POST ECO-RESTORATION CHANGES IN VEGETATION AND EDAPHIC ATTRIBUTES OF EASTERN ATTAPPADY, KERALA

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2012-17-112

THESIS

Submitted in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE IN FORESTRY

Faculty of Forestry

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF FOREST MANAGEMENT AND UTILISATION

COLLEGE OF FORESTRY

KERALA AGRICULTURAL UNIVERSITY

VELLANIKKARA, THRISSUR- 680656

KERALA, INDIA

2016

DECLARATION

I hereby declare that this thesis entitled **"Post eco-restoration changes in vegetation and edaphic attributes of Eastern Attappady, Kerala"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Place: Vellanikkara,

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Certified that this thesis, entitled **"Post eco-restoration changes in vegetation and edaphic attributes of Eastern Attappady, Kerala"** is a record of research work done independently by **Mr. Sumit Sonalkar (2012-17-113)** under my guidance and supervision and it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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ACKNOWLEDGEMENT

*First and foremost, I exalt and praise the "**Almighty**" for having blessed me and who finally made this humble effort a reality.*

*I appraise my deep sense of gratitude and indebtedness to my benevolent and perspicacious Professor, Dept. of Forest Management and Utilization, Chairperson of my advisory committee, **Dr. K. Vidyasagaran** for his erudite counseling, untiring interest and constructive ideas which helped in completing this thesis and whose encouragement, constant guidance and support from the initial to the final level enabled me to develop an understanding of the subject. My sense of gratitude and indebtedness to him will remain till eternity.*

*My sincere thanks are due to **Dr. S. Gopakumar,** Professor, Dept. of Forest Management and Utilization, College of Forestry, Vellanikkara, member of my advisory committee, for the valuable guidance and help rendered in the conduct of the experiment.*

*It is a gratifying moment to express my indebtedness with devotion to **Dr. P. K. Sushama,** Professor, Department of Soil Sci. and Ag. Chem., College of Horticulture, Vellanikkara, member of my advisory committee, for her inspiring guidance, support and encouragement rendered in the conduct of the experiment.*

*My sincere thanks are due to convey my sincere gratitude to **Dr. V. N. Nandakumar,** Scientist – F, Head, Silviculture Department, Kerala Forest Research Institute, Peechi, Thrissur, member of the advisory committee, for his valuable guidance rendered in the conduct of the experiment.*

*It is a great pleasure to record my sincere thanks to **Dr. V. Jamaludheen,** Associate Professor, Department of Silviculture and Agroforestry, College of Forestry, for his untiring support and help during my course of study.*

*My sincere thanks to **Ashish Alex, Freddy Timmy** and **Tejkaran Patidar** who helped me in several ways for the completion of this venture.*

I wish to express my sincere thanks to all the non-teaching staff members of College of Forestry for their whole-hearted cooperation and timely assistance. I also appreciate and acknowledge the facilities provided at AHADS, Attappady and College of Horticulture, Vellanikkara for the successful completion of my research work.

My heartfelt gratitude cannot be captured in words for the unflinching support, constant encouragement, warm concern, patience and valuable advice of my friend classmates ***Mobin, Kiran, Jijith, Raneesh, Remya, Sujith and Laxmi*** *whose prayers, love and affection rendered me a successful path which propped up my career all along. My duty is incomplete if I forget my Senior friends* ***Saveen, Vinu, Samrithika, Bhimmappa and Manjunatha*** *and juniors* ***Deepak, Harsha*** *whose helping hands, guidance and affection fetched a remarkable place in my days in Kerala.*

I take this opportunity to express my deep sense of gratitude to Kerala Agricultural University and College of Forestry for all the support rendered for the present study.

Above all, I am forever beholden to my beloved parents, my brother, my sister and my family members for their unfathomable love, boundless affection, personal sacrifice, incessant inspiration and constant prayers, which supported me to stay at tough tracks.

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CHAPTER – I

INTRODUCTION

Attappady, a tribal block in Kerala is an extensive mountain valley at the headwaters of the Bhavani River nestled below the Nilgiri Hills of the Western Ghats. Western part of Attappady has thick evergreen forests and as one proceeds eastwards thick evergreen forest and deciduous forests are seen whereas, Coimbatore plateau has a dry deciduous type of forests. Presently considered as one of the driest part of Kerala with denuded and rocky hills, the eastern slopes are in the rain shadow region with rainfall less than 1000 mm per annum whereas the western half of the Attappady receives close to 3000 mm per annum. Dry winds during summer months, with erratic rainfall along with poor soil moisture retention have rendered these lands an erosional landscape leading to desertification. Attappady region was once being rich in forests and a fertile land. Settlement of immigrants increased during 1940's from the neighboring states and other regions of Kerala added to the encroachment by settlers and imposition of their cultivation practices which created a crisis in resource allocation in tribal settlements. All this led to a progressive decline of vegetative cover and loss of top soil due to unscientific management and extraction of forest products having a disastrous impact, especially on watersheds and productivity of the soil leading to a severe ecological degradation, adversely affecting livelihood security of the people, especially the tribal people.

The increasing unrest and attention towards the degrading valley lead to the focus towards some concrete steps to be taken to reverse this degradation. Thus, Attappady Wasteland Comprehensive Environmental Conservation Project (AWCECOP), a scheme implemented with help of Japanese Overseas Economic Co-operation Fund, conceptualized by Centre for Water Resources Development and Management (CWRDM) in 1996 to overcome the issues in Attappady valley was initiated. The project was aimed at restoring the environmental ambiance of Attappady with the objective of halting the processes of ecological and social degradation, improving the livelihood with special focus on the tribal communities. The AWCECOP aimed at ecological restoration of Attappady, prevention of further ecological degradation, development of replicable models of participatory eco-restoration and promotion of sustainable livelihood options for the local people. The project was implemented by Attappady Hills Area Development Society (AHADS), an autonomous institution under the Local Self Government Department of Kerala. Restoration management by AHADS included fencing to remove grazing pressure, followed by active techniques like frequent weeding of invasive and native weeds, intensive planting of drought-resistant tree species to minimize soil erosion and to facilitate regeneration of native tree species. However, in each site under restoration, the frequency and intensity of on-site activities like weeding and planting reduced along the temporal trajectory.

Since the completion of the project in 2006 only a few studies have been conducted to understand and analyze the post restoration scenario. While the results from other studies are encouraging towards the upliftment of the tribal locals and rejuvenation of several areas, it is important to continuously monitor and analyze the changes in the valley, so as to give concrete data for later references and decision making.

The present study intended to compare and analyze the floral diversity, and soil physicochemical characteristics in the regions of eco-restored and non eco-restored areas of eastern Attappady. The relevance of the floral diversity is that the vegetation structure, species diversity, and ecosystem processes, as these were identified as essential components for a long-term persistence of an ecosystem. Vegetation structure and species diversity provide information on habitat suitability, ecosystem productivity, help predict successional pathways and trophic structure necessary for ecosystem resilience. Restoration of ecosystem health and productivity has generally relied on regeneration in an area. In nature, species diversity is maintained through regeneration of component species (Sagar and Singh, 2005). The adult individuals on a site or of a species constitute the reproductive pool. Therefore, under normal conditions in a forest one would expect a significant relationship between number of adult individuals and number of seedlings.

Edaphic attributes are one of the most important determining factors in the productivity of an area. Nutrient balance and its enrichment determines the self-sustainability of a site as the availability of nutrients in an ecosystem depends on efficient recycling of nutrients within the ecosystem. Edaphic attributes and vegetational aspects are closely linked to each other as any of the part has a direct or reciprocal effect among themselves. Thus the study of soil physio-chemical properties will help to provide an insight to the broad range of changes and impact of vegetation occurred in the study area.

The study looked the ecological impact of restoration activities and provided insight into problems and prospects of eco-restoration activities. The study also drew information on sustainability of restored areas in terms of ecological balance. The study helps to evaluate the strategy followed in eco-restoration process with a view towards the implementation of the eco-restoration projects and the major impact of such projects result on the floristic diversity and soil attributes.

Review of Literature

CHAPTER-II

REVIEW OF LITERATURE

In this chapter an attempt has been made to review the study on ""Post eco-restoration changes in vegetation and edaphic attributes of Eastern Attappady, Kerala" carried out in Attappady, Palakkad district in Kerala during the year 2012-2014. Due to lack of sufficient information on few aspects, the similar types of studies carried out in other forest ecosystem are also cited. The literature is broadly reviewed under the following major aspects.

1. Attappady as a hot spot for restoration studies in India
2. Ecorestoration studies in India and world wide
3. Impact of restoration on vegetational attributes
4. Impact of restoration on edaphic attributes

2.1 ATTAPPADY AS A HOT SPOT FOR RESTORATION STUDIES IN INDIA

The Western Ghats, stretching from Tapti valley in Gujarat to Kanyakumari in Tamil Nadu covering as a narrow belt over distance of 1600 km is one of the nine biogeographic regions of India and is reported to support nearly 4000 species of flowering plants and also form a catchment area for several river systems covering about 40 per cent area of India. The hills account for 22,000 km^2 of Kerala and is worldwide known for its rare abundance of endemic flora and fauna. The Western Ghats possess various types of tropical forests ranging from the wet evergreen to dry deciduous. On higher elevation it also holds montane sub tropical and montane temperate forests. The upper reaches of the Western Ghats are considered as one of the most diverse and interesting biomes in India (Babu, 1998).

Attappady is an east sloping plateau located in the northeastern part of Palakkad district, in the Western ghats region of Kerala, in South India. Located between 10° 55 ' N to 11° 15'N latitude and 76° 21' to 76° 48'E longitude, Attappady covers an area of 745 km^2 spread over three panchayats namely Agali, Pudur and Sholayur, which is part of the Nilgiri biosphere reserve. To its north is the Nilgiris district and the east the Coimbatore of Tamilnadu while on the southwest and northwest, the Palakkad district of Kerala borders Attappady. The region differs from the rest of the humid tropical area in Kerala state mainly because of the rainfall characteristics and its peculiar geographical location and physiography, the eastern portion of Attappady being in a rain shadow region receives an average rainfall of less than 600 mm/year whereas the western side of Attappady is a rain-fed area with an average rainfall of 2500 mm/year (Vishnudas *et al.*, 2012). Both South west and North east monsoons are experienced in the region, but the major share of the rainfall is from South west monsoon and in the hottest month the temperature varies from 21° c to 40° c in the plains and ranges from 10° c to 32° c in the hills (Kumar *et al.*,2012)

Despite existence of three perennial rivers and fertile soils along with a forest cover containing diverse species, Attappady has been a hot spot of ecological destruction mainly due to deforestation and non eco-friendly farming practices (Madhu, 2005). Private forest act, 1971 passed by Kerala Government, authorized itself to acquire thousands of hectares of private forest land without any compensation to the owner or disclaimer of the land which lead to clearing of trees in these lands indiscriminately and resulted in drastic changes in the landscape of the region. This further disturbed the biotic potential and degradation in edaphic characters of the land (KFRI, 2005).

A study conducted by (Muralidharan *et al.*, 1991) claimed that over 70 percent of the hamlets in attappady are on degraded land and out of 142 hamlets in Attappady only 2 of the hamlets were free from soil erosion , while all others hamlets were under threat of loss of soil cover and higher degrees of soil erosion.

Attappady is a relic of vegetal luxuriance change, soil properties changes overtime. Acidity decreases and conversely exchangeable bases increase markedly as one moves from evergreen to dry deciduous forestd (Alexander *et al.*, 1986). According to status report (AHADS, 2010) a transition from wet tropical forest situation in the west to dry thorny scrub to the east is observed in Attappady, also the loss of forests in past have affected the water absorption and retention capacity leading to loss of soil fertility.

Eastern Attappady has a biotype with dry deciduous forest along with the frequent presence of individual tree species of moist deciduous forest. The majority of area has been converted or in the process of changing to euphorbeaceous scrub jungle. The area is severely affected by the grazing activities and unscientific ways of collecting Non Timber Forest Products, stall feeding of animals is absent and whatever a few regeneration occurs is eaten by these grazers leading to permanently barren land in Attappady (KFRI, 1991) .

For past many decades Attappady has been infamous for its high cost failed developmental projects, such as projects under agriculture department , minor irrigation department , AVMP (Attappady valley irrigation project), animal husbandry, fisheries , sericulture, forestry, soil conservation etc. Reasons for such failures were mainly due to poor planning and understanding of the local problems, corruption including other reasons while the real sufferers and losers of such failures were the poor tribal villagers (Madhu, 2005) .

The Attapaddy restoration project (AHADS) commenced with the division of whole area in to 146 micro watersheds and organized plan for in-situ conservation in a ridge to valley fashion with the help of expertise from forestry, agriculture, soil conservation, civil engineering and extension. According to the project report (AHADS, 2008), the works concluded for restoration and regeneration in the project area of 10,999.9 ha of forest land which included 3776.2 ha of forest plantations and 7223.6 ha of natural forests. Along with 157 km of fencing to protect from grazing, 782 km fire protection lines and soil and water conservation works cover an area of 4664 ha. Also 4000 units of energy efficient units and stoves were provided to the tribals for checking the consumption of fuel woods.

According to Kumar *et al.* (2012) that a major change in vegetation of Attappady has occurred in the restoration zone after the implementation of project. Vegetation cover has changed positively as the dense, open forest along with scrub lands have increased considerably during 2001-2005, approximately 2.14 percent barren land is reduced in 2005 compared to 2001.

In the forest lands the survival rate of planted species was 68 percent whereas in the private waste lands it was reported to be 62 percent. The initial studies show improved vegetation cover, surface runoff has been significantly dropped, water levels in the wells and rivers have been improved cosiderably and has resulted in to rejuvenation of other dry areas (AHADS, 2008).

According to a study by (KSPB, 2010) degraded lands have been reduced in Attapaddy and an increase in agricultural lands is observed, the study concludes that degraded lands have been reduced from 238.18 km^2 in 2001 to 180.29 km^2 in 2005. Success of any restoration program depends on proper scientific evaluation of ecosystem, practice used for its restoration and its regular monitoring. A study in Attappady was conducted to assess the efficiency of restoration efforts using ground insect communities. Many countries like Australia, Brazil, South Africa and Italy have already successfully designed and monitored the restoration projects using ground insect community. Diversity and species richness of most of the ground insect community was found relatively higher in the sites under restoration as compared to pre- restored and control sites. This may be due to the response to the local disturbance such as de-weeding and planting activities in the restored sites. Substitution of space in time or chronological sequence by the ground insect communities approach based on comparison of restored areas of different ages that represent different stages of succession is a method feasible and effective in understanding dynamics of succession in ecological communities subjected to restoration (Ramalingam and Rajan, 2009).

According to (Kumar, 2005), in the restoration of Attappady, agroforestry will play a crucial role by three vital mechanism namely sequestration, conservation and substitution of carbon. Sequestration will form carbon stocks in trees and soil, and will also lead to reduction of anthropogenic stress thus resulting in conservation. Lastly these stocks created will timely/ readily meet the energy requirements of the locals thus controlling the illicit felling of timber and fuel woods from forest.

2.2 ECO-RESTORATION STUDIES IN INDIA AND WORLD

With the fast changing environment and increasing degradation of natural forests and agricultural land, forest restoration and conservation has became a necessity. Convention on Biodiversity, 2010 held at Nagoya Japan brought together all the major countries of the world to make a firm decision over the drastically reducing natural forests and climate change. It was decided to restore 15 % of the degraded ecosystems worldwide by 2020. According to a study by Kettle (2012) about 2 billion hectares of land with majority of such lands belonging to developing nations like India, eco-restoration provides an opportunity to enhance ecological and socio-economic conditions.

According to a study by Bonn (2011) southern and eastern Asia which comprise of China, India and Indonesia offer an immense scope for restoration with around 400 million ha of lands suitable for restoration and conservation purpose. It offers an opportunity to check poverty, provide food security, mitigating climate change and conserve diversity.

Despite continued forest conversion and degradation, forest cover is increasing in countries across the globe. New forests are regenerating on former agricultural land and forest plantations are being established for commercial and restoration purposes. Plantation and restored forests can improve ecosystem services and enhance biodiversity conservation, but will not match the composition and structure of the original forest cover. Approaches to restoring forest ecosystems depend strongly on levels of forest and soil degradation, residual vegetation, and desired restoration outcomes. Opportunities abound to combine ambitious forest restoration and regeneration goals with sustainable rural livelihoods and community participation. New forests will require adaptive management as dynamic, resilient systemsthat can withstand stress of climate change, habitat fragmentation and other anthropogenic effects.

ITTO has distinguished three types of degradation namely degraded primary forest which result from excessive and damaging timber exploitation, secondary forest which are regrowing on land that had been largely cleared and lastly degraded forest land which are so degraded that forest regrowth has not occurred and now mainly is occupied by grasses and shrubs. It has been estimated that almost 500 million ha of degraded primary and secondary forest and 350 million ha of degraded forest land is present in the tropics. Most of the degraded systems are not able to recover naturally reason being the changes in soil fertility, recurring disturbance which hamper succession and natural regeneration, even if the site is recovering naturally the process may be too slow. These factors enlarge the role of human interventions to initiate or accelerate the recovery process (Lamb and Gilmour, 2003).

Reclamation is a very intricate process and the evaluation of the reclaimed site is crucial to evaluate the success of reclamation once the reclamation plan is completed and vegetation has established. Success of reclamation can be assured by the performance of soil microflora, nutrient availabilities, functioning of mycorrhizal symbiosis and various enzymatic activities in soil (Sheoran *et al.*,2010). Identification of the objectives prior to the restoration program is a crucial key for success, and it decides the methods of restoration and selection of tree species, whether it is to enhance the biodiversity, providing local communities with financial and livelihood benefits or both (Orsi *et al.*, 2011). Appraisal of restoration projects is a complex task due to the limited information given the lower monitoring, assessment and analysis. Most of the comprehensive studies conducted on the restoration projects conclude that about less than half of the restoration projects set assessable targets and quantitative data to evaluate the project success (Bonn, 2011)

Tropical dry forests have a great resilience capability to recover when subjected to various degradations and anthropogenic factors. It was observed that the forests recover shortly under the circumstances of small fires and grazing, but the synergistic effect of all these degrading factors leads to greater reduction in forest cover when compared to the individual effects of these disturbances (Cantarello, et al, 2011). It is a fact that forest cover in most of the nations has increased but the major portion of such forests are highly degraded and are under various biotic and abiotic influences. Composition of the species is an important factor as plantations with a few species or monoculture may provide an optimal wood production site but it has been found that a mixed tree species especially with native species have given superior results with a range of benefits including soil stabilization , attracting native wildlife , enhancing water quality (Ciccarese, *et al.*, 2012)

Our neighboring country China has taken major steps towards the restoration and rehabilitation of its natural resources, a study by Wenhua (2004) reported that the forest cover has increased from 12.98 percent to 13.92 percent in China which is a significant improvement. Five ecological and eco-restoration projects have been in place for such conservation strategies which cover 42.4 percent of land area of the country and aims to transform 1.3 million ha of sandy and degraded lands in to farm land with the help of planned afforestation, aerial seeding and watershed management, especially in the mountainous regions to improve the conditions of poverty in such regions.

In a study to assess the role of artificial restructuring of vegetation in a mine spoil (Singh & Singh, 1999) found that eco-restoration is an essential step to check soil erosion, restoring soil fertility and speed up the natural recovery process. As the vegetation contributes to buildup soil organic matter and plant nutrients supports microorganisms to re-establish biogeochemical processes, and play an important role in soil redevelopment and in the maintenance of soil fertility. It was further advised that a desirable species for rehabilitation of mine spoil must have endurance to grow on poor and dry soil, develop vegetation cover and accumulate biomass quickly, and improve the soil organic matter status and microbial biomass, thereby enhancing the supply of plant available nutrient

An analysis of 89 restoration projects by (Bullock *et al.,* 2011) suggested that restoration projects mostly increase ecosystem services when compared to degraded systems but the design of a restoration must be in consideration to the response of management actions upon the biodiversity and ecosystem services, along with less focus on a particular ecosystem service which may have some ill effects on the biodiversity or other services, also non-native species may cause severe damage to native species and prompt invasion. In most of the restoration projects cost benefit analysis are limited and have inadequate records of scientific literature. It was found that the restoration projects using low-cost methods are more thriving, cost effective however proper land planning is a must.

A study by Singh *et al* (2012) to understand the long term effect of afforestation and cropping on soil physicochemical and biochemical properties over the degraded sodic lands after 50 years of rehabilitation it was observed that afforestation for the restoration of degraded sodic lands was ecologically better than cropping. Pal and Sharma (2001) in a salt affected wasteland located in the semi-arid Aravalli hills enumerated after 5.5 and 13.5 years of soil amelioration in plantations observed that out of 12 species grown only ten survived after 5.5 years with three having less than 5 percent survival rate and by the age of 13.5 years only five species survived. The study revealed that the choice of species to reclaim the difficult sites are restricted and only few species can survive as a primary species and exhibit its role in succession, also it was found that the tendency to produce multiple stems declines with the ageing of plantation which may be linked to the soil amelioration, moisture retention and protection due to social fencing. The soil pH, electrical conductivity, organic carbon, available phosphorus and other soil parameters were noted to be improved significantly in the three depths with age, thus making the edaphic conditions more suitable for plant growth.

A study conducted by Sharma and Sunderraj (2005) in Central Gujarat to understand the suitability of plant species for restoration in the mine degraded areas through systematic procedures including Importance Value Index and regeneration values for tree species in mines, diversity of mines area was found more than plantations and dump areas, it was observed that water management was crucial in restoration to promote perennial species and also protection from grazing and cutting is important. Monitoring must be done in regular intervals to understand the survivability and growth patterns of plant species. Monitoring of bird communities are a good indicator for the study of environmental changes.

A study conducted by Fajardo *et al* (2013) to assess the restoration in dry forests found that water is the most important key factor in any restoration project in a dry environment among all the natural regeneration factors like seed bank, seed rain and soil nutrition. The regeneration also gets hampered in such conditions and even if the seeds germinate the seedlings mostly fail to establish themselves, it was found that the use of hydrogels in such water limited ecosystems can play a crucial role as they are cheaper, nature friendly and easier to use.

In a study conducted at Southern Ohio, USA by Giai and Boerner (2006) to determine the effects of alternative restoration management strategies on the edaphic conditions and soil microbial activities, they found that out of various restoration management strategies applied in the study, thinning treatments gave the best result with higher microbial activities underneath the plantations, also the C:N ratio was significantly greater in such sites. After the four years of treatments in such sites it was found that there was no marked difference between the soil organic matter and microbial activities, but effects on the microbial diversity were persistent.

Management of the restored sites determine the accomplishment of a restoration programme. A study by Campoe *et al* (2010) in Brazil has reported that intensive management with proper cultivation, fertilizer application and weed control can have significant affect in the plant growth. An abandoned and degraded agricultural land when restored with intensive management was found to turn into nearly closed forest within four years of planting. Seed dispersal and their source are another important factor towards a successful restoration program. Restoration can be negatively effected by a depleted seed bank without proper seed sources, fragmented landscapes and absence of favorable species in the locality (Kirmer *et al.*, 2009).

Recovery in the disturbed areas is possible relative to the reference sites especially if the soil and physical characteristics of that area is intact, for eg. in Wetlands of Ohio complete recovery was observed within five years mostly due to its seed banks. In another instance fencing to check grazers have resulted in recovery of vegetation in a cliff top within 16 years of restoration works it has been noted that as compared to temperate terrestrial ecosystems, tropical ecosystems have shown marked improvement in the ecosystems and resulted in net optimistic benefits, although the recovery in the ecosystems did not reach the level of reference natural ecosystems.

Community participation is an essential element for the success of any restoration project, it depends upon the involvement of local community, their aspiration for development and success, public awareness about ecological issues and their response to the changes in forests and in due course of time a project then may shift from a cost to the community and begin providing direct economic benefits (Lamb and Gilmour, 2003).

Gaining and maintaining community support is elementary to the accomplishment of landscape management. This can be done by clearly defining what landscape management is, and making sure that its multiple goals and benefits, such as for human health and environmental issues, are understood, principally by decision makers. Innovative technologies using remote sensing and geographic information systems (GIS) supporting stakeholder planning and learning platforms can also aid this process.

In Himalayan region, the efforts of large scale afforestation and reforestation in the degraded lands have largely been a failure and the main reason being ignorance and lack of interest of people who want immediate tangible benefits. Development of agroforestry and appreciation of traditional knowledge along with more participation in decision making by the community over the wastelands and degraded lands may mobilize the local participation. Stress over the location specific development models for restoration were suggested for different ecological and socio-economic conditions (Maikhuri *et al.*, 1997).

The approach of "Forest Landscape Restoration" promoted by IUCN, WWF and other conservation organization aims to enhance the well being in deforested and degraded areas of forests by inclusion of rural livelihoods in restoration projects, producing goods and services, linking all the existing systems of environmental, social and economic needs (Orsi and Geneletti, 2010)

2.3 IMPACT OF RESTORATION ON VEGETETIONAL ATTRIBUTES.

India is a biodiversity hotspot with rich flora of about 45000 species because of its extreme climatic and altitudinal variations, out of this total flora 5000 to 7500 species are endemic (Babu, 1998) Western ghats in India is one of the biodiversity hotspots of the world and contains around 4000 species of flowering plants and many endemic plants belong to this region.

Of the total tropical forests, tropical dry forests constitute about 42 percent and have been a priority destination for most of the settlements because of their approachability and accessibility and thus human intervention has been extreme in these areas and have lead to greater degradation and irreversible changes in these areas.

Singh and Singh (1991) studied the species composition and diversity index in mixed dry deciduous forests of Vindhyan region. The basal cover of vegetation varied from 3.8 to 10.4 m^2 $ha^{-1}$for trees and 3.1 to 7.8 m^2 ha^{-1} for shrubs. Shannon and Weiner index and concentration of dominance ranged between 1.93 to 2.18 and 0.18 to 0.38, respectively. The beta diversity was 3.1

Verghese and Menon (1998) conducted studies in south moist mixed deciduous forests of Agasthyamalai region of Kerala, India through quadrate sampling method. The stand density, species density and basal area of these forests were 535 trees/ha, 12 species per 0.1 ha and 26.57 /ha, respectively. Shannon index of these forests was 1.89, while evenness index was 0.73. *Terminalia paniculata, Pterocarpus marsupium* and *Careya arborea* were found as dominant plant association. A study was conducted by (Sharma and Sunderraj, 2005) in Gujarat to determine the best performing species in a eco-restored area, they found that out of 29 species *Tectona grandis* was found to have maximum Importance Value Index and performed very well under both the forest and plantation conditions whereas *Gmelina arborea* and *Albezia lebbeck* were noted to be performing well under plantations.

Sahoo *et al.* (2008) have studied the phytosociological analysis of *Pinus kesiya* stands exposed to varying intensities of disturbance in north east India and suggested that the disturbance can lead to the formation of mixed forest and the mildly disturbed sites are the best for regeneration and more assemblage of plant species thereby providing scope for proper silvicultural and managemental implications in the undisturbed forest stands to provide the growth of seedlings and saplings of the dominant species.

A study conducted by Mohandas and Priya (2009) on the floristic structure and diversity of tropical montane evergreen forests of the Nilgiri Mountains. Random plots of 30 x 30 m (0.09ha) were laid and plants having diameter equal or greater than 1cm at breast height were inventoried in sholas of the area. A total of 30495 individuals from 87 species, 65 genera and 42 families were recorded. Of these 57 species of trees, 13 lianas, 12 shrubs and 5 large herbs were recorded. Species diversity was measured to be 11; stem density was 2652 stems ha^{-1} and basal area

59.4m^2ha^{-1}. Chauhan *et al* (2008) compared the natural and planted deciduous forests in western Uttar Pradesh in terms of tree diversity, floral diversity and regeneration. Species diversity as well as species evenness was found to be higher in planted forests. Natural forest sites also had higher mature tree, pole, sapling and seedling densities compared with planted forests. Species composition was found to be similar in the natural and planted forests. Of the 126 species found in both sites, 32.5% showed good regeneration, 19.8% fair, 24.6% poor and 11.1% lacked regeneration.

A study conducted by (Anita *et al.*, 2010) in the Attappady region reports the presence of 106 tree species in the area with maximum individuals of *Pleiospermum alatum* (9.45%), whereas lantana were found as dominant shrubs and *Aristida sps.* among herbs. Shannon Weiner diversity index were 2.91, 3.44 and 3.84 for herbs shrubs and trees respectively. Girth at Breast Height was found highest for *Steriospermum personatum,* around 38 percent of individual belonged to 20-30 cm GBH classes. Basal area was reported maximum for *Albizia amara* (2245.58 cm^2) followed by *Nothopegia racemosa* (1004.95 cm^2) and *Steriospermum personatum* (777.41cm^2). Highest Importance Value Index was found for *Albizia amara* and then *Pleiospermum alatum*. The study suggests that the upper storey of the species in the area which is dominated by *Albizia amara, Anogeisus latifolia, Nothopegia racemosa* are being replaced by scrub forest species such as *Pterolobium hexapetalum* , *Acacia canescens* and *Grewia florescens* and the reason may be attributed to be primarily due to disturbances.

Species diversity was observed as 106 which was quite high as compared to other dry ecosystems like for e.g. Mudumalai wildlife sanctuary with 63 species, Nilgiri biosphere reserve having 38 species, Agastyamalai region with 49 species and Vindhyan hills with 49 species. Thus this high number of species can be attributed to the intermediate disturbance hypothesis, which supports that in a restored semi-disturbed and changing area more number of species are observed than a complete degraded and an undisturbed or a natural area. Shannon Weiner diversity index for this study was found to be 3.84 which was much higher than the other same kind of areas under dry forest conditions. In Nilgiri biosphere reserve the value was recorded to be between 2.06 -2.94, in Bandipur national park it was found to be 2.40 and in Wayanad wildlife sanctuary to be 2.12.

