum polystachyon* (L.) Schult.		Poaceae	Herb	Degr. Moist decd. For.,Open ares		
84	*Peperomia pellucida* (L.)Kunth	Mashipatcha	Piperaceae	Erect herb	Degr. For., Open areas		
85	*Perotis indica* (L.)O.Ktze		Poaceae	Herb	Open areas		
86	*Phaulopsis imbricata* (Forssk.) Sweet.	Kallurukki	Acanthaceae	Herb	Semi ev.gr.for,Decd.for.,Plains		
87	*Phyllanthus amarus* Schum.& Thonn.	kizhukanelli	Euphorbiaceae	slender herb	Degr.moist.decd.for.		
88	*Pilea microphylla (L.) Liebm.*		Urticaceae	Herb	Cultivated		
89	*Piper longum* L.	*Kattuthipali*	*Piperaceae*	*Scandent shrub*	Ev gr. For., Sem ev. Gr. For., Moist decd for., *Open areas*		
90	*Rungia parviflora* (Retz.) Nees		Acanthaceae	Herb	open areas		
91	*Salacia oblonga* Wall. Ex Wight & Arn.	Ponkoranti	Hippocrateaceae	Climbing shrub	Ev.gr.for.,Semi ev.gr. For.		
92	*Scoparia dulcis* L.	Kallurukki	Scrophulariaceae	Erect herb	Open areas		
93	*Sida rhombifolia* L.	Kurunthotti	Malvaceae	shrub	Degr. For., Open areas		
94	*Sida rhomboidea* Roxb.ex Fleming	Kurunthotti	Malvaceae	shrub	degr.for, open areas		
95	*Spilanthus calva* Dc.	Kuppamanjal	Asteraceae	Herb	wet marshy open areas		
96	*Stachytarpheta indica* (L.) Vahl.		Verbenaceae	Sub shrub	Open areas		
97	*Suregada augustifolia* (Baill.exMuell.-Arg.)Airy Shaw		Euphorbiaceae	Small tree	Ev gr. For.		Endemic to peninsular India
98	*Symplocos cochin chinensis* (Lour.) Moore ssp laurind	Pachotti	Symplocaceae	Small tree	Ev. Gr. For., Semi ev. Gr. For., Shola for., Sacred groves		
99	*Syzygium calophyllifolium* Walp.		Myrtaceae	Large tree	Ev gr. For		

100	*Tabernaemontana divaricata* (L.) R.Br.	Nandiyarvattom	Apocynaceae	Shrub	Cultivated		
101	*Tephrosia pumila* (Lam.) Pers.		Fabaceae	Slender herb	Wet rocky areeas		
102	*Tephrosia purpurea* (L.) Pers.	Kodikozhingil, Kozhuva	Fabaceae	Shrub	Moist decd. for., Grasslands,plains		
103	*Trema orientalis* (L.)	Pottama	Ulmaceae	Small tree	Moist and dry decd. For.,Plains		
104	*Tylophora indica* (Burm.f.) Merr.	Vallipala	Asclepiadaceae	Slender climber	along bushes and thickets		
105	*Urena lobata* ssp *sinuata*(L.) Borss.	Uram,Uthiram	Malvaceae	Sub shrub	Moist decd.for.,Plains		
106	*Utricularia stellaris* Lf.		Lentibulariaceae	Herb	Stagnant and slow running water		
107	*Vernonia cinerea* (L.) Less.	Poovan kurunal	Asteraceae	Herb	Decd for.,Plains		
108	*Vernonia elliptica* DC.	curtain chadi	Asteraceae	Shrub	cultivated		
109	*Waltheria indica* L.		Bombacaceae	Sub shrub	Degr. Moist decd. For., Plains		
110	*Xenostegia tridentata* (L.)Austin &Staples	Cheruvayera,Prasaram	Convolvulaceae	prostrate herb	Decd. for.,Plains		
Gymnosperm							
1	*Cycas circinalis* L.	Eenth	Cycadaceae	Small palm	Moist decd. For., Open areas		
Pteridophytes							
1	*Adiantum lunulatum* Burm.f.		Adiantaceae	Small terrestrial herb	Open areas rock crevices,forests		very common
2	*Nephrolepis delicatula (Decne.) Pic.Serm*		Oleandraceae	Terrestrial herb	Shaded rocky areas		common
3	*Pyrrosia heterophylla* (L.) M.G.Price		Polypodiaceae	Epiphytic	rocky areas,forests		common
4	*Selaginella delicatula* (Desv.ex Poir.) Alston		Lycopodiaceae	terrestrial herb	Forests, plains		common

Table 4.7 - Taxonomic , ecological description and conservation status of the plant species in the Forest areas

Sno.	Name of the plant	Vernacular name	Family	Habit	Distribution		Status
Angiosperms							
1	*Abrus precatorius* L.	Kunni	Fabaceae	Twining shrub	Dry decd for.,Plains		
2	*Acacia catechu (L.f.) Wild.*	Karingali	Mimosaceae	Small tree	Dry decd. For.		
3	*Acacia pennata* (L.)Wild.	Karincha	Mimosaceae	scandent shrub	Moist decd.for		
4	*Acrocarpus fraxinifolius* Wight& Arn.	Narivenga	Caesalpiniaceae	Very large tree	Ev .gr.for., Semi ev. Gr. For.		
5	*Acrotrema arnottianum* Wight	Nilampunna	Dilleniaceae	Rhizomatous herb	Ev. Gr. For.		Endemic to South Western ghats
6	*Actinodaphne bourdillonii* Gamble	Eeyoli	Lauraceae	Medium tree	Ev gr. For., Shola for.		Endemic to South Western Ghats
7	*Actinodaphne malabarica* Balakr.	Kambilivirinji	Lauraceae	Medium tree	Ev. Gr. Fro.		Endemic to South Western ghats, Rare (Nayar,1997)
8	*Adenanthera pavonina L.*	*Manchadi*	*Mimosaceae*	*Medium tree*	*Cultivated*		
9	*Aganope thyrsiflora* (Benth.)		Fabaceae	Shrub	Semi ev.gr. For.,Plains		
10	*Agnosma cymosa* (Roxb.) G. Don		Apocynaceae	Climber	Semi ev.gr. For., Alongside streams		
11	*Alstonia scholaris* (L.) R.Br.	Ezhilampala	Apocynaceae	Large tree	Moist decd for. ,Sacred groves,plains		
12	*Andrographis paniculata* (Burm.f.)Wall.ex Nees	Nilavepu	Acanthaceae	Sub shrub	Scrub jungles,plains		
13	*Aneilemma montana* (Wight) Clarke		Commelinaceae	Herb	Ev gr. For., Semi ev. Gr. For.		Endemic to peninsular India
14	*Aneilemma scaberrimum* (Blume) Kunth		Commelinaceae	Herb	Ev gr. For., Semi ev. Gr. For.		
15	*Antidesma acidum* Retz.	Areepazham	Euphorbiaceae	Small tree	Semi ev.gr. For.,Moist decd for.,Sacred groves		
16	*Apodytes dimidiata* Meyer ex Arn.	Slatematthi,Karineeli	Icacinaceae	Medium tree	Ev. Gr. For., Semi ev. Gr. For.		
17	*Aporosa lindleyana* (Wight) Baill.	Vetti	Euphorbiaceae	Medium tree	Ev. Gr for., Semi ev. Gr. For., Plains		
18	*Ardisia pauciflora* Heyne ex Roxb.	Muttumaram	Myrsinaceae	Small tree	Ev gr. For., Shola for.		
19	*Artocarpus hirsutus* Lam.	Anjili	Moraceae	Large tree	Semi ev gr,Moist decd.for,Plains		Endemic to South Western ghats
20	*Asystasia dalzelliana* Sant.		Acanthaceae	Herb	Ev gr.for.,Semi ev.gr. For.		
21	*Atalantia monophylla* (L.) DC.	Katunaranga	Rutaceae	Small tree	Dry decd for.		
22	*Azadirachta indica* A. Juss.	Aariyaveppu	Meliaceae	Medium tree	Dry decd. For., Cultivated		

23	*Bidens pilosa* L.		Asteraceae	Shrub	Open areas,a weed		
24	*Biophytum reinwardtii* (Zucc.) Klotzsch.var *reinwardtii*		Oxalidaceae	Erect herb	Moist decd. for. ,Plantations, Plains		
25	*Biophytum sensitivum*(L.) DC. Var *candolleanum* (Wight) Edgew.&Hook.f.	Nilamthengu	Oxalidaceae	Herb	Dry decd. For. , Grasslands		
26	*Biophytum sensitivum*(L.) DC. Var sensitivum	Mukkutti	Oxalidaceae	Herb	Dry decd. for.,Grasslands		
27	*Bixa orellana* L.	Kunkumapoo vu,Sindooram	Bixaceae	Small tree	Cultivated		
28	*Bombax cieba* L.	Elavu	Bombacaceae	Very large tree	Semi ev.gr. For.,Moist decd. For.		
29	*Bracharia ramosa* (L.) Stapf		Poaceae	Herb	Grasslands,Moist decd forest,Open ares		
30	*Bridelia scandens* (Roxb.) Willd.	Cheru panachi	Euphorbiaceae	Scandent shrub	Semi ev. Gr. For.,Moist decd for.,Sacred groves		
31	*Caesalpinia bonduci* (L.) Roxb.	Kazhanji	Caesalpiniaceae	Climbing shrub	Ev.gr.for.,Moist decd for.		
32	*Calamus thwaitesii* Becc.& Hook.f.	Pannichural	Arecaceae	Climbing Palm	Ev. Gr. For.,Semi ev. Gr. For.		
33	*Calophyllum polyanthum* Wall.	Punna	Clusiaceae	Large tree	Ev. Gr. For.		
34	*Calycopteris floribunda* Lam.	Pullanni	Combretaceae	Woody climber	Moist decd. For.,, Plains		
35	*Canthium augustifolium Roxb.*	Kattaramullu	Rubiaceae	Scandent shrub	Semi Ev.gr.for.		
36	*Cardiospermum halicacabum* L.	Paluruvam	Sapindaceae	Climbing herb	Moist decd for., Scrub jungles		
37	*Careya arborea* Roxb.	Aalam	Lecythidaceae	Small tree	Moist & Dry decd. For., Plains		
38	*Cassia fistula* L.	Kanikonna	Caesalpiniaceae	Medium tree	Moist decd. For., Cultivated		
39	*Centrosema pubescens* Benth.	Kattupayani	Fabaceae	Slender climber	Decd. For., Plantations, Plains		
40	*Ceropegia maculata* Bedd.		Asclepiadaceae	Herb	Semi ev. Gr. For.		Possibly extinct(Nayar 1997)
41	*Chasssalia curviflora* Wall.ex Kurzz Thw. Var ophioxyloides (Wall.) Deb & Krishna	Vellakurinji	Rubiaceae	Shrub	All types of forests, Plains		
42	*Chionanthus mala-elengi* (Dennst.) P.S Green	Mala-elengi	Oleaceae	Small tree	Semi ev. Gr. For., Moist decd. For.		Endemic to peninsular India
43	*Chromolaena odorata* (L.) King & Robins.	Cummunist pacha	Asteraceae	Shrub	Open areas		
44	*Cinnamomum sulphuratum Nees*	Kattu karuva	Lauraceae	Medium tree	Ev. Gr. For., Shola for.		Endemic to Western ghats
45	*Cissampelose pareira* L. Var hirsuta	Malathangi	Menispermaceae	Herbaceous climber	Decd. For., Plains		
46	*Citrus maxima* (Burm. F. Merr.	Pomelo	Rutaceae	small tree	cultivated		
47	*Clerodendron viscosum* Vent.	Perivelum	Verbenaceae	Small tree	Degrd for., Plains		

48	*Commelina maculata* Edgew		Commelinaceae	Erect herb	Ev.gr.for.		
49	*Conyza bonariensis* (L.) Cronq.		Asteraceae	Herb	Moist decd for., Grasslands		
50	*Costus speciosus* (Koenig) J.E.Smith	Channa	Zingiberaceae	Herb	Semiev.gr.,Moistdecd.for.,Plains		
51	*Crotalaria evovuloides* Wight ex Wight & Arn.		Fabaceae	Herb	Moist decd for. Grasslands		
52	*Cucurligo orchiodes* Gaertn	Nilapana	Hypoxidaceae	Herb	Moist decd. For. Grasslands ,Plains		
53	*Cucurma neilgherrensis* Wight	Koova	Zingiberaceae	Rhizomatous herb	Grasslands		
54	*Cyathula prostrata* (L.) Blume	Cherukadaladi	Amaranthaceae	Herb	Semi ev.gr.for.,Moist decd.for.,plains		
55	*Cyclea peltata* (Lam.)Hook.f.Thoms.	Padathalli	Menispermaceae	Climber	Ev.gr.,Semiev.gr. For.		
56	*Cymbopogon flexosus* (Nees ex Steud.) Wats.	Malabar grass, Inchpulli	Poaceae	Herb	Degr. For.,Grasslands, Plains		
57	*Cynodon dactylon (L.) Pers*	Karuka	Poaceae	Herb	Paddy fields ,Open areas		
58	*Cyperus rotundus L.*	Muthanga	Cyperaceae	Herb	Plains ,Open areas		
59	*Cyrtococcum patens* (L.) A. Camus		Poaceae	herb	Moist decd.for.Plains		
60	*Desmodium gangeticum* (L.) DC	Orila	Fabaceae	Shrub	Moist decd.for.,plantations		
61	*Desmodium triangulare* (Retz.)Mers.		Fabaceae	Shrub	Moist decd.for.,plantations		
62	*Desmodium triquetrum* (L.)DC.	Adakkapanal	Fabaceae	Shrub	Semi ev.gr.for.Moist decd.for.,Plains		
63	*Digitaria longiflora* (Retz.)Pers.		Poaceae	Herb	Grasslands,Open areas		
64	*Dioscorea bulbifera* L.	Kattu kaachil	Dioscoreaceae	Climbing shrub	Moist decd.for.,Plains		
65	*Dioscorea pentaphylla* L.	Noorakizhangu	Dioscoreaceae	Climbing shrub	Degraded decd for.		
66	*Diospyros buxifolia* (Blume) Hiertn	Elicheviyan	Ebenaceae	Large tree	Ev. Gr. For., Semi ev. Gr. For.		
67	*Diploclisia glaucescens* (Blume) Diels	Vattoli	Menispermaceae	Woody climber	Ev.gr.,Semi ev.gr.fro.,moist decd for.		
68	*Elaeocarpus glandulosus Wall.*	Kara	Elaeocarpaceae	Medium tree	Ev gr. For, Semi ev. Gr. For., Shola for.		
69	*Ficus benghalensis* **L**.	Aal maram	Moraceae	Medium tree	Dry decd. For. , Plains		
70	*Ficus exasperata* Vahl	Therakom	Moraceae	Small tree	Moist decd for., Plains		
71	*Ficus heterophylla* L.F.	Valli therakom	Moraceae	Scandent shrub	Along river banks		

