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MANAGEMENT STRATEGIES FOR PROMOTING SUCCESSION IN PLANTATIONS OF PARAMBIKULAM AND WAYANAD WILDLIFE SANCTUARIES

(Final Report of Research Project KFRI/348/2000)

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ABSTRACT OF PROJECT PROPOSAL

Code	:	KFRI/348/2000
Title	:	Management Strategies for Promoting Succession in Plantations of Parambikulam and Wayanad Wildlife Sanctuaries
Objectives	:	i. To compare the habitat in the area under plantation with that of the adjoining natural forest and bring out the disadvantages suffered by various species of animals in terms of their habitat requirement. ii. To study the regeneration and growth patterns of indigenous tree species in plantations of different age groups and in nearby natural forests. iii. To assess the regeneration status of indigenous tree species in plantations subjected to treatment for conversion into natural plantations. iv. To suggest suitable management strategies for triggering ecological succession. v. To study the effect of timber operations on fauna in the study area. vi. Develop suitable techniques for planting in intensive wildlife areas. vii. Weed management in plantations and natural forests. viii. to prepare action plan with calendar of operations for achieving the above objectives
Expected outcome	:	The study will bring out management strategies for promoting succession and for converting plantations in wildlife sanctuaries to natural forests
Date of Commencement	:	April, 2000
Scheduled date of completion	:	March, 2002
Funding Agency	:	Kerala Forest Department (World Bank Assisted Kerala Forestry Project)
Investigators	:	N Sasidharan ARR Menon PS Easa (NC Induchoodan - Principal Investigator from April, 2000 to March, 2001)
Project Fellows	:	Jeesa Thomas; Pius OL; K Manjula Menon

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Wayanad WLS

ABSTRACT

The study was carried out in the Parambikulam and Wayanad Wildlife Sanctuaries with emphasis on promoting growth of indigenous species in plantations. The study also aimed at assessing the disadvantages suffered by various species of animals in terms of their habitat requirements. In both the sanctuaries, teak is the major plantation species and occupies about 90 km^2 area in Parambikulam and 74 km^2 in Wayanad. About 14 km^2 is covered by *Eucalyptus* and a few other species in Wayanad Sanctuary. The *Eucalyptus* plantations have been clearfelled and planted with seedlings of indigenous species from 1997 onwards. The regeneration pattern of trees in the treatment areas was also studied.

The teak plantations in the sanctuaries were grouped into four broad age classes (year of planting) of 20 year interval. The number of teak trees, number of naturally regenerated and established indigenous trees, their seedlings, status of shrubs, herbs and climbers in the plantations of all the four age classes as well as in the neighbouring natural forests were assessed from the data generated from the sample plots. The seedlings of indigenous tree species in the plantations of the four age classes vary from 1700-8600 per ha. However, 74 to 97 per cent seedlings belong to the height classes below one metre. This trend indicates heavy mortality to the newly recruited seedlings every year. The major reasons are fire, grazing and weed growth.

In teak plantations the succession of indigenous trees is taking place through regeneration. Though quite a large number of indigenous species have established in the plantations, their total basal area is very low as compared to the total basal area of teak trees. While promoting the growth of indigenous species, the ideal situation is to have a structural composition similar to that of neighbouring natural forests. The average number of teak trees in the natural forests is 19 per hectare in Wayanad. In Parambikulam the number of teak trees is 11 per hectare in moist deciduous forests and four in semi-evergreen forests.

In Parambikulam Sanctuary, several evergreen tree species are regenerating and have established in teak plantations in the Orukomban and Karimala Ranges, due to the proximity of the plantations to semi-evergreen/evergreen forests. The regeneration status of indigenous species indicates that no enrichment planting is needed in these plantations.

The plantations are heavily infested by exotic weeds like *Eupatorium odoratum* and *Lantana camara*. These weeds occupy 34 to 71 per cent of the shrubs in the plantations of different age classes. *Imperata cylindrica* is smothering the seedlings in the treatment areas in the Muthanga Range in Wayanad Sanctuary.