Dry forests are highly variable in precipitation and face frequent dry spells with inconsistent rainfall which act as major force for the mortality by desiccation in seeds and newly germinated seedlings. Thus these forests are characterized by a relatively high number of tree species with small dry wind dispersed seeds over the small areas and it has been observed that wind dispersed seeds are better able to colonize the degraded areas than the vertebrate dispersed plants, small seeds with lower moisture content are proven to be less susceptible to desiccation which is one of the major obstacle during the establishment of the seedlings in the open areas. Grasses has been found very useful in enhanced germination. (Vieira and Scariaot, 2006)

In a study by (Maikhuri *et al.*, 1997) in the Garhwal region after 5 years of rehabilitation it was concluded that the water management is crucial for rehabilitating degraded community lands, in an irrigated condition the survival of the species ranged from 75 percent to 100 percent as compared to the unirrigated conditions with the survival percentage ranging just around 36 percent to 65 percent , and in case of government plantations the average survival was 30 percent only. A study by (Parrota *et al.*, 1997) in a 10 year old native species reforested area reported that the planting of fast growing pioneer species along with slower growing and longer leaved native species are recommended as they provide greater canopy and habitat diversity within the reforested area. Out of 125 tree species about 40 percent of the tree species were found in the soil seed bank of the plantation and regenerated from seeds produced by the planted trees, this internal regeneration represent a significant head start for forest regeneration or succession process.

During restoration, the tree characteristics that relate to the ecosystem restoration are species specific, such as attractiveness of individual species to seed dispersers and also the understorey woody species in a mixed forest plantation are significantly and positively related to the width and density of the crown of the over story tree (Wishnie *et al.*, 2007).

Regeneration is affected by a lot of abiotic factors like soil fertility, humidity, gap dynamics and biotic factors like vectors, pollination and seed dispersal. Habitat modification and anthropogenic activities could lead to effect ecological processes like pollination and seed dispersal. The regeneration studies in the Attappady area have suggested that out of 117 tree species, around 12 species were showing good regeneration and 21 species showing poor regeneration. 27 species show failure of regeneration which may be due to lack of pollinators or key animal species and other anthropogenic factors and may face local extinction (Anita et al., 2010).

2.4 IMPACT OF RESTORATION ON EDAPHIC ATTRIBUTES.

Most of the researchers have the opinion that success of a reclamation project cannot be measured by merely presence of vegetation on the degraded land. The conditions and functionality of soils i.e basic soil biological processes and rearrangement of soil particles into stable aggregates is very important (Sheoran et al., 2010). In addition to its multi benefit traits a desirable species in a restoration program must have an aptitude to develop the vegetal cover, accrue biomass rapidly and improve the soil organic status and microbial activities, thereby ensuring the availability of plant soil nutrients.

In a restoration process three distinct phases have been distinguished firstly an establishment phase which is the most initial phase of 0-5 years characterized by the harsh and rugged conditions and a microclimate with huge temperature variations with the changes in soils confined to surface only this phase continue up to canopy closure. In the second phase which is the transitional phase of 5-7 years marked with the highest tree growth, expansion of their root system and increased litter production. Lastly an enrichment phase characterized by soil stabilization and improvement in soil physio-chemical properties down to the profile (Bhojvaid and Timmer, 1998).

In a study by Singh *et al* (2012) to evaluate the restored degraded lands in north India, they compared the physio-chemical soil properties of the plantations and rehabilitated mixed forests to the natural forests and non restored degraded lands at two soil depths of 0-15 and 15-30 cm. The results show that the bulk density, pH, EC reduced during the restoration in both the plantations and mixed forests, Organic Carbon , soil nutrients, microbial biomass also improved significantly in the restored sites. The overall gain varied from 54 percent in plantations to 77 percent under mixed forests for the soil physio -chemical attributes.

A study conducted in Lucknow, India on wastelands to assess the performance and impact of plant densities on the soil. Three planting densities of *Terminalia arjuna* (10000, 20,000 and 30,000 per ha) were evaluated and the results showed a marked reduction in soil bulk densities with the highest reduction in the plantation with highest density i.e from 1.89 gm/ cm^3 for 10,000 trees per ha to 1.36 gm/ cm^3 for 30,000 trees per ha. It was also concluded that soil pH, Exchangeable Sodium Percentage reduced with the plant age and plant density whereas C and soil nutrients improved along with plant growth and density (Jain and Singh 1998). In a study conducted by Singh *et al* (2013) at Lucknow in the degraded lands which were restored by *Jatropha curcus*, growth and yields were monitored over the period from 2006 to 2010 and the results depict good ability of the species to perform under the degraded areas, significant changes in the soil properties were supported by increase in soil nutrient status.

Arunachalam and Arunachalam, (2002) conducted studies on various bamboo species on the degraded sites to evaluate the performance of bamboos in eco-restoration. Three bamboo species planted under same conditions viz. *Bambusa nutans, Bambusa arundinacea* and *Dendrocalamus hamiltonii* were analyzed for soil and microbial properties and ground diversity. It was noted that bamboos impact higher for N and P than C turnover, species diversity was found to be highest underneath of *Bambusa nutans*, while soil organic matter did not vary significantly between these bamboo species, but total nitrogen was greater under the canopy of *Dendrocalamus hamiltonii.*

Singh and Singh (1999) conducted another study on Bamboos to assess the performance of *Dendrocalamus strictus* in an open cast coal mine planted during different years. The results of the study imply *Dendrocalamus strictus* was found to be quick growing and hardy species in wide range of harsh conditions mainly due to its shallow root system and accumulation of leaf mulch which serves as an efficient agent in preventing soil erosion and conserving moisture. The soils in the plantation reflected increased contents of soil organic carbon and Kjeldahl N with the increasing age. The soils under 5 year old plantations had 98 percent greater C and 67 percent greater N compared to the 3 year old plantation, also the N mineralization was observed to be increased with age of the *Dendrocalamus strictus* plantations.

In a study to evaluate the performance of two species of *Albizia sp.* on a restored area found that *Albizia lebbeck* reflected more soil C and N than *Albizia procera* because of significantly greater biomass and production efficiency of foliage by *Albizia lebbeck* indicating its better potential for improvement in soil properties. This study infers that all leguminous species may differ in their efficiency towards the restoration and may not be equally well in restoration activities and certain tree species thus may result better rehabilitation and boost soil nutrient efficiency (Singh *et al.*, 2004)

In a study by Singh and Singh (2006) to understand the suitability of 17 indigenous species in the restoration of degraded land in dry tropical areas and their ability to restore the soil fertility. It was found that *Azadirachta indica* performed best on slopy areas whereas *Dendrocalamus strictus* added highest biomass among all the native species. A linear significant relationship between foliage biomass and tree layer net primary productivity was found. In another study by Shrivastava et al (1989) in the mines restoration activities in 5, 10, 12, 16, 20 years after plantation found soil microbial C, N, P to be positively related with the age of mine spoil.

A study in Aravalli hills after 5.5 and 13.5 years of eco-restoration to assess the growth parameters, soil pH, organic carbon, soil nutrients and various socio-economic benefits, showed that five species thrived out of twelve species planted. There was significant improvement in the physio-chemical properties of soil up to the depth of 45 cm when compared to the initial status. *Albizia lebbeck, Leucaena leucocephala* , *Acacia nilotica* and *Eucalyptus hybrid* performed promising under the dry degraded condition while others did not survive, thus making the choice of revegetation in difficult site restricted (Pal and Sharma, 2001).

Bhojvaid and Timmer (1998) in the degraded soils of Haryana to study the long term soil dynamics of *Prosopis juliflora* and the performance for the rehabilitation of the degraded lands, collected Soil samples from an age sequence of 0, 5, 7 and 30 year old plantations. They concluded that the carbon buildup in the top 15 cm of soil increased 2, 5 and 10 times respectively from the original site for 5, 7 and 30 year plantations. A 10 fold increase was noted in the total N accumulation for the 30 year old plantation over the control site. Bulk density is an important aspect which can limit the growth if the bulk density is higher as it impede the plant to extend their roots. In the study it was observed that at the initial phase (0-5 years) bulk density was reduced for the top soil only but with time (7-30 years) bulk density reduced progressively towards down the soil profile. Saidi (2012) found that the restoration helps to improve CEC, (Cation Exchange Capacity) of a soil which measures the surface electric charge of soil components and is an important soil parameter to evaluate the properties of soil components. Water retention properties of soils are closely related to CEC.

A study was conducted in an afforested area after 18 years of plantation assessing the role of six multipurpose trees. The result showed that there was an increase of about 142% in soil organic carbon for *Eucalyptus tereticornis*, followed by *Terminalia arjuna* and *Albizia procera*. The study revealed that dissolved organic carbon is a major factor in soil formation and plays an important role in many chemical and biological processes in soils, the interaction of DOC was found significant to be $P < 0.001$ with the effects of different plants and seasons. (Laik *et al.*, 2009)

Introduction of non-native species must be done very carefully as there is always probability of pests infestation under many situations. Maintenance of legumes in a degraded land is very crucial as they show greater improvement in soil fertility. It has been found that native leguminous species enhance the soil characters and its fertility is higher than the non-leguminous species and also the non-native leguminous and exotic legumes in a short term (Sheoran *et al.*, 2010)

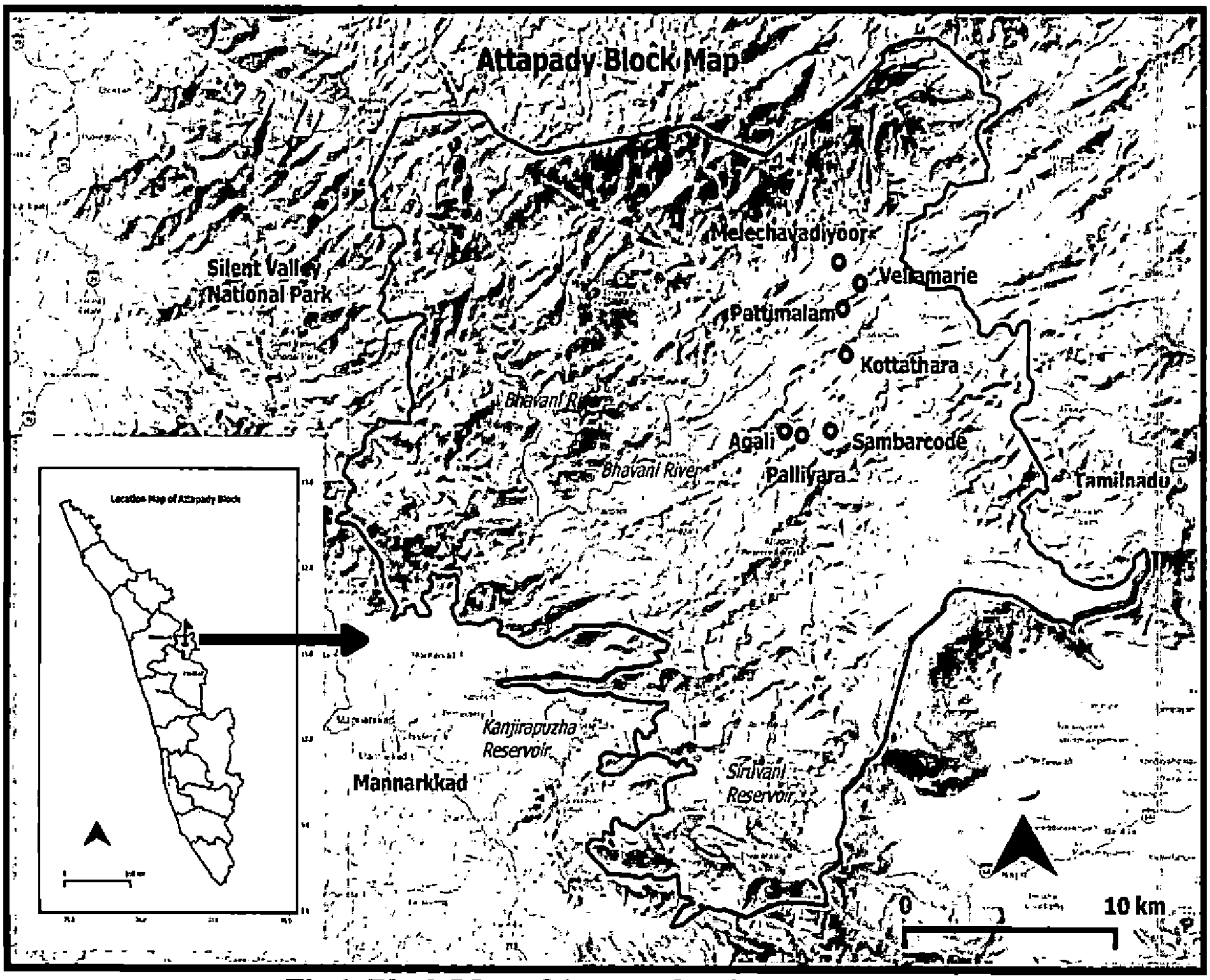


Fig.1. Block Map of Attappady with study sites

At the present scenario of climate change, majority of the nations focus on the sustainable development and major steps has been taken towards various eco-restoration projects and their detailed studies and analysis have been promoted.

Reviewing the literature, it was noted that studies regarding the floristic diversity and edaphic changes in eco-restored area were scanty and limited to certain aspects only. The literature cites only few works with respect to post eco-restoration studies. Hence the present study is oriented to explore on the above mentioned topics and thus would be useful in vegetational and edaphic changes in eco-restored areas and other ecological studies.

Materials and Methods

CHAPTER-III

MATERIALS AND METHODS

The study on "Post eco-restoration changes in vegetation and edaphic attributes of Eastern Attappady, Kerala" was carried out in Attappady, Pallakad district in Kerala during the year 2012-2014. The details of the Study site, Topography and Geology, Climate, Rainfall, Soils, Land use pattern, Vegetational spectrum, Socio-economic profile and other features of land along with the methodologies adopted are described below:

3.1 Study site

3.1.1 Location and extent

The proposed study was conducted in Attappady, located between the coordinates of 10^0 55'and 11^0 15'N latitude and 76^0 22' and 76^0 46'E longitudes in the Western Ghat region of Kerala. It is an eastern sloping plateau in the North eastern part of Palakkad district. Attappady is spread over an area of 745 km^2 covering Agali, Pudur and Sholayur panchayats. The study was concentrated towards the eastern region of Attappady because most of the eco-restoration works were focused in this region. The Attapady landscape comprising of Attapady, Anaikatty, Gopinari and Thadakam areas falls in the foothills of Nilgiri Biosphere Reserve, and is predominantly covered with mixed dry deciduous vegetation. The total extent is 1140 km^2 falling administratively in the Palakkad (Kerala), Coimbatore and Nilgiri (both in Tamil Nadu) districts.

3.1.2 Elevation Topography and Geology

Attappady region on the basis of elevation has been divided in to three classes viz. above 1200 m, between 600-1200 m and below 600 m. Northern Attappady is demarcated by the Southern Nilgiris with high elevation. Southern and South eastern Attappady extends from Muthikulam at an elevation of 1500 m. Eastern Attappady is a region with undulating flat relief features and it finally merges in to Coimbatore plains. Attappady region is dominated by the medium elevation zones (approx 60.6 %).

3.1.3 Rainfall and Climate

Attappady experiences both South West monsoon and North East monsoon in a year but still it is considered one of the driest parts of Kerala Western Ghats. On the western side of Attappady, hills are higher and steeper and receives rainfall mainly from South West monsoon. The rainfall varies from above 2000 mm to 3000 mm for high rainfall western half.

The Eastern half receives most of its rainfall from the North East monsoon. The eastern half experiences scanty rainfall with less than 1000 mm with breaks between Thavalam and Agali regions which receive medium rainfall of 1000 mm to 2000 mm. Dry season in this region may continue from 6 to 9 months with rainfall even below 800 mm. The dryness in this region is attributed to the rain shadow effect of the mountains (Muralitharan et al., 1991).

3.1.4 Vegetational Spectrum

Eastern Attappady being a low rainfall zone experiences biotype of the area as dry deciduous with frequent presence of moist deciduous plant species. Attappady has been under continuous stress due to human encroachment and degradation which resulted in the present scenario, the area being dominated by the euphorbiaceous scrub jungles.

Champion and Seth have classified the vegetation of this area as:-

1. **Tropical wet evergreen forests**

   Found on elevation between 300 and 1100 m, these forest are humid and cover Attapady blocks of I, V and VI.

2. **West coast tropical semi-evergreen forest:**

   Found in Attappady blocks I and Block VI are originally evergreen forests but have been degraded to secondary evergreen forests due to practice of shifting cultivation.

3. **South Indian moist deciduous forests:**

   Found in the dry belts of Pudur indicate the dominance of these forests in the past in this region but have been destroyed due to indiscriminate felling for their valuable timber.

4. **Southern tropical dry deciduous forests**

   Under stocked and degraded due to felling, fire and grazing these forests constitute 30% of Attappady.

5. **Pioneer euphorbeacus scrub**

   Found in Mulli and Thoova regions, these are retrograded form of dry deciduous forests.

6. **Subtropical hill forests**

   Found beyond elevations of 1500 m, which are stunted with fewer species.

7. **Southern montane temperate forests**

   Also known as Shola forests these vegetations are found in patches in the areas above 1900 m along with grasslands. These forest can be found in Western Attappady blocks I and V.

8. Grasslands

High level grassland found above 1500 m elevation and the low level grasslands are found below 1500 m elevation which are mainly result of fire and timber removal.

Soils, Rocks and Geology

The Western Ghats correspond to two major categories of rock formation. One is the highly varied Pre-Cambrian shield, and the other, to the north of Goa, is the basaltic lava flows of the Deccan Trap. The non-metamorphic sedimentary formations are very rare and found only along the coastal belt. The Western Ghats are essentially the Western edge of the Indian peninsular plateau, which is the stable mark of Archaean and Pre-Cambrian formations, where the mountain building has ceased in the Pre- Cambrian times. The Western Ghats presents an almost sheer, abrupt and straight face along its eastern edge to the south of the Palghat gap up to the Shencottah gap. Structurally the entire Western Chats were part of the continental block of peninsular India, made up of metamorphic archean, i.e. Pre-Cambrian rocks (mainly gneisses, charnockites and schists). Most of the exposed gneisses of the Western Ghats are 2,500 million years old. There are seven main soil groups found in the region viz. laterites (high and low), red loam, medium black soils, hill soils, red gravelly soils, alluvial soils including coastal alluvium, mixed red and black soils.

The terrain of the landscape is quite undulating, holding a large number of hillocks of varying elevation and ranges from 100 to 2300 meters above the mean sea level. Rock formation in the study area is gneiss of Archaean age group, comprising a variety of rock types. The major type of soil in the area is formed as a product of destruction of the ancient crystalline and metamorphic rocks, under the influence of semi-arid to sub-humid climate vegetation. Soils under evergreen and semievergreen forests are brown to dark yellowish brown, whereas those under moist and dry deciduous forests are dark brown to dark grayish brown in colour. Soil type of this forest is generally hard gravel in major portions and red loamy in some patches. The area is the watershed of two major rivers, viz., Bhavani and Bharathapuzha.

3.2.1 Experimental Details

Forests cover an area of 341 sq. km out of total 731 sq km area of Attappady. Degraded forests cover an area of about 210 km^2 and grasslands covering an area of 46 km^2 area. Attappady region under the AHADS eco-restoration project was divided into three categories

Natural forests which were predominantly dense forests and those areas which required no intervention or minimum interventions under the eco-restoration activity.

Biomass areas were the areas having a vegetation cover of 40 per cent or more but needed sufficient work and intervention so as to check them from further degradation.

Plantation areas were the most degraded with less than 40 per cent vegetation cover and required immediate attention towards restoration as they were highly affected by the human exploitation and degradation activities. Major work under the AHADS project were undertaken in these areas.

3.2.2 Sample plots

A pilot study was made with the AHADS officials in whole of Eastern Attappady. Experimental sites were chosen with utmost care so as to cover the maximum area.

A total of 10 eco-restored areas were chosen to carry out the study. Out of these 10 study sites, 7 were plantations and 3 biomass areas. As a control 10 Non-ecorestored areas were chosen which were nearby/ adjacent to eco-restored areas and most of these were vacant waste lands or private lands/ forests.

The vegetation was analyzed for various phyto-sociological parameters. The trees and saplings were analyzed by randomly laying quadrats of size 20 x 20 m along the transect and a minimum distance of 250 m was maintained between two consecutive quadrats. The girth at breast height (i.e., 1.37m above the ground) of all the trees and saplings above 10 cm GBH in each quadrat were measured and recorded individually. The seedlings (<10 cm GBH) and shrubs were measured at the collar height.

Vegetational data was quantitatively analysed for frequency, density, abundance (Curtis and McIntosh, 1950) and A/F ratio (Whiteford, 1949). The relative frequency, relative density, and relative basal area values were calculated following Phillips (1959). The sum of relative frequency, relative density, and relative basal area values represented as Importance Value Index (IVI) for the various species and for each experimental site were calculated.

1. Density = No. of trees / Hectare
2. Percentage Frequency = No. of quadrats of occurence x 100 / Total no. of quadrats studied.
3. Abundance = Total no. of individuals of a spp. in all quadrats / Total no. of quadrats in which the spp. occur

Basal area of trees was calculated as cross sectional area of stem at breast height i.e. at 1.37 m from the ground level. The relative frequency, relative density and relative basal area, were calculated by following equations.

Relative Density = No. of individuals of the species x 100/ No of individuals of all species

Relative Frequency = No. of occurence of a species / No. of occurence of all species.

Basal Area = $(GBH)^2/4\pi$

Relative Basal Area = Basal area for the species x 100/ Basal area of all species

Importance Value Index = Relative Density + Relative Frequency + Relative Basal Area

The Importance Value Index (IVI) was determined as the sum total of relative frequency, relative density and relative dominance (Phillips, 1959).

3.2.3. Species diversity analysis

Diversity indices like Simpson's index and Shannon- Weiner's function were found out using the following formulae:

1. **Simpson's index, (D)** (Simpson, 1949)

$$D = 1 - \Sigma(ni/N)2$$

This index is a measure of the dominance.

2. **Shannon-Weiner's index (H')** (Shannon, 1948)

(A) $H' = 3.3219(\log N - \frac{1}{N}\Sigma\, ni \log ni)$

(B) $H_{max} = 3.3219 \log_{10} S$

Where,

N - Total number of all individuals of all the species.

ni - No. of individuals of a species.

S - Total no. of species

3. **Concentration of dominance** was measured by Simpson index (Simpson, 1949)

$Cd = (Ni / N)^2$

Ni and N were same as explained above and it varies between 0-1.

4. **Equitability (e)** was calculated as suggested by Pielou (1966)

e = H' / lnS.

H' = Shannon index and S = the number of species.

5. **Species richness** was calculated by the following equation (Marglef 1958).

d = S-1 / lnN.

Where,

S = total number of species,

N = basal area of all species (m^2ha^{-1})

3.2.4. Regeneration survey

Each quadrat was randomly divided into 10 sub quadrats of size 1m x 1m. All the plants less than 10 cm girth were identified and information like number of individuals of each species were counted. From the data Relative density and Abundance were calculated.

3.3 Soil Sampling and Edaphic Studies

Soil samples were collected from each of 10 plantations (restored areas) and 10 non-restored areas from the three depths *viz.* 0-20 cm, 20-40 cm, and 40-60 cm. From each plantation / biomass areas/ non- restored areas, three quadrats were randomly selected to collect the soil samples. Composite samples were collected from the respective soil depths and were preserved in one kg polythene bags and were emptied and spread out on plastic trays. Coarse concentrations, rocks peebles, pieces of roots, leaves and other composed organic matter were removed. Large lumps of moist soils were broken by hands.

Samples were air dried and were mixed and homogenized. After air drying, the soil samples were crushed gently in mortar and pestle and then sieved though a 2 mm sieve. Soil samples were then analyzed for various physico-chemical attributes like pH, EC, total nitrogen, available phosphorous and exchangeable potassium, soil organic carbon, Cation Exchange Capacity, bulk density, soil moisture content by standard methods.

3.3.1 Soil moisture

Soil moisture content was determined by gravimetric method after drying wet soil at 100-110°C for 24 hour and then calculated the soil moisture content using the formula.

$$Soil\ moisture\ content\ (\%) = \frac{Wet\ soil\ (g) - Dry\ Soil\ (g)}{\text{Dry soil (g)}} \times 100$$

3.3.2 Bulk density

Bulk density was estimated by taking out a core of undisturbed soil by using steel cylinder. The soil was oven dried and weight was determined. The volume of soil was calculated by measuring the volume of cylinder ($\pi r^2 h$). The bulk density was calculated by dividing the oven dry weight of soil samples (g) by volume of the soil (Jackson, 1958).

3.3.3 Soil pH

The pH of soil was determined using an aqueous suspension of soil (soil and water in 1:2.5 ratio) using an Elico pH analyser (Model Li 614).

3.3.4 Organic carbon

Organic carbon content of the soil was determined by wet digestion method (Walkley and Black, 1934). Organic matter in the soil was oxidized with a mixture of pottassium dichromate ($K_2Cr_2O_7$) and concentrated H_2SO_4 utilizing the heat of dilution of H_2SO_4. Unused $K_2Cr_2O_7$ was then back titrated with Ferrous Ammonium Sulphate [$FeSO_4.(NH_4)_2SO_2.6H_2O$] to get organic carbon %. Soil organic matter was determined by multiplying the value of organic carbon (%) by 1.724 (Van Bemmelen factor).

3.3.5 Total nitrogen

Total nitrogen content in soil samples was determined by Skalar method.

Sulphuric acid and Se powder mixture – In to a two litre beaker 3.5 g selenium powder was weighed and 1 litre of conc. H_2SO_4 was carefully and slowly poured in to it. The powder was then dissolved into the H_2SO_4 by heating the beaker for 4 to 5 hours at 300^0 C. The black colour of the solution changed to deep blue color and then light yellow. The solution was then cooled.

Digestion mixture – 10.8 g salicylic acid was weighed and added to 150 ml of H_2SO_4 and selenium mixture.

Procedure

Soil sample (0.4 g) was weighed into the digestion tube and 2.5 ml of the digestion mixture was added. The tube was then swirled well and allowed to stand for two hours or overnight. It was then inserted into the digestion block and heated at 100^0 C for two hours. After cooling, the tubes were removed from the block and one ml of 30 % H_2O_2 was added and again after reaction one ml of 30 % H_2O_2 was added. After the reaction ceased, they were again placed in the digestion block and heated at 330^0 C for two hours. When the digest turned colourless, the digestion was completed. The digest was made upto 75 ml in a standard flask. The readings were then taken from the Skalar directly using the reagents.

3.4.6 Available phosphorus

Available Phosphorus content of the soil to the plants was determined by the Bray and Kurtz , 1945.

3.4.7 Exchangeable potassium

Exchangeable potassium in the soil samples were extracted using one normal neutral ammonium acetate and estimated using flame photometry (Jackson, 1958).

3.4.8 Cation Exchange Capacity (CEC)

It is the total capacity of a soil to hold exchangeable cations and influences the soil's ability to hold on to essential nutrients and provide buffer against soil acidification. CEC was determined by the sodium acetate leaching method.

In this method one normal sodium acetate trihydrate solution was added in air dried soil samples in 40 ml centrifuge tubes and shaken for 5 minutes and then centrifuged at 3000 rpm till the supernatant liquid was clear. Supernatant liquid was decanted completely. The same process was repeated for four times. After this procedure centrifuge tubes were shaken with 95 % ethanol for five minutes and again centrifuged. This washing with ethanol was repeated for three times. The final step was to replace the adsorbed sodium (Na^+) from the sample by extraction with one normal ammonium acetate solution. Samples were shaken for 5 minutes and centrifuged until supernatant liquid was clear. The three supernatant liquids were decanted completely as possible in to a 100 ml volumetric flask bringing the final volume with one normal ammonium acetate solution and mixed well.

A series of Na standards was run and a calibration curve was drawn. The emission readings were taken for the soil samples by a flame photometer at 767 nm wavelength. Sodium (Na) concentration was calculated according to the calibration curve. The following formulae were used to calculate CEC:

$$\text{CEC (meq/100 g)} = \text{meq/L Na (from calibration curve)} \times \frac{A}{Wt} \times \frac{100}{1000}$$

Where: A = Total volume of the extract (ml)

Wt = Weight of the air- dry soil (g)

3.4.9 Soil Carbon Sequestration

To calculate mass of carbon in a single stratum (layer of soil in a horizontal stratum), it takes three factors using formula:

$$CT = CF \times D \times V$$

Where, CT is total carbon for the layer in metric tons, CF is the fraction of carbon (percentage carbon divided by 100), D is density, and V is volume of the soil layer in cubic meters.

3.7 Statistical analysis

Statistical analysis was done by using SPSS statistical software.

Results

CHAPTER – IV

RESULTS

The study on "Post eco-restoration changes in vegetation and edaphic attributes of eastern Attappady, Kerala" was carried out in Attappady, Palakkad district in Kerala during the year 2012-2014. The investigation intended to study vegetational attributes and analysis of soil physico-chemical properties viz., moisture content, bulk density, pH, organic carbon, available nitrogen, total nitrogen, available phosphorus, exchangeable potassium and vegetational attributes. The results obtained from this study are detailed hereunder:-

4.1. Vegetation Attributes

4.1.1. Floristic structure and species composition

4.1.1.1. Agali plantation

Representative quadrats were taken into account for the study of this plantation. A total of 948 individuals of GBH>10 cm belonging to 48 species were recorded over an area of 5600 m^2. The maximum number of individuals were recorded for *Leucaena leucocephala*. The relative density was found maximum for *Leucaena leucocephala* (33.12) followed by *Santalum album* and *Albizia amara* (8.33 and 7.91). Lowest values were recorded for *Melia azedarach, Haldina cordifolia, Dalbergia latifolia, Anogeissus latifolia and Commiphora caudata* (0.11). Abundance was highest for *Leucaena leucocephala* (22.43) followed by *Albizia amara* (10.71) and *Naringi crenulata* (9.88).