72	*Fluggea virosa* (Roxb.ex Willd.) Baill.	Perimklavu	Euphorbiaceae	Small tree	Dry and Moist decd for.,Plains		
73	*Glycosmis pentaphylla* (Retz.) DcC.	Panal	Rutaceae	Small tree	Semi ev gr,Moist decd.for,Plains		
74	*Gomphandra tetrandra* (Wall) Sleumer		Icacinaceae	Small tree	Ev.gr. For.,Semi ev.gr.for.		
75	*Grewia glabra* Blume	Aanakotti maram	Tiliaceae	Small tree	Semi ev. Gr. For.,Moist decd. For.,Plains		
76	*Grewia tillifolia* Vahl.	Unnam	Tiliaceae	Large tree	Moist decd for.		
77	*Helectris isora* L.	Edampiri vallampiri	Sterculiaceae	Small tree	Decd. For., Plantation, Plains		
78	*Hemidesmus indicus*(L.) R.Br.	,naruneendi	Periplocaceae	Shrub	Decd for,Plains,Plantations		
79	*Hibiscus hispidissimus* Griff.	Mattipuli,Uppanacham	Malvaceae	Rambling shrub	Dry& Moist decd for., Plains		
80	*Holarrhena pubescens* (Buch-Ham.) Wall. Ex G.Don	Kadalapala	Apocynaceae	Small tree	Moist decd. For., Dry decd. For. ,Plains		
81	*Hydnocarpus pentandra* (Buch.-Ham.) Oken	Marotti	Flacourtiaceae	Medium tree	Semi ev. Gr., moist decd. For., Plains		Endemic to western ghats
82	*Ichnocarpus frutiscens* (L)R.Br.	Palvalli	Asclepiadaceae	climber	Moist dry decd.for.,plains		
83	*Ipomea barlerioides* (Choisy) Benth. Ex Clarke.		Convolvulaceae	Herb	Grasslands,Savannahs		
84	*Ixora johnsonnii* Hook.f.		Rubiaceae	Shrub	Ev.gr.for.		
85	*Ixora nigricans* R.Br. Ex Wight & Arn.		Rubiaceae	Small tree	Ev. Gr. For., Semi ev. Gr. For.		
86	*Jasminum azoricum* L. var azoricum		Oleaceae	Climbing shrub	Ev.gr. For., Semi ev.gr. For.,Shola for.		
87	*Jasminum brevilobum* A.DC..	Kattumulla	Oleaceae	Climbing shrub	Shola for.		Endemic to peninsular India
88	*Jasminum rottlerianum* Wall.ex A. DC. Var.rottlerianum	Kattumulla	Oleaceae	Climbing shrub	Ev.gr. For.,moist decd.for., Shola		
89	*Knema attenuata* (Hook. F. & Thoms.) Warb.	Chorapayin	Chloranthaceae	Medium tree	Ev.gr. For., Semi ev.gr. For.,		Endemic to Western ghats
90	*Lagerstroemia indica* L.	May flower	Lythraceae	Small tree	Cultivated		
91	*Lagerstroemia microcarpa* Wight	Venthekku	Lythraceae	Large tree	Moist decd. For., Plains		Endemic to western ghats
92	*Lagerstroemia speciosa* (L.) Pers.	Poomarathu	Lythraceae	medium tree	Ev.gr.for.,Semi ev.gr.for.,Along banks of rivers,Cultivated		
93	*Lannea coromandelica* (Houtt.) Merr.	Odiya maram	Sabiaceae	Large tree	Decd. For., Plains		
94	*Lantana camara* L.	Poochedi, Konda	Verbenaceae	Shrub	Wid ,Cultivated		

95	*Lantana camara* L. var.aculeata (L.) Moldenke	Konda	Verbenaceae	Shrub	Cultivated		
96	*Leea indica*(Burm.f.) Merr.Philipp.	Chorianthali, Njallu	Leeaceae	Small tree	Degr. Ev gr.for.,Semi ev.gr. For.,Plains		
97	*Malvastrum coromandelianum* (L.) Garcke		Malvaceae	Woody herb	Degrd Moist decd. For., Open areas		
98	*Mangifera indica*L.	Maavu	Anacardiaceae	medium tree	Ev gr. For., Semi ev. Ger. For.,widely cultivated		
99	*Maranta arundinaceae* L.	Koova	Marantaceae	Perennial herb	Cultivated		
100	*Melochia corchorifolia* L.		Sterculiaceae	Woody herb	Degr. Decd for., Open areas		
101	*Merremia umbellata*(L.)Hall.f.	Vayara	Convolvulaceae	Prostrate twining herb	All types of for.,Plains		
102	*Merremia vitifolia*(Burm.f.)Hall.f.	Manja kolambi	Convolvulaceae	Climber	Degraded for.,Plains		
103	*Michelia nilagirica* Zenk.	Kattuchempa kam	Magnoliaceae	Small tree	Ev.gr. For.		Endemic to western ghats
104	*Mitrcarpus villosus* (S w) DC..		Rubiaceae	Erect herb	Degr.moist decd.for.,Open areas,plains		
105	*Mitragyna parvifolia (Roxb.) Korth.*	Veembu	Rubiaceae	Medium tree	Moist decd. For.		
106	*Monochoria vaginalis* (Burm.f.)	Karinmkoval um	Pontederiaceae	herb	Paddy fields,Low wetlands		
107	*Myristica malabarica Lam.*	Panampalaka	Chloranthaceae	Medium tree	Ev. Gr. For., Swamp for.		Endemic to Western ghats, Vulnerable (IUCN, 2000)
108	*Naragamia alata* Wight&Arn.	Nilanaragam	Meliaceae	Herb	Moist decd for.,Plantation		
109	*Naringi crenulata*(Roxb.) Nicols	Kattunarakam	Rutaceae	Small tree	Semi ev. Gr. For., Moist decd. For., Plains		
110	*Neolamarckia cadamba* (Roxb.) Bosser	Aattu thekku	Rubiaceae	Large tree	Along river banks		
111	*Nothapodytes nimmoniana (Graham) Mabb.*	Peenari	Icacinaceae	Small tree	Ev. Gr. For.,Moist decd for.,Shola for.		
112	*Olea dioica* Roxb.	Edala	Oleaceae	Medium tree	Semi ev gr.Moist decd.for,Plains		
113	*Pajanelia longifolia (Willd.) K. Schum.*	Payyani,Azha ntha	Bignoniaceae	Medium tree	Semi ev. Gr. For., Moist decd. For., Plains		
114	*Panicum brevifolium* L.		Poaceae	Herb	Margins of forests,Backwat ers,Open areas		
115	*Passiflora foetida* L. var. foetida	Chadayn	Passifloraceae	Climbing shrub	Degr. For.,Open areas		
116	*Persea macrantha* (Nees) Kosterm.	Kulamavu	Lauraceae	Large tree	Ev. Gr. For., Semi ev. Gr. For., Moist decd. For., Sacred groves		

117	*Phyla nodiflora*(L.) Greene	Kattuthippali	Verbenaceae	Creeping herb	coastal sandy areas,paddy fields ,banks of streams		
118	*Phyllanthus embelica* L.		Euphorbiaceae	Medium tree	Moist &Dry decd.for. ,Plains		
119	*Pilea kingii* Fischer		Urticaceae	Herb	Ev gr for.		Endemic to south western ghats
120	*Piper barberi* Gamble	Kattukurumulagu	Piperaceae	Climbing shrub	Evergreen forest		Endemic to south western ghats, Vulnerable (Nayar,1997)
121	*Piper longum* L.	Kattuthipali	Piperaceae	Scandent shrub	Ev. gr. For., Sem ev. Gr. For., Moist decd for., Open		
122	*Piper nigrum* L.	Karumulaku	Piperaceae	Climbing shrub	Ev. Gr. For., Semi ev. Gr. For., Cultivated		
123	*Plumbago zeylanica* L.	Tumbakoduveli	Ericaceae	Shrub	Decd. For., Plains		
124	*Pogostemon purpurascens* Dalz.	Choriyanthalli	Lamiaceae	Sub shrub	Semi ev. Gr. For., Moist decd for. Plains		
125	*Polyalthia coffeoides* (Thw.ex Hook. F. & Thoms.)	Nedunar	Annonaceae	Small tree	Ev fr. For., Semi ev. gr. For.		
126	*Polyalthia fragrans* (Dalz.) Bedd.	Kodangi	Annonaceae	Large tree	Ev fr. For., Semi ev. gr. For.		Endemic to South Western ghats
127	*Pseudarthria viscida* (L.) wight & Arn.	Moovila	Fabaceae	Sub shrub	Moist decd. For., Plains		
128	*Psydrax dicoccus* Gaertn.	Irumbarappan	Rubiaceae	Small tree	Ev. Gr. For., Semi ev. Gr. For., Dry decd. For., Plains		
129	*Pterocarpus marsupium Roxb.*	Vega	Fabaceae	Large tree	Moist and Dry decd. For., Plains		
130	*Rauvolfia micrantha* Hook.f.		Apocynaceae	Shrub	Ev. Gr. For., Semi ev. Gr. For.		Endemic to South Western ghats.Endangered (Nayar,1997)
131	*Rauvolfia serpentina* (L.) Benth.	Amalpuri,Sarpagandhi	Apocynaceae	Herb	Moist decd. For. ,Plains		
132	*Ricinus communis* L.	Aavannakku	Euphorbiaceae	Shrub	Cultivated, Open areas		
133	*Sapindus trifoliata* L.	Pasakotta	Sapindaceae	small tree	Semi ev. Gr. For., Moist decd for.,Plains		
134	*Schleichera oleosa (Lour.) Oken*	Poovanam	Sapindaceae	Large tree	Semi ev. Green for., Moist decd. For.,,Plains		
135	*Scleria terrestris*(L.) Fassett		Cyperaceae	Herb	Semi ev.gr. For., Decd. For.		
136	*Scoparia dulcis* L.	Kallurukki	Scrophulariaceae	Erect herb	Open areas		
137	*Setaria barbata*(Lam.) Kunth		Poaceae	Herb	Banks of streams, canals,Open areas		
138	*Sida cordata*(Burm.f.)Borss.	Valli kurunthotti	Malvaceae	Trailing herb	All types of for.,Plains		

139	*Sida rhombifolia* L.	Kurunthotti	Malvaceae	shrub	Degr. For., Open areas		
140	*Smilax zeylanica* L.	Kareeelanchi	Smilacaceae	Climber	Semi ev. Gr. For.,Moist decd. For.,Plains		
154	*Tabernaemontana heyneana* Wall.	Koonam pala	Apocynaceae	Small tree	Moist decd. For., Sacred groves		Endemic to south western ghats,lower risk near threatened(IUCN,2000)
142	*Spilanthus calva* Dc.	Kuppamanjal	Asteraceae	Herb	wet marshy open areas		
143	*Spondias pinnata* (L.f.) Kurz.	Ambazham	Anacardiaceae	Large tree	Semi ev. Gr. For., Moist decd. For., plains		
144	*Stachyphyrnium spicatum* (Roxb.) Schum.		Marantaceae	Herb	Semi ev. Gr. For.,Moist decd. For.		Endemic to south India
145	*Sterculia guttata* Roxb.ex DC.	Thondi	Sterculiaceae	Medium tree	Semi ev. Gr. For.,Moist decd. For.,Plains		
146	*Streblus asper* Lour.	Paravamaram	Moraceae	Small tree	Moist and Dry decd.for.,Plains		
147	*Strobilanthus ciliatus* Nees.	Karimkurinji	Acanthaceae	Shrub	Ev. Gr. For.,Semi ev. Gr. for		Endemic to Peninsular India
148	*Strychnos colubrina* L.	Vallikanjiram	Loganiaceae	Climbing shrub	Ev.gr.for.,Semi ev.gr. For., Banks of streams		
149	*Strychnos lenticellata*		Loganiaceae	Climbing shrub	Ev.gr. For.		Endemic to South Western ghats
150	*Strychnos nux- vomica* L.	Kanjiram	Loganiaceae	Medium tree	Moist and Dry decd. For., Sacred groves		
151	*Syzygium caryophyllatum* (L.) Alston	Karinjara	Myrtaceae	small tree	Ev.gr.for,Semi ev.gr. For.		
152	*Syzygium cumini* (L.) Skeels	Njaval	Myrtaceae	Large tree	Ev.gr. For., Plains		
153	*Tabernaemontana divaricata* (L.) R.Br.	Nandiyarvattom	Apocynaceae	Shrub	Cultivated		
155	*Tectona grandis* L.f.	Thekku	Verbenaceae	Large tree	Moist decd for., Cultivated		
156	*Terminalia bellirica* (Gaertn.) Roxb.	Thanni	Rhizophoraceae	Large tree	Semi ev. Gr. For.,Moist decd. For.,Plains		
157	*Terminalia elliptica* Willd.	Karimaruthu, Thembavu	Rhizophoraceae	Large tree	Moist and dry decd for.		
158	*Terminalia paniculata* Roth	Maruthu ,	Rhizophoraceae	Large tree	Moist and dry decd for., Plains		
159	*Tetrameles nudiflora* R.Br.	Cheeni	Datiscaceae	Large decd. Tree	Ev gr. For., Semi ev. Gr. For., Moist decd. For.		
160	*Thespesia lampas* (Cav.) Dalz.& Gibs.	Kattuparathi	Malvaceae	Sub shrub	Moist decd. For.		
161	*Tiliacora acuminata* (Poir.)n Miers ex Hook. f.& Thoms.	Vallikanjiram	Menispermaceae	Climbing shrub	Moist decd. For.		
162	*Toona ciliata* Roem.	Vembu	Meliaceae	Large tree	Ev.gr. For.,Semi ev gr. For.		