The abundance and diversity of elephant, gaur, sambar deer, frogs, spiders and soil fauna were estimated. The results do not follow a fixed pattern. The natural forests in Wayanad were better in terms of abundance and diversity of selected species. However, there were differences in these parameters in Parambikulam depending on the year of plantations. In most cases, the plantations were more or equally rich in abundance and diversity. The abundance and diversity of some groups of animals indicate that the preference of animals varies depending on the shrub cover, availability of food species and litter depth.

1. INTRODUCTION

Wildlife Sanctuaries and National Parks are essentially meant for conserving biological diversity and natural ecosystems. In the State of Kerala, about 24 per cent of the forests have been brought under protected areas through the establishment of 12 Wildlife Sanctuaries and two National Parks. Parambikulam and Wayanad Wildlife Sanctuaries are two among them. These sanctuaries are well known for their rich wildlife. The flora of Parambikulam Sanctuary has been recently studied. The sanctuary possesses an amazingly rich flora including several endemic as well as rare and threatened species (Sasidharan, 2002). The flora of Wayanad Wildlife Sanctuary has not yet been evaluated through detailed floristic study. In both the sanctuaries teak is the major plantation species. In Parambikulam 90 km^2 out of the 285 km^2 area is covered by teak plantations. Wayanad has an area of 344 km^2 of which 74 km^2 area is under teak and 14 km^2 area under *Eucalypts*.

Plantation forestry is an alternative measure to meet the demand for the desired species. However, it has several demerits. Being generally monocultures, pests and diseases are associated with plantation species. Moreover, plantations are generally known to adversely affect the biodiversity of the forests. This has led to the concept of managing natural forests, keeping their original structure and diversity undisturbed and promoting natural regeneration. The concept of protecting biodiversity is being increasingly felt nowadays. Thus the practice of sustainable management and utilization of natural forest resource is given greater attention.

Wildlife management strategies are to be based on understanding the animal populations, dynamics of these populations and functional relationship between habitat conditions. The preference or avoidance of a given habitat or plant species in terms of its availability has long been recognised (Glading *et al.*, 1940; Bellrose and Anderson, 1943; Neu *et al.*, 1974). Herbivores are known to favour habitat types where nutrient intake could be maximised (Westoby, 1974; Owen-Smith and Novellie, 1982; Owen-Smith, 1985). Seasonal movements of large herbivores between different habitats have also been well established (Bell, 1971; McNaughton, 1987).

The Management Plans of the Sanctuaries propose reconversion of the plantations and to promote the growth of indigenous species through appropriate management practices (Uniyal, 1987). The present study was taken up with the objectives i) to compare the habitat in the area under plantation with that of the adjoining natural forest and bring out the disadvantages suffered by various species of animals in terms of their habitat requirement, ii) to study the regeneration and growth patterns of indigenous tree species in plantations of different age groups and in nearby natural

forests, iii) to assess the regeneration status of indigenous tree species in plantations subjected to treatment for conversion into natural plantations, iv) to suggest suitable management strategies for triggering ecological succession, v) to study the effect of timber operations on fauna in the study area, vi) to develop suitable techniques for planting in intensive wildlife areas, vii) weed management in plantations and natural forests and viii) to prepare action plan with calendar of operations for achieving the above objectives.

Though, eight objectives were included in the project some of the objectives could not be fully achieved. During the first year of the project, essential baseline data could not be generated due to the reversion of the Principal Investigator, who initiated the project, back to the Forest Department. Further progress and activities of the objectives such as weed management and planting trials were dependent on these essential baseline information. Furthermore, precise information on forestry operations carried out in individual plantations was not available. Hence, the objective to study the impact of logging of fauna could not be achieved. But, conclusions based on abundance and diversity of selected group of animals have been made and compared with the natural forests.