The species distribution in the plantation concluded that the highest relative frequency for *Leucaena leucocephala* (6.48) followed by *Acacia ferruginea* (6.02) and lowest being reported for *Melia azedarach, Givotia molucana , Dalbergia latifolia, Anogeissus latifola* and 7 others (0.46). Relative basal area was recorded to be highest for *Leucaena leucocephala* (23.09) followed by *Senna siamea* (9.48) and *Acacia ferruginea* (8.62) whereas lowest relative basal area values were found for *Melia azedarach (0.02) and Haldina cordifolia (0.05).*

Importance value index was found maximum for *Leucaena leucocephala* (62.70) followed by *Santalum album* (20.25) *and Naringi crenulata* (20.18) while the lowest values were found to be for *Anogeissus latifolia* (0.61), *Haldina cordifolia* (0.62) *and Dalbergia latifolia* (0.62).

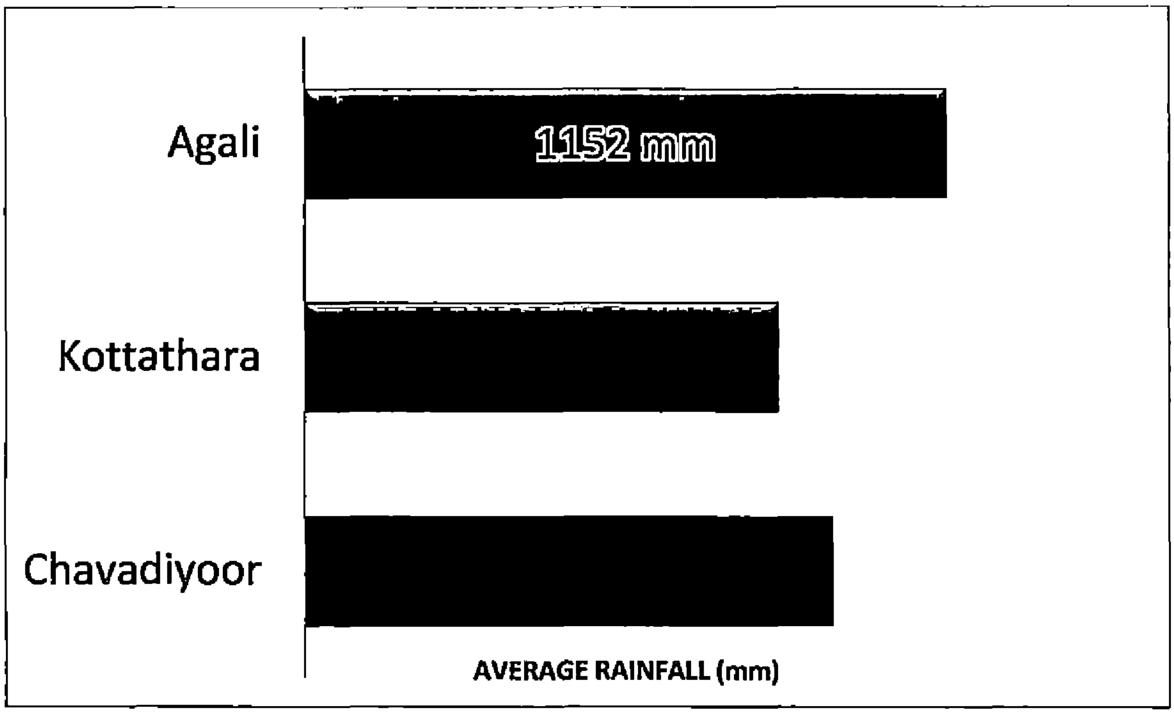
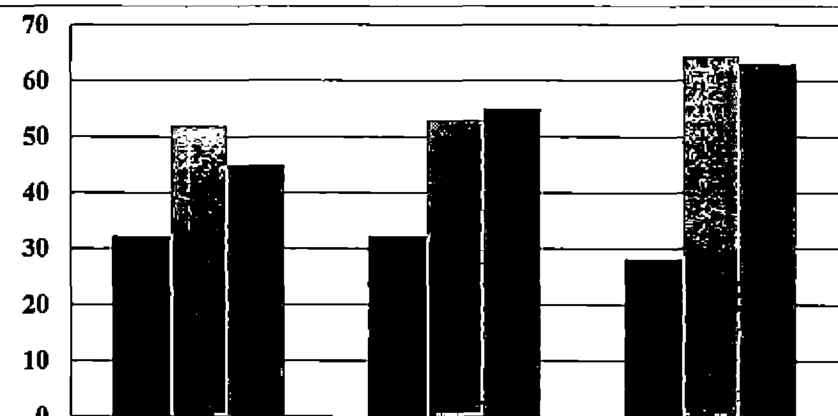


Fig.2. Average rainfall in various observatory stations of Attappady



	MeleChavadiyoor, Vellamari	Kottathara, Pattimalam	Agali, Sambarkode, Palliyara
■ Average max. temperature (°C)	32	32	28
■ Average Humidity (%)	52	53	64.5
■ Average rainy days	45	55	63

Fig.3. Average climatological data of Attappady

Table 1. Structural analysis of vegetation in Agali Plantation at Attappady

Sl no.	species	Density (No/ha)	Rel. Density	Abundance	Percentage frequency	Rel. frequency	RBA*	IVI**	RIVI***
1	*Acacia ferruginea*	66.07	3.9	2.85	92.86	6.02	8.62	18.54	6.18
2	*Acacia leucophloea*	12.5	0.74	1.17	42.86	2.78	1.16	4.68	1.56
3	*Acacia planifrons*	5.36	0.32	1.5	14.29	0.93	0.20	1.44	0.48
4	*Acacia sinuata*	1.79	0.11	1	7.14	0.46	0.07	0.64	0.21
5	*Albizia amara*	133.93	7.91	10.71	50	3.24	7.39	18.54	6.18
6	*Albizia lebbeck*	44.64	2.64	2.5	71.43	4.63	6.06	13.33	4.44
7	*Albizia procera*	16.07	0.95	1.5	42.86	2.78	2.34	6.07	2.02
8	*Anogeissus latifolia*	1.79	0.11	1	7.14	0.46	0.04	0.61	0.20
9	*Azadirachta indica*	30.36	1.79	1.55	78.57	5.09	1.50	8.38	2.79
10	*Bauhinia racemosa*	7.14	0.42	1	28.57	1.85	0.73	3.00	1.00
11	*Bombax cieba*	7.14	0.42	1	28.57	1.85	1.23	3.51	1.17
12	*Cassine albens*	50	2.95	4.67	42.86	2.78	4.56	10.29	3.43
13	*Casuarina equisetifolia*	1.79	0.11	1	7.14	0.46	0.10	0.67	0.22
14	*Commiphora caudata*	1.79	0.11	1	7.14	0.46	0.07	0.64	0.21
15	*Dalbergia latifolia*	1.79	0.11	1	7.14	0.46	0.06	0.62	0.21
16	*Dichrostachys cinerea*	25	1.48	2.33	42.86	2.78	1.06	5.32	1.77
17	*Diospyros cordifolia*	41.07	2.43	3.83	42.86	2.78	0.97	6.17	2.06
18	*Erythroxylum monogynum*	3.57	0.21	1	14.29	0.93	0.22	1.36	0.45
19	*Givotia moluccana*	1.79	0.11	1	7.14	0.46	0.21	0.78	0.26
20	*Gmelina arborea*	23.21	1.37	1.86	50	3.24	0.84	5.45	1.82
21	*Grevillea robusta*	12.5	0.74	2.33	21.43	1.39	0.22	2.34	0.78
22	*Grewia species*	5.36	0.32	1	21.43	1.39	0.06	1.77	0.59
23	*Grewia tiliaefolia*	8.93	0.53	1.25	28.57	1.85	0.73	3.11	1.04
24	*Haldina cordifolia*	1.79	0.11	1	7.14	0.46	0.05	0.62	0.21
25	*Holoptelia integrifolia*	10.71	0.63	1.5	28.57	1.85	0.41	2.89	0.96
26	*Jatropha curcus*	14.29	0.84	2.67	21.43	1.39	0.04	2.27	0.76
27	*Leucaena leucocephala*	560.71	33.12	22.43	100	6.48	23.09	62.70	20.90
28	*Melia azedarach*	1.79	0.11	1	7.14	0.46	0.02	0.58	0.20
29	*Murraya koenigii*	3.57	0.21	2	7.14	0.46	0.52	1.20	0.40
30	*Morinda tincroria*	12.5	0.74	2.33	21.43	1.39	1.26	3.39	1.13
31	*Naringi crenulata*	141.07	8.33	9.88	57.14	3.7	8.15	20.18	6.73
32	*Peltophorum pterocarpum*	7.14	0.42	1.33	21.43	1.39	0.60	2.41	0.81
33	*Phyllanthus embellica*	10.71	0.63	3	14.29	0.93	0.44	2.00	0.67
34	*Pleiospermium alatum*	19.64	1.16	1.57	50	3.24	0.46	4.87	1.62
35	*Pongamia pinnata*	3.57	0.21	2	7.14	0.46	0.18	0.86	0.29
36	*Psidium guajava*	5.36	0.32	1.5	14.29	0.93	0.13	1.37	0.46
37	*Pterocarpus marsupium*	7.14	0.42	2	14.29	0.93	1.18	2.52	0.84
38	*Pterolobium hexapetalum*	5.36	0.32	3	7.14	0.46	0.26	1.04	0.35
39	*Santalum album*	141.07	8.33	7.18	78.57	5.09	6.83	20.25	6.75

40	*Senna siamea*	76.79	4.54	4.78	64.29	4.17	9.48	18.19	6.06
41	*Simarouba glauca*	19.64	1.16	1.57	50	3.24	1.12	5.52	1.84
42	*Stereospermum colais*	3.57	0.21	1	14.29	0.93	0.19	1.32	0.44
43	*Strychnos potatorum*	25	1.48	3.5	28.57	1.85	0.86	4.19	1.40
44	*Tamarindus indica*	10.71	0.63	1.5	28.57	1.85	0.43	2.92	0.97
45	*Tectona grandis*	10.71	0.63	1.5	28.57	1.85	0.55	3.04	1.01
46	*Trewia nudiflora*	3.57	0.21	1	14.29	0.93	0.21	1.34	0.45
47	*Wrightia tinctoria*	66.07	3.9	5.29	50	3.24	4.76	11.90	3.97
48	*Ziziphus mauritiana*	26.79	1.58	2.14	50	3.24	0.35	5.18	1.73

* Relative Basal Area (RBA)

**Importance Value Index (IVI)

*** Relative Importance Value Index (RIVI)

4.1.1.2. Kottathara plantation

In Kottathara plantation, a total of 634 individuals of GBH>10 cm belonging to 17 species were recorded over an area of 4800 m^2. The maximum numbers of individuals were recorded for *Albizia amara* (318) in the study area. The relative density was found maximum for *Albizia amara* (45.89) followed by *Mundulea serecia (22.94)* and *Chloroxylon swietenia* (14.57). Lowest values were recorded for *Naringi crenulata, Acacia ferruginea, Gmelina arborea* and *Sterculia guttata* (0.14). Abundance was highest for *Albizia amara* (26.50) followed by *Mundulea serecia (13.25)* and *Chloroxylon swietenia* (12.63)

The species distribution studies in the plantation indicated the relative frequency being highest for *Albizia amara* and *Mundulea serecia* (18.18) followed by *Jatropha curcus* (13.64) and lowest was reported for *Narenga crenulata, Morinda tinctoria, Gmelina arborea* and 5 others (1.52). Relative basal area was recorded to be highest for *Albizia amara* (56.47) followed by *Mundulea serecia (11.25)* and *Chloroxylon swietenia* (11.23). Whereas lowest relative basal area values were found for *Narenga crenulata (0.04)* followed by *Pongamia pinnata (0.10).*

Importance value index was reported maximum for *Albizia amara* (124.81) followed by *Mundulea serecia (54.51)* and *Jatropha curcus* (31.27) while the lowest values were found to be for *Narenga crenulata* (1.71) followed by *Acacia ferruginea* (1.79).

Table 2. Structural analysis of vegetation in Kottathara Plantation at Attappady

Sl no.	Species	Density	Rel. density	Abundance	Percentage Frequency	Rel. Frequency	RBA	IVI	RIVI
1	*Acacia ferruginea*	2.08	0.14	1	8.33	1.52	0.11	1.79	0.6
2	*Acacia planifrons*	20.83	1.44	2	41.67	7.58	1.37	10.52	3.51
3	*Albizia amara*	662.49	45.89	26.5	100	18.18	56.47	124.81	41.6
4	*Chloroxylon swietenia*	210.41	14.57	12.63	66.67	12.12	11.23	29.81	9.94
5	*Dichrostachys cinerea*	6.25	0.43	1	25	4.55	0.51	5.53	1.84
6	*Diospyros cordifolia*	10.42	0.72	1	41.67	7.58	0.28	8.64	2.88
7	*Gmelina arborea*	2.08	0.14	1	8.33	1.52	0.24	2.07	0.69
8	*Jatropha curcus*	152.08	10.53	8.11	75	13.64	6.12	31.27	10.42
9	*Morinda tinctoria*	4.17	0.29	2	8.33	1.52	1.27	3.1	1.03
10	*Mundulea serecia*	331.24	22.94	13.25	100	18.18	11.25	54.51	18.17
11	*Naringi crenulata*	2.08	0.14	1	8.33	1.52	0.04	1.71	0.57
12	*Phyllanthus emblica*	4.17	0.29	2	8.33	1.52	0.12	1.95	0.65
13	*Pleiospermium alatum*	6.25	0.43	3	8.33	1.52	0.13	2.12	0.71
14	*Pongamia pinnata*	4.17	0.29	2	8.33	1.52	0.1	1.93	0.64
15	*Pterolobium hexapetalum*	10.42	0.72	2.5	16.67	3.03	0.15	3.97	1.32
16	*Senna siamea*	12.5	0.87	3	16.67	3.03	1.4	5.38	1.79
17	*Sterculia guttata*	2.08	0.14	1	8.33	1.52	9.22	10.9	3.63

4.1.1.3. Mellechavadiyoor plantation

A total of 435 individuals of GBH>10 cm belonging to 36 species were recorded over an area of 4800 m^2 in the plantation. The maximum numbers of individuals were recorded from *Albizia amara* (119) in the study area. The relative density was found maximum for *Albizia amara* (27.6) followed by *Erythroxylum monogynum (13.56)* and *Eucalyptus tereticornis* (13.10). Lowest values were recorded for *Dichrostachys cineria, Acacia farnesiana, Bombax cieba* and 7 others including *Leucaena leucocephala and Melia azedarach* (0.23). Abundance was highest for *Albizia amara* (10.82) followed by *Erythroxylum monogynum (5.36)* and *Eucalyptus tereticornis* (5.18).

The species distribution studies in the plantation conclude that the relative frequency was found highest for *Albizia amara, Erythroxylum monogynum,* and *Eucalyptus tereticornis* all with the value of (8.09) followed by *Sapindus emarginatus* and *Diospyros cordifolia* (6.62) and lowest being reported for *Naringi crenulata, Dichrostachys cineria* and 10 others (0.74). Relative basal area was recorded to be highest for *Albizia amara* (30.61) followed by *Eucalyptus tereticornis* (30.47) and *Eucalyptus grandis* (8.14). Whereas lowest relative basal area values were found for *Acacia farnesiana* and *Acacia sinuata* (0.02).

Importance value index was calculated to be maximum for *Albizia amara* (66.05) followed by *Eucalyptus tereticornis (51.66)* and *Erythroxylum monogynum* (27.49) while the lowest values were found to be for *Melia azedarach* (1.00) followed by *Tamarindus indica* (1.01).

Table 3. Structural analysis of vegetation in Mellechavadiyoor Plantation at Attappady

Sl no.	Species	Density	Rel. density	Abundance	Percentage Frequency	Rel. Frequency	RBA	IVI	RIVI
1	*Acacia auriculiformis*	2.08	0.23	1.00	8.33	0.74	0.28	1.25	0.42
2	*Acacia farnesiana*	2.08	0.23	1.00	8.33	0.74	0.02	0.98	0.33
3	*Acacia ferruginea*	10.42	1.15	1.25	33.33	2.94	0.63	4.72	1.57
4	*Acacia planifrons*	4.17	0.46	1.00	16.67	1.47	0.04	1.97	0.66
5	*Acacia sinuata*	2.08	0.23	1.00	8.33	0.74	0.02	0.98	0.33
6	*Albizia amara*	247.91	27.36	10.82	91.67	8.09	30.61	66.05	22.02
7	*Atalantia monophylla*	20.83	2.30	1.67	50.00	4.41	1.06	7.77	2.59
8	*Azadirachta indica*	25.00	2.76	2.40	41.67	3.68	1.06	7.50	2.50
9	*Bauhinia racemosa*	10.42	1.15	1.67	25.00	2.21	0.59	3.95	1.32
10	*Bombax cieba*	2.08	0.23	1.00	8.33	0.74	0.06	1.03	0.34
11	*Cassia fistula*	6.25	0.69	1.50	16.67	1.47	0.53	2.69	0.90
12	*Cassine paniculata*	4.17	0.46	2.00	8.33	0.74	0.44	1.63	0.54
13	*Chloroxylon swietenia*	50.00	5.52	3.00	66.67	5.88	4.38	15.77	5.26
14	*Cordia monoica*	4.17	0.46	1.00	16.67	1.47	0.12	2.05	0.68
15	*Dichrostachys cinerea*	2.08	0.23	1.00	8.33	0.74	0.17	1.14	0.38
16	*Diospyros cordifolia*	37.50	4.14	2.00	75.00	6.62	1.21	11.96	3.99
17	*Erythroxylum monogynum*	122.91	13.56	5.36	91.67	8.09	5.84	27.49	9.16
18	*Eucalyptus grandis*	22.92	2.53	1.57	58.33	5.15	8.14	15.82	5.27
19	*Eucalyptus tereticornis*	118.75	13.10	5.18	91.67	8.09	30.47	51.66	17.22
20	*Ficus spp.*	6.25	0.69	1.50	16.67	1.47	0.15	2.31	0.77
21	*Givotia moluccana*	10.42	1.15	1.00	41.67	3.68	3.13	7.95	2.65
22	*Gmelina arborea*	14.58	1.61	2.33	25.00	2.21	0.39	4.21	1.40
23	*Haldina cordifolia*	2.08	0.23	1.00	8.33	0.74	0.06	1.02	0.34
24	*Holoptelia integrifolia*	4.17	0.46	1.00	16.67	1.47	0.16	2.09	0.70

25	*Jatropha curcus*	4.17	0.46	1.00	16.67	1.47	0.04	1.97	0.66
26	*Leucaena leucocephala*	2.08	0.23	1.00	8.33	0.74	0.07	1.04	0.35
27	*Melia azedarach*	2.08	0.23	1.00	8.33	0.74	0.03	1.00	0.33
28	*Murraya koenigii*	25.00	2.76	3.00	33.33	2.94	0.37	6.07	2.02
29	*Mundulea serecia*	10.42	1.15	1.25	33.33	2.94	0.14	4.23	1.41
30	*Naringi crenulata*	4.17	0.46	2.00	8.33	0.74	1.45	2.64	0.88
31	*Pleiospermium alatum*	2.08	0.23	1.00	8.33	0.74	0.05	1.02	0.34
32	*Sapindus emarginatus*	52.08	5.75	2.78	75.00	6.62	3.49	15.86	5.29
33	*Strychnos potatorum*	27.08	2.99	3.25	33.33	2.94	1.33	7.26	2.42
34	*Tamarindus indica*	2.08	0.23	1.00	8.33	0.74	0.04	1.01	0.34
35	*Wrightia tinctoria*	31.25	3.45	5.00	25.00	2.21	3.34	8.99	3.00
36	*Ziziphus mauritiana*	10.42	1.15	1.00	41.67	3.68	0.11	4.94	1.65

4.1.1.4. Palliyara plantation

In Palliyara plantation, a total of 690 individuals of GBH>10 cm belonging to 38 species were recorded over an area of 5200 m^2. The maximum numbers of individuals were recorded from *Leucaena leucocephala* (214) in the study area. The relative density was found maximum for *Leucaena leucocephala* (31.01) followed by *Albizia amara* (21.45), *Wrightia tinctoria (7.39)* and *Tamarindus indica* (7.10). Lowest values were recorded for *Bombax cieba, Acacia ferruginea, Tectona grandis, Gmelina arborea* and 5 others (0.14). Abundance was highest for *Leucaena leucocephala* (16.46) followed by *Albizia amara (11.38)* and *Jatropha curcus* (10.00).

The species distribution studies in the plantation show that the relative frequency being found highest for *Albizia amara*, and *Leucaena leucocephala* with (9.63) followed by *Azadirachta indica* (8.15) and lowest being reported for *Pterocarpus marsupium, Aegle marmaloes, Murraya koenigii, Tectona grandis* and 8 others (0.74). Relative basal area was recorded to be highest for *Leucaena leucocephala* (34.62) followed by *Acacia polyacantha* (17.26) and *Albizia amara* (12.34). Whereas lowest relative basal area values were found for *Aegle marmaloes* and *Atalantia monophylla* (0.02).

Importance value index was found to be maximum for *Leucaena leucocephala* (75.26) followed by *Albizia amara (43.42)* and *Acacia polyacantha* (29.43) while the lowest values were found to be for *Aegle marmaloes* (0.90) followed by *Naringi crenulata* (0.92).

Table 4. Structural analysis of vegetation in Palliyara Plantation at Attappady

Sl. No.	Species	Density	Rel. density	Abundance	Percentage frequency	Rel. frequency	RBA	IVI	RIVI
1	*Acacia ferruginea*	1.92	0.14	1.00	7.69	0.74	0.08	0.96	0.32
2	*Acacia nilotica*	11.54	0.87	3.00	15.38	1.48	0.81	3.16	1.05
3	*Acacia planifrons*	5.77	0.43	1.50	15.38	1.48	0.24	2.16	0.72
4	*Acacia polyacantha*	73.08	5.51	4.22	69.23	6.67	17.26	29.43	9.81
5	*Acacia sinuata*	5.77	0.43	3.00	7.69	0.74	0.2	1.38	0.46
6	*Aegle marmaloes*	1.92	0.14	1.00	7.69	0.74	0.02	0.9	0.3
7	*Albizia amara*	284.61	21.45	11.38	100	9.63	12.34	43.42	14.47
8	*Albizia lebbeck*	11.54	0.87	2.00	23.08	2.22	0.53	3.62	1.21
9	*Albizia procera*	17.31	1.3	2.25	30.77	2.96	0.98	5.24	1.75
10	*Annona squamosa*	9.62	0.72	1.25	30.77	2.96	0.11	3.8	1.27
11	*Atalantia monophylla*	3.85	0.29	2.00	7.69	0.74	0.02	1.06	0.35
12	*Azadirachta indica*	65.38	4.93	3.09	84.62	8.15	1.12	14.2	4.73
13	*Bombax cieba*	1.92	0.14	1.00	7.69	0.74	4.36	5.24	1.75
14	*Cassine paniculata*	3.85	0.29	1.00	15.38	1.48	0.34	2.11	0.7
15	*Commiphora caudata*	9.62	0.72	2.50	15.38	1.48	1.54	3.75	1.25
16	*Delonix regia*	9.62	0.72	1.67	23.08	2.22	1.84	4.78	1.59
17	*Dichrostachys cinerea*	13.46	1.01	2.33	23.08	2.22	0.42	3.65	1.22
18	*Diospyros cordifolia*	36.54	2.75	4.75	30.77	2.96	0.39	6.11	2.04
19	*Gmelina arborea*	1.92	0.14	1.00	7.69	0.74	0.04	0.93	0.31
20	*Gravelia robusta*	11.54	0.87	1.20	38.46	3.7	0.39	4.96	1.65
21	*Holoptelia integrifolia*	38.46	2.9	4.00	38.46	3.7	2.23	8.83	2.94
22	*Jacaranda mimosifolia*	1.92	0.14	1.00	7.69	0.74	0.11	0.99	0.33
23	*Jatropha curcus*	19.23	1.45	10.00	7.69	0.74	0.49	2.68	0.89
24	*Leucaena leucocephala*	411.54	31.01	16.46	100	9.63	34.62	75.26	25.09
25	*Murraya koenigii*	3.85	0.29	1.00	15.38	1.48	0.1	1.87	0.62
26	*Naringi crenulata*	1.92	0.14	1.00	7.69	0.74	0.04	0.92	0.31
27	*Pterocarpus marsupium*	1.92	0.14	1.00	7.69	0.74	0.1	0.99	0.33
28	*Santalum album*	5.77	0.43	1.00	23.08	2.22	0.36	3.01	1
29	*Senna siamea*	13.46	1.01	2.33	23.08	2.22	1.19	4.43	1.48
30	*Simarouba glauca*	5.77	0.43	1.00	23.08	2.22	0.14	2.8	0.93
31	*Stereospermum*	3.85	0.29	2.00	7.69	0.74	0.27	1.3	0.43

	colais								
32	*Strychnos potatorum*	26.92	2.03	2.80	38.46	3.7	0.42	6.16	2.05
33	*Tamarindus indica*	94.23	7.1	5.44	69.23	6.67	10.11	23.88	7.96
34	*Tectona grandis*	1.92	0.14	1.00	7.69	0.74	0.06	0.94	0.31
35	*Terminalia bellerica*	1.92	0.14	1.00	7.69	0.74	0.04	0.93	0.31
36	*Trewia nudiflora*	5.77	0.43	1.00	23.08	2.22	0.25	2.9	0.97
37	*Wrightia tinctoria*	98.08	7.39	8.50	46.15	4.44	6.31	18.15	6.05
38	*Ziziphus mauritiana*	9.62	0.72	1.67	23.08	2.22	0.15	3.1	1.03

4.1.1.5. Pattimalam plantation

A total of 1006 individuals of GBH>10 cm belonging to 20 species were recorded over an area of 7200 m^2 in Pattimalam Plantation. The maximum number of individuals were recorded from *Albizia amara* (328) in the study area. The relative density was found maximum for *Albizia amara* (32.60) followed by *Mundulea serecia* (26.94) and *Leucaena leucocephala* (17.00). Lowest values were recorded for *Givotia moluccana, Phyllanthus emblica* and 2 others (0.10). Abundance was highest for *Albizia amara* (18.22) followed by *Mundulea serecia* (15.94) and *Leucaena leucocephala* (10.06).

The species distribution studies in the plantation show that the relative frequency being found highest for *Albizia amara* (14.06) followed by *Mundulea serecia* and *Leucaena leucocephala (13.28)* and lowest being reported for *Givotia moluccana, Phyllanthus emblica* and 2 others (0.78). Relative basal area was recorded to be highest for *Albizia amara* (66.17) followed by *Leucaena leucocephala* (14.06) and *Mundulea serecia* (5.28). Whereas lowest relative basal area values were found for *Cassine albens* (0.01).

Importance value index was calculated to maximum for *Albizia amara* (112.83) followed by *Mundulea serecia* (45.50) and *Leucaena leucocephala* (44.34) while the lowest values were found to be for *Cassine albens* (0.89).

Table 5. Structural analysis of vegetation in Pattimalam Plantation at Attappady

Sl. No.	Species	Density	Rel. density	Abun-dance	Percentage frequency	Rel. frequency	RBA	IVI	RIVI
1	*Acacia leucophloea*	23.61	1.69	1.89	50	7.03	0.53	9.25	3.08
2	*Acacia planifrons*	45.83	3.28	3.30	55.56	7.81	3.97	15.06	5.02
3	*Albizia amara*	455.53	32.60	18.22	100	14.06	66.17	112.83	37.61
4	*Azadirachta indica*	5.56	0.40	1.33	16.67	2.34	0.09	2.84	0.95
5	*Cassine albens*	1.39	0.10	1.00	5.56	0.78	0.01	0.89	0.30
6	*Chloroxylon swietenia*	94.44	6.76	5.67	66.67	9.38	4.39	20.52	6.84
7	*Dichrostachys cinerea*	5.56	0.40	1.33	16.67	2.34	0.03	2.77	0.92
8	*Diospyros cordifolia*	19.44	1.39	2.80	27.78	3.91	0.27	5.56	1.85
9	*Euphorbia antiquorum*	6.94	0.50	1.67	16.67	2.34	1.83	4.67	1.56
10	*Ficus spp.*	1.39	0.10	1.00	5.56	0.78	0.02	0.90	0.30
11	*Givotia moluccana*	1.39	0.10	1.00	5.56	0.78	0.07	0.95	0.32
12	*Gmelina arborea*	59.72	4.27	4.30	55.56	7.81	1.78	13.87	4.62
13	*Holoptelia integrifolia*	5.56	0.40	1.00	22.22	3.13	0.55	4.07	1.36
14	*Leucaena leucocephala*	237.48	17.00	10.06	94.44	13.28	14.06	44.34	14.78
15	*Mundulea serecia*	376.36	26.94	15.94	94.44	13.28	5.28	45.50	15.17
16	*Murraya koenigii*	2.78	0.20	1.00	11.11	1.56	0.04	1.80	0.60
17	*Phyllanthus embellica*	1.39	0.10	1.00	5.56	0.78	0.03	0.91	0.30
18	*Pterolobium hexapetalum*	29.16	2.09	5.25	22.22	3.13	0.18	5.40	1.80
19	*Senna siamea*	13.89	0.99	2.00	27.78	3.91	0.26	5.16	1.72
20	*Wrightia tinctoria*	9.72	0.70	3.50	11.11	1.56	0.45	2.71	0.90

4.1.1.6. Sambarkode plantation

In Sambarkode Plantation a total of 844 individuals of GBH>10 cm belonging to 43 species were recorded over an area of 7200 m^2. The maximum numbers of individuals were recorded from *Chloroxylon swietenia* (180) in the study area. The relative density was found maximum for *Chloroxylon swietenia* (21.33) followed by *Leucaena leucocephala* (15.17) and *Azadirachta indica* (13.39). Lowest values were recorded for *Grevellia robusta, Bauhinia racemosa, Cordia monoica* and 10 others (0.12). Abundance was highest for *Chloroxylon swietenia (*10.59) followed by *Leucaena leucocephala* (8.00) and *Albizia amara* (7.82).