163	*Trema orientalis* (L.)	Pottama	Ulmaceae	Small tree	Moist and dry decd. For.,Plains		
164	*Triumphetta rhomboidea* Jacq.	Oorpam	Tiliaceae	Erect herb	Degr. Decd. For., Plains		
165	*Tylophora indica* (Burm.f.) Merr.	Vallipala	Asclepiadaceae	Slender climber	along bushes and thickets		
166	*Tylophora mollisma* Wight&Arn		Asclepiadaceae	herb	Shola for.		Endemic to South India
167	*Urena lobata* L.ssp lobata	Oorpan	Malvaceae	Shrub	Degr.for.,Plains		
168	*Urena lobata* ssp *sinuata*(L.) Borss.	Uram,Uthiram	Malvaceae	Sub shrub	Moist decd.for.,Plains		
169	*Vernonia cinerea*(L.) Less.	Poovan kurunal	Asteraceae	Herb	Decd for.,Plains		
170	*Xanthophyllum arnottianum* Wight	Madakka,mottal	Polygalaceae	Small tree	Ev.gr.for,Semi ev.gr. For.		Endemic to Western ghats
171	*Xenostegia tridentata*(L.)Austin& Staples	Cheruvayera, Prasaram	Convolvulaceae	prostrate herb	Decd. for.,Plains		
172	*Xylia xylocarpa* (Roxb.) Taub.	Irul,Irulpool	Mimosaceae	Large tree	Moist decd.for.,Plains		
173	*Zanthozylum rhetsa* (Roxb.) DC.	Mullilam	Rubiaceae	Medium tree	Moist decd. For., Plains		
174	*Zizyphus oenoplea*(L.) Mill.	Cheruthudali	Rhamnaceae	Climber	Moist &Dry decd for.,Plains		
175	*Zizyphus rugosa*,Lam.	Thodali	Rhamnaceae	Scandent shrub	Decd.for,Grasslands,Plains		
Gymnosperm							
	Cycas circinalis L.	Eenth	Cycadaceae	Small palm	Moist decd. For., Open areas		
Pteridophytes							
1	*Bolbotis prolifera*(Bory) C.Chr.& Tardieu		Lomariopsidaceae	Lithophytic herb	Shaded rocks,forest floors, banks of streams		common
2	*Drynaria quercifolia* (L.) J.Sm.		Polypodiaceae	A large gregaroius epiphyte	Coastal plains , forests of western ghats		common
3	*Lygodium flexuosum* (L.) Sw.		Schizaceae	Terrestrial climbing herb	Open areas, Plains, forest margins		common
4	*Nephrolepis auriculata (L.) Trimen*		Oleandraceae	Terrestrial herb	Open forest areas		common
5	*Parahemionites cordata* Roxb.ex Hook.& Grev. Fraser-Jenk		Hemionitidaceae	Small terrestrial herb	coastal plains,high altitude forest		not common
6	*Polystichum moluccense* (Blume) T. Moore		Aspleniaceae	Small terrestrial herb	Ev. Gr. For		Rare
7	*Pteris biaurita* L.		Pteridaceae	Terrestrial herb	Forests,stream banks		Not common
8	*Pteris confusa*T.G.Walker		Pteridaceae	Terrestrial herb	Forests,stream banks		Not common
9	*Pteris scabripes* Wall.ex J. Agardh		Pteridaceae	Terrestrial herb	Ev gr. For.		Rare
10	*Pyrrosia heterophylla* (L.) M.G.Price		Polypodiaceae	Epiphytic	rocky areas,forests		common
11	*Selaginella delicatula* (Desv.ex Poir.) Alston		Lycopodiaceae	terrestrial herb	Forests, plains		common

Table- 4.12 Description of medicinal plants present in the Rubber plantations.

S.No	Name of the plant	Vernacular name	Family	Part of the plant used	Medicinal use	Status
1	*Abrus precatorius* L.	Kunni	Fabaceae	root, stem, seed	emetic, alexiteric,for diarrhea, night blindness,gum inflammation	
2	*Acacia pennata* (L.)Wild.	Karincha	Mimosaceae	bark	for dandruff anf snake bites	
3	*Acacia sinuata* (Lour.)Merr.	Chenikka	Mimosaceae	leaf,friut	a cathartic foot, biliousness,emetic,expectorantand aperient	
4	*Acalypha indica* L.	Kuppameni	Euphorbiaceae	whole plant	laxative,emetic,scabies,poulticeon ulcers,for snakebites	
5	*Achyranthes aspera* L.	Kadaladi	Amaranthaceae	whole plant	used for snake bite and jaudice	
6	*Adenostemma lavenia* (L.) O. Ktze.		Asteraceae	leaf	for cuts ,wunds and insect bites	
7	*Aerva lanata* (L.) Juss.ex Schult.	Cherula	Amaranthaceae	whole plant	infant diarrhea,cholera,dysentry	
8	*Ageratum conizoides* L.	Appa,Katappa	Asteraceae	whole plant	antilithic juice,prevents bleeding,snake bites	
9	*Agnosma cymosa* (Roxb.) G. Don		Apocynaceae	whole plant	emetic,used for eye disease	
10	*Ailanthus triphysa (Dennst.) Alston*	Permaram	Simaroubaceae	bark	febrifuge,tonic, carminative, resin for dysentry	
11	*Albizia amara* (Roxb.) Boivin	Oonjal	Mimosaceae	leaf, seed, flower	to cure ophthalmia,for ulcers,boils and inflammation,astringent,piles	
12	*Albizia lebbeck* (L) Willd.	Vaka	Mimosaceae	bark,root,stem,leaf	night blindness,boils,carbuncles,swellings,piles,gonorrhea	
13	*Albizia odoratissima* (L.f.) Benth.	Kunni vagha	Mimosaceae	bark,leaf	leprosy,persistent ulcers	
14	*Alstonia scholaris* (L.) R.Br.	Ezhilampala	Apocynaceae	root and bark	anthelmintic,rheumatism	
15	*Alternanthera sessilis* (L.) R.Br.	Kozhuppa	Amaranthaceae	root	for hazy vision, night blindness	
16	*Anamirta cocculus* (L.) Wight & Arn.	Pollakai	Menispermaceae	fruit	ointment made from the drupes used for chronic diseases,an insecticide to kill body-lice	
17	*Andrographis paniculata* (Burm.f.) Wall.ex Nees	Nilavepu	Acanthaceae	root,stem,leaf	febrifuge,anthelmintic	
18	*Anisochilus carnosus (L.f.) Wall. Ex Benth.*	Kattukoorkka	Lamiaceae	whole plant	expectorant,stimulant,	
19	*Antidesma acidum* Retz.	Areepazham	Euphorbiaceae	root, bark,leaf	on sores,applied onchest for pnuemonia,for blood dysentry	
20	*Aporosa lindleyana* (Wight) Baill.	Vetti	Euphorbiaceae	root	decoction used for insanitty,headache, fever,loss of semen, jaundice	
21	*Aristolochia tagala* Cham.	Garuda kod	Aristolochiaceae	whole plant	rheumatism,malaria,snakebite,toothache	
22	*Artocarpus heterophyllum* Lam.	Plavu	Moraceae	leaf,flower	for sores,smallpox,carbuncles, anthelmintic,in childbirth to clear foetus	
23	*Artocarpus hirsutus* Lam.	Anjili	Moraceae	leaf,flower	applied for bubo and swollen testicles	Endemic to S.Western ghats

Table 4.12 Chapter 4: Results

24	*Asystacia gangetica* (L.) Andersvar. gangetica	Upputhali	Acanthaceae	whole plant	juice is anthelmintic, for rhuematism and swellings	
25	*Azadirachta indica* A. Juss.	Aariyaveppu	Meliaceae	all parts of the plant	tonic, alterative for skin disease, astringent,vermifuge,demulcent,stimulant,contraceptive,anthelmintic	
26	*Barleria buxifolia* L.		Acanthaceae	root na dleaf	to treat cough and inflammation	
27	*Blumea lacera*(Burm.f.) DC.	Rakilla	Asteraceae	leaf	anthelmintic,diuretic,stimulant,febrifuge	
28	*Boerhaaavia diffusa* L.	Thazhuthama	Nyctaginaceae	root,leaf,seed,whole plant	diuretic,laxative,expectorant,asthma,oedema,anaemia,jaundice,internal inflammation	
29	*Bombax cieba* L.	Elavu	Bombacaceae	root	for cholera,tubercular fistula,diuretic,cough, impotency	
30	*Bridelia retusa* (L.) Spreng.	Mulluvenga	Euphorbiaceae	bark	liniment in rheumatism,contraceptive	
31	*Caladium bicolor*(Ait.ex Dryand.)Vent.	Kaatu chembu	Araceae	rhizome	applied for facial paralysis	
32	*Calycopteris floribunda* Lam.	Pullanni	Combretaceae	root,leaf	laxative,,astringent,anthelmintic	
33	*Cardiospermum halicacabum* L.	Paluruvam	Sapindaceae	whole plant	emmenagotgue, diaphoretic,rubefacient,diuretic,laxative4, aperient	
34	*Careya arborea* Roxb.	Aalam	Lecythidaceae	bark, flower	for propapsus,snakebit, cold and cough	
35	*Centella asiatica (L.)*	Kudakkan	Apiaceae	whole plant	for skin disease, leprosy	
36	*Chromolaena odorata* (L.) King & Robins.	Cummunist pacha	Asteraceae	leaf	dysentry,applied on fresh cuts and wounds to stop bleeding	
37	*Chukrasia tabularis* A. Juss.	Karadi	Meliaceae	bark	tanin containing astringent	
38	*Cissampelose pareira* L. Var.hirsuta	Malathangi	Menispermaceae	root,leaf,stem	for heat stroke,,carbuncles,epilepsy,colic,delirium,haematuria,bronchitis,cold cough,to treat bite of rabid dog	
39	*Cleome monophylla* L.		Capparaceae	root	pouded roots placed on lips restores consciousness	
40	*Clerodendron viscosum* Vent.	Perivelum	Verbenaceae	leaf	on sores and tumors, as tonic	
41	*Clitoria ternatea* L.	Shankhapushpam	Fabaceae	root,leaf,seed	for goitre, leprosy,on swelling, snakebite	
42	*Commelina benghalensis* L.	Kanavazhai	Commelinaceae	whole plant	laxative,demlcent,emolient,and refrigerant	
43	*Costus speciosus* (Koenig) J.E.Smith	Channa	Zingiberaceae	rhizome, bark, stem, leaf	for constipation, tonic, antispasmodic, diuretic, depressant on central nervous system, dropsy anasarca, phthisis, asthmaantifertility and antiarthritic activity	
44	*Cucurma zedoaria* (Christm.) Rosc.	Manja koova,Kasthuri manjal	Zingiberaceae	rhizome	to treat jaundice	
45	*Cyathula prostrata* (L.) Blume	Cherukadaladi	Amaranthaceae	whole plant	applied externally for skin condition	
46	*Cyclea peltata* (Lam.)Hook.f. Thoms.	Padathalli	Menispermaceae	root	for smallpox	
47	*Cynodon dactylon (L.) Pers*	Karuka	Poaceae	whole plant	antifertility in women, dropsy, epilepsy,bleeding piles,urinary complaints	

48	*Dalbergia horrida* (Dennst.) Mabb.	Aanamullu	Fabaceae	stem,leaf	bark used to remove pimples	Endemic to South Western ghats
49	*Dalbergia lanceolaria* L.f. ssp lanceolaria	Velleeti	Fabaceae	stem,seed	remedy for intermittent fever,for dyspepsia,alleviating rheumatism	
50	*Dalbergia volubilis* Roxb.		Fabaceae	root, leaf	for gonorrhea,juice of leaf placed on aphthae, gargled to relive sore throat	
51	*Dendrocnide sinuata* (Blume)Chew	Anamayakki	Urticaceae	root, seed	to treat protracted fever	
52	*Desmodium gangeticum*(L.)DC	Orila	Fabaceae	root	bilious disorders, diuretic, tonic, carminative	
53	*Desmodium heterophyllum*(Wild) DC.		Fabaceae	whole plant	diuretic,tonic, carminative	
54	*Desmodium pulchellum*(L.) Benth.	Cherupachotti	Fabaceae	root	for burning sensation in the abdomen	
55	*Desmodium triflorum* (L.)DC.	Cherupulladi	Fabaceae	leaf	fresh leaves placed for abscesses and wounds, galactagogue,for control of convulsions	
56	*Desmodium triquetrum*(L.)DC.	Adakkapanal	Fabaceae	root	for snakebite,cough,cold,abdominal pain	
57	*Dioscorea bulbifera* L.	Kattu kaachil	Dioscoreaceae	tuber	remedy for,piles,leprosy, gonorrhoea, worms	
58	*Dioscorea pentaphylla* L.	Noorakizhangu	Dioscoreaceae	tuber	rheumatism,bile,cough and asthma	
59	*Diploclisia glaucescens*(Blume) Diels	Vattoli	Menispermaceae	leaf	cure for gonorrhoea, biliousness and syphilis	
60	*Eclipta prostrata (L.)* L.	Kayyunni	Asteraceae	whole plant	elephantiasis,skin rash,leucoderma	
61	*Elephantopus scaber* L.	Anachuvadi	Asteraceae	root and leaf	checks vomiting,used for pimples, wound of cattle	
62	*Elettaria cardamomum* (L.)	Elam	Zingiberaceae	seed	promotes digestion, removes flatulence, for phthisis, cure for bronchitis and asthma	
63	*Emilia sonchifolia* (L.) DC.	Muyalchevian	Asteraceae	root and leaf	diarrhea, gangarene, eye disease	
64	*Euphorbia hirta* L.	kuzhinagappala	Euphorbiaceae	whole plant	for asthma,boils and ulcers of the mouth,promotes lactation,for kidney disorders	
65	*Ficus exasperata* Vahl	Therakom	Moraceae	bark and juice	for enlarged spleen and liver	
66	*Ficus hispida* L.f.	Thonditherakom	Moraceae	bark,fruit and seed	emetic and purgative	
67	*Flemingia strobilifera* (L.) R.Br. Ex Ait.f.	Kumalu	Fabaceae	leaf,root	vermifuge,relieve hysteria, fever, epilepsy	
68	*Globba marantina* L.		Zingiberaceae	root	for cough and asthma	
69	*Glochidion zeylanicum* (Gaertn.) A Juss.	Neervetti	Euphorbiaceae	stem,leaf	for itching skin,as restorative,cooling	Endemic to Western ghats
70	*Gloriosa superba* L.	Menthonni	Liliaceae	root,leaf	purgative, anthelmintic,on lepros, septic ulcer,skin infections, piles,insect bites	
71	*Glycosmis pentaphylla* (Retz.) DcC.	Panal	Rutaceae	root	for fever, post delivery pains, worms	

72	*Gmelina arborea* Roxb.	Kumbil	Verbenaceae	bark,root	for cholera, choking and swelling of throat, rheumatism, epilepsy, dropsy and anasarca, convulsions, syphilis	
73	*Hedyotis auricularia* L.	Erachiketti	Rubiaceae	whole plant	cholera and dysentry, emollient	
74	*Hedyotis corymbosa* (L.) Lam.	Onathumba	Rubiaceae	whole plant	to treat liver diseases, jaundice, an anthelmintic, decoction used for nervous depression, gastric irritation	
75	*Helectris isora* L.	Edampiri vallampiri	Sterculiaceae	root, leaf	on sores, carbuncles, stomach ache, colic,cholera,rickets of babies, oil massage on body to relieve pain	
76	*Heliotropium indicum L.*	Thelkkada	Boraginaceae	whole plant	for ulcers, boils, insect bites,throat infectons, reptile bites	
77	*Hemidesmus indicus*(L.) R.Br.	.naruneendi	Periplocaceae	root, whole plant	for stomach pain, skin disease, urinary complication, blood purifier, diaphoretic, masticatory, galactogogue, nutritive, for fever	
78	*Indigofera linnaei* Ali.	Cherru-pulladi	Fabaceae	whole plant	diuretic,antiscorbutic,alterative	
79	*Ipomea alba L.*	Mandavalli	Convolvulaceae	part unspecified	for snake bites	
80	*Ipomea cairica* (L.)Sweet	Kolambipoo	Convolvulaceae	seed	laxative	
81	*Ipomea obscura* (L.)Ker-Gawl.	Thiruthali	Convolvulaceae	leaf	treatment for aphthous vescilces	
82	*Ipomea pes-caprae* (L.)R.Br.	Adumbuvalli	Convolvulaceae	leaf, seedand whole plant	rheumatism,for stomach ache,laxative,astrigent,tonic diuretic	
83	*Ixora coccinea* L.	Chetti	Rubiaceae	root, flower	acute dysentry, loss of appetite, chronic ulcers, catarrhal bronchitis, leucorrhoea	
84	*Jasminum rottlerianum* Wall.ex A. DC. Var.*rottlerianum*	Kattumulla	Oleaceae	leaf	for treatment of eczema	
85	*Justicia betonica* L.	Vellakurunji	Acanthaceae	whole plant	for diarrheea,applied to swellings	
86	*Justicia procumbens* L.		Acanthaceae	whole plant	diuretic, diaphoreticandd laxative and for ophthalmia	
87	*Lagerstroemia speciosa* (L.) Pers.	Poomarathu	Lythraceae	root, fruit	febrifuge, stimulant, astringent, purgative,narcotic	
88	*Lantana camara* L.	Poochedi, Konda	Verbenaceae	whole plant	for atoxy of abdominal viscera, rheumatism, malaria, tetanus	
89	*Lepidagathis incurva* Buch.Ham		Acanthaceae	leaf, fruit	chewed to relieve cough, used as ear drop	
90	*Leucas indica* (L.)R.Br.ex Vatke	Thumba	Lamiaceae	whole plant	febrifuge,colds,stop bleeding from nose,chronic headache	
91	*Macaranga indica* Wight	Vatta	Euphorbiaceae	whole plant	gum is applied to sores	
92	*Macaranga peltata* Roxb.) Muell.- Arg.	Vatta	Euphorbiaceae	whole plant	cures veneral sores	
93	*Maesa indica* (Roxb.) DC.	Kireethi	Myrsinaceae	root.fruit	for syphilis,an anthelmintic	
94	*Mallotus philippensis* (Lam.)Muell.- Arg.	Chenkoli	Euphorbiaceae	glandular hairs on fruit,fruit	destroys tapeworms,purgative,oral contraceptive,tonic for pregnant women	
95	*Melastoma malabathricum* L.	Athirani,Kadali	Melastomaceae	bark,root,leaf	on skin disease,diarrhea and dysentry, smallpox,wounds	
96	*Melochia corchorifolia* L.		Sterculiaceae	stem and leaf	remdy for after affects of water snake bites	
97	*Memecylone umbellatum* Burm.f.	Anakombi	Melastomaceae	root,leaf	remedy for ecessive mentrual discharge, gonorrhea,leucorrhoea, astringent lotionfor conjunctivitis	