2. REVIEW OF LITERATURE

The monitoring of eco-resource needs to be viewed from multiple angles, along with qualitative and quantitative evaluation of vegetation for the proper management. Studies on these lines were conducted by many researchers (Britwum, 1975; Synnott, 1975; Daryano, 1990). All populations change the size and density over time and such shift may eventually result in the extinction of species (Reveal, 1981). This threat is more difficult to characterize since it may be a natural consequence of biological or geographical process or can be a result of past or present human activities directly or indirectly influencing the plant populations or their environment (Britwum, 1975).

Raising of forest plantations for increasing production of desired species by clearing the natural vegetation adversely affects the flora and fauna of the area. Apart from restricting the area and the amount of resources available for wildlife populations, human exploitations of the forests for timber, fuel-wood and fodder may also degrade the habitat and lower the resource base considerably (Takeshi, 1993). Such anthropogenic effects will definitely change the successional status of the ecosystem resulting in a sudden change in the dominant associations especially the weed status in the plantations. The structural status of such area has always been an attraction of many ecologists in the past (Clements, 1905; Colwell, 1968; Bakuzis, 1969; Beals, 1969). Measuring the abundance of a species is the starting point of modern

population/community ecology (Begon *et al.,* 1986). In this regard Takeshi (1993) is of the opinion that in plant community or even in animal population some species are common and others are rare; species can be arranged on a spectrum of abundance, from the commonest to the rarest. The mechanistic approach, where the relative abundance of species is used as a basic measure (Odum, 1971) with which many of the phenomena affecting community such as predators, competition and distribution, etc. are analysed. Indeed investigators, often, employ the general term 'Community structure' to mean the actual status of relative abundance of species in a community when evaluating the influence of abiotic and biotic factors.

The earliest attempt to suggest the relationship of relative abundance in a community was by Motomura (1932) in his studies to describe ecological communities with particular reference to the complexity of species composition. Later several ecological models were formulated by many authors (Fisher *et al.,* 1943; Williams, 1944 and 1964; Preston, 1962; May 1975; Taylor *et al.,* 1976; Sugihara, 1980; Ugland and Gray, 1982). Plantation forestry is an alternative measure to increase the turnover of yield of desired species, even though it has the demerits of monoculture. Again, this type of forest management will normally lead to a special site quality status promoting extensive growth of site-specific weeds in the ecosystem. Very little work on these lines, evaluating the status of weed growth in such ecosystem, has been done in tropical ecosystem (Jayanarayanan, 2000). Shortage of teak and need for its continuous supply led to the first teak plantation in India and Burma (Stebbing, 1922). This was a breakthrough in plantation forestry. Later the concept of 'production forestry' rather than 'protection forestry' took a lead in the management priorities which accelerated the plantation sector growth by the introduction of other preferential species like *Eucalyptus, Acacia,* etc. Literature on the subject of artificial regeneration is enormous and has been reviewed by Seymour *et al.* (1986). The correction-oriented approach for preservation of rare plants based on the knowledge of critical habitat and species distribution took momentum recently. A number of studies on these lines have been conducted by various researchers (Radford, 1981; Chand Basha, 1990; Das, 1990).

Wild animals often range over wide geographical areas in response to temporal abundance and quality of forages. Watson and Moss (1970) and McNaughton (1987) have supported the findings that the dispersion of animals are related to food availability. Seasonal habitat selection has also been reported in several species (Fuller, 1960; Shackleton, 1968; Duncan, 1975; Krasinka *et al.*, 1987). Animals select landscapes to enable themselves to attain fitness

maximization in response to various factors. Within landscapes, the selected plant communities or vegetation patches are utilised to optimise foraging efficiency, selecting feeding sites with enough forage with quality. Distribution pattern of large herbivores is reported to be largely influenced by resource availability such as food, shelter and water (Sinclair, 1975; Sinclair, 1985; Krasinska *et al.*, 1987, Owen-Smith, 1988). Dinerstein (1979) after studying the habitat-animal interaction in Nepal concluded that changes in plant distribution and phenology affected ungulate food habits, energy budget, movement and seasonal distribution. Studies on elephant in southern India have shown that density distribution of elephants is highly governed by food and water availability (Sukumar, 1989a, 1989b; Easa, 1989).