The species distribution studies in the plantation show that the relative frequency being found highest for *Chloroxylon swietenia* (21.33) followed by *Leucaena leucocephala* and *Azadirachta indica* (7.55) and *Acacia leucophloea* (6.60) while the lowest being reported for *Grevellia robusta, Bauhinia racemosa, Cordia monoica* and 9 others (0.47). Relative basal area was recorded to be highest for *Leucaena leucocephala* (42.34) followed by *Chloroxylon swietenia* (15.79) and *Ficus* spp. (9.17) whereas lowest relative basal area values were found for *Eucalyptus tereticornis* and *Ziziphus mauritiana* (0.01).

Importance value index was calculated to maximum for *Leucaena leucocephala* (65.06) followed by *Chloroxylon swietenia* (45.14) and *Azadirachta indica* (26.89) while the lowest values were found to be for *Eucalyptus tereticornis* and *Ziziphus mauritiana* (0.60).

Table 6. Structural analysis of vegetation in Sambarkode Plantation at Attappady

Sl. No	Species	Density	Rel. density	Abundance	Percentage frequency	Rel. frequency	RBA	IVI	RIVI
1	*Acacia ferruginea*	52.77	4.50	2.92	72.22	6.13	2.86	13.49	4.50
2	*Acacia leucophloea*	40.28	3.44	2.07	77.78	6.60	2.45	12.49	4.16
3	*Acacia mellifera*	11.11	0.95	1.60	27.78	2.36	0.93	4.24	1.41
4	*Acacia nilotica*	25.00	2.13	6.00	16.67	1.42	1.54	5.09	1.70
5	*Acacia planifrons*	22.22	1.90	2.00	44.44	3.77	0.75	6.42	2.14
6	*Acacia polyacantha*	2.78	0.24	1.00	11.11	0.94	0.23	1.41	0.47
7	*Acacia sps.*	2.78	0.24	2.00	5.56	0.47	0.09	0.80	0.27
8	*Albizia amara*	119.44	10.19	7.82	61.11	5.19	3.22	18.60	6.20
9	*Albizia lebbeck*	4.17	0.36	1.00	16.67	1.42	0.05	1.82	0.61
10	*Albizia procera*	2.78	0.24	1.00	11.11	0.94	0.34	1.52	0.51
11	*Annona squamosa*	13.89	1.18	2.00	27.78	2.36	0.22	3.76	1.25
12	*Anogeissus latifolia*	4.17	0.36	1.50	11.11	0.94	0.06	1.36	0.45
13	*Azadirachta indica*	156.93	13.39	7.06	88.89	7.55	5.96	26.89	8.96
14	*Bauhinia racemosa*	1.39	0.12	1.00	5.56	0.47	0.04	0.63	0.21
15	*Calamus spp.*	2.78	0.24	1.00	11.11	0.94	0.03	1.21	0.40
16	*Cassia fistula*	18.05	1.54	2.60	27.78	2.36	1.17	5.07	1.69
17	*Chloroxylon swietenia*	249.98	21.33	10.59	94.44	8.02	15.79	45.14	15.05
18	*Cordia monoica*	1.39	0.12	1.00	5.56	0.47	0.03	0.62	0.21
19	*Cycas circinalis*	1.39	0.12	1.00	5.56	0.47	0.08	0.67	0.22
20	*Dichrostachys cinerea*	4.17	0.36	1.00	16.67	1.42	0.05	1.82	0.61
21	*Diospyros cordifolia*	29.16	2.49	2.33	50.00	4.25	0.32	7.05	2.35
22	*Eucalyptus tereticornis*	1.39	0.12	1.00	5.56	0.47	0.01	0.60	0.20
23	*Ficus spp.*	1.39	0.12	1.00	5.56	0.47	9.17	9.76	3.25
24	*Givotia moluccana*	1.39	0.12	1.00	5.56	0.47	3.74	4.33	1.44
25	*Gmelina arborea*	55.55	4.74	3.33	66.67	5.66	2.15	12.55	4.18
26	*Grevelia robusta*	1.39	0.12	1.00	5.56	0.47	0.13	0.72	0.24
27	*Holoptelia integrifolia*	23.61	2.01	2.13	44.44	3.77	0.70	6.49	2.16

28	*Jacaranda mimosifolia*	5.56	0.47	1.00	22.22	1.89	0.14	2.50	0.83
29	*Jatropha curcus*	6.94	0.59	1.25	22.22	1.89	0.08	2.56	0.85
30	*Leucaena leucocephala*	177.77	15.17	8.00	88.89	7.55	42.34	65.06	21.69
31	*Mundulea serecia*	15.28	1.30	3.67	16.67	1.42	0.31	3.03	1.01
32	*Naringi crenulata*	54.16	4.62	4.88	44.44	3.77	2.28	10.67	3.56
33	*Persea macrantha*	1.39	0.12	1.00	5.56	0.47	0.02	0.61	0.20
34	*Pongamia pinnata*	9.72	0.83	1.75	22.22	1.89	0.53	3.24	1.08
35	*Sapindus emarginatus*	1.39	0.12	1.00	5.56	0.47	0.02	0.61	0.20
36	*Senna siamea*	12.50	1.07	1.50	33.33	2.83	1.08	4.98	1.66
37	*Simarouba glauca*	12.50	1.07	1.80	27.78	2.36	0.59	4.01	1.34
38	*Stereospermum colais*	2.78	0.24	1.00	11.11	0.94	0.14	1.32	0.44
39	*Strychnos potatorum*	15.28	1.30	1.83	33.33	2.83	0.19	4.32	1.44
40	*Syzygium cumini*	1.39	0.12	1.00	5.56	0.47	0.03	0.62	0.21
41	*Tamarindus indica*	1.39	0.12	1.00	5.56	0.47	0.03	0.62	0.21
42	*Ziziphus mauritiana*	1.39	0.12	1.00	5.56	0.47	0.01	0.60	0.20
43	*Ziziphus oenoplina*	1.39	0.12	1.00	5.56	0.47	0.09	0.68	0.23

4.1.1.7. Vellamari plantation

In Vellamari plantation, a total of 547 individuals of GBH >10 cm belonging to 29 species were recorded over an area of 6000 m^2. The maximum number of individuals were recorded from *Albizia amara* (246) in the study area. The relative density was found maximum for *Albizia amara* (44.97) followed by *Chloroxylon swietenia* (11.52) and *Erythroxylum monogynum* (8.41). Lowest values were recorded for *Strychnos potatorum, Simarouba glauca* and 3 others (0.18). Abundance was highest for *Albizia amara* (16.40) followed by *Erythroxylum monogynum* (5.75) and *Chloroxylon swietenia* (5.25).

The species distribution studies in the plantation show that the relative frequency being found highest for *Albizia amara* (11.45) followed by *Chloroxylon swietenia* (9.16) while the lowest being reported for *Strychnos potatorum, Simarouba glauca* and 3 others (0.76). Relative basal area was recorded to be highest for *Albizia amara* (65.90) followed by *Chloroxylon swietenia* (7.60) and *Leucaena leucocephala* (6.57) whereas lowest relative basal area values were found for *Ziziphus mauritiana* and *Cassine albens* (0.01).

Importance value index was calculated to maximum for *Albizia amara* (122.32) followed by *Chloroxylon swietenia* (28.28) and *Erythroxylum monogynum* (18.33) while the lowest values were found to be for *Ziziphus mauritiana* and *Cassine albens* (0.96).

Table 7. Structural analysis of vegetation in Vellamari Plantation at Attappady

Sl No.	Species	Density	Rel. density	Abundance	Percentage frequency	Rel. frequency	RBA	IVI	RIVI
1	*Acacia ferruginea*	5.00	0.55	1.50	13.33	1.53	0.13	2.21	0.74
2	*Acacia ferruginea*	15.00	1.65	4.50	13.33	1.53	1.07	4.25	1.42
3	*Acacia leucophloea*	28.33	3.11	2.43	46.67	5.34	1.12	9.57	3.19
4	*Acacia planifrons*	20.00	2.19	1.71	46.67	5.34	1.09	8.63	2.88
5	*Acacia sinuata*	5.00	0.55	1.00	20.00	2.29	0.03	2.87	0.96
6	*Albizia amara*	410.00	44.97	16.40	100.00	11.45	65.90	122.32	40.77
7	*Albizia procera*	11.67	1.28	1.75	26.67	3.05	3.25	7.59	2.53
8	*Annona squamosa*	1.67	0.18	1.00	6.67	0.76	0.02	0.97	0.32
9	*Azadirachta indica*	36.67	4.02	3.14	46.67	5.34	0.73	10.10	3.37
10	*Cassine albens*	1.67	0.18	1.00	6.67	0.76	0.01	0.96	0.32
11	*Cassine paniculata*	11.67	1.28	1.75	26.67	3.05	1.73	6.06	2.02
12	*Chloroxylon swietenia*	105.00	11.52	5.25	80.00	9.16	7.60	28.28	9.43
13	*Diospyros cordifolia*	20.00	2.19	1.71	46.67	5.34	0.52	8.06	2.69
14	*Erythroxylum monogynum*	76.67	8.41	5.75	53.33	6.11	3.81	18.33	6.11
15	*Euphorbia antiquoram*	15.00	1.65	2.25	26.67	3.05	3.67	8.37	2.79
16	*Gmelina arborea*	38.33	4.20	2.88	53.33	6.11	1.34	11.65	3.88
17	*Leucaena leucocephala*	41.67	4.57	3.13	53.33	6.11	6.57	17.25	5.75
18	*Mundulea serecia*	18.33	2.01	1.83	40.00	4.58	0.22	6.82	2.27
19	*Murraya koengii*	8.33	0.91	2.50	13.33	1.53	0.22	2.66	0.89
20	*Murraya koenigii*	15.00	1.65	1.13	53.33	6.11	0.32	8.07	2.69
21	*Pleiospermium alatum*	3.33	0.37	1.00	13.33	1.53	0.03	1.92	0.64
22	*Simarouba glauca*	1.67	0.18	1.00	6.67	0.76	0.06	1.01	0.34
23	*Stereospermum colais*	3.33	0.37	1.00	13.33	1.53	0.08	1.97	0.66
24	*Strychnos potatorum*	1.67	0.18	1.00	6.67	0.76	0.05	0.99	0.33
25	*Tamarindus indica*	5.00	0.55	1.50	13.33	1.53	0.11	2.18	0.73
26	*Tectona grandis*	3.33	0.37	1.00	13.33	1.53	0.03	1.92	0.64
27	*Terminalia bellerica*	3.33	0.37	1.00	13.33	1.53	0.08	1.97	0.66
28	*Wrightia tinctoria*	3.33	0.37	1.00	13.33	1.53	0.17	2.06	0.69
29	*Ziziphus mauritiana*	1.67	0.18	1.00	6.67	0.76	0.01	0.96	0.32

4.1.1.8. Kottathara Biomass Conservation Area

In Kottathara Biomass area, a total of 547 individuals of GBH >10 cm belonging to 31 species were recorded over an area of 4000 m^2. The maximum numbers of individuals were recorded from *Albizia amara* (190) in the study area. The relative density was found maximum for *Albizia amara* (29.73) followed by *Azadirachta indica* (20.34) and *Mundulea serecia* (8.76). Lowest values were recorded for *Pleiospermium alatum, Anogeissus latifolia* and 7 others (0.16). Abundance was highest for *Albizia amara* (19.00) followed by *Azadirachta indica* (13.00) and *Pterolobium hexapetalum* (7.00).

The species distribution studies in the biomass show that the relative frequency being found highest for *Albizia amara, Azadirachta indica* and *Diospyros cordifolia* (8.85) and followed by *Mundulea serecia* (7.96) while the lowest being reported for *Dalbergia lanceolaria, Albizia procera* and 10 others (0.76). Relative basal area was recorded to be highest for *Albizia amara* (48.43) followed by *Azadirachta indica* (14.93) and *Euphorbia antiquorum* (11.25) whereas lowest relative basal area values were found for *Pleiospermium alatum* (0.02). Importance value index was calculated to maximum for *Albizia amara* (87.01) followed by *Azadirachta indica* (44.13) and *Euphorbia antiquorum* (22.67) while the lowest values were found to be for *Pleiospermium alatum* (1.06).

Table 8. Structural analysis of vegetation in Kottathara Biomass conservation area at Attappady

Sl no.	Species	Density	Rel. density	Abundance	Percentage frequency	Rel. frequency	RBA	IVI	RIVI
1	*Acacia sps.*	2.50	0.16	1.00	10.00	0.88	0.06	1.10	0.37
2	*Albizia amara*	475.00	29.73	19.00	100.00	8.85	48.43	87.01	29.00
3	*Albizia procera*	5.00	0.31	2.00	10.00	0.88	0.64	1.84	0.61
4	*Anogeissus latifolia*	2.50	0.16	1.00	10.00	0.88	0.06	1.10	0.37
5	*Azadirachta indica*	325.00	20.34	13.00	100.00	8.85	14.93	44.13	14.71
6	*Bombax cieba*	2.50	0.16	1.00	10.00	0.88	0.03	1.07	0.36
7	*Cassine albens*	5.00	0.31	1.00	20.00	1.77	0.17	2.26	0.75
8	*Cassine paniculata*	2.50	0.16	1.00	10.00	0.88	0.06	1.11	0.37
9	*Chloroxylon swietenia*	22.50	1.41	1.80	50.00	4.42	1.45	7.28	2.43
10	*Cordia monoica*	5.00	0.31	1.00	20.00	1.77	0.08	2.17	0.72
11	*Dalbergia lanceolaria*	2.50	0.16	1.00	10.00	0.88	0.15	1.20	0.40
12	*Diospyros cordifolia*	75.00	4.69	3.00	100.00	8.85	3.19	16.73	5.58
13	*Erythroxylum monogynum*	125.00	7.82	6.25	80.00	7.08	2.95	17.86	5.95
14	*Euphorbia antiquorum*	97.50	6.10	6.50	60.00	5.31	11.25	22.67	7.56
15	*Ficus spp.*	5.00	0.31	1.00	20.00	1.77	0.07	2.15	0.72
16	*Gmelina arborea*	55.00	3.44	3.14	70.00	6.19	2.52	12.16	4.05
17	*Grewia tiliaefolia*	5.00	0.31	1.00	20.00	1.77	0.04	2.12	0.71
18	*Leucaena leucocephala*	20.00	1.25	2.67	30.00	2.65	0.30	4.21	1.40

19	*Mundulea serecia*	140.00	8.76	6.22	90.00	7.96	2.96	19.69	6.56
20	*Murraya koenigii*	10.00	0.63	1.33	30.00	2.65	0.10	3.38	1.13
21	*Pleiospermium alatum*	2.50	0.16	1.00	10.00	0.88	0.02	1.06	0.35
22	*Pongamia pinnata*	2.50	0.16	1.00	10.00	0.88	0.18	1.22	0.41
23	*Prosopis juliflora*	22.50	1.41	2.25	40.00	3.54	0.97	5.92	1.97
24	*Pterolobium hexapetalum*	122.50	7.67	7.00	70.00	6.19	1.13	14.99	5.00
25	*Sapindus emarginatus*	5.00	0.31	2.00	10.00	0.88	0.70	1.90	0.63
26	*Senna siamea*	37.50	2.35	2.14	70.00	6.19	5.85	14.39	4.80
27	*Strychnos potatorum*	5.00	0.31	1.00	20.00	1.77	0.07	2.15	0.72
28	*Tamarindus indica*	2.50	0.16	1.00	10.00	0.88	0.81	1.85	0.62
29	*Tectona grandis*	7.50	0.47	3.00	10.00	0.88	0.63	1.99	0.66
30	*Terminalia bellerica*	2.50	0.16	1.00	10.00	0.88	0.13	1.17	0.39
31	*Ziziphus mauritiana*	5.00	0.31	1.00	20.00	1.77	0.04	2.13	0.71

4.1.1.9. Palliyara Biomass Conservation Area

In Palliyara Biomass area, a total of 907 individuals of GBH >10 cm belonging to 57 species were recorded over an area of 5200 m^2. The maximum numbers of individuals were recorded from *Santalum album* (237) in the study area. The relative density was found maximum for *Santalum album* (26.13) followed by *Tectona grandis* (17.86) Lowest values were recorded for *Trewia nudiflora, Flugea virosa* and 2 others (0.11). Abundance was highest for *Santalum album* (18.23) followed by *Tectona grandis* (16.20), *Cassia fistula (13.67) and Pterocarpus marsupium* (10.33). The species distribution studies in this biomass area show that the relative frequency being found highest for *Santalum album* (5.78) followed by *Zyziphus mauritiana* (4.89) while the lowest being reported for *Trewia nudiflora, Flugea virosa* and 10 others (0.76). Relative basal area was recorded to be highest for *Tectona grandis* (26.41) followed by *Givotia mollucana* (15.03) and *Santalum album* (14.20) whereas lowest relative basal area values were found for *Dalbergia lanceolaria* and *Murraya paniculata* (0.01)

Importance value index was calculated to maximum for *Tectona grandis* (48.71) followed by *Santalum album* (46.11) and *Givotia mollucana* (16.80) while the lowest values were found to be for *Dalbergia lanceolaria, Flugea virosa* and 2 others (0.57).

Table 9. Structural analysis of vegetation in Palliyara Biomass conservation area at Attappady.

Sl NO.	Species	Density	Rel. density	Abundance	Percentage frequency	Rel. frequency	RBA	IVI	RIVI
1	*Acacia chundra*	13.46	0.77	1.40	38.46	2.22	1.76	4.76	1.59
2	*Acacia ferruginea*	40.38	2.32	2.33	69.23	4.00	4.15	10.47	3.49
3	*Acacia leucophloea*	7.69	0.44	1.33	23.08	1.33	0.89	2.67	0.89
4	*Acacia planifrons*	40.38	2.32	4.20	38.46	2.22	2.01	6.54	2.18
5	*Acacia sinuata*	5.77	0.33	1.00	23.08	1.33	0.04	1.70	0.57
6	*Albizia amara*	1.92	0.11	1.00	7.69	0.44	0.04	0.59	0.20
7	*Albizia lebbeck*	36.54	2.09	2.71	53.85	3.11	3.25	8.46	2.82
8	*Albizia procera*	7.69	0.44	1.33	23.08	1.33	0.16	1.94	0.65
9	*Annona squamosa*	11.54	0.66	1.50	30.77	1.78	0.10	2.54	0.85
10	*Anogeissus latifolia*	61.54	3.53	3.20	76.92	4.44	2.78	10.75	3.58
11	*Anogeissus spp.*	23.08	1.32	4.00	23.08	1.33	0.49	3.14	1.05
12	*Atalantia monophylla*	3.85	0.22	1.00	15.38	0.89	0.02	1.13	0.38
13	*Azadirachta indica*	9.62	0.55	1.00	38.46	2.22	0.48	3.25	1.08
14	*Bombax cieba*	3.85	0.22	1.00	15.38	0.89	0.10	1.21	0.40
15	*Bridelia retusa*	15.38	0.88	1.60	38.46	2.22	1.64	4.75	1.58
16	*Cassia fistula*	78.85	4.52	13.67	23.08	1.33	2.08	7.93	2.64
17	*Cassia sps.*	1.92	0.11	1.00	7.69	0.44	0.02	0.57	0.19
18	*Cassine paniculata*	76.92	4.41	5.71	53.85	3.11	2.35	9.87	3.29
19	*Dalbergia horida*	3.85	0.22	1.00	15.38	0.89	0.21	1.32	0.44
20	*Dalbergia lanceolaria*	1.92	0.11	1.00	7.69	0.44	0.01	0.57	0.19
21	*Dalbergia latifolia*	9.62	0.55	1.00	38.46	2.22	0.11	2.88	0.96
22	*Dichrostachys cinerea*	7.69	0.44	1.33	23.08	1.33	0.25	2.03	0.68
23	*Diospyros cordifolia*	9.62	0.55	1.67	23.08	1.33	0.24	2.12	0.71
24	*Diospyros melanoxylon*	17.31	0.99	2.25	30.77	1.78	1.28	4.05	1.35
25	*Erythrina sp.*	1.92	0.11	1.00	7.69	0.44	0.02	0.58	0.19
26	*Eucaluptus sp.*	19.23	1.10	2.50	30.77	1.78	0.17	3.05	1.02
27	*Ficus spp.*	1.92	0.11	1.00	7.69	0.44	0.02	0.57	0.19
28	*Flugea virosa*	1.92	0.11	1.00	7.69	0.44	0.01	0.57	0.19
29	*Givotia moluccana*	7.69	0.44	1.33	23.08	1.33	15.03	16.80	5.60
30	*Gmelina arborea*	7.69	0.44	1.00	30.77	1.78	0.15	2.37	0.79
31	*Gmelina spp.*	9.62	0.55	5.00	7.69	0.44	0.48	1.47	0.49
32	*Gravelia robusta*	19.23	1.10	2.00	38.46	2.22	0.52	3.84	1.28
33	*Grewia species*	7.69	0.44	1.33	23.08	1.33	0.14	1.91	0.64
34	*Grewia tiliaefolia*	50.00	2.87	2.60	76.92	4.44	2.00	9.31	3.10
35	*Leucaena leucocephala*	11.54	0.66	2.00	23.08	1.33	0.07	2.07	0.69
36	*Melia azedarach*	1.92	0.11	1.00	7.69	0.44	0.99	1.55	0.52

37	*Morinda tinctoria*	9.62	0.55	1.00	38.46	2.22	0.96	3.73	1.24
38	*Murraya paniculata*	1.92	0.11	1.00	7.69	0.44	0.01	0.57	0.19
39	*Murraya koenigii*	13.46	0.77	1.40	38.46	2.22	0.17	3.17	1.06
40	*Naringi crenulata*	21.15	1.21	2.20	38.46	2.22	0.71	4.14	1.38
41	*Phyllanthus embellica*	13.46	0.77	2.33	23.08	1.33	0.19	2.29	0.76
42	*Pleiospermium alatum*	5.77	0.33	1.50	15.38	0.89	2.19	3.41	1.14
43	*Pongamia pinnata*	3.85	0.22	1.00	15.38	0.89	0.09	1.20	0.40
44	*Psidium guajava*	9.62	0.55	1.25	30.77	1.78	0.09	2.42	0.81
45	*Pterocarpus marsupium*	59.62	3.42	10.33	23.08	1.33	5.25	10.00	3.33
46	*Santalum album*	455.77	26.13	18.23	100.00	5.78	14.20	46.11	15.37
47	*Simarouba glauca*	25.00	1.43	2.60	38.46	2.22	1.52	5.17	1.72
48	*Stereospermum colais*	15.38	0.88	2.00	30.77	1.78	0.70	3.36	1.12
49	*Streblus asper*	3.85	0.22	2.00	7.69	0.44	0.07	0.73	0.24
50	*Strychnos potatorum*	21.15	1.21	2.20	38.46	2.22	0.47	3.91	1.30
51	*syzygium cumini*	15.38	0.88	2.67	23.08	1.33	0.43	2.64	0.88
52	*Tamarindus indica*	13.46	0.77	1.40	38.46	2.22	0.09	3.08	1.03
53	*Tectona grandis*	311.54	17.86	16.20	76.92	4.44	26.41	48.71	16.24
54	*Terminalia chebula*	1.92	0.11	1.00	7.69	0.44	0.04	0.59	0.20
55	*Trewia nudiflora*	1.92	0.11	1.00	7.69	0.44	0.04	0.59	0.20
56	*Wrightia tinctoria*	7.69	0.44	1.33	23.08	1.33	0.05	1.83	0.61
57	*Ziziphus mauritiana*	107.69	6.17	5.09	84.62	4.89	2.28	13.35	4.45

4.1.1.10. Sambarkode Biomass Conservation Area

A total of 576 individuals of GBH >10 cm belonging to 54 species were recorded over an area of 4800 m^2 in Sambarkode biomass conservation area. The maximum number of individuals were recorded from *Chloroxylon sweitenia* (88.00) in the study area. The relative density was found maximum for *Chloroxylon sweitenia* (15.28) followed by *Azadirachta indica* (14.76) while lowest values were recorded for *Tectona grandis, Annona squamosa, Santalum album* and 11 others (0.17). Abundance was highest for *Chloroxylon sweitenia* (9.78) followed by *Azadirachta indica* (7.08), *Simarouba glauca* (7.00) *and Prosopis juliflora* (5.00).

The species distribution studies in this biomass area show that the relative frequency being found highest for *Chloroxylon sweitenia* (6.78) and followed by *Anogeissus latifolia* (5.65), and *Albizia almara, Givotia mollucana, Chloroxylon sweitenia* with value of (5.08). Relative basal area was recorded to be highest for *Givotia mollucana* (41.23) followed by *Chloroxylon sweitenia* (11.56) and *Albizia amara* (7.60) whereas lowest relative basal area values were found for *Acacia sinuata, Annona squamosa* and 3 others (0.01).

Importance value index was calculated to maximum for *Givotia mollucana* (50.31) followed by *Chloroxylon sweitenia* (31.92) while the lowest values were found to be for *Erythroxylum monogynum* and 2 others (0.75).

Table 10.Structural analysis of vegetation in Sambarkode Biomass conservation area, Attappady

Sl No.	Species	Density	Rel. density	Abundance	Percentage Frequency	Rel. Frequency	RBA	IVI	RIVI
1	*Acacia ferruginea*	2.08	0.17	1.00	8.33	0.56	0.23	0.97	0.32
2	*Acacia leucophloea*	2.08	0.17	1.00	8.33	0.56	0.35	1.09	0.36
3	*Acacia planifrons*	16.67	1.39	4.00	16.67	1.13	0.87	3.38	1.13
4	*Acacia planifrons*	20.83	1.74	2.50	33.33	2.26	2.10	6.09	2.03
5	*Acacia sinuata*	2.08	0.17	1.00	8.33	0.56	0.01	0.75	0.25
6	*Albizia amara*	89.58	7.47	4.78	75.00	5.08	7.60	20.15	6.72
7	*Albizia lebbeck*	10.42	0.87	1.67	25.00	1.69	1.41	3.97	1.32
8	*Albizia procera*	22.92	1.91	2.75	33.33	2.26	2.06	6.23	2.08
9	*Albizia sps.*	27.08	2.26	2.60	41.67	2.82	2.36	7.44	2.48
10	*Annona squamosa*	2.08	0.17	1.00	8.33	0.56	0.01	0.75	0.25
11	*Anogeissus latifolia*	54.17	4.51	2.60	83.33	5.65	1.34	11.50	3.83
12	*Azadirachta indica*	177.08	14.76	7.08	100.00	6.78	7.29	28.82	9.61
13	*Bauhinia racemosa*	2.08	0.17	1.00	8.33	0.56	0.01	0.75	0.25
14	*Bombax cieba*	2.08	0.17	1.00	8.33	0.56	0.18	0.91	0.30
15	*Cassia fistula*	12.50	1.04	2.00	25.00	1.69	0.33	3.07	1.02
16	*cassia tora*	4.17	0.35	2.00	8.33	0.56	0.03	0.94	0.31
17	*Cassine albens*	16.67	1.39	4.00	16.67	1.13	0.53	3.05	1.02
18	*Cassine paniculata*	10.42	0.87	1.25	33.33	2.26	0.23	3.36	1.12
19	*Chloroxylon swietenia*	183.33	15.28	9.78	75.00	5.08	11.56	31.92	10.64
20	*Dalbergia horrida*	2.08	0.17	1.00	8.33	0.56	0.08	0.82	0.27
21	*Dalbergia latifolia*	4.17	0.35	1.00	16.67	1.13	0.17	1.65	0.55
22	*Dichrostachys cinerea*	12.50	1.04	1.20	41.67	2.82	0.40	4.27	1.42
23	*Diospyros cordifolia*	22.92	1.91	1.57	58.33	3.95	0.14	6.00	2.00
24	*Diospyros melanoxylon*	4.17	0.35	1.00	16.67	1.13	0.16	1.63	0.54
25	*Erythroxylum monogynum*	2.08	0.17	1.00	8.33	0.56	0.01	0.75	0.25
26	*Givotia moluccana*	47.92	3.99	2.56	75.00	5.08	41.23	50.31	16.77
27	*Gmelina arborea*	16.67	1.39	1.60	41.67	2.82	0.25	4.46	1.49
28	*Gravelia robusta*	10.42	0.87	2.50	16.67	1.13	0.17	2.17	0.72
29	*Grewia tiliaefolia*	4.17	0.35	2.00	8.33	0.56	0.18	1.09	0.36

30	*Haldina cordifolia*	10.42	0.87	1.67	25.00	1.69	1.23	3.80	1.27
31	*Holoptelia integrifolia*	6.25	0.52	1.00	25.00	1.69	0.93	3.15	1.05
32	*Jacaranda mimosifolia*	6.25	0.52	3.00	8.33	0.56	0.03	1.12	0.37
33	*Leucaena leucocephala*	31.25	2.60	3.00	41.67	2.82	2.38	7.81	2.60
34	*Melia species*	2.08	0.17	1.00	8.33	0.56	0.03	0.77	0.26
35	*Morinda tinctoria*	4.17	0.35	2.00	8.33	0.56	0.14	1.06	0.35
36	*Murraya koenigii*	6.25	0.52	1.50	16.67	1.13	0.06	1.71	0.57
37	*Naringi crenulata*	4.17	0.35	2.00	8.33	0.56	0.19	1.11	0.37
38	*Phyllanthus embellica*	18.75	1.56	3.00	25.00	1.69	0.24	3.50	1.17
39	*Pleiospermium alatum*	2.08	0.17	1.00	8.33	0.56	0.03	0.77	0.26
40	*Prosopis juliflora*	20.83	1.74	5.00	16.67	1.13	1.12	3.99	1.33
41	*Santalum album*	2.08	0.17	1.00	8.33	0.56	0.14	0.88	0.29
42	*Senna siamea*	50.00	4.17	4.00	50.00	3.39	2.33	9.89	3.30
43	*Simarouba glauca*	43.75	3.65	7.00	25.00	1.69	1.79	7.13	2.38
44	*Sterculia guttata*	2.08	0.17	1.00	8.33	0.56	0.04	0.78	0.26
45	*Sterculia urens*	6.25	0.52	1.00	25.00	1.69	2.01	4.22	1.41
46	*Stereospermum colais*	10.42	0.87	1.25	33.33	2.26	0.32	3.45	1.15
47	*Strychnos nux-vomica*	4.17	0.35	2.00	8.33	0.56	0.09	1.00	0.33
48	*Strychnos potatorum*	58.33	4.86	3.50	66.67	4.52	0.81	10.19	3.40
49	*Tecoma stans*	16.67	1.39	2.67	25.00	1.69	0.16	3.25	1.08
50	*Tectona grandis*	2.08	0.17	1.00	8.33	0.56	0.16	0.90	0.30
51	*Terminalia bellerica*	12.50	1.04	2.00	25.00	1.69	0.53	3.26	1.09
52	*Wrightia tinctoria*	77.08	6.42	4.63	66.67	4.52	3.68	14.63	4.88
53	*Ziziphus mauritiana*	2.08	0.17	1.00	8.33	0.56	0.01	0.75	0.25
54	*Ziziphus xylopyrus*	14.58	1.22	3.50	16.67	1.13	0.24	2.58	0.86

4.2 DIVERSITY ANALYSIS

4.2.1 Shannon Weiner index (H′)

Shannon-weiner index values varied among plantations and biomass in the study area of Eastern Attappady. The Shannon-weiner index values for different study areas ranged from 2.10 to 4.60. The Shannon index value was found maximum for the Agali plantation (3.93) followed by Sambarkode plantation (3.88) whereas Shannon Weiner value was found lowest for the Kottathara plantation (2.10). Among the biomass conservation area Sambarkode biomass had the highest value (4.6) followed by Palliyara biomass (4.2) while lowest value was reported for Kottathara biomass (3.29).