98	*Merremia umbellata* (L.)Hall.f.	Vayara	Convolvulaceae	whole plant	for fistula,tumors,poultice on burns,scalds and scores	
99	*Merremia vitifolia* (Burm.f.)Hall .f.	Manja kolambi	Convolvulaceae	whole plant	for urethral discharge, stmgury,diuretic,,applied to iflammed eye	
100	*Mesua ferrea* L.	Churuli	Clusiaceae	flower,seed,bark	for cough, dysentry, septic ulcers	
101	*Mikania macrantha* Kunth		Asteraceae	leaf and stem	poultice on wounds,haemostatic on cuts	
102	*Mimosa pudica* L.	Thottavadi	Mimosaceae	root,leaf,stem	for hydrocele,for sinus,piles,	
103	*Monochoria vaginalis* (Burm.f.)	Karinmkovalum	Pontederiaceae	root, bark	chewed to relieve toothache,eaten with sugar to relieve asthma	
104	*Morinda citrifolia* L.	Cherumanjanathi	Rubiaceae	root, leaf, fruit	cathartic, febrifuge, applied for gout,,for throat and gum compaints, leucorrhea	
105	*Mucuna pruriens* (L.) DC.	chorivalli	Fabaceae	root,fruit	tonic,diuretic,purgative,for renal and nervous diseases	
106	*Myxopyrum smilacifolium* (Wall.)Blume	Chathuravalli	Oleaceae	leaf	to relieve nervous disorders, asthma, rheumatism and coughing	Endemic to Western ghats
107	*Naragamia alata* Wight&Arn.	Nilanaragam	Meliaceae	whole plant	for itching and rheumatism,,acute dysentry,emetic,expectorant,cholagogue	Endemic to Western ghats. Vulnerable (IUCN, 2000)
108	*Ochna obtusata* DC.		Ochnaceae	root,leaf	for epilepsy,as poultice on sores for lumbago	
109	*Ocimum gratissimum* L.	Kattuthrithavu	Lamiaceae	whole plant	for treatment for paralysis and rheumatism,for seminal weakness,neuralgia and headache	
110	*Olea dioica* Roxb.	Edala	Oleaceae	bark	a febrifuge	
111	*Ophiorrhiza mungos* L.	Avilpori	Rubiaceae	root	remedy for bites of mad dog, venomous snake, tonic	
112	*Oroxylum indicum* (L.) Benth. Ex Kurz	Palakapayyani	Bignoniaceae	root,leaf, fruit	tonic, diaphoretic,astringent,rheumatism	
113	*Oryza sativa* L.	Nellu	Poaceae	fruit	rice water releives inflammed intestineand febrile diseases,relieves poor digestion and upset bowels	
114	*Pajanelia longifolia (Willd.) K. Schum.*	Payyani,Azhantha	Bignoniaceae	leaf	decoction used for stomach disorders	
115	*Passiflora edulis* Sims.	Passion fruit	Passifloraceae	leaf	for pain in stomach	
116	*Passiflora foetida* L. var. foetida	Chadayn	Passifloraceae	whole plant	applied for itching,emenagogue,headache,emetic for asthma and biliousness	
117	*Pavetta indica* L. var. indica	Kamatta	Rubiaceae	root, leaf	for treatment of dropsy, visceral obstruction, relieve pains of hemorrhoids	
118	*Persea macrantha* (Nees) Kosterm.	Kulamavu	Lauraceae	bark	for rheumatism,asthma,or ulcers	
119	*Phyllanthus urinaria* L.	chuvanna keezhamelli	Euphorbiaceae	root	iduces sleep,appetizer for children,diuretic	
120	*Piper longum* L.	Kattuthipali	Piperaceae	root, fruit	for cough, cold, fever and thirst,spleen,tonic,on liniment for pains and paralysis,analgesic for muscular pain,sedative for epilepsy	
121	*Piper nigrum* L.	Karumulaku	Piperaceae	stem,leaf, fruit	postnatal complaints,antiperiodic in malarial fever,for cholera,prtracted labor, convulsions,costipation, indigestion,rabid dog,stings,diaphoretic	Endemic to south western ghats, Vulnerable (Nayar,1997)
122	*Pogostemon purpurascens* Dalz.	Choriyanthalli	Lamiaceae	root, leaf	for uterine haemorrhage, antidote for snake bite, scorpion sting	

123	*Pothos scandens* L.	Anapparuva	Araceae	root,stem,leaf	applied on abscesses,smoked with camphor for asthma	
124	*Pouzolzia zeylanica* (L.) Bennett		Urticaceae	whole plant	poultice on sores and boils, for expulsion of worms,inflammation of the eye and body, cicatrizant for gangrenous ulcers	
125	*Pseudarthria viscida* (L.) wight & Arn.	Moovila	Fabaceae	whole plant	to expel worms,for piles,biliousness,asthma,rheumatism,heart disease	
126	*Pterocarpus marsupium Roxb.*	Vega	Fabaceae	wood, leaf	infusion used for diabetes,body pain,stomach ache,for tongue disease,toothache	
127	*Rauvolfia serpentina* (9 L.)0 Benth.	Amalpuri,Sarpa gandhi	Apocynaceae	whole plant	antihypertensive,sedative,	
128	*Rourea minor* (Gaertn.) Marr.	Kuriel	Connaraceae	root,twig and stem	tonic for rheumatism,scurvy,diabetes,mild aperient	
129	*Salacia oblonga* Wall. Ex Wight & Arn.	Ponkoranti	Hippocrateaceae	root	gonorrhoea,rhuematism, itches, asthma and ear trouble	
130	*Sauropus androgynous* (L.) Merr.		Euphorbiaceae	whole plant	rich in vitamin called 'multi vitamin green',for fever and urinary bladder complaints	
131	*Scoparia dulcis* L.	Kallurukki	Scrophulariaceae	whole plant	for acute malaria, facilitate birth delivery, antidiabetic, sexual strength, bronchitis, gargle for toothache	
132	*Sebastiana chamaelea* (L.) Muella.-Arg.	kodiyarannakku	Euphorbiaceae	whole plant	tonic relief for vertigo, astringent	
133	*Sida acuta* Burm.f.ssp acuta	Malatanni	Malvaceae	root,leaf	nervous and urinary diseases, as tonic, antipyretic,to expel worms,demulcent,diuretic,emolient	
134	*Sida cordata* (Burm.f.)Borss.	Valli kurunthotti	Malvaceae	whole plant	bark for leucorrhoa,gonorrhoea, for boen fracture,veneral diseases, impotence	
135	*Sida cordifoliaL.*	Anakurunthoti	Malvaceae	whole plant	general tonic,for dysentry, gonorrhoea,sexual strenght,astringent, diuretic,sciatica, facial paralysis	
136	*Sida rhombifolia* L.	Kurunthotti	Malvaceae	root,leaf, stem	for rheumatism,bile complaints,asthma,demulcent, diuretic,skin troubles	
137	*Smilax zeylanica* L.	Kareeelanchi	Smilacaeae	root,stem	for pain in body, ulcerated tongue, sunstroke,measles, small pox, ophthalmia,dysuria, veneral and skin disease	
138	*Solanum torvum* Sw.	Anachunda	Solanaceae	whole plant, leaf, fruit	a sedative, diuretic, digestive, tonic, for cracks in feet,antidote to poisoning, haemostatic	
139	*Stachytarpheta jamaicensis* (L.) Vahl		Verbenaceae	whole plant, root, leaf, bark	for intestinal worms, veneral diseases, ulcers, erysipelas, dropsy, removing cataract, abortifacient	
140	*Strobilanthus ciliatus* Nees.	Karimkurinji	Acanthaceae	stem	bark is an emollient	Endemic to Peninsular India
141	*Strychnos minor* Dennst.	Cherukanjiram	Loganiaceae	root,leaf	applied on rheumatismjpurgative, febrifuge, anthelmintic, skin diseases	
142	*Strychnos nux-vomica* L.	Kanjiram	Loganiaceae	root, bark	as febrifuge, for epilepsy,stomach ache,poultice for maggot infected ulcers,chicken pox, nervous disorders	
143	*Symplocos cochin chinensis* (Lour.) Moore ssp laurind	Pachotti	Symplocaceae	bark	for bilousness, diarrhea, haemorrhage, gonorrhoea, eye disease	

144	*Tabernaemontana divaricata* (L.) R.Br.	Nandiyarvattom	Apocynaceae	rootand stem	applied locally as an anodyne,treatment of the eye	
145	*Tectona grandis* L.f.	Thekku	Verbenaceae	wood, seed, bark	put on eczema, ringworm, inflammation,bronchitis, bilousness, urinary discharges	
146	*Tephrosia purpurea* (L.) Pers.	Kodikozhingil, Kozhuva	Fabaceae	whole plant	tonic for impotency, gonorrhoea, dyspepsia,colic,liniment on elephantiasis	
147	*Tiliacora acuminata* (Poir.)n Miers ex Hook. f.& Thoms.	Vallikanjiram	Menispermaceae	root	drink to cure venomous snake bites	
148	*Trema orientalis* (L.)	Pottama	Ulmaceae	part unspecified	for leprosy	
149	*Trichosanthes nervifolia* L.	Kattupadavalam	Cucurbitaceae	whole plant	febriuge,tonic,purgative	
150	*Tridax procumbens* L.	Odiyancheera	Asteraceae	whole plant	leaf juice insecticidal,piscicidal,checks hemorrage	
151	*Triumphetta rhomboidea* Jacq.	Oorpam	Tiliaceae	whole plant, root, bark, leaf	for antifertility, for dysentry, intestinal ulcers, leprosy and impotency	
152	*Tylophora indica* (Burm.f.) Merr.	Vallipala	Asclepiadaceae	root,leaf	stimulant emetic,cathartic,expectorant,diaphoretic	
153	*Urena lobata* ssp *sinuata*(L.) Borss.	Uram,Uthiram	Malvaceae	root	diuretic, for rheumatism	
154	*Vernonia cinerea* (L.) Less.	Poovan kurunal	Asteraceae	whole plant	diaphoretic,plant juice for piles,,for conjunctivitis,alexipharmic and anthemintic	
155	*Vigna umbellata* (Thunb.) Ohwi & Ohashi		Fabaceae	leaf	a cataplasm for weak eyes, sedative, tonic	
156	*Xylia xylocarpa* (Roxb.) Taub.	Irul,Irulpool	Mimosaceae	bark	gonorrhea,diarrhea,stopping vomitting,vermifuge	
157	*Zingiber zerumbet* (L.) J.E.Smith	Kattinchi	Zingiberaceae	rhizome	for cough, stomach ache, asthma, as a vermifuge, on leprosy and other skin diseases	
158	*Zizyphus mauritiana* Lam.	Jujuba	Rhamnaceae	root, bark, leaf, seed	for headache,fever,colic, stomach ache, dysentry,on sores,wounds,astringent,diaphoretic, whooping cough, blood purifier	
159	*Zizyphus oenoplea* (L.) Mill.	Cheruthudali	Rhamnaceae	root, bark, fruit	for ascaris infection, abdominal pain, on local swelling	
160	*Zizyphus rugosa*,Lam.	Thodali	Rhamnaceae	bark, flower	for diarrhea, bleeding gum,sores in mouth, tongue, veneral sores,carbuncles, menorrhagia	

Table- 4.13 Description of medicinal plants present in the Open areas.

S.No	Name of the plant	Vernacular name	Family	Part of the plant used	Medicinal use	Status
1	*Acacia pennata*(L.)Wild.	Karincha	Mimosaceae	bark	for dandruff anf snake bites	
2	*Acalypha indica* L.	Kuppameni	Euphorbiaceae	whole plant	laxative,emetic,scabies,poulticeon ulcers,for snakebites	
3	*Adenostemma lavenia* (L.) O. Ktze.		Asteraceae	leaf	for cuts ,wunds and insect bites	
4	*Ageratum conizoides* L.	Appa,Katappa	Asteraceae	whole plant	antilithic juice,prevents bleeding,snake bites	
5	*Albizia lebbeck* (L) Willd.	Vaka	Mimosaceae	bark,root,stem,leaf	night blindness,boils,carbuncles,swellings,piles,gonorrhea	
6	*Alternanthera sessilis* (L.) R.Br.	Kozhuppa	Amaranthaceae	root	for hazy vision, night blindness	
7	*Antidesma acidum* Retz.	Areepazham	Euphorbiaceae	root, bark,leaf	on sores,applied onchest for pnuemonia,for blood dysentry	
8	*Asystacia gangetica* (L.) Andersvar. gangetica	Upputhali	Acanthaceae	whole plant	juice is anthelmintic, for rhuematism and swellings	
9	*Caladium bicolor* (Ait.ex Dryand.)Vent.	Kaatu chembu	Araceae	rhizome	applied for facial paralysis	
10	*Chromolaena odorata* (L.) King & Robins.	Cummunist pacha	Asteraceae	leaf	dysentry,applied on fresh cuts and wounds to stop bleeding	
11	*Cissampelose pareira* L. Var.hirsuta	Malathangi	Menispermaceae	root,leaf,stem	for heat stroke,,carbuncles,epilepsy,colic,delirium,haematuria,bronchitis,cold cough,to treat bite of rabid dog	
12	*Cleome monophylla* L.		Capparaceae	root	pouded roots placed on lips restores consciousness	
13	*Clerodendron viscosum* Vent.	Perivelum	Verbenaceae	leaf	on sores and tumors, as tonic	
14	*Commelina benghalensis* L.	Kanavazhai	Commelinaceae	whole plant	laxative,demlcent,emolient,and refrigerant	
15	*Cyathula prostrata* (L.) Blume	Cherukadaladi	Amaranthaceae	whole plant	applied externally for skin conditions	
16	*Cyclea peltata* (Lam.)Hook.f. Thoms.	Padathalli	Menispermaceae	root	for smallpox	
17	*Desmodium pulchellum* (L.) Benth.	Cherupachotti	Fabaceae	root	for burning sensation in the abdomen	
18	*Dioscorea bulbifera* L.	Kattu kaachil	Dioscoreaceae	tuber	remedy for,piles,leprosy, gonorrhoea, worms	
19	*Diploclisia glaucescens* (Blume) Diels	Vattoli	Menispermaceae	leaf	cure for gonorrhoea, biliousness and syphilis	
20	*Elephantopus scaber* L.	Anachuvadi	Asteraceae	root and leaf	checks vomiting,used for pimples, wound of cattle	
21	*Emilia sonchifolia* (L.) DC.	Muyalchevian	Asteraceae	root and leaf	diarrhea, gangarene, eye disease	
22	*Ficus exasperata* Vahl	Therakom	Moraceae	bark and juice	for enlarged spleen and liver	
23	*Ipomea alba* L.	Mandavalli	Convolvulaceae	part unspecified	for snake bites	
24	*Ipomea cairica* (L.)Sweet	Kolambipoo	Convolvulaceae	seed	laxative	
25	*Ipomea obscura* (L.)Ker-Gawl.	Thiruthali	Convolvulaceae	leaf	treatment for aphthous vescilces	

26	*Jasminum rottlerianum* Wall.ex A. DC. Var.*rottlerianum*	Kattumulla	Oleaceae	leaf	for treatment of eczema	
27	*Justicia procumbens* L.		Acanthaceae	whole plant	diuretic, diaphoreticandd laxative and for ophthalmia	
28	*Lantana camara* L.	Poochedi, Konda	Verbenaceae	whole plant	for atoxy of abdominal viscera, rheumatism, malaria, tetanus	
29	*Lepidagathis incurva* Buch.Ham		Acanthaceae	leaf, fruit	chewed to relieve cough, used as ear drop	
30	*Macaranga indica* Wight	Vatta	Euphorbiaceae	whole plant	gum is applied to sores	
31	*Merremia vitifolia* (Burm.f.)Hall .f.	Manja kolambi	Convolvulaceae	whole plant	for urethral discharge, strngury,diuretic,,applied to iflammed eye	
32	*Mikania macrantha* Kunth		Asteraceae	leaf and stem	poultice on wounds,haemostatic on cuts	
33	*Mimosa pudica* L.	Thottavadi	Mimosaceae	root,leaf,stem	for hydrocele,for sinus,piles,	
34	*Piper longum* L.	Kattuthipali	Piperaceae	root, fruit	for cough, cold, fever and thirst,spleen,tonic,on liniment for pains and paralysis,analgesic for muscular pain,sedative for epilepsy	
35	*Salacia oblonga* Wall. Ex Wight & Arn.	Ponkoranti	Hippocrateaceae	root	gonorrhoea,rhuematism, itches, asthma and ear trouble	
36	*Scoparia dulcis* L.	Kallurukki	Scrophulariaceae	whole plant	for acute malaria, facilitate birth delivery, antidiabetic, sexual strength, bronchitis, gargle for toothache	
37	*Symplocos cochin chinensis* (Lour.) Moore ssp laurind	Pachotti	Symplocaceae	bark	for bilousness, diarrhea, haemorrhage, gonorrhoea, eye disease	
38	*divaricata* (L.) R.Br.	Nandiyarvattom	Apocynaceae	rootand stem	the eye	
39	*Tephrosia purpurea* (L.) Pers.	Kodikozhingil, Kozhuva	Fabaceae	whole plant	tonic for impotency, gonorrhoea, dyspepsia,colic,liniment on elephantiasis	
40	*Trema orientalis* (L.)	Pottama	Ulmaceae	part unspecified	for leprosy	
41	*Tylophora indica* (Burm.f.) Merr.	Vallipala	Asclepiadaceae	root,leaf	stimulant emetic,cathartic,expectorant,diaphoretic	
42	*Urena lobata* ssp *sinuata*(L.) Borss.	Uram,Uthiram	Malvaceae	root	diuretic, for rheumatism	
43	*Vernonia cinerea* (L.) Less.	Poovan kurunal	Asteraceae	whole plant	diaphoretic,plant juice for piles,,for conjunctivitis,alexipharmic and anthemintic	

Source : Jain and Defilipps(1991)

Table- 4.14 Description of medicinal plants present in the Forest areas.						
S.No	Name of the plant	Vernacular name	Family	Part of the plant used	Medicinal use	Status
1	*Abrus precatorius* L.	Kunni	Fabaceae	root, stem, seed	emetic, alexiteric,for diarrhea, night blindness,gum inflammation	
2	*Acacia catechu (L.f.) Wild.*	Karingali	Mimosaceae	Heartwood, bark	for cancerous sores, bronchitis, sore in mouth, pain in chest, facilitates child birth	
3	*Acacia pennata* (L.)Wild.	Karincha	Mimosaceae	bark	for dandruff anf snake bites	
4	*Adenanthera pavonina L.*	Manchadi	Mimosaceae	leaf, seed	decoction used for haematuria, chronic rhuematism and gout, to remedy inflammation and boils	
5	*Agnosma cymosa* (Roxb.) G. Don		Apocynaceae	whole plant	emetic,used for eye disease	
6	*Alstonia scholaris* (L.) R.Br.	Ezhilampala	Apocynaceae	root and bark	anthelmintic,rheumatism	
7	*Anamirta cocculus* (L.) Wight & Arn.	Pollakai	Menispermaceae	fruit	ointment made from the drupes used for chronic diseases,an insecticide to kill body-lice	
8	*Andrographis paniculata* (Burm.f.)Wall.ex Nees	Nilavepu	Acanthaceae	root,stem,leaf	febrifuge,anthelmintic	
9	*Antidesma acidum* Retz.	Areepazham	Euphorbiaceae	root, bark,leaf	on sores,applied onchest for pnuemonia,for blood dysentry	
10	*Aporosa lindleyana* (Wight) Baill.	Vetti	Euphorbiaceae	root	decoction used for insanitty,headache, fever,loss of semen, jaundice	
11	*Artocarpus hirsutus* Lam.	Anjili	Moraceae	leaf,flower	applied for bubo and swollen testicles	Endemic to S.Western ghats
12	*Atalantia monophylla* (L.) DC.	Katunaranga	Rutaceae	root, leaf, fruit	as a stimulant, antispasmodic, for snakebite, berries yield oil applied externally for paralysis and chronic rheumatism	
13	*Azadirachta indica* A. Juss.	Aariyaveppu	Meliaceae	all parts of the plant	tonic, alterative for skin disease, astringent,vermifuge,demulcent,stimulant,contraceptive,anthelmintic	
14	*Bixa orellana* L.	Kunkumapoovu, Sindooram	Bixaceae	Root, fruit, seed, leaf	bark of root antipyretic and aperient, seed astringent antiperiodic and febrifuge	
15	*Bombax cieba* L.	Elavu	Bombacaceae	root	for cholera,tubercular fistula,diuretic,cough, impotency	
16	*Calycopteris floribunda* Lam.	Pullanni	Combretaceae	root,leaf	laxative,,astringent,anthelmintic	
17	*Cardiospermum halicacabum* L.	Paluruvam	Sapindaceae	whole plant	emmenagotgue, diaphoretic,rubefacient, diuretic,laxative4, aperient	
18	*Careya arborea* Roxb.	Aalam	Lecythidaceae	bark, flower	for propapsus,snakebit, cold and cough	
19	*Cassia fistula* L.	Kanikonna	Caesalpiniaceae	whole plant	antiviral, on burns,dysuria, haematuria,antibacterial, for liver complaints, heart disease, antipyretic,demulcent	
20	*Chromolaena odorata* (L.) King & Robins.	Cummunist pacha	Asteraceae	leaf	dysentry,applied on fresh cuts and wounds to stop bleeding	

21	*Cissampelose pareira* L. Var.hirsuta	Malathangi	Menispermaceae	root,leaf,stem	for heat stroke,,carbuncles,epilepsy,colic,delirium ,haematuria,bronchitis,cold cough,to treat bite of rabid dog	
22	*Citrus maxima* (Burm. F. Merr.	Pomelo	Rutaceae	leaf , fruit	for convulsive cough, chorea and epilepsy, cardiotonic, refrigerant	
23	*Clerodendron viscosum* Vent.	Perivelum	Verbenaceae	leaf	on sores and tumors, as tonic	
24	*Costus speciosus* (Koenig) J.E.Smith	Channa	Zingiberaceae	rhizome, bark, stem, leaf	for constipation, tonic, antispasmodic, diuretic, depressant on central nervous system, dropsy anasarca, phthisis, asthmaantifertility and antiarthritic activity	
25	*Cyathula prostrata* (L.) Blume	Cherukadaladi	Amaranthaceae	whole plant	applied externally for skin conditions	
26	*Cyclea peltata* (Lam.)Hook. f.Thoms.	Padathalli	Menispermaceae	root	for smallpox	
27	*Cymbopogon flexosus* (Nees ex Steud.) Wats.	Malabar grass, Inchpulli	Poaceae	leaf	oil used in pain balmas, disinfectants, paste given to cattle for flartulence	
28	*Cynodon dactylon (L.) Pers*	Karuka	Poaceae	whole plant	antifertility in women, dropsy, epilepsy,bleeding piles,urinary complaints	
29	*Cyperus rotundus* L	Muthanga	Cyperaceae	whole plant	for heat stroke, for stomach disorder	
30	*Desmodium gangeticum* (L.) DC	Orila	Fabaceae	root	bilious disorders, diuretic, tonic, carminative	
31	*Desmodium triquetrum* (L.)DC.	Adakkapanal	Fabaceae	root	for snakebite,cough,cold,abdominal pain	
32	*Dioscorea bulbifera* L.	Kattu kaachil	Dioscoreaceae	tuber	remedy for,piles,leprosy, gonorrhoea, worms	
33	*Dioscorea pentaphylla* L.	Noorakizhangu	Dioscoreaceae	tuber	rheumatism,bile,cough and asthma	
34	*Diploclisia glaucescens* (Blume) Diels	Vattoli	Menispermaceae	leaf	cure for gonorrhoea, biliousness and syphilis	
35	*Ficus benghalensis L.*	Aal maram	Moraceae	aerial root,latex, leaf, stipules	for diarrhea, toothache, apin in the gum, boils and blisters, for spermatorrhea , on cuts and injuries	
36	*Ficus exasperata* Vahl	Therakom	Moraceae	bark and juice	for enlarged spleen and liver	
37	*Ficus heterophylla* L.F.	Valli therakom	Moraceae	root,leaf	remedy of asthma and cough, for colic, dysentry	
38	*Glycosmis pentaphylla* (Retz.) DcC.	Panal	Rutaceae	root	for fever, post delivery pains, worms	
39	*Helectris isora* L.	Edampiri vallampiri	Sterculiaceae	root, leaf	on sores, carbuncles, stomach ache, colic,cholera,rickets of babies, oil massage on body to relieve pain	
40	*Hemidesmus indicus(* L.) R.Br.	,naruneendi	Periplocaceae	root, whole plant	for stomach pain, skin disease, urinary complication, blood purifier, diaphoretic, masticatory , galactogogue, nutritive, for fever	
41	*Jasminum rottlerianum* Wall.ex A. DC. Var.*rottlerianum*	Kattumulla	Oleaceae	leaf	for treatment of eczema	

42	*Lagerstroemia indica* L.	May flower	Lythraceae	bark, leaf flower	febrifuge, stimulant, purgative , hydragogue	
43	*Lagerstroemia speciosa* (L.) Pers.	Poomarathu	Lythraceae	root, fruit	febrifuge, stimulant, astringent, purgative,narcotic	
44	*Lantana camara* L.	Poochedi, Konda	Verbenaceae	whole plant	for atoxy of abdominal viscera, rheumatism, malaria, tetanus	
45	*Malvastrum coromandelianum* (L.) Garcke		Malvaceae	lead, flower	as a slve to both cool and heal inflammed wounds ans sores, diaphoretic and pectoral	
46	*Mangifera indicaL.*	Maavu	Anacardiaceae	Bark, gum, fruit	for fever of sunstroke, cholera, rheumatism, sty in the eye, ulcerated tongue, stomach ache, poisononig, uterine haemorrhage	
47	*Maranta arundinaceae L.*	Koova	Marantaceae	rhizome	acrid, rubefacient, for dysentry, starch is demulcent	
48	*Melochia corchorifolia* L.		Sterculiaceae	stem and leaf	remdy for after affects of water snake bites	
49	*Merremia umbellata* (L.)Hall.f .	Vayara	Convolvulaceae	whole plant	for fistula,tumors,poultice on burns,scalds and scores	
50	*Merremia vitifolia* (Burm.f.)H all.f.	Manja kolambi	Convolvulaceae	whole plant	for urethral discharge, strngury,diuretic,,applied to iflammed eye	
51	*Michelia nilagirica* Zenk.	Kattuchempakam	Magnoliaceae	bark	febrifuge	Endemic to western ghats
52	*Mitragyna parvifolia (Roxb.) Korth.*	Veembu	Rubiaceae	bark	ground into paste for muscular pains, for fever and colic	
53	*Monochoria vaginalis* (Burm.f.)	Karinmkovalum	Pontederiaceae	root, bark	chewed to relieve toothache,eaten with sugar to relieve asthma	
54	*Naragamia alata* Wight&Arn.	Nilanaragam	Meliaceae	whole plant	for itching and rheumatism,,acute dysentry,emetic,expectorant,cholagogue	Endemic to Western ghats, Vulnerable (IUCN, 2000)
55	*Naringi crenulata* (Roxb.) Nicols	Kattunarakam	Rutaceae	root, leaf, fruit	to cure cardialgia and colic, sudorific, purgative, for bilousness, a carminative, aromatic, dried fruit an antidote for several reptlile and insect poison	
56	*Olea dioica* Roxb.	Edala	Oleaceae	bark	a febrifuge	
57	*Pajanelia longifolia (Willd.) K. Schum.*	Payyani,Azhanth a	Bignoniaceae	leaf	decoction used for stomach disorders	
58	*Passiflora foetida* L. var. foetida	Chadayn	Passifloraceae	whole plant	applied for itching,emenagogue,headache,emetic for asthma and biliousness	
59	*Persea macrantha* (Nees) Kosterm.	Kulamavu	Lauraceae	bark	for rheumatism,asthma,or ulcers	
60	*Phyla nodiflora* (L.) Greeene	Kattuthippali	Verbenaceae	whole plant	as a diuretic, febrifuge, for boils, swollen glands, erysipelas, indigestion in children, to women after birth delivery	
61	*Piper longum* L.	Kattuthipali	Piperaceae	root, fruit	for cough, cold, fever and thirst,spleen,tonic,on liniment for pains and paralysis,analgesic for muscular pain,sedative for epilepsy	