4.2.2 Simpson's index

Simpson's index values during the study ranged from 0.67 to 0.93. The Simpson's index diversity was found maximum for the Sambarkode plantation (0.89) followed by Mellechavadiyoor plantation (0.88) whereas lowest recorded for the Kottathara plantation (0.67) followed by Vellamari plantation (0.77). The diversity analysis in the biomass conservation area indicated that Sambarkode biomass had the highest value (0.93) followed by Palliyara biomass (0.89) while lowest value was reported for Kottathara biomass (0.84).

4.2.3 Equitability (e)

Along with diversity indices, Equitability was analyzed for the study area which was found to be ranged from 0.50 to 0.80. Equitability was found maximum for the Mellechavadiyoor plantation (0.73) followed by Sambarkode plantation (0.72) whereas lowest recorded for the Kottathara plantation (0.50) followed by Pattimalam plantation (0.61). Equitability in the biomass conservation area was found to be highest (0.80) for Sambarkode biomass followed by Palliyara biomass (0.72) while lowest value was reported for Kottathara biomass (0.66).

4.3.4 Concentration of dominance (Cd)

The concentration of dominance values for different vegetations were found in the range of 0.33 to 0.07. Concentration of dominance was found highest for the Sambarkode plantation (0.11) and lowest for Kottathara plantation (0.33). In the biomass conservation areas, Sambarkode biomass area had highest concentration of dominance (0.07) while lowest was noted for Kottathara biomass area (0.16).

Table 11. Analysis of Diversity indices in Plantation and Biomass conservation areas, Attappady

Sl No.	Plantation/ Biomass	Cd (Concentration of Dominance)	Simpson index	Shannon - Weiner's index	H MAX	Equitabilty (E)
1	Agali Plantation	0.14	0.86	3.93	5.58	0.70
2	Kottathara Plantation	0.33	0.67	2.10	4.17	0.50
3	Melle Chavadiyur Plantation	0.12	0.88	3.79	5.17	0.73
4	Palliyara Plantation	0.16	0.84	3.48	5.25	0.66
5	Pattimalam Plantation	0.22	0.78	2.70	4.39	0.61
6	Sambarkode Plantation	0.11	0.89	3.88	5.43	0.72
7	Vellamari Plantation	0.23	0.77	3.14	4.86	0.65
8	Kottathara Biomass	0.16	0.84	3.29	4.95	0.66
9	Palliyara Biomass	0.11	0.89	4.20	5.83	0.72
10	Sambarkode Biomass	0.07	0.93	4.60	5.75	0.80

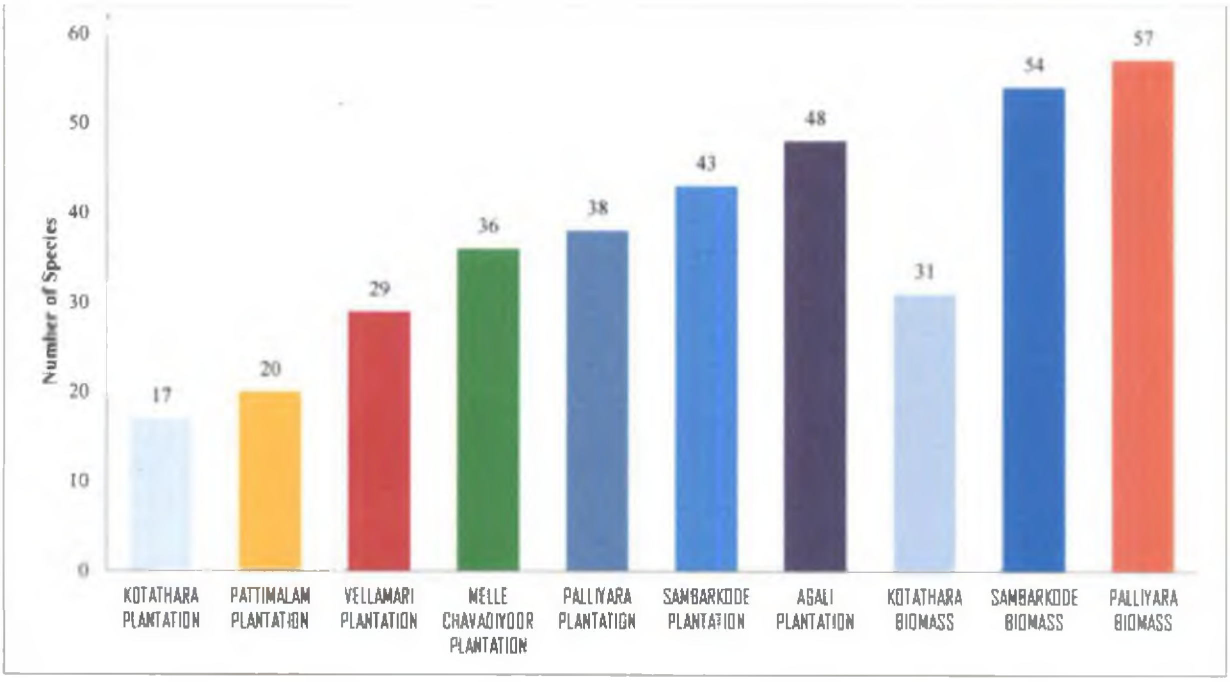


Fig.4. Total species recorded in plantations and biomass

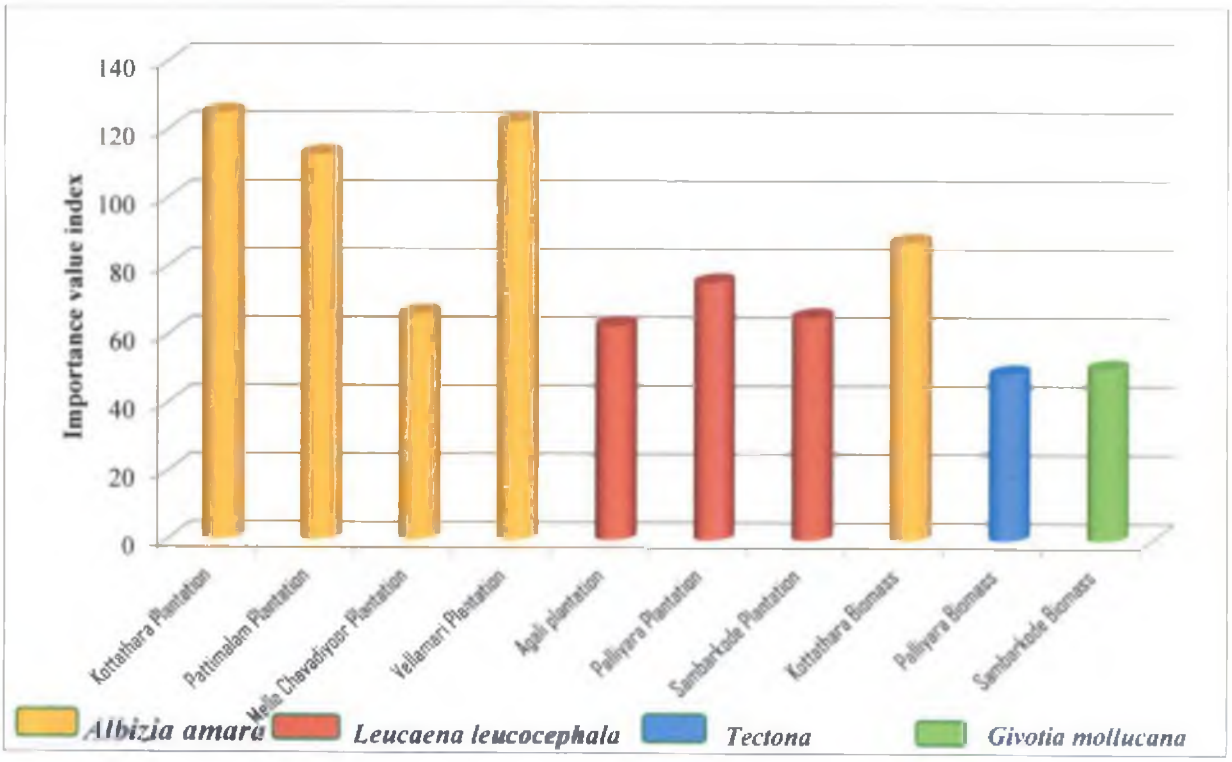


Fig.5. Importance value Index of the dominant species in the study areas of Eastern Attappady

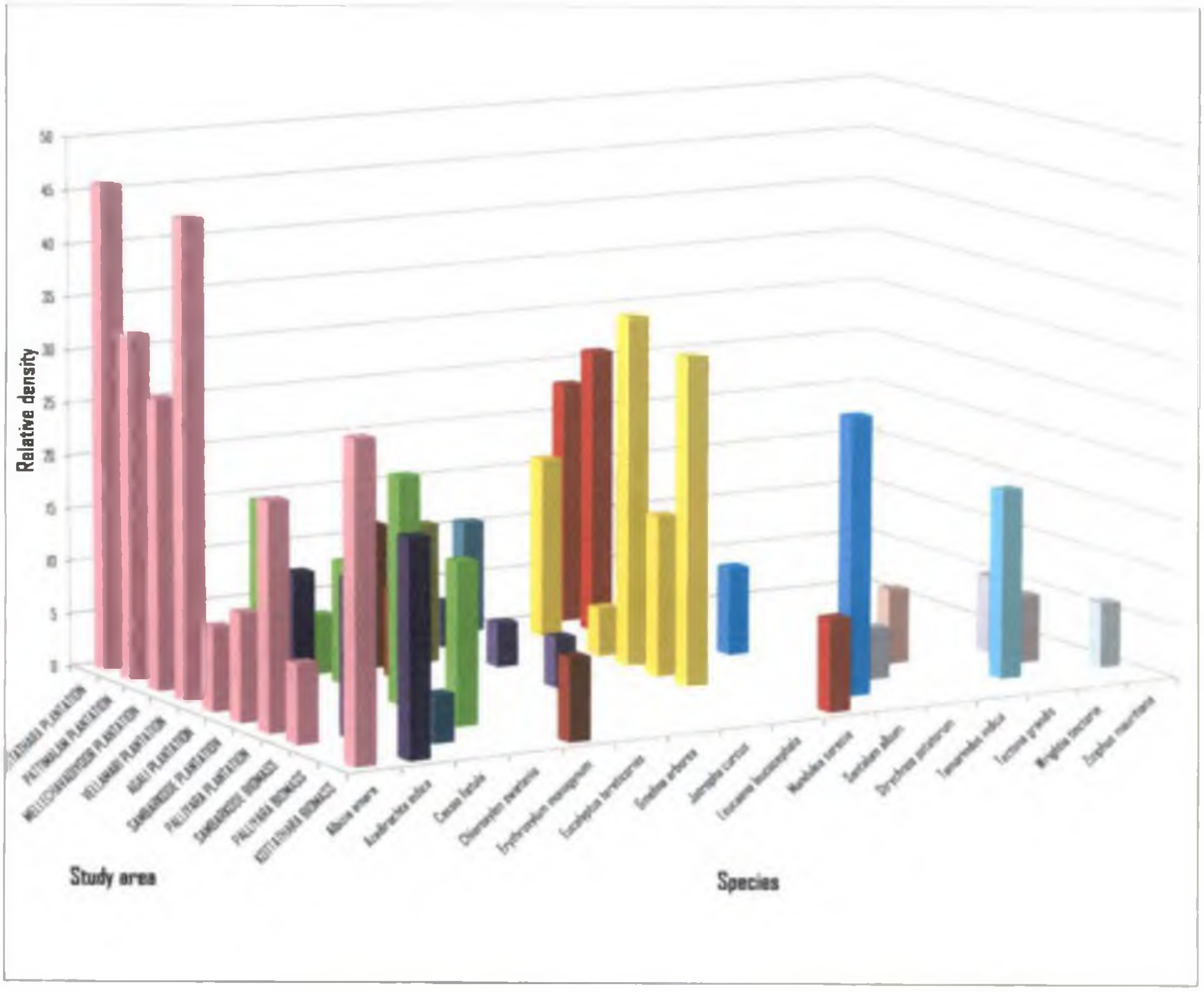


Fig.6. Dominant Species in Attappady

4.3 REGENERATION ANALYSIS

4.3.1 Kottathara Plantation

Regeneration analysis of the Kottathara plantation revealed that the relative density was found maximum for *Mundulea serecia* (33.33) followed by *Albizia amara* (23.81) while lowest values were recorded for *Acacia planifrons and Naringi crenulata* (0.17). Abundance was highest for *Mundulea serecia* (3.50) followed by *Azadirachta indica* (3.00). The species distribution studies for regeneration in the plantation show that the relative frequency was found highest for *Albizia amara, Chloroxylon swietenia* and *Mundulea serecia* (22.22) while the lowest being reported for *Diospyros cordifolia* and 3 others (5.56).

Table 12. Regeneration analysis of vegetation in Kottathara plantation at Attappady.

Sl no	Species	Density	Rel. Density	Abundance	Percentage Frequency	Rel. Frequency
1	*Acacia planifrons*	4.17	2.38	1.00	16.67	5.56
2	*Albizia amara*	41.67	23.81	2.50	66.67	22.22
3	*Chloroxylon swietenia*	37.50	21.43	2.25	66.67	22.22
4	*Diospyros cordifolia*	4.17	2.38	1.00	16.67	5.56
6	*Jatropha curcus*	12.50	7.14	1.50	33.33	11.11
7	*Mundulea serecia*	58.33	33.33	3.50	66.67	22.22
10	*Naringi crenulata*	4.17	2.38	1.00	16.67	5.56
11	*Senna siamea*	12.50	7.14	3.00	16.67	5.56

4.3.2 Melle Chavadiyoor Plantation

In Melle Chavadiyoor plantation the relative density was found maximum for *Murraya koenigii* (56.50) followed by *Albizia amara* (11.58) while lowest values were recorded for *Givotia molucana, Azadirachta indica* and two others (0.28). Abundance was highest for *Murraya koenigii* (40.00) followed by *Atalantia monophylla* (17.50). The species distribution studies for regeneration in the plantation show that the relative frequency was found highest for *Zizyphus mauritiana* (18.75) while lowest being reported for *Givotia molucana, Azadirachta indica* and 3 others (3.13).

Table 13. Regeneration analysis of vegetation in Melle Chavadiyoor plantation at Attappady.

Sl no	Species	Density	Rel. Density	Abundance	Percentage Frequency	Rel. Frequency
1	*Acacia ferruginea*	5.55	0.56	1.00	22.22	6.25
2	*Albizia amara*	113.86	11.58	13.67	33.33	9.38
3	*Atalantia monophylla*	97.20	9.89	17.50	22.22	6.25
4	*Azadirachta indica*	2.78	0.28	1.00	11.11	3.13
5	*Bauhinia racemosa*	2.78	0.28	1.00	11.11	3.13
6	*Chloroxylon swietenia*	72.20	7.34	6.50	44.44	12.50
7	*Cordia monoica*	2.78	0.28	1.00	11.11	3.13
8	*Diospyros cordifolia*	91.64	9.32	16.50	22.22	6.25
9	*Givotia mollucana*	2.78	0.28	1.00	11.11	3.13
10	*Gmelina arborea*	8.33	0.85	3.00	11.11	3.13
11	*Mundulea serecia*	8.33	0.85	1.00	33.33	9.38
12	*Murraya koenigii*	555.40	56.50	40.00	55.56	15.63
13	*Ziziphus mauritiana*	19.44	1.98	1.17	66.67	18.75

4.3.3 Pattimalam Plantations.

In Pattimalam plantation the relative density was found maximum for *Albizia amara* (29.47) followed by *Mundulea serecia* (26.49) while lowest values were recorded for *Dichrostachys ceneria* and two others (0.17). Abundance was highest for *Murraya koenigii* (64.00) followed by *Albizia amara* (44.50). The species distribution studies for regeneration in the plantation show that the relative frequency was found highest for *Diospyros cordifolia* (16.67) while the lowest being reported for *Murraya koenigii, Senna siamea* and 3 others (2.78).

Table 14. Regeneration analysis of vegetation in Pattimalam plantation at Attappady.

Sl no.	Species	Density	Rel. Density	Abundance	Percentage Frequency	Rel. Frequency
1	*Acacia leucophloea*	5.00	0.33	1.00	20.00	5.56
2	*Acacia planifrons*	7.50	0.50	1.50	20.00	5.56
3	*Albizia amara*	445.00	29.47	44.50	40.00	11.11
4	*Azadirachta indica*	7.50	0.50	1.50	20.00	5.56
5	*Chloroxylon swietenia*	35.00	2.32	3.50	40.00	11.11
6	*Dichrostachys cinerea*	2.50	0.17	1.00	10.00	2.78
7	*Diospyros cordifolia*	335.00	22.19	22.33	60.00	16.67
8	*Gmelina arborea*	15.00	0.99	2.00	30.00	8.33
9	*Holoptelia integrifolia*	2.50	0.17	1.00	10.00	2.78
10	*Leucaena leucocephala*	87.50	5.79	8.75	40.00	11.11
11	*Mundulea serecia*	400.00	26.49	40.00	40.00	11.11

12	*Murraya koenigii*	160.00	10.60	64.00	10.00	2.78
13	*Pongamia sp..*	2.50	0.17	1.00	10.00	2.78
14	*Senna siamea*	5.00	0.33	2.00	10.00	2.78

4.3.4 Sambarkode Plantations.

Regeneration analysis of the Sambarkode plantation unveiled that the relative density was found maximum for *Leucaena leucocephala* (78.6) followed by *Azadirachta indica* (7.20) while lowest values were recorded for *Tamarindus indica* and *Mundulea serecia* (0.10). Abundance was highest for *Leucaena leucocephala* (133.90) followed by *Azadirachta indica* (17.20). The species distribution studies for regeneration in the plantation show that the relative frequency was found highest for *Leucaena leucocephala* (133.90) followed *Gmelina arborea* (16.67) while the lowest being reported for *Mundulea serecia, Cassia fistula* and 2 others (2.00).

Table 15. Regeneration analysis of vegetation in Sambarkode plantation at Attappady

Sl no	Species	Density	Rel. Density	Abundance	Percentage Frequency	Rel. Frequency
1	*Albizia amara*	5.60	0.20	1.00	22.20	3.90
2	*Annona squamosa*	47.20	1.40	8.50	22.20	3.90
3	*Azadirachta indica*	238.90	7.20	17.20	55.60	9.80
4	*Cassia fistula*	11.10	0.30	4.00	11.10	2.00
5	*Chloroxylon swietenia*	63.90	1.90	4.60	55.60	9.80
6	*Diospyros cordifolia*	25.00	0.80	2.30	44.40	7.80
7	*Gmelina arborea*	30.60	0.90	1.80	66.70	11.80
8	*Holoptelia integrifolia*	47.20	1.40	5.70	33.30	5.90
9	*Leucaena leucocephala*	2602.70	78.60	133.90	77.80	13.70
10	*Mundulea serecia*	2.80	0.10	1.00	11.10	2.00
11	*Naringi crenulata*	16.70	0.50	1.50	44.40	7.80
12	*Simarouba glauca*	8.30	0.30	3.00	11.10	2.00
13	*Strychnos potatorum*	61.10	1.80	5.50	44.40	7.80
14	*Tamarindus indica*	2.80	0.10	1.00	11.10	2.00
15	*Ziziphus sp.*	147.20	4.40	10.60	55.60	9.80

4.3.5 Vellamari Plantations

In Vellamari plantation the relative density was found maximum for *Leucaena leucocephala* (45.60) followed by *Mundulea serecia* (16.50) while lowest values were recorded for *Wrightia tinctoria* (0.20) followed by *Cassine albens* (0.40). Abundance was highest for *Leucaena leucocephala* (34.00) followed by *Mundulea serecia* (21.50) while the lowest were recorded for

Cassine albens and *Wrightia tinctoria* (0.10). The species distribution studies for regeneration in the plantation show that the relative frequency was found highest for *Leucaena leucocephala* and *Murraya koenigii* (14.00) while the lowest being reported for *Diospyros cordifolia and 2* others (2.00).

Table16. Regeneration analysis of vegetation in Vellamari plantation at Attappady

Sl no.	Species	Density	Rel. Density	Abundance	Percentage Frequency	Rel. Frequency
1	*Acacia ferruginea*	7.50	0.60	3.00	10.00	2.00
2	*Acacia planifrons*	7.50	0.60	1.50	20.00	4.00
3	*Albizia amara*	175.00	13.40	11.70	60.00	12.00
4	*Azadirachta indica*	70.00	5.40	4.70	60.00	12.00
5	*Cassine albens*	5.00	0.40	1.00	20.00	4.00
6	*Chloroxylon swietenia*	52.50	4.00	5.30	40.00	8.00
7	*Diospyros cordifolia*	7.50	0.60	3.00	10.00	2.00
8	*Erythroxylum monogynum*	12.50	1.00	1.30	40.00	8.00
9	*Gmelina arborea*	20.00	1.50	1.60	50.00	10.00
10	*Leucaena leucocephala*	595.00	45.60	34.00	70.00	14.00
11	*Mundulea serecia*	215.00	16.50	21.50	40.00	8.00
12	*Murraya koenigii*	135.00	10.30	7.70	70.00	14.00
13	*Wrightia tinctoria*	2.50	0.20	1.00	10.00	2.00

4.3.6 Agali Plantations

Regeneration analysis of the Agali plantation revealed that the relative density was found maximum for *Leucaena leucocephala* (92.70) followed by *Zyziphus oenoplina* (2.30) while lowest values were recorded for *Commiphora caudata and 4 others* (0.10). Abundance was highest for *Leucaena leucocephala* (1545.50) followed by *Zyziphus oenoplina* (47.70) while lowest values were recorded for *Commiphora caudata and 4 others* (1.00). The species distribution studies for regeneration in the plantation show that the relative frequency was found highest for *Leucaena leucocephala* (9.80) and *Ziziphus mauritiana* (8.90) followed by *Santalum album* and *Ziziphus oenoplina* (8.00) while the lowest being reported for *Givotia mollucana and 5* others (2.00).

Table 17. Regeneration analysis of vegetation in Agali plantation at Attappady

Sl. No.	Species	Density	Rel. Density	Abundance	Percentage Frequency	Rel. Frequency
1	*Albizia amara*	9.10	0.02	2.00	18.20	1.80
2	*Albizia lebbeck*	9.10	0.02	1.30	27.30	2.70
3	*Annona squamosa*	47.70	0.11	3.50	54.50	5.40
4	*Azadirachta indica*	9.10	0.02	1.30	27.30	2.70
5	*Bauhinia racemosa*	6.80	0.02	1.50	18.20	1.80
6	*Bombax cieba*	22.70	0.05	2.00	45.50	4.50
7	*Commiphora caudata*	2.30	0.01	1.00	9.10	0.90
8	*Diospyros cordifolia*	84.10	0.20	7.40	45.50	4.50
9	*Givotia moluccana*	4.50	0.01	2.00	9.10	0.90
10	*Gravelia robusta*	2.30	0.01	1.00	9.10	0.90
11	*Grewia hirsuta*	186.30	0.45	11.70	63.60	6.30
12	*Grewia tiliaefolia*	172.70	0.41	9.50	72.70	7.10
13	*Haldina cordifolia*	2.30	0.01	1.00	9.10	0.90
14	*Holoptelia integrifolia*	6.80	0.02	1.50	18.20	1.80
15	*Leucaena leucocephala*	38624.00	92.70	1545.50	100.00	9.80
16	*Naringi crenulata*	727.00	1.74	45.70	63.60	6.30
17	*Santalum album*	338.50	0.81	16.60	81.80	8.00
18	*Senna siamea*	11.40	0.03	5.00	9.10	0.90
19	*Simarouba glauca*	2.30	0.01	1.00	9.10	0.90
20	*Strychnos potatorum*	29.50	0.07	2.60	45.50	4.50
21	*Tectona grandis*	31.80	0.08	2.00	63.60	6.30
22	*Wrightia tinctoria*	50.00	0.12	4.40	45.50	4.50
23	*Ziziphus mauritiana*	311.30	0.75	13.70	90.90	8.90
24	*Ziziphus oenoplia*	974.70	2.34	47.70	81.80	8.00

4.3.7 Palliyara Plantations

In Palliyara plantation the relative density was found maximum for *Leucaena leucocephala* (93.70) followed by *Albizia amara* (1.90) and *Murraya koenigii* (1.30) while lowest values were recorded for *Canthium coromandelicum* (0.01). Abundance was highest for *Leucaena leucocephala* (2200.00) followed by *Albizia amara* (60.80) and *Murraya koenigii* (35.00) while the lowest were recorded for *Canthium coromandelicum* (1.00). Regeneration in the plantation show that the relative frequency was found highest for *Zizyphus spp*. and *Leucaena leucocephala* (9.30) followed by *Murraya koengii* and *Naringi crenulata* (8.10) while the lowest being reported for *Canthium coromandelicum* (1.20).

Table 18. Regeneration analysis of vegetation in Palliyara plantation at Attappady

Sl. No.	Species	Density	Rel. Density	Abundance	Percentage Frequency	Rel. Frequency
1	*Tamarindus indica*	175.00	0.37	11.70	60.00	7.00
2	*Strychnous potatorum*	127.50	0.27	12.80	40.00	4.70
3	*Holoptelia integrifolia*	17.50	0.04	2.30	30.00	3.50
4	*Dichrostachys cineraria*	47.50	0.10	6.30	30.00	3.50
5	*Albizia amara*	912.50	1.94	60.80	60.00	7.00
6	*Leucaenae leucocephala*	44000.00	93.66	2200.00	80.00	9.30
7	*Bamboosa bambos*	25.00	0.05	3.30	30.00	3.50
8	*Dendrocalamus strictus*	120.00	0.26	24.00	20.00	2.30
9	*Murraya koenigii*	612.50	1.30	35.00	70.00	8.10
10	*Naringi crenulata*	197.50	0.42	11.30	70.00	8.10
11	*Azadiracta indica*	135.00	0.29	10.80	50.00	5.80
12	*Acacia leucopholea*	12.50	0.03	2.50	20.00	2.30
13	*Zizyphus spp.*	377.50	0.80	18.90	80.00	9.30
14	*Dichrostachys cineraria*	15.00	0.03	3.00	20.00	2.30
15	*Grewia tilifolia*	85.00	0.18	8.50	40.00	4.70
16	*Achras sapota*	12.50	0.03	1.70	30.00	3.50
17	*Holoptelia integrifolia*	17.50	0.04	2.30	30.00	3.50
18	*Acacia polycantha*	52.50	0.11	4.20	50.00	5.80
19	*Canthium coromandelicum*	2.50	0.01	1.00	10.00	1.20
20	*Acacia sinuata*	35.00	0.07	3.50	40.00	4.70

4.3.8 Kottathara biomass

Regeneration analysis of the Kottathara biomass have found that the relative density was maximum for *Erythroxylum monogynum* (40.55) followed by *Azadirachta indica* (23.32) while lowest values were recorded for *Cordia monoica and Holoptelia integrifolia* (0.21). Abundance was highest for *Erythroxylum monogynum* (38.60) followed by *Leucaena leucocephala* (18.33). Structural attributes of regeneration in the plantation indicated that the relative frequency was found highest for *Azadirachta indica* (15.25) followed by *Mundulea serecia* and *Gmelina arborea* (10.17) while the lowest being reported for *Cordia monoica* and *Holoptelia integrifolia* (1.69).

Table 19. Regeneration analysis of vegetation in Kottathara biomass at Attappady

Sl. No.	Species	Density	Rel. Density	Abundance	Percentage Frequency	Rel. Frequency
1	*Albizia amara*	19.44	1.47	1.40	55.56	8.47
2	*Azadirachta indica*	308.33	23.32	12.33	100.00	15.25
3	*Cassine albens*	8.33	0.63	1.50	22.22	3.39
4	*Chloroxylon swietenia*	8.33	0.63	1.00	33.33	5.08
5	*Cordia monoica*	2.78	0.21	1.00	11.11	1.69
6	*Diospyros cordifolia*	27.78	2.10	2.50	44.44	6.78
7	*Erythroxylum monogynum*	536.11	40.55	38.60	55.56	8.47
8	*Gmelina arborea*	75.00	5.67	4.50	66.67	10.17
9	*Grewia tiliaefolia*	5.56	0.42	1.00	22.22	3.39
10	*Holoptelia integrifolia*	2.78	0.21	1.00	11.11	1.69
11	*Leucaena leucocephala*	152.78	11.55	18.33	33.33	5.08
12	*Mundulea serecia*	136.11	10.29	8.17	66.67	10.17
13	*Murraya koenigii*	5.56	0.42	1.00	22.22	3.39
14	*Prosopis juliflora*	5.56	0.42	1.00	22.22	3.39
15	*Senna siamea*	5.56	0.42	1.00	22.22	3.39
16	*Strychnos potatorum*	5.56	0.42	1.00	22.22	3.39
17	*Ziziphus mauritiana*	16.67	1.26	1.50	44.44	6.78

4.3.9 Palliyara biomass.

Regeneration analysis of the Palliyara biomass unveiled that the relative density was found maximum for *Santalum album* (34.69) followed by *Zizyphus mauritiana* (27.19) while lowest values were recorded for *Dalbergia lanceolaria, Dalbergia latifolia and 3 others* (0.08). Abundance was highest for *Santalum album* (54.38) followed by *Zizyphus mauritiana* (42.63). Regeneration in the plantation shows that the relative frequency was found highest for *Santalum album* and *Ziziphus mauritiana* (8.89) while the lowest being reported for *Dalbergia lanceolaria, Pterocarpus marsupium and 6 others* (1.11).

Table 20. Regeneration analysis of vegetation in Palliyara biomass at Attappady

Sl no.	Species	Density	Rel. Density	Abundance	Percentage Frequency	Rel. Frequency
1	*Acacia ferruginea*	43.75	1.12	7.00	25.00	2.22
2	*Acacia sinuata*	18.75	0.48	6.00	12.50	1.11
3	*Albizia amara*	12.50	0.32	1.33	37.50	3.33
4	*Albizia lebbeck*	21.88	0.56	1.75	50.00	4.44
5	*Annona squamosa*	9.38	0.24	1.50	25.00	2.22
6	*Anogeissus latifolia*	12.50	0.32	1.33	37.50	3.33
7	*Azadirachta indica*	6.25	0.16	1.00	25.00	2.22
8	*Bombax cieba*	28.13	0.72	2.25	50.00	4.44
9	*Bridelia retusa*	3.13	0.08	1.00	12.50	1.11
10	*Cassia fistula*	21.88	0.56	3.50	25.00	2.22
11	*Cassine paniculata*	159.38	4.07	17.00	37.50	3.33
12	*Dalbergia lanceolaria*	3.13	0.08	1.00	12.50	1.11
13	*Dalbergia latifolia*	3.13	0.08	1.00	12.50	1.11
14	*Givotia moluccana*	6.25	0.16	1.00	25.00	2.22
15	*Gmelina arborea*	18.75	0.48	3.00	25.00	2.22
16	*Grevillea robusta*	6.25	0.16	2.00	12.50	1.11
17	*Grewia tiliaefolia*	278.13	7.10	17.80	62.50	5.56
18	*Holoptelia spp.*	3.13	0.08	1.00	12.50	1.11
19	*Leucaena leucocephala*	250.00	6.38	40.00	25.00	2.22
20	*Murraya koenigii*	225.00	5.74	18.00	50.00	4.44
21	*Naringi crenulata*	9.38	0.24	1.50	25.00	2.22
22	*Phyllanthus embellica*	53.13	1.36	8.50	25.00	2.22
23	*Pongamia pinnata*	6.25	0.16	1.00	25.00	2.22
24	*Psidium guajava*	15.63	0.40	2.50	25.00	2.22
25	*Pterocarpus marsupium*	3.13	0.08	1.00	12.50	1.11
26	*Santalum album*	1359.38	34.69	54.38	100.00	8.89
27	*Simarouba glauca*	21.88	0.56	2.33	37.50	3.33
28	*Stereospermum colais*	103.13	2.63	33.00	12.50	1.11
29	*Strychnos potatorum*	6.25	0.16	1.00	25.00	2.22
30	*Syzigium spp.*	12.50	0.32	2.00	25.00	2.22
31	*Tamarindus indica*	31.25	0.80	2.00	62.50	5.56
32	*Tectona grandis*	93.75	2.39	7.50	50.00	4.44
33	*Wrightia tinctoria*	6.25	0.16	1.00	25.00	2.22
34	*Ziziphus mauritiana*	1065.63	27.19	42.63	100.00	8.89

4.3.10 Sambarkode biomass

Regeneration analysis of the Sambarkode biomass unveiled that the relative density was found maximum for *Leucaena leucocephala* (69.87) followed by *Zizyphus mauritiana* (8.99) and *Azadirachta indica* (8.42) while lowest values were recorded for *Jacaranda mimosifolia and Grevellia robusta (0.05).* Abundance was highest for *Leucaena leucocephala* (169.00) followed by *Azadirachta indica* (18.11) The species distribution studies for regeneration in the plantation show that the relative frequency was found highest for *Ziziphus mauritiana* (11.46) while the lowest being reported for *Naringi crenulata, Acacia planifrons and 4 others* (1.04).

Table 21. Regeneration analysis of vegetation in Sambarkode biomass at Attappady

Sl	Species	Density	Rel. density	Abundance	percentage frequency	Rel. frequency
1	*Givotia moluccana*	22.92	0.57	1.57	58.33	7.29
2	*Albizia lebbeck*	8.33	0.21	2.00	16.67	2.08
3	*Chloroxylon swietenia*	79.17	1.96	5.43	58.33	7.29
4	*Azadirachta indica*	339.58	8.42	18.11	75.00	9.38
5	*Murraya koenigii*	64.58	1.60	7.75	33.33	4.17
6	*Leucaena leucocephala*	2816.62	69.87	169.00	66.67	8.33
7	*Albizia amara*	29.17	0.72	2.33	50.00	6.25
8	*Ziziphus mauritiana*	362.49	8.99	15.82	91.67	11.46
9	*Wrightia tinctoria*	168.75	4.19	13.50	50.00	6.25
10	*Strychnos potatorum*	14.58	0.36	1.40	41.67	5.21
11	*Anogeissus latifolia*	8.33	0.21	1.33	25.00	3.13
12	*Gmelina arborea*	22.92	0.57	2.75	33.33	4.17
13	*Acacia planifrons*	4.17	0.10	2.00	8.33	1.04
14	*Jacaranda mimosifolia*	2.08	0.05	1.00	8.33	1.04
15	*Dichrostachys cinerea*	18.75	0.47	3.00	25.00	3.13
16	*Haldina cordifolia*	2.08	0.05	1.00	8.33	1.04
17	*Stereospermum colais*	6.25	0.16	1.50	16.67	2.08
18	*Simarouba glauca*	4.17	0.10	2.00	8.33	1.04
19	*Senna siamea*	12.50	0.31	2.00	25.00	3.13
20	*Annona squamosa*	14.58	0.36	1.75	33.33	4.17
21	*Diospyros cordifolia*	10.42	0.26	2.50	16.67	2.08
22	*Grevellia robusta*	2.08	0.05	1.00	8.33	1.04
23	*Bombax cieba*	8.33	0.21	2.00	16.67	2.08
24	*Holoptelia integrifolia*	4.17	0.10	1.00	16.67	2.08
25	*Naringi crenulata*	4.17	0.10	2.00	8.33	1.04

4.3 EDAPHIC ATTRIBUTES

4.3.1 Organic Carbon (%)

Organic Carbon is one of the most important parameter to assess the fertility of an area, Organic Carbon was analyzed for all the plantations and biomass conservation area. The results show clear variance between the Organic C percentage in the restored and non restored areas. The values of the Organic carbon content ranged from 0.30±0.05 to 1.81±0.12 in the plantations whereas it ranged from 0.19±0.03 to 0.61±0.1 in case of Non-Restored areas. For the Plantations restored areas Organic Carbon content in the top layer (0-20 cm) was found highest in Pattimalam plantations 1.81±0.12 and it decreased as the depth increased. The same trend continued for the lower layers i.e. 20-40 cm and 40-60 cm of soils in all the plantations. While in the Non- restored area, organic carbon percent was 0.61±0.1 at the top soil and it gradually decreased down to the profile.

Table 22 : Organic Carbon content for plantation areas of Attapaddy

Soil depth (cm)	Pattimalam Plantation	Sambarkod e plantation	Kottathara plantation	Palliyara plantation	Mellechavadi yur plantation	Vellamari plantation	Agali plantation	NER
0-20	1.81 ± 0.12 ^{b}	1.63 ± 0.01 ^{b}	1.21 ± 0.27 ^{b}	1.48 ± 0.23 ^{b}	1.42 ± 0.23 ^{b}	1.03 ± 0.15 ^{a}	1.48 ± 0.25 ^{b}	0.61 ± 0.1 ^{a}
20-40	1.20 ± 0.17 ^{b}	1.18 ± 0.10 ^{b}	0.72 ± 0.15 ^{b}	0.93 ± 0.05 ^{b}	0.89 ± 0.26 ^{b}	0.54 ± 0.05 ^{a}	0.65 ± 0.12 ^{a}	0.38 ± 0.04 ^{a}
40-60	0.83 ± 0.23 ^{b}	0.70 ± 0.06 ^{b}	0.57 ± 0.12 ^{b}	0.53 ± 0.03 ^{b}	0.61 ± 0.21 ^{b}	0.30 ± 0.05 ^{a}	0.39 ± 0.09 ^{a}	0.19 ± 0.03 ^{a}

'a' indicates statistically homogenous groups 'b' indicates statistically different groups

In the biomass conservation areas, the value for Organic Carbon percent ranged from 0.76±0.05 to 2.61±0.41 while it ranged from 0.20±0.04 to 0.61±0.06 for the Non- restored areas. Organic Carbon percent was found highest in Palliyara biomass (2.61±0.41) followed by Sambarkode biomass (2.38±0.28) in 0-20 cm depths and as the depth increased organic carbon percent decreased, the same trend continued for all the layers i.e. 0-20, 20-40 cm and 40-60 cm of soils in all the biomass areas. In Non- restored areas, Organic Carbon percent was 0.61±0.06 at 0-20 cm depth and it decreased down to the profile.

Table 23: Organic Carbon content for biomass areas of Attapaddy

Soil Depth (Cm)	Palliyara Biomass	Sambarkode Biomass	Kottathara Biomass	NER
0-20	2.61 ± 0.41 [b]	2.38 ± 0.28 [b]	1.58 ± 0.20 [b]	0.61 ± 0.06 [a]
20-40	1.45 ± 0.07 [b]	1.24 ± 0.36 [b]	0.95 ± 0.02 [a]	0.43 ± 0.03 [a]
40-60	1.25 ± 0.14 [b]	0.96 ± 0.44 [a]	0.76 ± 0.05 [a]	0.20 ± 0.04 [a]

'a' indicates statistically homogenous groups 'b' indicates statistically different groups

4.3.2 Organic Matter (%)

Organic Matter percentage was analyzed for all the plantations and biomass conservation area. The values in the restored areas ranged from 0.52±0.09 to 3.11±0.2 in the plantations whereas 0.32±0.05 to 1.06±0.18 in case of Non-Restored areas. Among the Plantation areas Organic Matter percent was found highest in Pattimalam plantation (3.11±0.2) followed by Sambarkode plantation (2.82±0.02). With the increase in depth, organic matter percent decreased. In the Non-restored area organic matter percent was noted 1.06±0.18 at the top soil (0-20cm) and it decreased to 0.32±0.05 at the depth of 40-60 cm.

Table 24 : Organic matter in plantation areas of Attapaddy

Soil Depth (Cm)	Pattimalam Plantation	Sambarkode Plantation	Kottathara Plantation	Palliyara Plantation	Mellechavadiyur Plantation	Vellamari Plantation	Agali Plantation	NER
0-20	3.11 ± 0.2 [b]	2.82 ± 0.02 [b]	2.08 ± 0.46 [b]	2.55 ± 0.39 [b]	2.46 ± 0.4 [b]	1.78 ± 0.26 [a]	2.55 ± 0.43 [b]	1.06 ± 0.18 [a]
20-40	2.07 ± 0.30 [b]	2.04 ± 0.18 [b]	1.25 ± 0.26 [b]	1.61 ± 0.08 [b]	1.53 ± 0.44 [b]	0.92 ± 0.09 [a]	1.12 ± 0.21 [a]	0.65 ± 0.06 [a]
40-60	1.43 ± 0.40 [b]	1.21 ± 0.10 [b]	0.98 ± 0.20 [b]	0.91 ± 0.05 [b]	1.05 ± 0.37 [b]	0.52 ± 0.09 [a]	0.67 ± 0.15 [a]	0.32 ± 0.05 [a]

'a' indicates statistically homogenous groups 'b' indicates statistically different groups

In the biomass conservation areas, the value for Organic matter percent ranged from 1.32±0.08 to 4.51±0.71 for the Restored areas while it ranged from 0.35±0.07 to 1.05±0.10 for the Non-restored areas. Organic matter percent was found highest in Palliyara biomass (4.51±0.71) followed by Sambarkode biomass (4.11±0.48) in the top soil (0-20), it is also found that as the depth increase values decreased. In Non- restored area Organic matter percent was 1.05±0.10 and then it gradually decreased down to the profile.

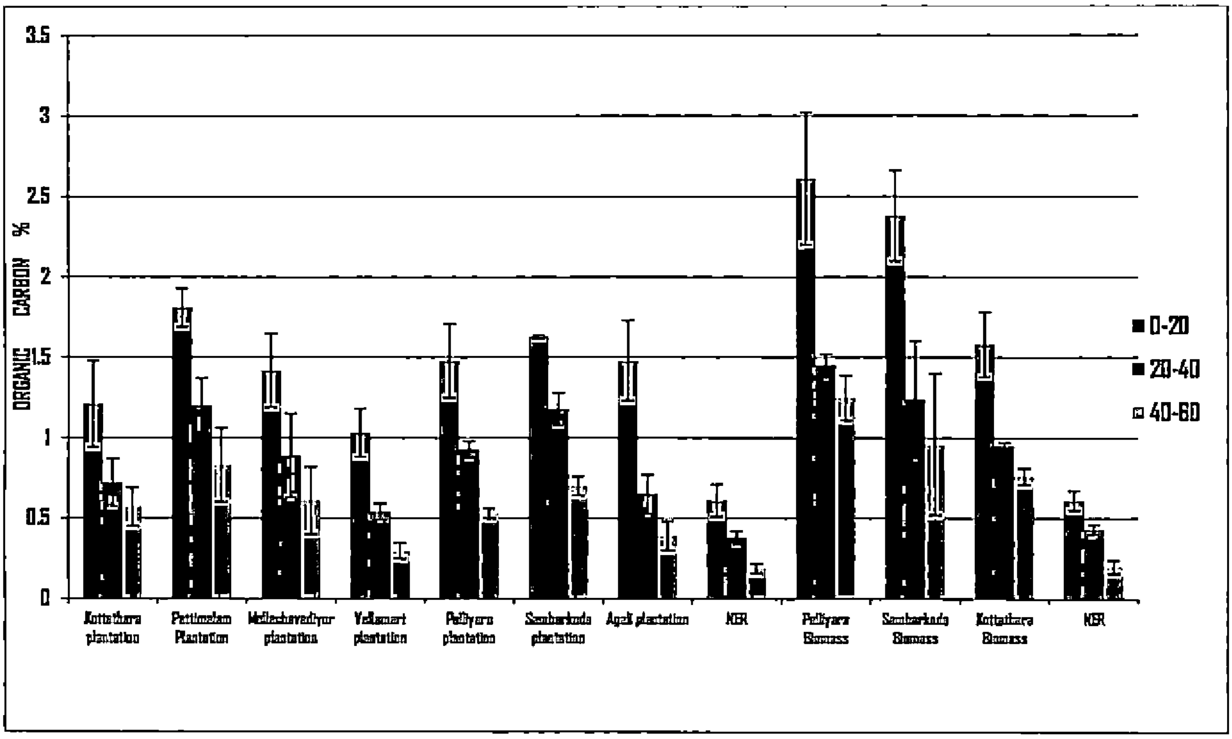


Fig.7. Organic carbon content in the soils of Eastern Attappady

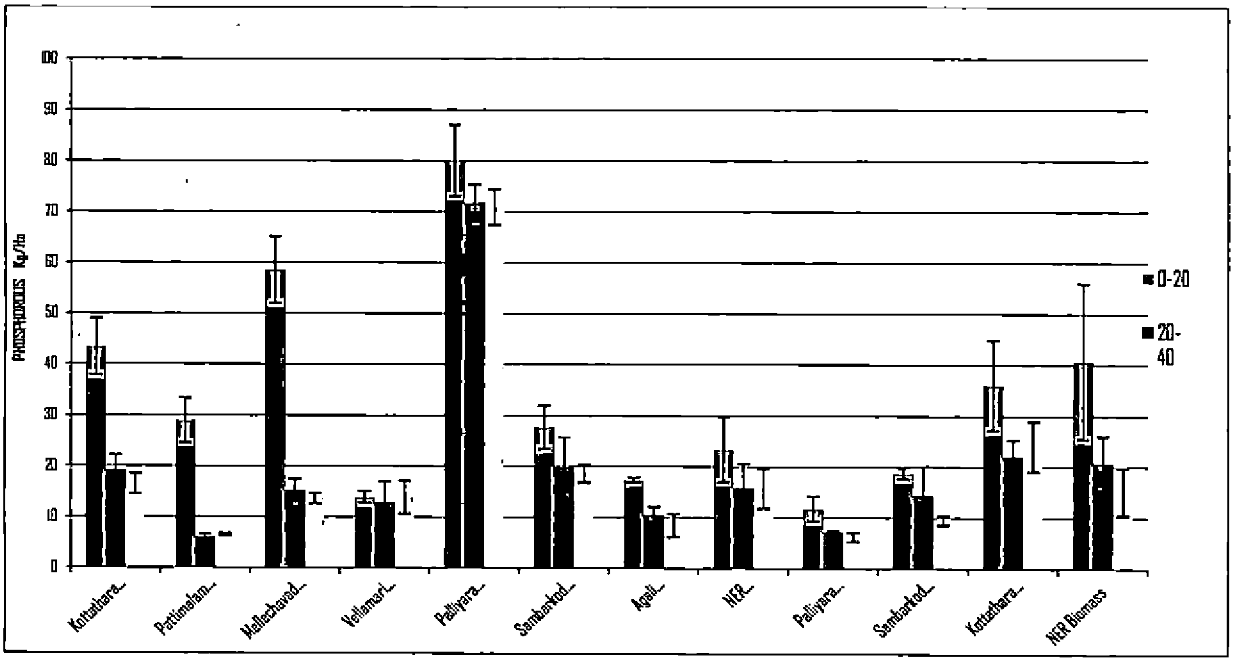


Fig.8. Available Phosphorous Content in Soils of Eastern Attappady

Table 25: Organic matter in biomass areas of Attapaddy

Soil Depth (Cm)	Palliyara Biomass	Sambarkode Biomass	Kottathara Biomass	NER
0-20	4.51 ± 0.71^{b}	4.11 ± 0.48^{b}	2.73 ± 0.35^{b}	1.05 ± 0.10^{a}
20-40	2.50 ± 0.13^{b}	2.13 ± 0.62^{b}	1.64 ± 0.03^{a}	0.75 ± 0.06^{a}
40-60	2.16 ± 0.24^{b}	1.65 ± 0.76^{a}	1.32 ± 0.08^{a}	0.35 ± 0.07^{a}

'a' indicates statistically homogenous groups 'b' indicates statistically different groups

4.3.3 Available Phosphorous

Phosphorous was analyzed for all the plantations and biomass conservation area. The values in the restored areas ranged from 6.55 ±0.23 to 80.11 ± 7.02 Kg/ha in the plantations whereas it ranged from 15.73±3.89 to 23.3±6.41 Kg/ha in case of Non-Restored areas. Among the Plantations Phosphorous content was found highest in Palliyara plantations (80.11±7.02) followed by Melechavadiyoor plantations (58.56 ± 30.58 Kg/ha). The values of available Phosphorous decreased as the soil depth increased in all the plantations.

Table 26: Available Phosphorous in plantation areas of Attapaddy

Soil depth (cm)	Pattimalam Plantation	Sambarkode Plantation	Kottathara Plantation	Palliyara Plantation	Mellechavadiyur Plantation	Vellamari Plantation	Agali Plantation	NER
0-20	28.98 ± 4.43^{a}	27.71 ± 4.29^{a}	43.37 ± 5.6^{a}	80.11 ± 7.02^{b}	58.56 ± 6.58^{b}	13.9 ± 1.15^{a}	17.37 ± 0.43^{a}	23.43 ± 6.41^{a}
20-40	6.07 ± 0.53^{a}	19.77 ± 5.92^{a}	19.07 ± 3.10^{a}	71.72 ± 3.64^{b}	15.24 ± 2.25^{a}	12.84 ± 4.24^{a}	10.44 ± 1.65^{a}	15.86 ± 4.79^{a}
40-60	6.55 ± 0.23^{a}	18.59 ± 1.71^{a}	16.52 ± 2.03^{a}	70.92 ± 3.52^{b}	13.64 ± 1.01^{a}	13.90 ± 3.25^{a}	8.42 ± 2.25^{a}	15.73 ± 3.89^{a}

'a' indicates statistically homogenous groups 'b' indicates statistically different groups

In the biomass conservation areas the value for Phosphorus ranged from 6.23±0.87 to 36.02±8.83 Kg/ha for the Restored areas while it ranged from 15.13±4.66 to 40.76±15.24 for the Non- restored areas. Phosphorous was found highest in Kottathara biomass (36.02±8.83) followed by Sambarkode biomass (18.75±1.13).

Table 27: Available Phosphorous in biomass areas of Attapaddy

Soil Depth (Cm)	Palliyara Biomass	Sambarkode Biomass	Kottathara Biomass	NER
0-20	11.77 ± 2.40 [a]	18.75 ± 1.13 [a]	36.02 ± 8.83 [a]	40.76 ± 15.24 [a]
20-40	7.24 ± 0.28 [a]	14.38 ± 5.75 [a]	22.06 ± 3.23 [a]	20.78 ± 5.31 [a]
40-60	6.23 ± 0.87 [a]	9.48 ± 0.91 [a]	24.03 ± 4.94 [a]	15.13 ± 4.66 [a]

'a' indicates statistically homogenous groups 'b' indicates statistically different groups

4.3.4 Available Pottassium

Available Pottassium was analyzed for all the plantations and biomass conservation areas. The values in the restored areas ranged from 86.43±6.0 to 481.04±66.63 Kg/ha in the plantations whereas 108.40±12.05 to 200.08±15.85 Kg/ha in case of Non-Restored areas. Among the Plantations for the restored areas available Potassium was found highest in Pattimalam plantation (481.04±66.63 Kg/ha) followed by Sambarkode plantation (469.28±70.07 Kg/ha), the values decreased as the depth increased irrespective of the plantations. While in the Non- restored area the available Potassium at the top soil was (200.08±15.85 kg/ha).

Table 28: Available Potassium in plantation areas of Attapaddy

Soil Depth (Cm)	Pattimalam Plantation	Sambarkode Plantation	Kottathara Plantation	Palliyara Plantation	Mellechavadi yur Plantation	Vellamari Plantation	Agali Plantation	NER
0-20	481.04 ± 66.63 [b]	469.28 ±70.07 [b]	326.85 ±70.52 [a]	394.99 ± 81.74 [b]	390.51± 90.23 [b]	216.53 ±24.84 [a]	378.75±92.87 [b]	200.08 ± 15.85 [a]
20-40	119.28 ± 20.20 [a]	219.52 ± 31.54 [b]	122.27 ± 6.39 [a]	166.13 ± 54.87 [a]	147.65 ± 55.81 [a]	111.07 ± 10.83 [a]	109.76 ±26.60 [a]	126.64 ± 9.75 [a]
40-60	113.87 ± 9.54 [a]	152.88 ± 23.96 [a]	106.40 ± 8.16 [a]	117.97 ± 31.47 [a]	114.99 ±36.06 [a]	131.60 ± 12.09 [a]	86.43 ± 6.00 [a]	108.40 ± 12.05 [a]

'a' indicates statistically homogenous groups 'b' indicates statistically different groups

In the biomass conservation areas the value for available Potassium ranged from 142.43±47.11 to 587.44±48.58 Kg/ha for the Restored areas while it ranged from 73.49±17.50 to 180.89±53.50 Kg/ha for the Non- restored areas. Available Potassium was found highest in Sambarkode biomass (587.44±48.58 Kg/ha) followed by Kottathara biomass (413.65±71.22 Kg/ha) the values decreased from top to bottom layer of soils in all the biomass areas.

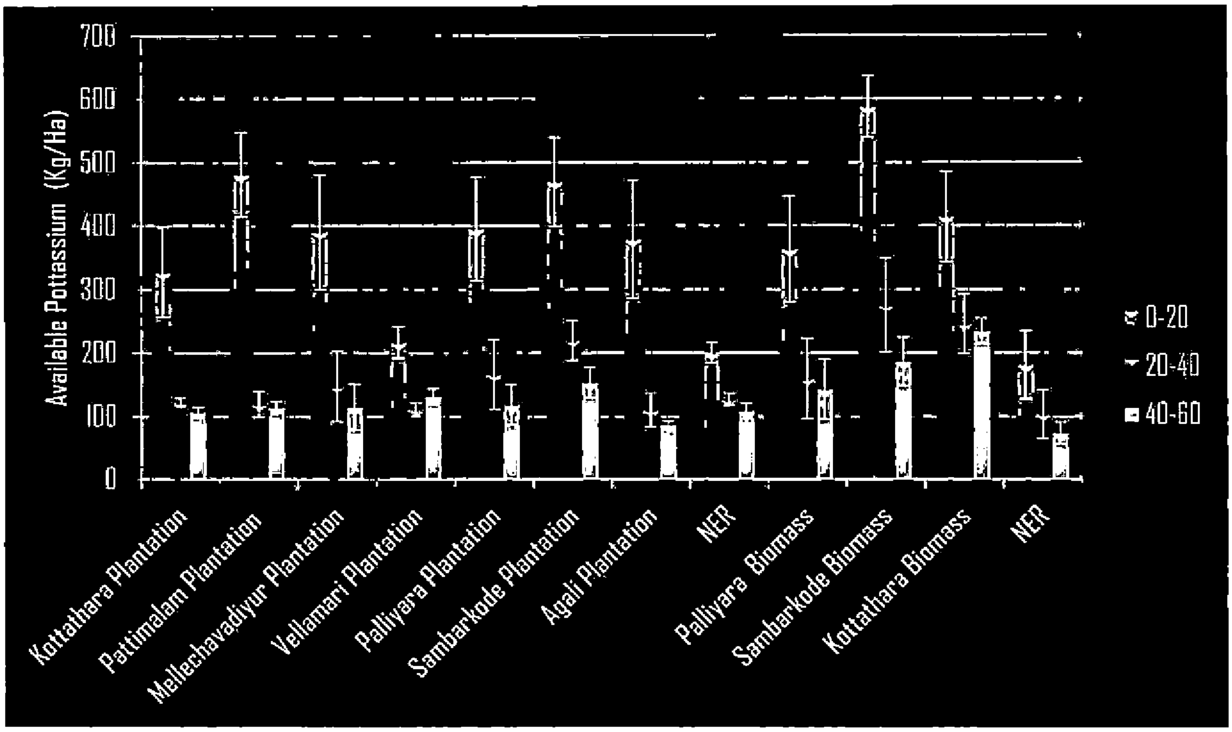


Fig.9. Exchangeable Potassium content in the soils of Eastern Attappady

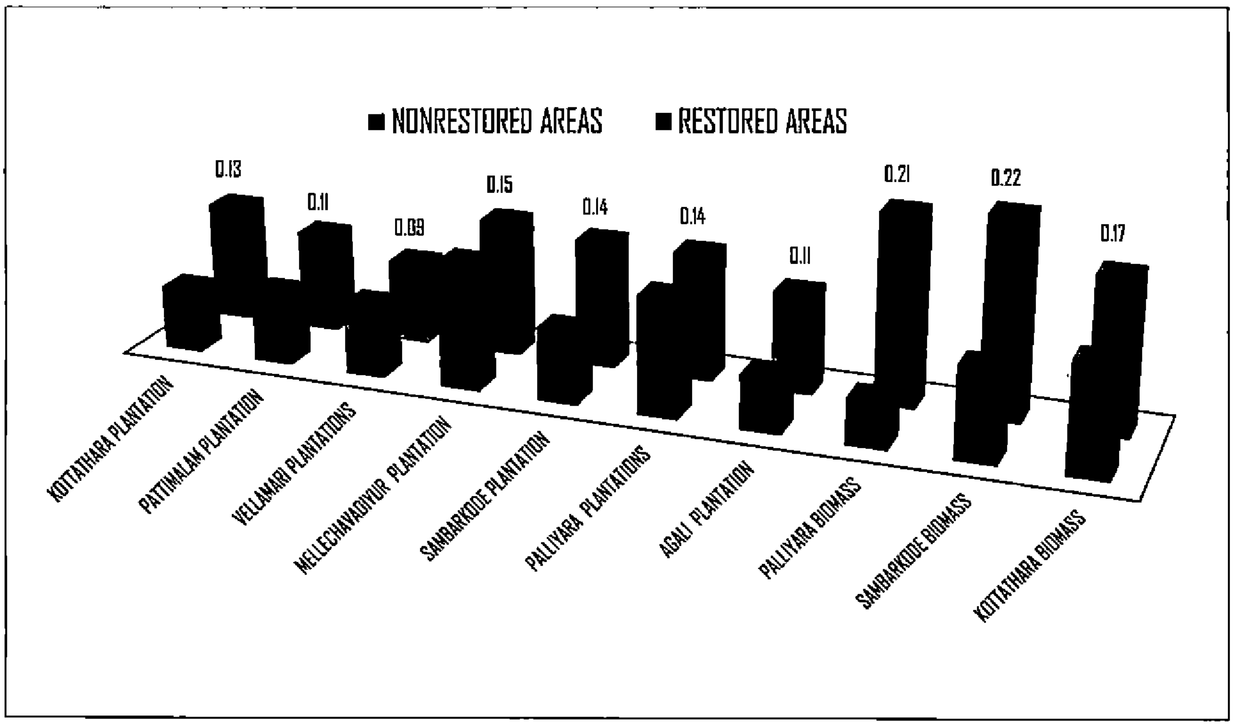


Fig.10. Total Nitrogen (%) content in the soils of Eastern Attappady

Table 29: Available Potassium analysis for biomass areas of Attapaddy

Soil Depth (Cm)	Palliyara Biomass	Sambarkode Biomass	Kottathara Biomass	NER
0-20	363.07 ± 82.97 [a]	587.44 ± 48.58 [b]	413.65 ± 71.22 [a]	180.89 ± 53.50 [a]
20-40	159.41 ± 62.91 [a]	274.77 ± 73.73 [a]	245.47 ± 46.72 [a]	102.95 ± 38.50 [a]
40-60	142.43 ± 47.11 [a]	185.92 ± 38.13 [b]	234.45 ± 19.86 [b]	73.49 ± 17.50 [a]

'a' indicates statistically homogenous groups 'b' indicates statistically different groups

4.3.5 Total Nitrogen

Total Nitrogen was analyzed for all the plantations and biomass conservation areas by taking the composite samples of different soil depths. In all the plantations and biomass areas there was significant difference for the values of restored and non-restored areas. The values in the restored areas ranged from 0.09 to 0.15 in the plantations whereas 0.06 to 0.14 in case of Non-Restored areas. Among the plantations, Total N was found highest in Mellechavadiyoor plantations (0.15) followed by Sambarkode plantations and Palliyara plantations (0.14) and the lowest being recorded for Vellamari plantations (0.9), While in the Non- restored areas value for Total N was found highest for Mellechavadiyoor plantations (0.14) followed by Palliyara plantations (0.13) and lowest being reported for Agali plantations (0.6).