62	*Piper nigrum* L.	Karumulaku	Piperaceae	stem,leaf, fruit	postnatal complaints,antiperiodic in malarial fever,for cholera,prtracted labor, convulsions,costipation, indigestion,rabid dog,stings,diaphoretic	Endemic to south western ghats, Vulnerable (Nayar,1997)
63	*Pogostemon purpurascens* Dalz.	Choriyanthalli	Lamiaceae	root, leaf	for uterine haemorrhage, antidote for snake bite, scorpion sting	
64	*Pseudarthria viscida* (L.) wight & Arn.	Moovila	Fabaceae	whole plant	to expel worms,for piles,biliousness,asthma,rheumatism,heart disease	
65	*Pterocarpus marsupium Roxb.*	Vega	Fabaceae	wood, leaf	infusion used for diabetes,body pain,stomach ache,for tongue disease,toothache	
66	*Rauvolfia serpentina* (9 L.)0 Benth.	Amalpuri,Sarpagandhi	Apocynaceae	whole plant	antihypertensive,sedative,	
67	*Ricinus communis* L.	Aavannakku	Euphorbiaceae	root, leaf, seed	in lumbago,sciatica, on burns, for lactation, on joint pains, purgative, contraceptives, on skin disease	
68	*Schleichera oleosa (Lour.) Oken*	Poovanam	Sapindaceae			
69	*Scoparia dulcis* L.	Kallurukki	Scrophulariaceae	whole plant	for acute malaria, facilitate birth delivery, antidiabetic, sexual strength, bronchitis, gargle for toothache	
70	*Sida cordata* (Burm.f.)Borss.	Valli kurunthotti	Malvaceae	whole plant	bark for leucorrhoa,gonorrhoea, for boen fracture,veneral diseases, impotence	
71	*Sida rhombifolia* L.	Kurunthotti	Malvaceae	root,leaf, stem	for rheumatism,bile complaints,asthma,demulcent, diuretic,skin troubles	
72	*Smilax zeylanica* L.	Kareeelanchi	Smilacaeae	root,stem	for pain in body, ulcerated tongue, sunstroke,measles, small pox, ophthalmia,dysuria, veneral and skin disease	
73	*Spondias pinnata* (L.f.) Kurz.	Ambazham	Anacardiaceae	root, fruit	For regulating menstruation, as a refrigerant, astringent, antiscorbutic, for bilous dyspesia	
74	*Streblus asper* Lour.	Paravamaram	Moraceae	root, bartk, stem, leaf,latex, seed	ulcers, boils swellings, dysentry, slow pulse, urinary disease, menorrhagia, cholera, toothache, leucoderma, piles	
75	*Strobilanthus ciliatus* Nees.	Karimkurinji	Acanthaceae	stem	bark is an emollient	Endemic to Peninsular India
76	*Strychnos nux-vomica* L.	Kanjiram	Loganiaceae	root, bark	as febrifuge, for epilepsy,stomach ache,poultice for maggot infected ulcers,chicken pox, nervous disorders	
77	*Syzygium cumini* (L.) Skeels	Njaval	Myrtaceae	shoot and leaf, fruit, seed	in gargles, sore throat, to purify blood, blisters in the mouth, fruit placed locally on cancerous sores, for diabetes, carminative	
78	*Tabernaemontana divaricata* (L.) R.Br.	Nandiyarvattom	Apocynaceae	rootand stem	applied locally as an anodyne,treatment of the eye	
79	*Tabernaemontana heyneana* Wall.	Koonam pala	Apocynaceae	Root, stem	applied locally as an anodyne,treatment of the eye	Endemic to south western ghats,lower risk near threatened(IUCN,2000)
80	*Tectona grandis* L.f.	Thekku	Verbenaceae	wood, seed, bark	put on eczema, ringworm, inflammation,bronchitis, bilousness, urinary discharges	

81	*Tetrameles nudiflora R.Br.*	Cheeni	Datiscaceae	stem	for icterus, oedema, ascites and rheumatism, as a diuretic and laxative	
82	*Thespesia lampas* (Cav.) Dalz.& Gibs.	Kattuparathi	Malvaceae	root and fruit	to treat syphilis and gonorrhea	
83	*Tiliacora acuminata* (Poir.)n Miers ex Hook. f.& Thoms.	Vallikanjiram	Menispermaceae	root	drink to cure venomous snake bites	
84	*Trema orientalis* (L.)	Pottama	Ulmaceae	part unspecified	for leprosy	
85	*Triumphetta rhomboidea* Jacq.	Oorpam	Tiliaceae	whole plant, root, bark, leaf	for antifertility, for dysentry, intestinal ulcers, leprosy and impotency	
86	*Tylophora indica* (Burm.f.) Merr.	Vallipala	Asclepiadaceae	root,leaf	stimulant emetic,cathartic,expectorant,diaphoretic	
87	*Urena lobata* ssp *sinuata*(L.) Borss.	Uram,Uthiram	Malvaceae	root	diuretic, for rheumatism	
88	*Vernonia cinerea* (L.) Less.	Poovan kurunal	Asteraceae	whole plant	diaphoretic,plant juice for piles,,for conjunctivitis,alexipharmic and anthemintic	
89	*Xylia xylocarpa* (Roxb.) Taub.	Irul,Irulpool	Mimosaceae	bark	gonorrhea,diarrhea,stopping vomitting,vermifuge	
90	*Zizyphus oenoplea* (L.) Mill.	Cheruthudali	Rhamnaceae	root, bark, fruit	for ascaris infection, abdominal pain, on local swelling	
91	*Zizyphus rugosa* ,Lam.	Thodali	Rhamnaceae	bark, flower	for diarrhea, bleeding gum,sores in mouth, tongue, veneral sores,carbuncles, menorrhagia	

Table 4.21 Statistical dispersion value (I) and the pattern of dispersion of each species in the rubber plantations, Open areas and Forest areas.

S No.	Plant species	Rubber Plantations		Open Areas		Forest areas	
		Statistical dispersion value (I)	Pattern of dispersion	Statistical dispersion value (I)	Pattern of dispersion	Statistical dispersion value (I)	Pattern of dispersion
1	*Dipteracanthus prostratus*	31.45	Aggregated	2.51	Aggregated	0	Nil
2	*Ischaemum indicum*	26.07	Aggregated	2	Aggregated	0	Nil
3	*Ischaemum timorense*	14.85	Aggregated	11.87	Aggregated	8	Aggregated
4	*Justicia procumbens*	14.18	Aggregated	3.8	Aggregated	0	Nil
5	*Eclipta prostrata*	11.98	Aggregated	8.55	Aggregated	0	Nil
6	*Selaginella delicatula*	11.6	Aggregated	1	Random	2.56	Aggregated
7	*Cyathula prostrata*	11.4	Aggregated	17.22	Aggregated	12	Aggregated
8	*Desmodium ferrugineum*	10.99	Aggregated	0	Nil	0	Nil
9	*Desmodium pulchellum*	10.99	Aggregated	0	Nil	0	Nil
10	*Peperomia pellucida*	10.81	Aggregated	22.01	Aggregated	0	Nil
11	*Oplismenus compositus*	10.79	Aggregated	65.5	Aggregated	8.47	Aggregated
12	*Scoparia dulcis*	10.75	Aggregated	6.4	Aggregated	0	Nil
13	*Achyranthes aspera*	10.68	Aggregated	5.33	Aggregated	0	Nil
14	*Spermacoce latifolia*	10.36	Aggregated	8.46	Aggregated	0	Nil
15	*Lepidagathis incurva*	9.23	Aggregated	2.93	Aggregated	0	Nil
16	*Piper longum*	9.21	Aggregated	0.96	Random	1.71	Aggregated
17	*Cyrtococcum patens*	9.16	Aggregated	9.87	Aggregated	0	Nil
18	*Cynodon dactylon*	8.95	Aggregated	11.98	Aggregated	3.05	Aggregated
19	*Naragamia alata*	8.75	Aggregated	7.11	Aggregated	9.89	Aggregated
20	*Bracharia ramosa*	8.74	Aggregated	1.68	Aggregated	3.41	Aggregated
21	*Asystasia dalzelliana*	8.46	Aggregated	1	Random	9.95	Aggregated
22	*Mitracarpus villosus*	7.1	Aggregated	16.07	Aggregated	2	Aggregated
23	*Elephantopus scaber*	6.93	Aggregated	7.92	Aggregated	0	Nil
24	*Cyrtococcum oxyphyllum*	6.91	Aggregated	6.16	Aggregated	0	Nil
25	*Ichnocarpus frutiscens*	6.81	Aggregated	4.15	Aggregated	3.06	Aggregated
26	*Cucurma zedoaria*	6.76	Aggregated	0	Nil	0	Nil
27	*Ottochloa nodosa*	6.61	Aggregated	6.23	Aggregated	8.32	Aggregated
28	*Pilea microphylla*	6.26	Aggregated	5.49	Aggregated	0	Nil
29	*Desmodium alysicarpoides*	5.85	Aggregated	0	Nil	0	Nil
30	*Smilax zeylanica*	5.57	Aggregated	0	Nil	1.29	Random
31	*Mikania macrantha*	5.47	Aggregated	3.08	Aggregated	1	Random
32	*Axonopus compressus*	5.37	Aggregated	8.11	Aggregated	0	Nil
33	*Kyllinga pumila*	5.21	Aggregated	0	Nil	0	Nil
34	*Justicia betonica*	5	Aggregated	1	Random	0	Nil
35	*Hedyotis auricularia*	4.94	Aggregated	4.75	Aggregated	0	Nil
36	*Urena lobata*	4.59	Aggregated	2.54	Aggregated	9.82	Aggregated
37	*Oxalis corniculata*	4.46	Aggregated	5.23	Aggregated	0	Nil
38	*Schleichera oleosa*	4.37	Aggregated	2.13	Aggregated	1	Random
39	*Desmodium heterophyllum*	4.33	Aggregated	4.39	Aggregated	0	Nil
40	*Mimosa pudica*	4.32	Aggregated	7.06	Aggregated	1	Random
41	*Desmodium microphyllum*	4.14	Aggregated	0	Nil	0	Nil

42	*Stachyphymium spicatum*	4.03	Aggregated	2.25	Aggregated	2.46	Aggregated
43	*Altemanthera sessilis*	4.01	Aggregated	4.96	Aggregated	2	Aggregated
44	*Allopteris cinicina*	4	Aggregated	2.89	Aggregated	0	Nil
45	*Biophytum reinwardtii*	4	Aggregated	9.38	Aggregated	1	Random
46	*Tylophora indica*	3.9	Aggregated	4.29	Aggregated	3.11	Aggregated
47	*Rungia pectinata*	3.88	Aggregated	0	Nil	0	Nil
48	*Cyperus rotundus*	3.8	Aggregated	0	Nil	3.26	Aggregated
49	*Kyllinga brevifolia*	3.73	Aggregated	1	Random	0	Nil
50	*Memecylone randerianum*	3.53	Aggregated	4	Aggregated	0	Nil
51	*Biophytum sensitivum*	3.51	Aggregated	1	Random		
52	*Mukia madraspatana*	3.49	Aggregated	3.23	Aggregated	0	Nil
53	*Clerodendron viscosum*	3.47	Aggregated	2.13	Aggregated	11.06	Aggregated
54	*Sida cordifolia*	3.38	Aggregated	0	Nil	0	Nil
55	*Spilanthus radicans*	3.38	Aggregated	10	Aggregated	0	Nil
56	*Digitaria ciliaris*	3.3	Aggregated	7.35	Aggregated	0	Nil
57	*Spillanthus calva*	3.25	Aggregated	4.27	Aggregated	0	Nil
58	*Aporosa lindleyana*	3.2	Aggregated	1.62	Random	2.38	Aggregated
59	*Desmodium triflorum*	3.1	Aggregated	6.54	Aggregated	0	Nil
60	*Nephrolepis auriculata*	3	Aggregated	0	Nil	0	Nil
61	*Piper nigrum*	3	Aggregated	0	Nil	0	Nil
62	*Adiantum lunulatum*	2.97	Aggregated	0	Nil	0	Nil
63	*Cucurma neilgherrensis*	2.97	Aggregated	0	Nil	2.46	Aggregated
64	*Andrographis atropurpurea*	2.96	Aggregated	0	Nil	0	Nil
65	*Desmodium zonatum*	2.96	Aggregated	8.21	Aggregated	0	Nil
66	*Justicia japonica*	2.96	Aggregated	5	Aggregated	0	Nil
67	*Phaulopsis imbricata*	2.96	Aggregated	3	Aggregated	0	Nil
68	*Mucuna pruriens*	2.87	Aggregated	2	Aggregated	0	Nil
69	*Hevea brasiliensis*	2.76	Aggregated	0	Nil	0	Nil
70	*Pteris scabripes*	2.73	Aggregated	0	Nil	0	Nil
71	*Cyclea peltata*	2.72	Aggregated	1	Random	2.73	Aggregated
72	*Hemidesmus indicus*	2.7	Aggregated	5.77	Aggregated	1	Random
73	*Hedyotis corymbosa*	2.69	Aggregated	8	Aggregated	0	Nil
74	*Clitoria ternatea*	2.61	Aggregated	2.52	Aggregated	10.98	Aggregated
75	*Chromolena odorata*	2.59	Aggregated	4.79	Aggregated	13.47	Aggregated
76	*Cucurligo orchiodes*	2.57	Aggregated	1	Random	0	Nil
77	*Desmodium triangulare*	2.57	Aggregated	0	Nil	3.74	Aggregated
78	*Strobilanthus heyneanus*	2.57	Aggregated	0	Nil	0	Nil
79	*Commelina benghalensis*	2.51	Aggregated	1.92	Aggregated	0	Nil
80	*Triumphetta rhomboidea*	2.48	Aggregated	0	Nil	0	Nil
81	*Phyllanthus amarus*	2.45	Aggregated	16.99	Aggregated	0	Nil
82	*Synedrella nodiflora*	2.45	Aggregated	6.19	Aggregated	0	Nil
83	*Pueraria phaseoloides*	2.43	Aggregated	0	Nil	0	Nil
84	*Rungia parviflora*	2.37	Aggregated	3	Aggregated	0	Nil
85	*Centella asiatica*	2.36	Aggregated	2.89	Aggregated	5	Aggregated
86	*Sebastiana chamaelea*	2.33	Aggregated	5.65	Aggregated	3.26	Aggregated
87	*Ixora coccinea*	2.3	Aggregated	2.25	Aggregated	3	Aggregated
88	*Sida rhombifolia*	2.3	Aggregated	12	Aggregated	2.08	Aggregated
89	*Desmodium gangeticum*	2.29	Aggregated	0	Nil	1.71	Aggregated
90	*Teriophonum faustosum*	2.29	Aggregated	0	Nil	0	Nil