In the biomass conservation areas, the value for Total N percent ranged from 0.17 to 0.22 for the Restored areas while it ranged from 0.05 to 0.12 for the Non- restored areas. Total N percent was found highest in Sambarkode biomass (0.22) followed by Palliyara biomass (0.21) While in the Non- restored areas, values were noted highest for Kottathara Biomass (0.12) followed by Sambarkode biomass (0.10).

Table 30: Total Nitrogen analysis for plantation and biomass areas of Attapaddy

Sl No.	Plantation/ Biomass	Restored Areas	Nonrestored Areas/Control
1	Sambarkode Plantation	0.14	0.08
2	Kottathara Plantation	0.13	0.07
3	Palliyara Plantations	0.14	0.13
4	Mellechavadiyur Plantation	0.15	0.14
5	Vellamari Plantations	0.09	0.08
6	Agali Plantation	0.11	0.06
7	Pattimalam Plantation	0.11	0.08
8	Palliyara Biomass	0.21	0.05
9	Sambarkode Biomass	0.22	0.10
10	Kottathara Biomass	0.17	0.12

4.3.6 Cation Exchange Capacity

Cation Exchange Capacity (CEC) was analyzed for all the plantations and biomass conservation areas by taking the composite samples from all the soil depths. In all the plantations and biomass areas there was significant difference for the values of restored and non-restored areas. The values in the restored areas ranged from 11.98 to 23.42 in the plantations whereas 5.4 to 20.8 in case of Non-Restored areas. Among the Plantations Cation Exchange Capacity was found highest in Agali plantations (0.15) followed by Mellechavadiyoor plantations (23.24) in the restored areas and the lowest being recorded for Sambarkode plantations(11.98), While in the Non- restored areas value for CEC was found highest for Mellechavadiyoor plantations (20.81) followed by Vellamari plantations (17.19) and lowest being reported for Sambarkode plantations(5.42).

In the biomass conservation areas the value for Cation Exchange Capacity ranged from 14.92 to 33.14 for the Restored areas while it ranged from 7.60 to 11.00 for the Non- restored areas. Total N percent was found highest in Palliyara biomass (33.14) followed by Sambarkode biomass (16.98) While in the Non- restored area values were noted highest for Sambarkode Biomass (11.00) followed by Kottathara biomass (10.51).

Table 31: Cation Exchange Capacity (meq/100 g) analysis for plantation and biomass areas of Attapaddy

Sl No.	Plantation/ Biomass	Restored Areas	Nonrestored Areas/Control
1	Sambarkode Plantation	11.98	5.42
2	Kottathara Plantation	18.38	16.92
3	Palliyara Plantations	13.39	15.45
4	Mellechavadiyur Plantation	23.24	20.81
5	Vellamari Plantations	16.56	17.20
6	Agali Plantation	23.42	6.60
7	Pattimalam Plantation	20.46	9.24
8	Palliyara Biomass	33.15	7.60
9	Sambarkode Biomass	16.98	11.00
10	Kottathara Biomass	14.92	10.51

4.3.7 pH

In all the plantations and biomass areas there was no significant difference for the values of restored and non-restored areas. Among the plantations pH values in the restored areas ranged from 6.03±0.3 to 7.21±0.21 whereas 6.83±0.26 to 7.14±0.24 in case of Non-Restored areas. Among the Plantations pH values were observed to be increased as one goes down from upper depth to lower depth of soils, in the restored areas the pH values tends to be more towards neutral.

Table 32: pH analysis for plantation areas of Attapaddy

Soil depth (cm)	Pattimalam Plantation	Sambarkode Plantation	Kottathara Plantation	Palliyara Plantation	Mellechavadiyur Plantation	Vellamari Plantation	Agali Plantation	NER
0-20	6.8 ±0.29 [a]	6.26 ±0.05 [a]	6.03 ±0.3 [b]	6.55 ±0.18 [a]	6.68 ±0.36 [a]	6.89± 0.22 [a]	7.15± 0.21 [a]	6.83± 0.26 [a]
20-40	6.86± 0.14 [a]	6.27± 0.10 [a]	6.41± 0.10 [a]	6.57± 0.12 [a]	6.41± 0.08 [a]	6.86 ±0.12 [a]	6.99 ±0.18 [a]	6.90 ±0.29 [a]
40-60	7.05± 0.17 [a]	6.43± 0.16 [b]	6.83± 0.14 [a]	6.65± 0.08 [a]	6.64± 0.29 [a]	6.85 ±0.08 [a]	7.21 ±0.23 [a]	7.14 ±0.24 [a]

'a' indicates statistically homogenous groups 'b' indicates statistically different groups

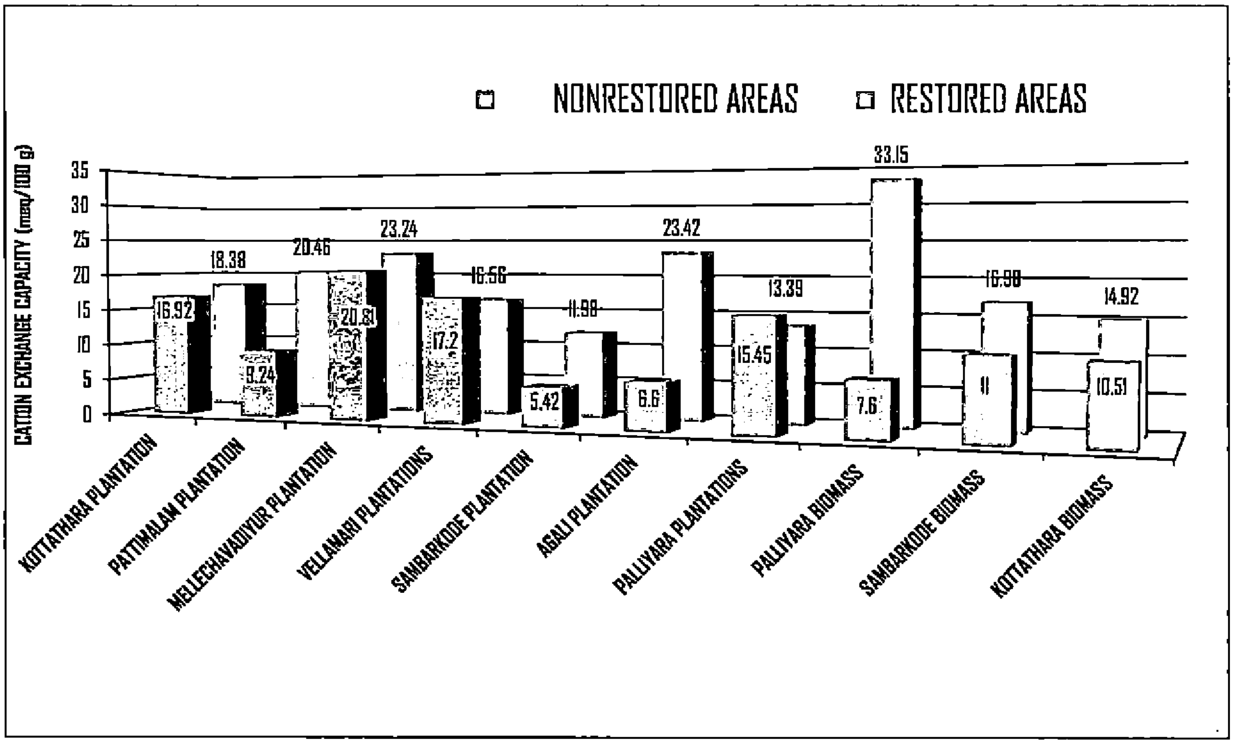


Fig.11. Cation Exchange Capacity in Soils of Eastern Attappady

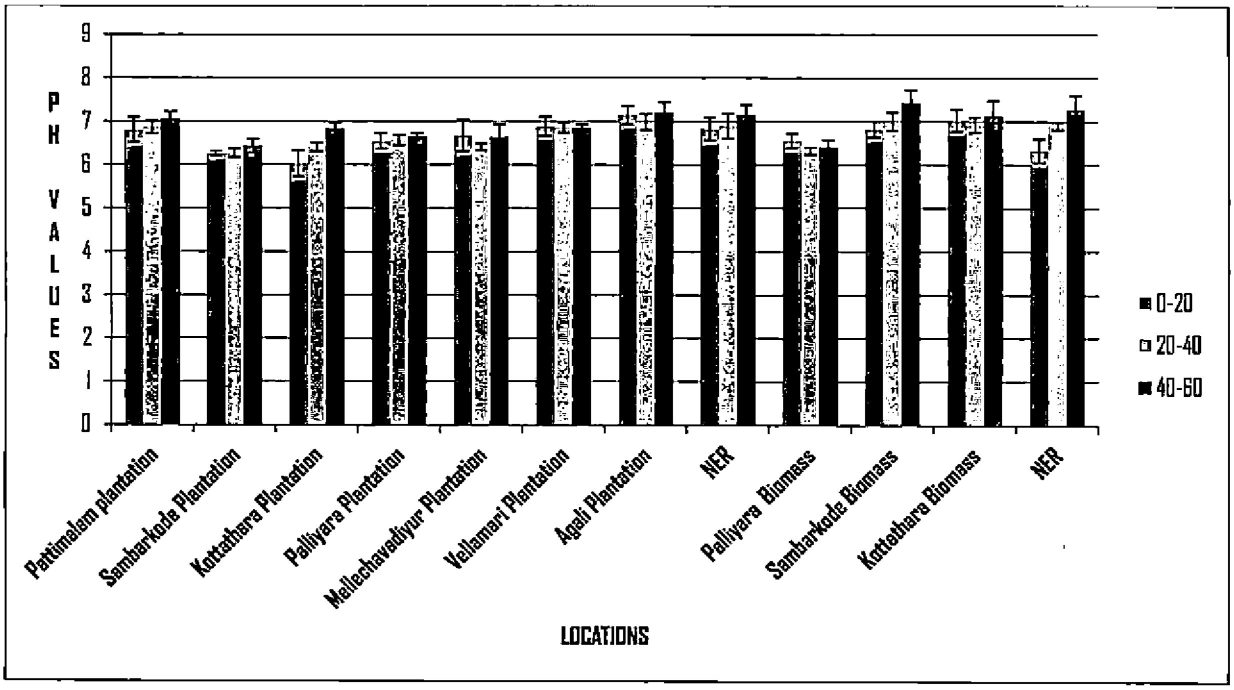


Fig.12. pH Analysis of Soils in Eastern Attappady

In the biomass conservation areas the value for pH ranged from 6.32±0.08 to 7.42±0.29 for the Restored areas while it ranged from 6.63±0.27 to 7.27±0.33 for the Non- restored areas. The values in the biomass areas also tend to be more towards the neutral pH. Non restored areas have shown higher variation in pH values.

Table 33: pH analysis for biomass areas of Attapaddy

Soil Depth (Cm)	Palliyara Biomass	Sambarkode Biomass	Kottathara Biomass	NER
0-20	6.56 ± 0.17 [a]	6.82 ± 0.18 [b]	7.03 ± 0.25 [a]	6.33 ± 0.27 [a]
20-40	6.32 ± 0.08 [a]	7.00 ± 0.21 [a]	6.92 ± 0.17 [a]	6.90 ± 0.09 [a]
40-60	6.40 ± 0.17 [a]	7.42 ± 0.29 [a]	7.13 ± 0.35 [a]	7.27 ± 0.33 [a]

'a' indicates statistically homogenous groups 'b' indicates statistically different groups

4.3.8 Electrical Conductivity

The EC values for the restored areas show an increase in the values when compared to the non-restored areas in both the plantations as well as biomass areas. The values ranged from 29.67±1.76 to 195±3.18 µs/cm in the plantation areas. The general trend for the values of EC show decreasing as the depth increases. Significant changes in the EC were observed when the values of restored and non- restored areas are compared.

Table 34: Electrical conductivity (µs/cm) analysis for plantation areas of Attapaddy

Soil depth (cm)	Pattimalam Plantation	Sambarkode Plantation	Kottathara Plantation	Palliyara Plantation	Mellechavadiyur Plantation	Vellamari Plantation	Agali Plantation	NER
0-20	181±39.17 [b]	63.67±9.33 [a]	195.67 ±3.18 [b]	145 ± 13.65 [b]	142.67 ±51.31 [b]	112.73 ±3.24 [a]	135 ± 5.57 [a]	79.86 ±13.2 [a]
20-40	64.33±21.3 [a]	40.00 ± 1.15 [a]	37.00 ± 3.06 [a]	46.33 ± 5.70 [a]	71.67 ± 17.52 [b]	62.73 ± 2.45 [a]	46.33± 4.26 [a]	42.86 ±4.52 [a]
40-60	65.33±16.9 [a]	31.67 ± 3.84 [a]	38.67 ± 3.76 [a]	29.67 ± 1.20 [a]	62.33 ± 19.77 [a]	53.27 ±3.32 [a]	29.67 ±1.76 [a]	50.16±26.8 [a]

'a' indicates statistically homogenous groups 'b' indicates statistically different groups

In the biomass areas values ranged from 37.00±10.60 to 129±12.34 µs/cm, while in the non restored area values ranged from 29.33±0.88 to 57.00±4.16 µs/cm. The values of EC show a decreasing trend as the depth increases.

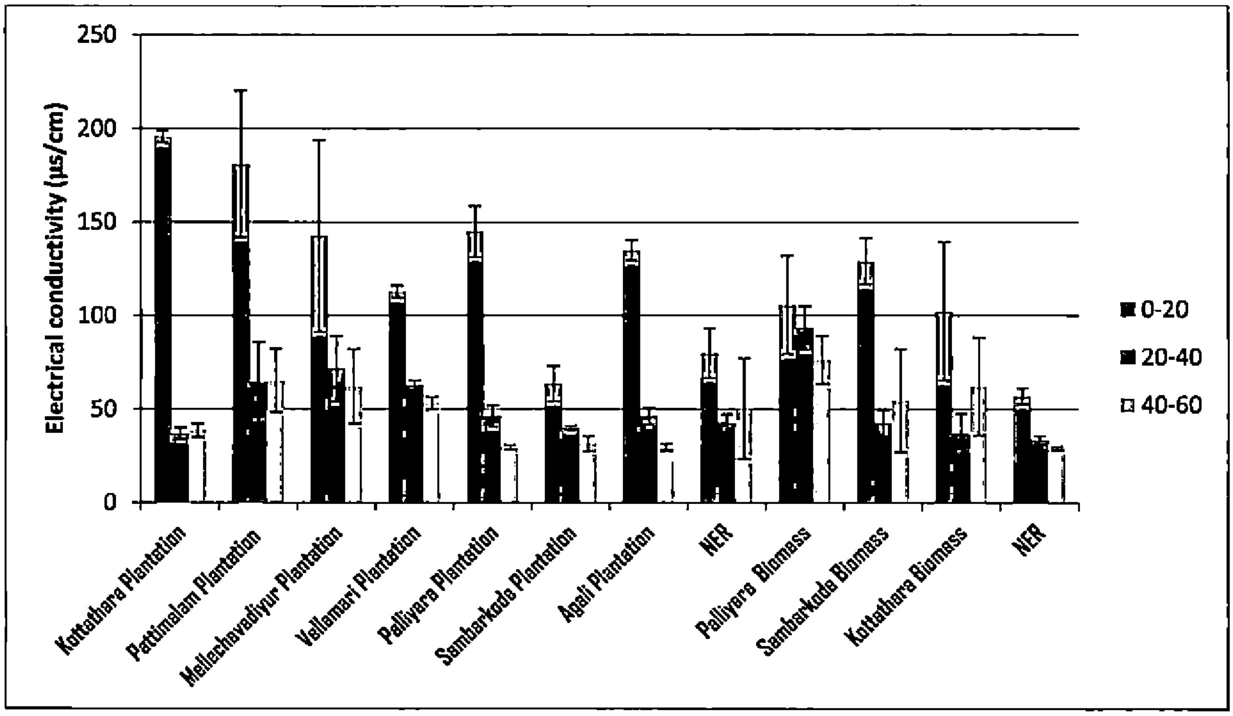


Fig.13. Electrical Conductivity analysis in soils of Eastern Attappady

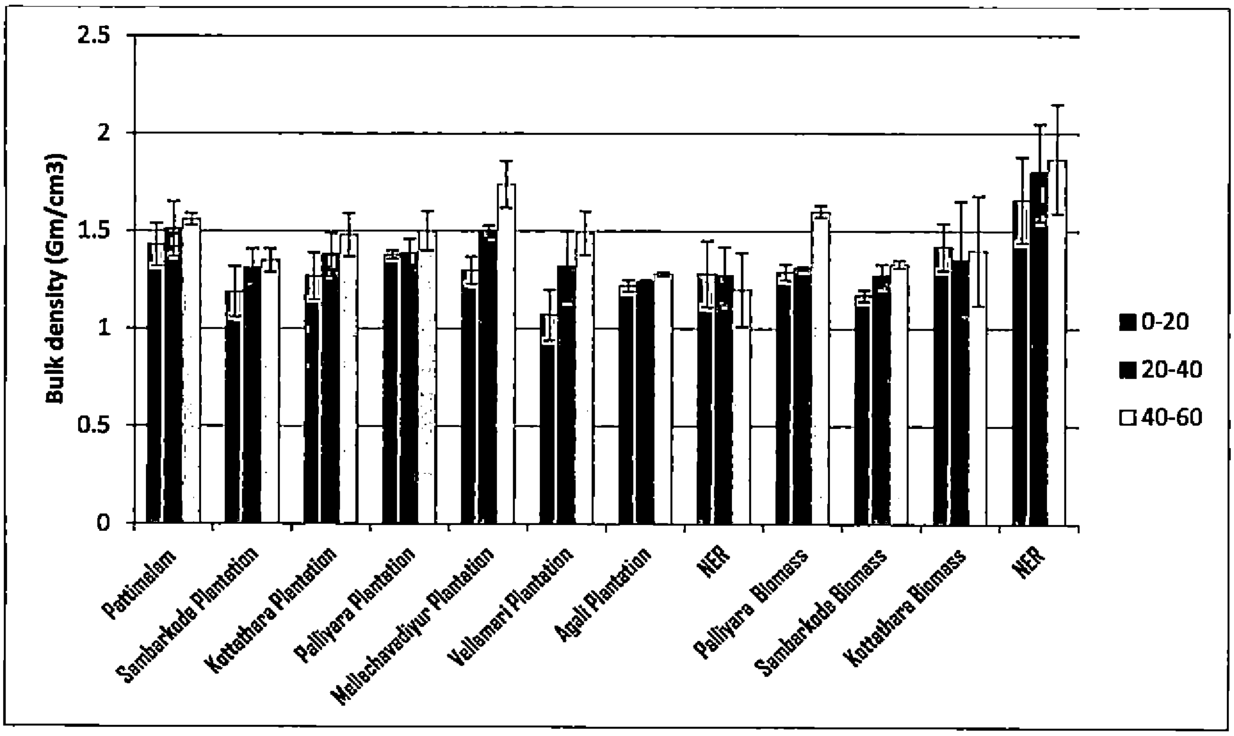


Fig.14. Bulk Density analysis in soils of Eastern Attappady

Table 35: Electrical conductivity (µs/cm) analysis for biomass areas of Attapaddy

Soil Depth (Cm)	Palliyara Biomass	Sambarkode Biomass	Kottathara Biomass	NER
0-20	105.67 ± 26.21 [a]	129.00 ± 12.34 [a]	102.33 ± 37.08 [a]	57.00 ± 4.16 [a]
20-40	93.33 ± 11.72 [b]	42.67 ± 7.22 [a]	37.00 ± 10.60 [a]	33.67 ± 2.19 [a]
40-60	76.33 ± 12.81 [a]	54.67 ± 27.42 [a]	62.33 ± 26.03 [a]	29.33 ± 0.88 [a]

'a' indicates statistically homogenous groups 'b' indicates statistically different groups

4.3.9 Bulk Density

In all the plantations and biomass areas there was no significant difference in the values of bulk density for restored and non-restored areas. The bulk density values in the restored areas ranged from 1.07 ± 0.33 to 1.56 ±0.03 gm/cm^3 in the plantations whereas 1.20 ± 0.19 to 1.28 ± 0.17 gm/cm^3 in case of Non-Restored areas. Among the Plantations bulk density values were observed to be increasing as one goes down from upper depth to lower depth of soils

Table 36: Bulk density (gm/cm3) analysis for plantation areas of Attapaddy

Soil depth (cm)	Pattimalam Plantation	Sambarkode Plantation	Kottathara Plantation	Palliyara Plantation	Mellechavadiyur Plantation	Vellamari Plantation	Agali Plantation	NER
0-20	1.43 ±0.11 [a]	1.19 ± 0.13 [a]	1.27 ± 0.12 [a]	1.38 ± 0.02 [a]	1.3 ± 0.07 [a]	1.07 ± 0.33 [a]	1.22 ± 0.03 [a]	1.28 ± 0.17 [a]
20-40	1.51±0.14 [a]	1.31 ± 0.10 [a]	1.38 ± 0.11 [a]	1.39 ± 0.07 [a]	1.50 ± 0.03 [a]	1.32 ± 0.48 [a]	1.24 ± 0.01 [a]	1.27 ± 0.15 [a]
40-60	1.56 ±0.03 [a]	1.35 ± 0.06 [a]	1.48 ± 0.11 [a]	1.50 ± 0.10 [a]	1.74 ± 0.12 [a]	1.49 ± 0.61 [a]	1.28 ± 0.01 [a]	1.20 ± 0.19 [a]

'a' indicates statistically homogenous groups 'b' indicates statistically different groups

In the biomass areas values ranged from 1.17 ± 0.03 to 1.60 ± 0.03 while in the non restored area values ranged from 1.66 ± 0.22 to 1.87 ± 0.28. The general trend for the values of EC show increasing bulk density values as the depth increased.

Table 37: Bulk density (gm/cm^3) analysis for biomass areas of Attapaddy

Soil Depth (Cm)	Palliyara Biomass	Sambarkode Biomass	Kottathara Biomass	NER
0-20	1.29 ± 0.04 [a]	1.17 ± 0.03 [a]	1.42 ± 0.12 [a]	1.66 ± 0.22 [a]
20-40	1.31 ± 0.01 [a]	1.27 ± 0.06 [a]	1.35 ± 0.30 [a]	1.80 ± 0.25 [a]
40-60	1.60 ± 0.03 [a]	1.33 ± 0.02 [a]	1.40 ± 0.28 [a]	1.87 ± 0.28 [a]

'a' indicates statistically homogenous groups 'b' indicates statistically different groups

4.3.10 Soil Carbon Sequestration

In all the plantations and biomass areas values of Soil Caron Sequestration for restored and non-restored areas were calculated. In the restored areas it ranged from 9.0 tons/ha to 51.6 tons/ha among the plantation areas whereas 4.6 to 15.6 tons/ha in case of Non-Restored areas. Among the Plantations values were observed to be increasing as one goes down to lower depth of soils.

Table 38: Carbon Sequestration (Tons/ha) analysis for plantation areas of Attapaddy

Soil depth (cm)	Pattimalam Plantation	Sambarkode plantation	Kottathara plantation	Palliyara plantation	Mellecha[illegible] plantation	[illegible]lamari plantation	Agali plantation	NER
0-20	51.6	38.9	30.7	40.8	37.1	22.1	36.0	15.6
20-40	36.3	31.0	20.0	25.9	26.6	14.2	16.1	9.7
40-60	25.8	18.9	16.9	15.8	21.3	9.0	9.9	4.6

In the biomass areas values ranged from 21.3 to 67.3 tons/ha while in the non restored area values ranged from 7.5 to 20.3 tons/ha. The general trend for the values show carbon sequestration decreased with an increase in the depth.

Table 39: Carbon Sequestration (Tons/ha) analysis for biomass areas of Attapaddy

Soil Depth (Cm)	Palliyara Biomass	Sambarkode Biomass	Kottathara Biomass	NER
0-20	67.3	55.7	44.9	20.3
20-40	38.0	31.5	25.7	15.5
40-60	40.0	25.5	21.3	7.5

Discussion

DISCUSSION

With restoration at the forefront of policy solutions to conserve biodiversity, improve ecosystem services, and ensure resilience against future environmental change, the demand for restoration science to inform practice and policy has never been greater. Though the safeguard towards the environmental stability is the primary goal, where the human impact is tremendous at present scenario, eco-restoration act as a secondary backup to check the further degradation and stabilize the ecosystem. The restoration of degraded ecosystems is becoming a primary focus of natural resource management for both terrestrial and aquatic environments (M.E.A, 2005).

Restoration ecology has established now as scientific discipline using restoration sites as model ecosystems for the clarification of general ecological mechanisms and theory testing (Kiehl, 2010). Another aspect of restoration is the timely monitoring and impact assessment to improvise the critical gaps in the knowledge and limitation of such projects, such analysis provide an understanding for the improvement in the decision making and implementation in coming ecological restoration projects, in the context that a few studies only have been made to understand the total backdrop of the changes which occur during an eco-restoration project.

Improved monitoring and increased access to monitoring data are crucial for better understanding the range of success in restoration projects as well as to adaptively manage projects themselves (Suding, 2011). The estimated changes in forest cover between 1973 and 1995 in the southern part of the Western Ghats using satellite data in a study area of approximately 40,000 km^2 showed a loss of 25.6% in forest cover over 22 years mainly due to anthropogenic activities (Jha *et al.*, 2000). The present study was taken to provide an insight to the impact of eco-restoration during a period of time and assess the present conditions prevailing in the restored areas of Eastern Attappady, Kerala. This study was done to investigate the impact of eco-restoration on the vegetative and edaphic attributes. The results of the study are discussed in this chapter.

5.1 VEGETATIONAL ATTRIBUTES

The study was conducted in the eastern region of Attappady and the plantations and biomass areas studied were different to each other in many aspects especially in the aspect that the rainfall regimes in these areas were quite varying. It was observed that the areas of Palliyara, Sambarkode and Agali were more nearer to the western region of Attappady, whereas the Kottathara, Pattimalam, Vellamari and Mele-Chavadiyoor areas were typical regions of Eastern Attappady. The microclimatic conditions in these areas varied to a large extent which can be figured out from the average climatological data observed in Attappady from 1997 to 2006 (AHADS, 2008).

Table 40. The climatoligical data observed in the observation stations of Attappady from 1997 to 2006.

SL NO.	Observation station	Plantations/ Biomass covered	Average Annual Rainfall (mm)	Average max. temperature (°C)	Average Humidity (%)	Average rainy days
1	Chavadiyoor	Mele-Chavadiyoor, Vellamari	948	32	52	45
2	Vadakottathara	Kottathara, Pattimalam	851	32	53	55
3	Agali	Agali, Sambarkode, Palliyara	1152	28	64.5	63

From the Table 1, it is clear that the microclimatic conditions varied and the areas under Agali and nearby areas like Sambarkode and Palliyara were more humid and received more rainfall as compared to other regions of study.

A total of 101 species were recorded in the study area. Among the plantations maximum number of species were recorded in Agali plantation (48) followed by Sambarkode plantation (43), Palliyara plantation (38), Melle-chavadiyoor plantation (36), Vellamari plantation (29), Pattimalam plantation (20) and the lowest number of species in Kottathara plantation (17). Among the biomass area maximum individuals were recorded in Palliyara Biomass (57), Sambarkode plantation (54) and lowest in Kottathara biomass area (31).

5.1.1 PLANTATIONS

AHADS project commenced on the ground level during the year 2000 and all the degraded areas with less than 40 per cent vegetation cover were treated as the plantations with the main focus on rejuvenation of these areas by introduction of hardy species and watershed management. The studies conducted by several agencies after the completion of the program in 2006 to understand the changes and impact of the implementation of the project, many have suggested the improvement in the conditions of the valley (KSPB, 2010; AHADS, 2008).

The main species included under the restoration project in Attappady were *Albizia amara, Leucaena leucocephala, Chloroxylon sweitenia, Azadirachta indica, Mundulea serecea* besides others. The results of this study indicate that *Albiza amara* and *Leucaena leucocephala* outstood dominant among the other species in almost all the plantations. Study conducted by Vidyasagaran and Anilkumar (2009) in ecorestored plantations of Attappady also found that *Leucaena leucocephala* and *Albizia amara* were predominant in whole Attappady region because they were planted extensively and their survival rate was higher. The reason for their extensive growth and high survival rate is that they are pioneer species suitable for this ecosystem.

In the plantations of Agali, Sambarkode, Palliyara which receive comparatively higher rainfall and humid conditions, the vegetation analysis revealed the most visible effect of the introduction of an exotic species i.e. *Leucaena leucocephala* for the restoration and the species established itself in the favourable microclimatic conditions and profusely regenerating to the highest capacity. *Leucaena leucocephala* grows well only in sub humid or humid climates with moderate dry seasons of up to 6-7 months and cannot withstand prolonged drought (Orwa *et al.*, 2009). IVI was highest for *Leucaena leucocephala* in all three of these plantations

These areas even being a plantation site represented some moist deciduous native tree species like *Santalum album, Anogeissus latifolia, Haldina cordifolia, Dalbergia latifolia, Murraya koenigii, Zizyphus species etc.* Preservation of native plant communities must be included in restoration if land managers and conservation biologists are to counter the pressures of urban development and the threat of invasive exotic species (Hufford and Mazer, 2003). The number of species in the restored areas were very much high than the non restored areas. Similar findings have been reported by Srivastava *et al.*, (2011) in restoration lands in U.P where species increased from 17 in non restored areas to 102 species in restored areas.

Kottathara plantation and Pattimalam plantation coming under typical drier belt of Attappady were featured by the least rainfall among all the plantations of study. The area is highly exposed with barren rocks and very few herbs, sparse euphorbeous plants and shrubs supporting the ground cover. Importance Value Index was found maximum for *Albizia amara* followed by *Mundulea serecea* in both the plantations. Both of these species are drought hardy and pioneer species in such dry tracts. *Albizia amara* is an indigenous fast growing pioneer species and it is a strong light-demander, intolerant of shade, very hardy and shows marked resistance to drought. *Albizia amara* can withstand higher temperatures up to 47^{0}C and low rainfall of 400 m (Orwa *et al.*, 2009). Thus the restoration efforts in this drier belt gave good results as these drought hardy species have stabilized themselves and help in increasing the plant cover.

Overall only 17 tree species in Kottathara and 20 species in Pattimalam plantations were noted in these areas which may be due to drier conditions. The floristic diversity of tropical dry deciduous forests appears to be poor since the dry habitat support only a fewer number of species. Similar condition of less floristic diversity was reported for a tropical dry deciduous forest in Orissa (Devi and Behera, 2003).

Kottathara plantation area is heavily grazed by the goats as in most of the places the fencing has been broken or removed. Instances of soil erosion also seem to be higher in this area as the soil is exposed in many areas. Whereas in Pattimalam the ground cover is severely hampered by the heavy to very heavy grazing and trampling caused by the animals mainly cows and goats and human activities. Nautiyal *et al.,* (2004) in Garhwal Himalayan region found species composition is altered by selective grazing of taller forbs, short and palatable grasses and reported intensity of grazing and exploitation as factors determining the vegetation composition and structure.

Melle Chavadiyoor and Vellamari plantations are in drier areas of eastern Attappady with low rainfall, but receive some more rainfall than most driest parts of the eastern Attappady i.e Vada-Kottathara region, the area is at lower altitude as compared to other plantations. Vegetation is strongly influenced by topography, altitude, moisture availability and pastoral practices. Also, distribution and abundance of several plant communities can be predicted based on the land forms (Kumar et al., 2015). *Albizia amara* is the dominant tree species. The area is typically covered with short height shrubs mainly, *Erythroxylum monogynum* and *Dodonea viscosa* which enhanced the soil cover and thus seems to reduce the soil erosion. These plantations are in vicinity of hamlets and is actively being trespassed by the villagers for their routine jobs, grazing is common and collection of timbers and fire woods is often noted. Marcial *et al.* (2001) also reported firewood extraction and livestock grazing account for more variance in the factor analysis than timber extraction and also found that increase in anthropogenic disturbances

reduced the number of canopy and understorey tree species drastically in the rain forests of Chiapas, Mexico. Thorny acacia species are present in abundance in these plantations.
Thus the study in all the plantations indicates that all the sites were different from each other in vegetational composition and structure. This may be attributed mostly to the varying microclimatic conditions. Sagar and Singh (2006) in the Vindhyan dry tropical forests found that the five dry tropical forest sites exhibited different combinations of dominant and co-dominant species, and thus represented different communities. The low similarity in tree species composition between the communities reflects differences in habitat conditions, topography and between-site distances.

5.1.2 BIOMASS AREAS

Degraded areas with more than 40 per cent vegetation cover were treated as the biomass conservation areas with the main focus on rejuvenation of these areas by introduction of hardy species, with importance on native species restoration and watershed management.

Study in the biomass areas suggest that the Sambarkode and Palliyara biomass areas were significantly different from Kottathara biomass area as it is located in the drier parts of Eastern Attappady, while the remaining two are in proximity to the Western Attappady and receives higher rainfall.

The vegetation in Sambarkode and Palliyara is lucrative with tall trees and big canopies, also the ground flora flourishes well under the shade of trees. Importance value index was found highest for *Tectona grandis* followed by *Santalum album* in both the biomass areas. Both these tree species are naturally growing in the area, also many other naturally growing tree species of moist deciduous forests were found. The highest numbers of individuals were noted from *Santalum album* species in Palliyara biomass while in Sambarkode relative density was maximum for *Chloroxylon sweitenia* which is a planted species during the restoration work and they survived successfully. Maximum numbers of species were recorded in these areas during the study.

Sambarkode and Palliyara biomass areas are located in the vicinity of the hamlets, thus the presence of villagers was noted during the study. Many villagers take their animals for grazing and also collect timber and fuel wood from this area. Logs and stumps can be often noted in the area. Sambarkode area is highly benefitted by the presence of elephants, which may help in the conservation of the sanctity of this area as the outsiders cannot approach these areas easily. It is very important to note that as the area is occupied by Sandal trees, the forest officials guard the sites and have marked all the trees and numbered which also leads to conservation of the area. There are incidences noted where the sandal trees were deliberately cut for profit making by the locals, also fire wood collections were noted in some sites. Jha *et al.*, (2000) in a study in Western Ghats reported the changes in the forest and land cover in the southern region of the Western Ghats exhibiting great spatial variation with most rapid changes noted in Kerala, which has a high population density and high rate of conversion of open forest into other land uses. Districts of Coimbatore and Palghat shown the highest annual rates of loss of dense forest, i.e. 2.4% and 2.1% decrease in forest area.

As the Kottathara region is devoid of plentiful rainfall the vegetation was quite varying than other two biomass areas, also the region is exposed to the external factors thus the species composition is more proximate to the plantations in the drier areas. But the vegetation has picked up in the area and the ground is fairly covered by the herb as well as shrubs. The restoration works helped the area to restore and avoid further degradations. The wide canopies of *Albizia amara* help the other ground flora to flourish. Sagar *et al.* (2012) reported positive relationships of tree canopy cover with soil moisture, herbaceous diversity and biomass, and suggested that the tree canopies facilitated the herbaceous communities by modifying environmental conditions that ultimately improve the diversity and productivity of the area.

Importance Value Index was found maximum for *Albizia amara* followed by *Azadirachta indica,* both of these species were mainly planted during the restoration period. Overall 31species were recorded in this region along with many natural species like *Tamaindus indica, Dalbergia spp. Grewia spp, Murraya koenigii,* etc. Kottathara biomass area is protected by means of fencing which is fairly intact, while in some cases trespassing by the grazers were noted. The intensity of grazing affects the balance between survival and vegetative spread of plants and establishment of its seedlings (Nautiyal *et al,*. 2004).

5.2 REGENERATION ANALYSIS

5.2.1 Regenerations in Plantation Areas

It is quite interesting to note that the regeneration in all the plantations varied according to the favorable microclimatic conditions prevailing in their respective sites. Regeneration in the dry and degraded areas of all the plantations was very much dependent on the species prevailing in the area. Similarly domination of regeneration of primary species in the tropical wet evergreen forest of Western Ghats was reported by Chandrashekhara and Ramakrishnan (2009).

Agali, Sambarkode and Palliyara plantations which received highest rainfall among all the studied plantations supported regeneration of *Leucaena leucocephala* to the maximum extent. *Leucaena leucocephala* is a pioneer species and a known aggressive colonizer of degraded sites and disturbed vegetation in many places. This has been attributed to its precious year-round flowering and fruiting, abundant seed production, self-fertility, hard seed coat, and ability to resprout after fire or cutting (Orwa *et al.,* 2009). The favourable microclimatic conditions supported *Leucaena leucocephala* to flourish and regeneratie to its maximum. Other regenerations were of *Santalum album, Azadirachta indica, Zizyphus species* to a fair extent.The moderately available sunlight ensures good regeneration of these species. Studies have reported that the increased insolation, more light penetration to the ground level, changes in soil moisture characteristics, faster decomposition of the larger organic matter accumulated on the soil surface and increased disturbance of the surface soil are some of the important changes that could have an effect on regeneration (Chandrashekhara and Ramakrishnan, 1993).

Kottathara plantation and Pattimalam plantations are drier belts of Attappady it is worth noting that regeneration in these areas are difficult due to highly exposed land with barren rocks and very few herbs and shrubs supporting the ground cover. Grazing and human interference also impact regeneration in these areas. Grazing and trampling causes seed mortality in addition to solar radiation and decreasing soil moisture availability at forest floor (Marcial *et al.*, 2001) The regeneration analysis has shown that in Kottahara plantation *Mundulea serecea* had maximum regeneration followed by *Albizia amara* while in Pattimalam it was found maximum for *Albizia amara* and *Mundulea serecia* which are the predominant species in the area.

Restoration works in these drier belt areas have supported the rehabilitation cause, especially the presence of drought hardy species like *Albizia amara* and *Mundulea serecia* along with *Leucaena leucocephala* immensely helped in slowly changing the microclimate of this region. Thus the external factors if checked, will help in rejuvenation and regeneration to a maximum extent in a short span of time.

Melle-Chavadiyoor and Vellamari plantations are located in the drier parts but receive some more rainfall than driest parts of the eastern Attappady i.e Vada-Kottathara region. In Melle-Chavadiyoor plantations, regeneration of *Murraya koenigii* was found maximum followed by *Albizia amara.* Closed canopy and moderate sunlight favours the *Murraya koenigii* regeneration in this region. Whereas in Vellamari plantation though *Albizia amara* and *Mundulea serecea* are dominant trees, they lag behind in terms of regeneration. *Leucaena leucocephala* trees which are often found in this area, profusely flower and disperse the seeds which can be noted in the regeneration analysis, as the relative density is found maximum for *Leucaena leucocephala* species followed by *Mundulea serecea.* It can be presumed from this fact that even *Albizia amara* is the dominant tree species but *Leucaena leucocephala* outperforms all the species in terms of regeneration. This also makes this species an aggressive invasive species. The inherent capability of these tree species which are drought hardy and more efficient in rehabilitation of degreaded areas, helped all the plantations in Attappady to rejuvenate and regenerate these sites. Dry forests are characterized by tree species with small, dry, wind dispersed seeds which are better to colonize the degraded areas with less susceptibility to dessication, also the shade and better moisture conditions favour the germinations (Viera and Scariot, 2006).

5.2.2 Regenerations in biomass conservation areas

In Kottathara biomass area drier conditions prevail as compared to other biomass regions of study. *Albizia amara* and *Azadirachta indica* are the dominant trees in this region, mainly planted during the restoration period. In regeneration analysis *Erytrhroxylum monogynum* was found the highest regenerating followed by *Azadirachta indica.* The regeneration is supported by the wide canopy of the *Albizia amara* species.

Sambarkode and Palliyara biomass are fairly wet regions with *Santalum album* and *Tectona grandis* as dominant species of the area.

It is also important to note that in Sambarkode region *Leucaena leucocephala* trees are also fairly found as the comparatively humid conditions and higher rainfall have helped this particular species to flourish. The regeneration studies depict the highest density of *Leucaena leucocephala* regenerations in the area. Thus the presence of *Leucaena leucocephala* may pose some threat to the natural regeneration of local species later as it is an invasive species. In the regeneration analysis of Palliyara biomass area, *Santalum album* was found to be one with the highest relative density followed by *Ziziphus spp.*

Regeneration in all the plantations and biomass areas were dependent on plant densities in the site. Assessment of the regeneration of plant species in natural and restored fragments of the tropical dry evergreen forest (TDEF) in the Puducherry region, South India which indicated that adult density was significantly related to sapling regeneration in all sites (Davidar *et al.*,2007).

5.3 Indices of diversity

Floristic diversity studies in Eastern Attappady revealed that species richness was higher in biomass conservation areas compared to plantations. Species richness between plantations and biomass conservation areas varied significantly. Shannon-Weiner index is an indication of the species richness as well as species evenness of an area. This index value generally ranges between 0.0 to 5.0. The Shannon-Weiner index values for different study areas in plantations and biomass areas ranged from 2.10 to 4.60. Shannon-Weiner index was found more for the biomass area as compared to plantations. Among the biomass conservation areas, Sambarkode biomass had the highest value (4.6) followed by Palliyara biomass (4.2). The Shannon-weiner index values was found maximum for the Agali plantation (3.93). The study conducted by Vidyasagaran and Anilkumar (2009) in the Attappady areas observed similar range of index for dry deciduous forest and moist deciduous forests in Attappady.

Simpson's index values during the study ranged from 0.67 to 0.93. The Simpson's index diversity was found maximum for the Sambarkode plantation (0.89) followed by Mellechavadiyoor plantation (0.88) whereas the lowest recorded is for the Kottathara plantation 0.67 followed by Vellamari plantation (0.77) the reason being the areas are the driest of all and the human interference also is higher. The diversity analysis in the biomass conservation area indicated that Sambarkode biomass had the highest value (0.93) followed by Palliyara biomass (0.89) while the lowest values were reported for Kottathara biomass (0.84). The values are in accordance with a study by Vidyasagaran and Anilkumar (2009) in Attappady where they have noted the index values in moist deciduous forest as (0.91) while in the dry deciduous forest values were lesser. Study conducted by Sagar *et al.* (2003) on the tree species composition, dispersion along a disturbance gradient in a dry tropical forest region of Vindhyan hill ranges, India found similar results of decreasing species richness (Simpson index) with disturbance regime.

Equitability was found to be ranged from 0.50 to 0.80. Equitability was found maximum for the Mellechavadiyoor plantation (0.73) followed by Sambarkode plantation (0.72). Equitability in the biomass conservation area was found to be highest (0.80) for Sambarkode biomass followed by Palliyara biomass (0.72) while the lowest values were reported for Kottathara biomass (0.66). These values support the fact that the disturbance factors in the biomass areas are much comparatively lesser than that of the plantations and the driest areas of the Attappady. Sagar et al., 2003 reported that dry tropical forest is characterized by a patchy distribution of species and individuals with mixed species composition, and the sites are represented by different combinations of the dominants and co-dominant species. The concentration of dominance values for different vegetations was found in the range of 0.33 to 0.07. Concentration of dominance was found the highest for Sambarkode plantation (0.11) and the lowest for Kottathara plantation (0.33). In the biomass conservation areas, Sambarkode biomass area had the highest concentration of dominance (0.07) while the lowest was noted for Kottathara biomass area (0.16).

5.4 EDAPHIC ATTRIBUTES

The soil properties were studied for the profile up to 60 cm depth. In many studies it has been reported that after restoration soil characteristics improved but there are many factors which drive the direction of improvement. Tree plantations can be used as tool for restoration as they have ability to restore soil fertility and ameliorate microclimatic conditions (Singh *et al.*, 2002)

The results showed significant variance between almost all the plantations and biomass areas for organic carbon and organic matter in the restored and non restored areas and the improvement in the carbon content of the soils in restored areas. With increase in soil organic carbon the functional diversity of soil microbial communities may increase and consequently increases the functionality and stability of soil ecosystems (Singh *et al.*, 2016). The value of the organic carbon content in the restored areas of plantations was much higher than the corresponding non eco-restored areas. For the Plantations in the top layer (0-20 cm) Organic Carbon was found much higher than the other depths. Organic carbon decreased as the depth increased, the same trend continued for the lower layers of soils in all the plantations and biomass areas. In Kerala, Soil carbon stock was reported directly related with plant diversity, the areas with higher species richness and tree density had higher soil carbon especially in top 50 cm when compared to lower ones (Saha *et al.*, 2009).

Biomass areas showed more organic carbon or organic matter percent in the soils as compared to the plantation areas. Higher organic carbon content in the soil under restored areas compared to non eco-restored control plots might be because of long term addition of organic matter through litter fall. Similar studies have suggested that the litter fall lead to increase in organic matter (FaMing *et al.* 2010). Muralidharan *et al.* (1991) reported that in Attappady valley organic carbon is as low as 1.2%, and the results of the present study show that the average carbon content of the soil has increased in the valley as a result of eco-restoration. Most of the plantations and biomass areas have shown an improvement in the carbon content in the soil after restoration of the area. Shrivastava et al., (2011) reported significant improvement in a 10 year old reclaimed sodic land with remarkable changes in soil organic matter and microbial content which increased by 480 percent, while the soil amelioration was more pronounced in the upper layer (0-30 cm) as compared to lower layers (below 30 cm).

Bulk density is the mass of dry soil per unit bulk volume and it generally increases with depth in forest soils. The bulk density in all the plantations and biomass areas increased with depth. The similar trend has been reported in most of the soil studies conducted in Western Ghats (Balagopalan and Jose, 1993). Bulk density in the plantations and biomass areas in most of the cases were below the Non Eco-restored areas.

The lower value of bulk density indicated the loose porous soils. The lower bulk density also indicates the improved organic matter content of the soils. Majority of studies have suggested strong correlation between soil organic matter and bulk density. In Coimbatore region studies indicated that as the organic matter increases bulk density decreased which is required for proper growth of plants (Chaudhari *et al.*, 2013).

In all the plantations and biomass areas there was no significant difference for the values of pH both in restored and non-restored areas. pH values in all the plantations and biomass areas were slightly acidic to neutral. Biomass areas like Palliyara pH was slightly acidic, due to higher organic matter and leaching effect. The neutral pH may be due to low rainfall in the region. In several studies it has been found that the low rainfall and drought conditions lead to the alkalinity of the soils. Srivastava *et al.,* (1989) in a study in dry tropical region found most of the degraded forest and mine soils in the alkaline conditions. Among the Plantations, pH values were observed to be increasing as one goes down to profile. The same trend in soil pH which is increasing to the lower layers of the profile was observed by Balagopalan and Jose (1995).

Available Phosphorous in the soil was found to be significantly different compared to the non eco-restored areas confined to a few plantations and biomass areas. The values of available P clearly depict the improvement in the P content of the soils. The phosphorous content was the highest in the top soil and it decreased downwards the profile. The same trend has been reported by Balagopalan and Jose (1993) in a study conducted in Kerala. The higher phosphorous content in the upper layer may be explained due to the higher organic matter content and litter recycling in the tree based ecosystem.

In biomass areas available phosphorous was found in higher concentrations in the Non restored areas. Phosphorous content in Kottathara biomass area was much more similar to the non restored areas which may be due to the fact that Kottathara region is drier than other two biomass areas *ie.* Sambarkode and Palliyara biomass areas which receive higher rainfall and more humid in comparision. The release of soil phosphorus is a dynamic process under the effect of low molecular weight organic acids. Organic acids in different concentrations also significantly affect phosphorus release (Xu et al., 2015).

The present study revealed that available phosphorus unlike other nutrients was uneven among the non-eco-restored areas and plantations/ biomass areas. This is because phosphorus is a highly immobile element (Smil, 2000). In the areas where vegetation is absent, the phosphorus in soil remains unfixed and remains accumulated for a longer period. As phosphorus is an element which is insoluble in water and are not able to convert to gaseous state the cycle of this nutrient is very slow among the vegetated ecosystems (Srivastava and Singh, 1991).

Exchangeable potassium in most of the plantations was found significantly different in the top soil, ie 0-20 cm when compared to non-restored areas. Potassium was found in higher content in all the plantations than the control areas. Availability of potassium decreased as the depth increased in all the plantations and biomass areas. Both the plantations and biomass areas K was much higher than the non restored areas which can be correlated to the higher litter and organic matter presence in these regions. Boruah and Nath (1992) reasoned that a layer of organic matter significantly improves the retention of K in the soils. Janssens *et al.* (1998) studied the relationship between plant biodiversity and different soil chemical factors in numerous sites and observed higher soil K content in sites with higher species diversity.

Exchangeable potassium varied considerably between soil depths among all the plantations and biomass areas as the profile goes downwards. Potassium being an element with high mobility, probably, its inconsistent presence in the soil explains the variability (George and Kumar, 1998). The greater availability of potassium favours the idea for restoration of the degraded areas.

Soil N is supposed to be the most limiting nutrient in a majority of terrestrial ecosystems (Sagar *et al.*, 2003). Total nitrogen was analyzed for all the plantations and biomass conservation areas by taking the composite samples from all the soil depths. In all the plantations and biomass areas there was significant improvement in the total N status. The values in the restored areas ranged from 0.09 to 0.15 percent in the plantations whereas 0.06 to 0.14 percent in case of Non-Restored areas. In the biomass conservation areas the value for Total N percent ranged from 0.17 to 0.22 percent, while it ranged from 0.05 to 0.12 percent for the Non- restored areas. Su and Zhao, (2003) in semi arid region of west China, reported that carbon and nitrogen concentrations increased significantly with increasing plantation age and had increased by 15.3/20.5-fold and 11.1/13.6-fold at 0/5 cm depth at 28 years of plantation compared with non-vegetated dune, although incremental rates were faster in the early establishment stage (0/13 year) than late successional stage (13/28 year).

Nitrogen content may be higher in the restored areas because of deliberate planting of nitrogen fixing tree species. It has been recorded that nitrogen availability increases in the areas with presence of Leguminaceae and such tree families which leads to biological nitrogen fixation (Gueye and Ndoye *et al.,* 1998). Total nitrogen was high in almost all the plantations and especially biomass areas due to increasing ground and litter cover which may lead to higher addition of organic carbon content compared to the non restored areas.

Cation Exchange Capacity (CEC) was analyzed for all the plantations and biomass conservation areas by taking the composite samples from all the soil depths. In all the plantations and biomass areas, the values of cation exchange capacity has been improved for restored areas as compared to the adjacent non-restored areas. The values in the restored areas ranged from 11.98 to 23.42 m in the plantations whereas 5.4 to 20.8 in case of non-restored areas. The increase in CEC can be attributed to the increase in organic matter content which in turn increase the water holding capacity of the soil and finally helps the soil to enhance exchange capacity of soils. Tongway and Ludwig (1996) also reported increase in CEC in the upper layers of soils after restoration of the semi areas of Australia and concluded that it may be due to increase in the individual cations partly due to improved exchange capacity because of the organic carbon accumulation during the three years of restoration.

Similar findings have been reported by Lal (2005), who recommended that the adoption of recommended management practices increased the carbon pool on degraded soils and deserted forest lands which enhanced the soil quality including the available water holding capacity, cation exchange capacity, soil aggregation, and susceptibility to crusting and erosion.

In the biomass conservation areas the value for Cation Exchange Capacity ranged from 14.92 to 33.14 meq/100 g for the Restored areas while it ranged from 7.60 to 11.00 meq/100 g for the Non- restored areas. It can be inferred from the results that there has been an improvement in the soil status of the restored areas.

The EC values for the restored areas of both the plantations as well as biomass areas show an increase in the values when compared to the non-restored areas. The values ranged from 29.67±1.76 to 195±3.18 µs/cm in the plantation areas. The general trend for the values of EC is a decreasing one with the increasing depth. Significant changes in the EC were observed in most of the plantations in the top soil 0-20 cm when the values of restored and non- restored areas are compared. Similar trends for the EC were observed by Bhojvaid and Timmer (1998) in the Nothern India for sodic soil restoration in an age sequence of *Prosopis juliflora* plantations.

In the biomass areas values ranged from 37.00±10.60 to 129±12.34 µs/cm, while in the non restored area values ranged from 29.33±0.88 to 57.00±4.16 µs/cm. In general, trend for the values of EC is a decreasing one with the increasing depth.

Improvement in the nutrient status of the soil leads to increase in electrical conductivity and the humus formation and is due to the litter degradation which improves the conductivity of the soil. Soil electrical conductivity is influenced by a combination of physico-chemical properties including soluble salts, clay content and mineralogy, soil water content, bulk density, organic matter, and soil temperature; consequently, measurements of EC have been used at field scales to map the spatial variation of several edaphic properties (Corwin and Leich, 2005).

The overall impact of eco restoration was prominently visible in the top layers of both the plantations and biomass areas. Vegetation was found positively correlated with the soil dynamics and nutrient status of the regions in all the plantations as well as biomass areas. There was significant difference in the status of non restored areas and restored areas in almost all the parameters of study depicting the success in the objective of eco restoration in Attappady region.

Enhanced nutrient contents in the lower depths of soil as compared to the same depths in non restored areas indicate the percolation of nutrients and improvement in the soil conditions of the restored areas in Attappady region.

The present study strongly recommends for knowledge imparting programs to the local tribes, bunds repair and intermediate camps for lantana removal in these areas so as to the educate the people for the conservation. These extension activities may help to check any further degradations or reversal of these areas which at present show improvement through recovery due to restoration activities.

Many instances of anthropogenic disturbances have been noticed during the course of study, thus proper planning and decisions may be taken for eco-friendly disposal of the matters and conflicts.

It may be recommended for the introduction of specific areas for grazing and energy plantations to conserve the developing plantations and regenerations.

The study also recommends introducing native species especially in the biomass areas, where in the further course of time the exotic species may lead to major changes in the floral diversity of these areas. *Leucaena leucocephala* came as a major success in regaining the vegetation cover as well as regeneration in the region, but further monitoring is suggested to understand the impact of this aggressive tree species in these areas in future.

Summary

6. SUMMARY

The present study was carried out in eastern part of Attappady to assess the impact of ecorestoration on the edaphic and vegetation attributes. The study focused on the impact of vegetation on the soil profile. Seven sites of plantation and three biomass conservation areas along with corresponding non eco-restored areas were selected for the study. Each sites were enumerated for the vegetation, regeneration also soil samples were collected for the physico-chemical analysis of the soil down the profile. Salient features of the study are summarized below.

1. A total of 101 species were recorded in the study area. Among the plantations maximum number of species were recorded in Agali plantation (48) followed by Palliyara plantation (38) however lowest number of species in Kottathara plantation (17). Among the biomass area maximum individuals were recorded in Palliyara Biomass (57) and minimum in Kottathara biomass area (31).
2. *Albizia amara* with the highest IVI values dominated in the drier sites of Attappady like Kottathara plantation, Melle-Chavadiyoor, Pattimalam, Vellamari and Kottathara biomass area.
3. *Leucaena leucocephala* was reported with the highest IVI in the plantations with better rainfall and humid conditions due to the proximity to the Western Attappady like Agali plantation (62.70), Sambarkode Plantation (65.66) and Palliyara Plantation (75.26).
4. In biomass areas the highest IVI were recorded for *Tectona grandis* (48.71) in Palliyara biomass, *Givotia mollucana* (50.31) in the Sambarkode biomass area. *Albizia amara* (87.01) dominated at the comparatively drier Kottathara biomass area,
5. *Leucaena leucocephala* regenerations were dominant in all the study sites with better rainfall areas and microclimatic conditions such as Sambarkode, Vellamari, Agali, Palliyara plantations and Sambarkode biomass.
6. *Santalum album* regenerations dominated in Palliyara biomass areas whereas *Erythroxylum monogynum* was dominant in Kottathara biomass areas.
7. *Leucaena leucocephala* and *Albizia amara* outstood among all other species planted during the restoration due to their extensive growth and high survival rates.

8. Except few, majority of plantations were affected by anthropogenic activities like timber and firewood collection and many instances of grazing by cows and goats were recorded during study period.
9. Among diversity indices, Shannon-Weiner index was found the highest for Sambarkode biomass (4.6) and Agali plantation (3.93). Simpsons index was highest for Sambarkode biomass (0.89) and Sambarkode plantation (0.83).
10. Significant variations are recorded between majority of plantations and biomass areas for organic carbon and organic matter. This was true for restored and non-restored areas.
11. Organic carbon decreased as the depth increased and the same trend was observed for the lower layers of soils in all the plantations and biomass areas. Also bulk density which is a close counterpart of organic matter increased with the depth in all study sites and their values were below the non- restored areas in most of the plantations and biomass areas.
12. No significant difference was observed between the pH values of restored and non-restored areas. pH values among all study sites ranged from slightly acidic to neutral. Both CEC and EC of soil also showed improvement in restored areas.
13. Significant variation was found for available phosphorous between the non-restored areas and restored areas. Phosphorous content mainly varied in study sites and was uneven among the study sites, which may be mainly due to its higher immobility.
14. Significant difference in potassium content was observed in the top layers of the soil among all the plantations and biomass areas when compared to non-restored areas.
15. In all the plantation and biomass areas there was significant improvement in total N status. Higher N content may be attributed to the prominent plantations of nitrogen fixing tree species during the restoration.
16. The present study recommends for conducting knowledge imparting programs to the local tribes, bunds repair and intermediate camps for lantana removal in these areas so as to educate the people for the conservation and check any further degradations.
17. It may be recommended for the introduction of specific areas or rotation of areas for grazing and energy plantations to conserve the developing plantations and regenerations.
18. The study also recommends introducing native species *Santalum album, Tectona grandis* etc, especially in the biomass areas, or else in the further course of time the exotic species may lead to major changes in the floral diversity of these areas.

19. *Leucaena leucocephala* came as a major success in regaining the vegetation cover as well as regeneration in the region, regular monitoring will be required to understand the impact of this aggressive tree species in these areas in future.

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Major Advisor: Dr. K. Vidyasagaran

Venue: Seminar hall
Date: 05-09-2016
Time: 2:00 p.m.

Post eco-restoration changes in vegetation and edaphic attributes of eastern Attappady, Kerala

Abstract

The present study was carried out in eastern part of Attappady to assess the impact of ecorestoration on the edaphic and vegetation attributes. The study focused on the impact of vegetation on the soil profile. Seven sites of plantations and three biomass conservation areas along with corresponding non eco-restored areas were selected for the study. Each sitewas enumerated for the vegetation, regeneration and soil samples were also collected for the physico-chemical analysis of the soil down the profile up to 60 cm depth.

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