91	*Euphorbia hirta*	2.25	Aggregated	4.06	Aggregated	0	Nil
92	*Ageratum conizoides*	2.22	Aggregated	2.35	Aggregated	1	Random
93	*Eleutheranthera ruderalis*	2.19	Aggregated	5.64	Aggregated	0	Nil
94	*Emilia sonchifolia*	2.18	Aggregated	3.06	Aggregated	0	Nil
95	*Tylophora mollisma*	2.17	Aggregated	2	Aggregated	0	Nil
96	*Sporobolus indicus*	2.11	Aggregated	3.6	Aggregated	0	Nil
97	*Vemonia cineria*	2.1	Aggregated	2.24	Aggregated	0	Nil
98	*Commelina attenuata*	2.09	Aggregated	1.85	Aggregated	1	Random
99	*Panicum brevifolium*	2.06	Aggregated	5.97	Aggregated	0	Nil
100	*Centrosema pubescens*	2.05	Aggregated	3.65	Aggregated	4.9	Aggregated
101	*Adiantum caudatum*	2	Aggregated	2	Aggregated	0	Nil
102	*Geophylla repens*	2	Aggregated	0	Nil	0	Nil
103	*Lygodium flexuosus*	2	Aggregated	3	Aggregated	0	Nil
104	*Pavetta tomentosa*	2	Aggregated	0	Nil	1.63	Aggregated
105	*Strobilanthus ciliatus*	2	Aggregated	0	Nil	4.62	Aggregated
106	*Themeda triandra*	2	Aggregated	4.11	Aggregated	0	Nil
107	*Allophylus cobbe*	1.98	Aggregated	1.62	Random	0	Nil
108	*Cissus discolor*	1.98	Aggregated	0	Nil	0	Nil
109	*Gomphostemma eriocarpa*	1.98	Aggregated	0	Nil	3	Aggregated
110	*Ochna obtusata*	1.98	Aggregated	0	Nil	0	Nil
111	*Syzygium caryophyllatum*	1.98	Aggregated	0	Nil	2.29	Aggregated
112	*Cissampelose pareira*	1.93	Aggregated	0	Nil	0	Nil
113	*Sida cordata*	1.91	Aggregated	2	Aggregated	0	Nil
114	*Hibiscus hispidissimus*	1.87	Aggregated	2.14	Aggregated	8.81	Aggregated
115	*Dioscorea bulbifera*	1.81	Aggregated	0	Nil	3.26	Aggregated
116	*Glycosmis pentaphylla*	1.81	Aggregated	2.51	Aggregated	1.63	Aggregated
117	*Anamirta cocculus*	1.76	Aggregated	0	Nil	2	Aggregated
118	*Helectris isora*	1.69	Aggregated	1.85	Aggregated	6.86	Aggregated
119	*Pycnospora lutescens*	1.68	Aggregated	2.19	Aggregated	2	Aggregated
120	*Ixora malabarica*	1.66	Aggregated	1.92	Aggregated	0	Nil
121	*Adenostemma lavenia*	1.65	Aggregated	2.03	Aggregated	0	Nil
122	*Commelina maculata*	1.65	Aggregated	1.26	Random	0	Nil
123	*Dioscorea tomentosa*	1.65	Aggregated	0	Nil	1	Random
124	*Hemiontes cordata*	1.65	Aggregated	2	Aggregated	0	Nil
125	*Merremia balaroides*	1.65	Aggregated	2	Aggregated	0	Nil
126	*Merremia umbellata*	1.65	Aggregated	1.56	Random	3.05	Aggregated
127	*Salacia beddomei*	1.65	Aggregated	0.96	Random	0	Nil
128	*Scleria terrestris*	1.65	Aggregated	2	Aggregated	0	Nil
129	*Sida rhomboidea*	1.65	Aggregated	0	Nil	0	Nil
130	*Solanum capsicoides*	1.65	Aggregated	0	Nil	1	Random
131	*Xanthophyllum arnottianum*	1.65	Aggregated	2	Aggregated	1.63	Aggregated
132	*Pteris biaurita*	1.62	Aggregated	0	Nil	0	Nil
133	*Stachytarpheta indica*	1.58	Aggregated	3.57	Aggregated	0	Nil
134	*Blumea mollis*	1.51	Aggregated	2.19	Aggregated		
135	*Canthium coromandelicum*	1.51	Aggregated	2	Aggregated	0	Nil
136	*Chassalia curviflora*	1.51	Aggregated	0	Nil	0	Nil
137	*Merremia vitifolia*	1.51	Aggregated	3.41	Aggregated	2.37	Aggregated
138	*Phyllanthus urinaria*	1.51	Aggregated	0	Nil	2.46	Aggregated
139	*Abutilon ramosum*	1.47	Aggregated	2.51	Aggregated	0	Nil

140	*Ficus hispida*	1.47	Aggregated	1	Random	0	Nil
141	*Melochia corchorifolia*	1.47	Aggregated	7.11	Aggregated	0	Nil
142	*Porana volubilis*	1.47	Aggregated	1.62	Random	0	Nil
143	*Pseudarthria viscida*	1.47	Aggregated	0	Nil	0	Nil
144	*Psychotria nilgiriensis*	1.47	Aggregated	0	Nil	0	Nil
145	*Sida alnifolia*	1.43	Aggregated	0	Nil	0	Nil
146	*Canthium augustifolium*	1.38	Aggregated	1.26	Random	0	Nil
147	*Hyptis sauveolens*	1.36	Aggregated	5.22	Aggregated	6.51	Aggregated
148	*Jasminum rotlarianum*	1.28	Random	2.19	Aggregated	0	Nil
149	*Grewia nervosa*	1.14	Random	2.32	Aggregated	1.63	Aggregated
150	*Xenostegia tridentata*	1.14	Random	2.88	Aggregated	4.29	Aggregated
151	*Acacia catechu*	1	Random	0	Nil	1.31	Random
152	*Andrographis paniculata*	1	Random	0	Nil	2	Nil
153	*Ardisia pauciflora*	1	Random	1	Random	2	Aggregated
154	*Cardiospermum halicacabum*	1	Random	1.62	Random	0	Nil
155	*Caryota eurens*	1	Random	1	Random	0	Nil
156	*Cassia javanica*	1	Random	0	Nil	0	Nil
157	*Chukrasia tabularis*	1	Random	1	Random	0	Nil
158	*Cleome rutidosperma*	1	Random	3	Aggregated	0	Nil
159	*Combretum albidum*	1	Random	2.81	Aggregated	0	Nil
160	*Cyanotis tuberosa*	1	Random	0	Nil	0	Nil
161	*Cycas circinalis*	1	Random	0	Nil	0	Nil
162	*Cyperus zollingeri*	1	Random	3.26	Aggregated	0	Nil
163	*Dalbergia horrida*	1	Random	1	Random	0	Nil
164	*Dalbergia latifolia*	1	Random	0	Nil	0	Nil
165	*Dalbergia volubilis*	1	Random	0.96	Random	0	Nil
166	*Diplazium esculentum*	1	Random	2	Aggregated	0	Nil
167	*Elaeocarpus glandulosus*	1	Random	1.62	Random	1	Random
168	*Eleusine indica*	1	Random	3	Aggregated	0	Nil
169	*Glochidion ellipticum*	1	Random	1	Random	0	Nil
170	*Gloriosa superba*	1	Random	0	Nil	1.63	Aggregated
171	*Hevea brasiliensis*	1	Random	0	Nil	0.97	Random
172	*Ipomea barlerioides*	1	Random	2.19	Aggregated	4	Aggregated
173	*Knoxia mollis*	1	Random	0	Nil	0	Nil
174	*Mallotus tetracoccus*	1	Random	0	Nil	0	Nil
175	*Meineckia longipes*	1	Random	1	Random	0	Nil
176	*Memecylone umbellatum*	1	Random	2.51	Aggregated	0	Nil
177	*Mimosa diplotricha*	1	Random	2.51	Aggregated	0	Nil
178	*Murdannia pauciflora*	1	Random	1	Random	0	Nil
179	*Plumbago zeylanica*	1	Random	0	Nil	5.09	Aggregated
180	*Salacia oblonga*	1	Random	1.62	Random	2.09	Aggregated
181	*Sterculia guttata*	1	Random	0	Nil	1.43	Random
182	*Strychnos minor*	1	Random	0	Nil	0	Nil
183	*Terminalia paniculata*	1	Random	1	Random	0.91	Random
184	*Tetracera akara*	1	Random	0	Nil	0	Nil
185	*Adiantum capillus veneris*	0.99	Random	0	Nil	0	Nil
186	*Agnosma cymosa*	0.99	Random	3	Aggregated	2.79	Aggregated
187	*Andrographis lineata*	0.99	Random	0	Nil	1	Nil
188	*Aneilemma montana*	0.99	Random	0	Nil	3	Nil

189	*Blepharistemma serratum*	0.99	Random	1.62	Random	1.63	Aggregated
190	*Blumea lacera*	0.99	Random	5	Aggregated		
191	*Diploclisia glaucescens*	0.99	Random	0	Nil	1.54	Random
192	*Ficus exasperata*	0.99	Random	1.62	Random	1.45	Random
193	*Glochdion zeylanicum*	0.99	Random	0	Nil	0	Nil
194	*Ipomea alba.*	0.99	Random	0	Nil	0	Nil
195	*Ixora brachiata*	0.99	Random	0	Nil	0	Nil
196	*Leucas aspera*	0.99	Random	1.4	Random	0	Nil
197	*Lophatherum gracile*	0.99	Random	1.96	Aggregated	0	Nil
198	*Olea dioica*	0.99	Random	0.96	Random	2	Aggregated
199	*Rauvolfia serpentina*	0.99	Random	0	Nil	0	Nil
200	*Salacia fruticosa*	0.99	Random	2	Aggregated	0	Nil
201	*Sauropus bacciformis*	0.99	Random	0.96	Random	0	Nil
202	*Tephrosia purpurea*	0.99	Random	2.85	Aggregated	0	Nil
203	*Theriophonum infaustum*	0.99	Random	0	Nil	0	Nil
204	*Waltheria indica*	0.99	Random	2	Aggregated	0	Nil
205	*Zizyphus oenoplea*	0.99	Random	0	Nil	5.89	Aggregated
206	*Alstonia scholaris*	0.98	Random	0	Nil	1.45	Random
207	*Pteris confusa*	0.98	Random	0	Nil	0	Nil
208	*Pterospermum reticulatum*	0.98	Random	1.62	Random	0.97	Random
209	*Pyrrosia heterophylla*	0.98	Random	0	Nil	0	Nil
210	*Tabernaemontana divaricata*	0.98	Random	1.62	Random	3.35	Aggregated
211	*Tiliacora acuminata*	0.98	Random	0	Nil	0	Nil
212	*Artocarpus hirsutus*	0.97	Random	0	Nil	0.94	Random
213	*Macaranga indica*	0.97	Random	0.96	Random	0	Nil
214	*Murdannia japonica*	0.97	Random	1	Random	2.79	Aggregated
215	*Strychnos nux vomica*	0.97	Random	0	Nil	0.97	Random
216	*Derris brevipes*	0.96	Random	0.96	Random	0	Nil
217	*Strychnos colubrina*	0.94	Random	0	Nil	6.38	Aggregated
218	*Apodytes dimidiata*	0	Nil	0	Nil	1.63	Aggregated
219	*Calamus thwaitesii*	0	Nil	0	Nil	1.71	Aggregated
220	*Antidesma acidum*	0	Nil	1.62	Random	0	Nil
221	*Caesalpinia bonduci*	0	Nil	1	Nil	2.08	Aggregated
222	*Calycopteris floribunda*	0	Nil	2	Aggregated	2.05	Aggregated
223	*Calophyllum polyanthum*	0	Nil	0	Nil	1.57	Aggregated
224	*Abrus precatorius*	0	Nil	0	Nil	1.82	Aggregated
225	*Acacia pennata*	0	Nil	0	Nil	1.63	Aggregated
226	*Acrocarpus fraxinifolius*	0	Nil	0	Nil	1.15	Random
227	*Actinodaphne bourdillonii*	0	Nil	0	Nil	1.82	Aggregated
228	*Actinodaphne malabarica*	0	Nil	0	Nil	1.88	Aggregated
229	*Adenanthera pavonina*	0	Nil	0	Nil	2.79	Aggregated
230	*Albizia lebbeck*	0	Nil	0	Nil	1.29	Random
231	*Antidesma acidum*	0	Nil	0	Nil	1.43	Random
232	*Aramban*	0	Nil	0	Nil	1	Random
233	*Arundinella purpurea*	0	Nil	4.37	Aggregated	0	Nil
234	*Asystacia gangetica*	0	Nil	2	Aggregated	0	Nil
235	*Atalantia racemosa*	0	Nil	0.96	Random	0	Nil
236	*Azadirachta indica*	0	Nil	0	Nil	1	Random
237	*Bixa orellana*	0	Nil	0	Nil	1.82	Aggregated

238	*Bombax cieba*	0	Nil	0	Nil	2.6	Aggregated
239	*Bridelia scandens*	0	Nil	0	Nil	1.63	Aggregated
240	*Careya arborea*	0	Nil	0	Nil	1	Random
241	*Caryota eurens*	0	Nil	0	Nil	0	Nil
242	*Cassia fistula*	0	Nil	0	Nil	2.36	Aggregated
243	*Chionanthus mala elengi*	0	Nil	0	Nil	3.06	Aggregated
244	*Cinnamomum sulphuratum*	0	Nil	0	Nil	3.21	Aggregated
245	*Digitaria longiflora*	0	Nil	5.34	Aggregated	0	Nil
246	*Dioscorea pentaphylla*	0	Nil	0	Nil	2	Aggregated
247	*Diospyros buxifolia*	0	Nil	0	Nil	10	Aggregated
248	*Ficus benghalensis*	0	Nil	0	Nil	0.97	Random
249	*Ficus heterophylla .*	0	Nil	0	Nil	1.94	Aggregated
250	*Ficus hispida*	0	Nil	0	Nil	0	Nil
251	*Flueggea virosa*	0	Nil	0	Nil	0.97	Random
252	*Gomphandra tetrandra*	0	Nil	0	Nil	1.71	Aggregated
253	*Grewia glabra*	0	Nil	0	Nil	1.63	Aggregated
254	*Grewia tillifolia*	0	Nil	0	Nil	1	Random
255	*Hedyotis auricularis*	0	Nil	53.25	Aggregated	1	Random
256	*Holarrhena pubescens*	0	Nil	0	Nil	1.43	Random
257	*Hugonia mystax*	0	Nil	1.62	Random	0	Nil
258	*Hydnocarpus pentandra*	0	Nil	0	Nil	1	Random
259	*Iran vaga*	0	Nil	0	Nil	2.29	Aggregated
260	*Ischaemum indicum*	0	Nil	0	Nil	0	Nil
261	*Ixora johnsonnii*	0	Nil	0	Nil	2.23	Aggregated
262	*Ixora nigricans*	0	Nil	0	Nil	2	Aggregated
263	*Jasminum azoricum*	0	Nil	0	Nil	2.91	Aggregated
264	*Jasminum brevilobum*	0	Nil	0	Nil	1.43	Random
265	*Knema attenuata*	0	Nil	0	Nil	1.43	Random
266	*Lagerstroemia indica*	0	Nil	0	Nil	0.97	Random
267	*Lagerstroemia microcarpa*	0	Nil	0	Nil	1.29	Random
268	*Lagerstroemia speciosa*	0	Nil	0	Nil	1.63	Aggregated
269	*Lannea coromandelica*	0	Nil	0	Nil	1	Random
270	*Lantana camara*	0	Nil	0	Nil	2.23	Aggregated
271	*Leea indica*	0	Nil	0	Nil	0.97	Random
272	*Lophatherum gracile*	0	Nil	0	Nil	3.05	Aggregated
273	*Mangifera indica*	0	Nil	0	Nil	1	Random
274	*Melicope lunu ankenda*	0	Nil	1.4	Random	0	Nil
275	*Michelia nilagirica*	0	Nil	0	Nil	8.42	Aggregated
276	*Mitragyne parviflora*	0	Nil	0	Nil	2	Aggregated
277	*Mucuna pruriens*	0	Nil	0	Nil	0	Nil
278	*Myristica malabarica*	0	Nil	0	Nil	0.97	Random
279	*Naravelia zeylanica*	0	Nil	1	Random	0	Nil
280	*Naringi crenulata*	0	Nil	0	Nil	1.53	Random
281	*Neolamarckia cadamba*	0	Nil	0	Nil	1	Random
282	*Nothapodytes nimmoniana*	0	Nil	0	Nil	3	Aggregated
283	*Ochna obtusata*	0	Nil	1.62	Random	0	Nil
284	*Ottuplavu*	0	Nil	0	Nil	1	Random
285	*Pajanelia longifolia*	0	Nil	0	Nil	2	Aggregated
286	*Pennisetum polystachyon*	0	Nil	2.51	Aggregated	0	Nil

287	*Peperomia pellucida*	0	Nil	0	Nil	0	Nil
288	*Persea macrantha*	0	Nil	0	Nil	0.97	Random
289	*Phyla nodiflora*	0	Nil	0	Nil	1.29	Random
290	*Phyllanthus embelica*	0	Nil	0	Nil	1.22	Random
291	*Piper barberi*	0	Nil	0	Nil	8.15	Aggregated
292	*Polyalthia coffeoides*	0	Nil	0	Nil	3.26	Aggregated
293	*Polyalthia fragrans*	0	Nil	0	Nil	0.94	Random
294	*Ponkurangu*	0	Nil	0	Nil	1.63	Aggregated
295	*Porana volubilis*	0	Nil	0	Nil	0	Nil
296	*Psydrax dicoccus*	0	Nil	0	Nil	1.63	Aggregated
297	*Pterocarpus marsupium*	0	Nil	0	Nil	1.63	Aggregated
298	*Pueraria phaseoloides*	0	Nil	0	Nil	3	Aggregated
299	*Ricinus communis*	0	Nil	0	Nil	2.56	Aggregated
300	*Sapindus trifoliata*	0	Nil	0	Nil	0.97	Random
301	*Spondias pinnata*	0	Nil	0	Nil	1	Random
302	*Streblus asper*	0	Nil	0	Nil	1.63	Aggregated
303	*Strobilanthus ciliatus*	0	Nil	0	Nil	0	Nil
304	*Strychnos lenticellata*	0	Nil	0	Nil	2.88	Aggregated
305	*Suregada augustifolia*	0	Nil	0.92	Random	0	Nil
306	*Syzygium cumini*	0	Nil	0	Nil	1.29	Random
307	*Tabernaemontana heyneana*	0	Nil	0	Nil	1.91	Aggregated
308	*Tectona grandis*	0	Nil	0	Nil	1	Random
309	*Terminalia bellirica*	0	Nil	0	Nil	1.28	Random
310	*Terminalia elliptica*	0	Nil	2	Aggregated	1.63	Aggregated
311	*Tetrameles nudiflora*	0	Nil	0	Nil	1	Random
312	*Thespesia lampas*	0	Nil	0	Nil	1.91	Aggregated
313	*Tiliacora acuminata*	0	Nil	0	Nil	4.69	Aggregated
314	*Toona ciliata*	0	Nil	0	Nil	1	Random
315	*Trema orientalis*	0	Nil	1.62	Random	1.71	Aggregated
316	*Xylia xylocarpa*	0	Nil	0	Nil	3.45	Aggregated
317	*Zanthozylum rhetsa*	0	Nil	0	Nil	1	Random
318	*Zizyphus rugosa*	0	Nil	0	Nil	1.88	Aggregated
319	*Citrus maxima*	0	Nil	0	Nil	0.97	Random
321	*Costus speciosus*	0	Nil	0	Nil	4.29	Aggregated
322	*Cymbopogon flexosus*	0	Nil	0	Nil	1	Random

Plate 8

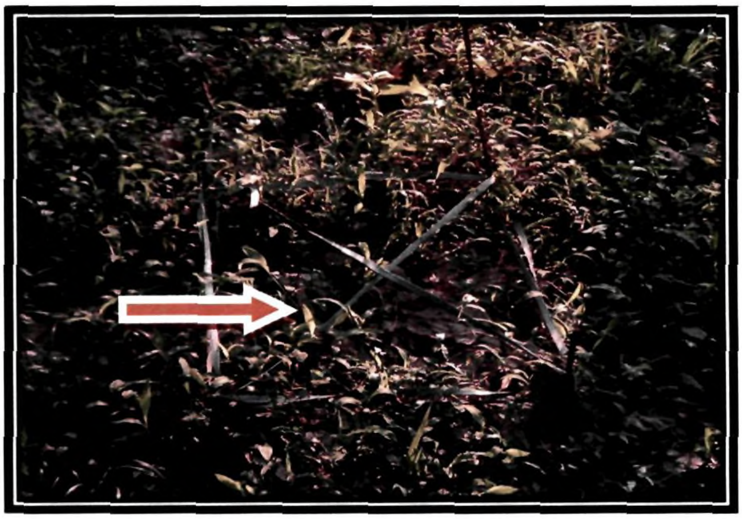
Quadrat sample showing varying light intensities on the ground flora in mature rubber plantations.

Plate 9a

Some **pioneer species (vectors)** found in the ground flora of Rubber

Axonopus compressus

Ischaemum indicum and *Cyathula prostrata*



Oplismenus compositus

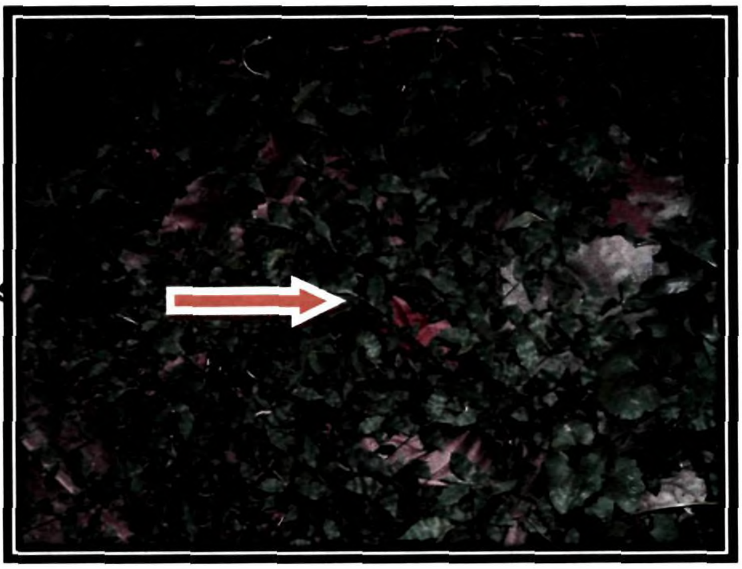


Plate 9b

Some **pioneer species (vectors)** found in the ground flora of

Axonopus compressus* and *Cissus discolor

Mitracarpus villosus

Cyrtococcum patens

Plate 10 a

Some **medicinal plants** found in the Rubber plantations

Gloriosa superb

Smilax zeylanicum

Naragamia alata

Plate 10b

Some **medicinal plants** found in the Rubber plantations

Ravolfia serpentine

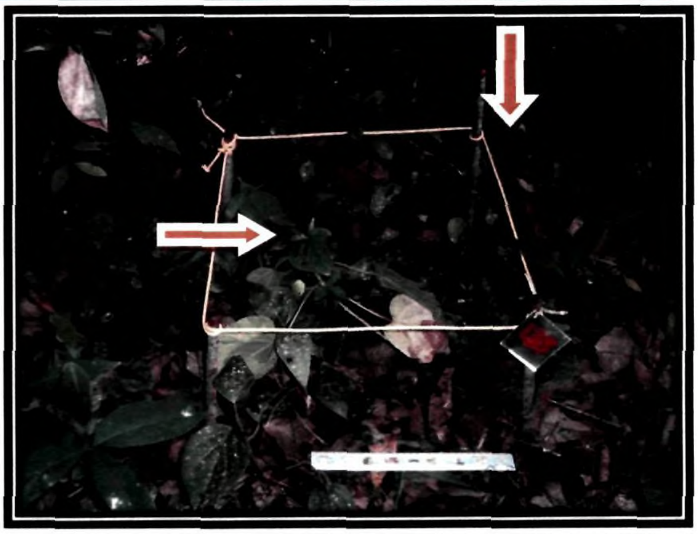
Ixora coccinea

Helectris isora

Plate 10c

Some **medicinal plants** found in the Rubber plantations

Piper nigrum* and *Clerodendron viscosum



Aporusa lindleyana

Tabernaemontana divaricata

Plate 10d

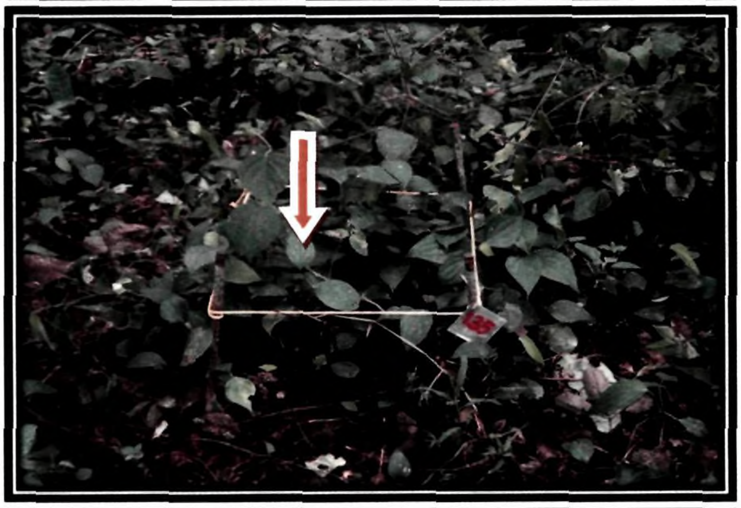
Some **medicinal plants** found in the Rubber plantations

Zyziphus oenoplea

and

Ficus hispida

Desmodium gangeticum

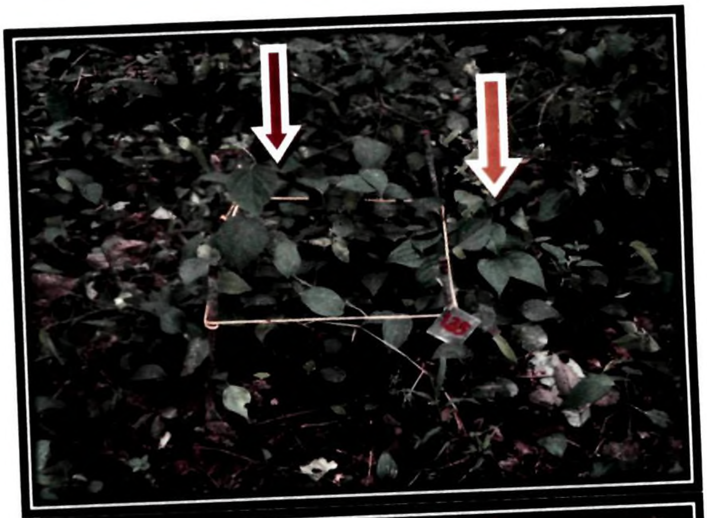


Cymbopogon flexosus

Plate 10e

Some **medicinal plants** found in the Rubber

Piper nigrum* and *Clerodendron viscosum



Glycosmis pentaphylla

Alternanthera sessilis

Plate 11a

Lagerstroemia microcarpa

Mussaenda bellila

Aneilema montana

Plate 11b

Some **Endemic plants** found in the ground flora of Rubber plantations

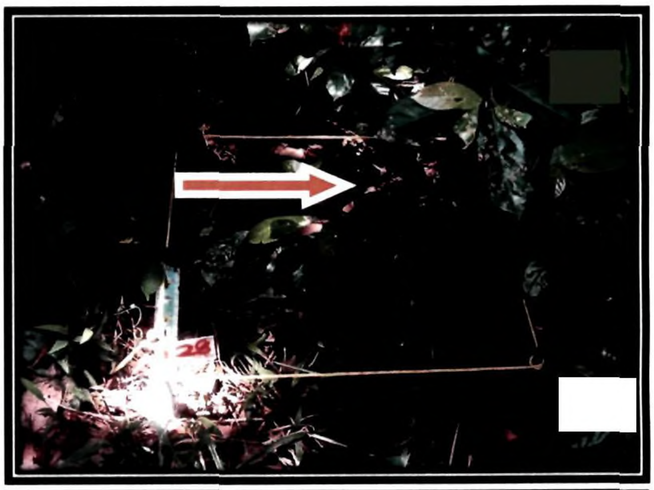
Artocarpus hirsutus

Ravolfia serpentina

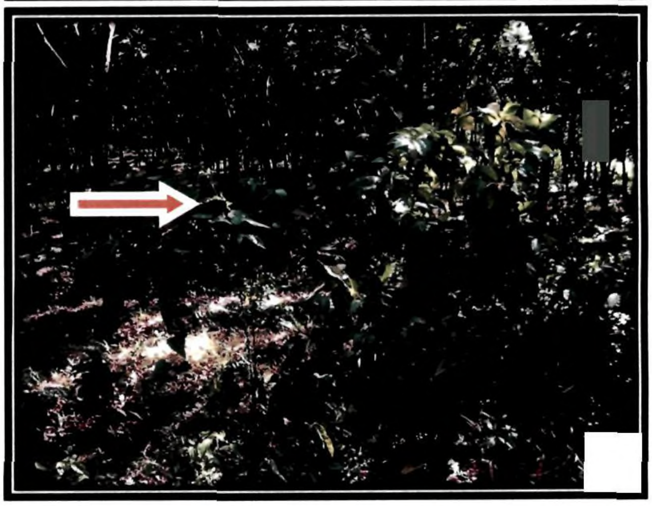
Memecylone randerianum

Plate 12

Some **zoochorous species** (deep forested) found in the ground flora of rubber plantations



Eleocarpus glandulosus



Canthium agustifolium

Grewia nervosa

Plate 13a

Some plant species with low abundance value found in the regenerated ground flora of rubber plantations

Chassalia curviflora

Antidesma acidum

Plate 13b

Some plant species with low abundance value found in the regenerated ground flora of rubber plantations

Ixora malabarica

Syzygium caryophyllatum

Plate 13c

Some plant species with low abundance value found in the regenerated ground flora of rubber plantations

Ochna obtusata

Hugonia mystax