Nair and Jayson (1988) conducted a study on the habitat utilization of large mammals in plantations and natural forests in Parambikulam and concluded that the animals showed varying degree of affinity to different age plantations. They commented that teak, a natural species in the Sanctuary and consumed by animals like elephants provides the necessary food and shelter to the animals. The mosaic of natural forest and plantations in the area reduce the expected adverse effect of monoculture.

Easa (1998) reported the preference of grasslands by gaur in Parambikulam. The second most preferred habitat of gaur in Parambikulam is moist deciduous forest. The study has also shown the influence of grass on the animal distribution. Higher percentage of food species is also observed in grasslands and moist deciduous forests in Parambikulam. Easa (1999), studying the habitat utilization of large mammals in Wayanad, reported a pattern in the distribution of animals where the environmental factors play important role. A seasonal pattern in the density distribution of elephant, gaur, sambar deer and chital was reported from Wayanad. The present investigation is specifically looking at the distribution and habitat utilization of animals in different age group plantations and natural forests in Parambikulam and Wayanad Wildlife Sanctuaries.

3. STUDY AREAS

3.1. Parambikulam Wildlife Sanctuary

Location

Parambikulam Wildlife Sanctuary is located in Chittur Taluk of Palakkad district between longitudes 76^0 35' and 76^0 50' East and latitudes 10^0 20' and 10^0 26' North.

Ecophysical features

Topographically, the Sanctuary exhibits hilly terrain with characteristic distribution of undulating plain areas with Vayals (Marsh Lands) interspersed in the valleys. The Nelliampathy hills in the north and west are in continuation to the Western Ghats which rise precipitously immediately south of the 'Palghat Gap'. The Kuchimudi peak (1169 m) is the north eastern mark of the Sanctuary. From here the hills drop steeply down the Thekkady-Keerapadi valley in the south west and again rise precipitously up to Pandaravaramalai. The hills slope down relatively gently towards south to Thunacadavu Valley of Sungam area. Here, the valley is fairly large and abruptly ascends southwards to Vengoli malai (1224 m). Afterwards, the tract is hilly. Few rolling grassy hills, merge ultimately with the chain of Anamalais in the deep south. From the north-west, the Nelliampathy hills descend gradually and open up in Thuthampara, Tellikkal and Parambikulam valley. This is the widest valley area in the Sanctuary. The valley gives way to the rising hills in Poopara and Karimala areas where the highest peak 'Karimala Gopuram' (1430 m) and its associated hills constitute the southern boundary of the Sanctuary. The valleys are low lying, having a gentle undulating surface and are covered with the artificially regenerated teak plantations. The distribution of Vayals is significant here. The altitude varies from 300 m to 1430 m, but the larger chunk of the Sanctuary has an average height of about 600 m (Uniyal, 1987).

Drainage

The Nelliampathy hill ranges are drained by the Thekkady ar, Parambikulam ar, Kuriarkutty ar, Thunacadavu ar, Tellickal ar, Karappara ar, Bagapallam ar, Vetti ar, and Pullickal ar, all of them, flow westwards (ar in Malayalam means river). All these rivers converge at Orukombankutty and finally drain into river Chalakudy. Some of the rivers such as Thekkady ar, Tellickal ar, Bagapallam ar, etc. tend to dry up during February and March.

Water supply: The crystalline rocks of the area are poor aquifers and water is confined mainly to the joint plains in the rocks. In general, the water level of the valley extends to a depth of 5.8 m from the surface of water supply. The water from the west flowing rivers of the Sanctuary is collected in three dams commissioned under Parambikulam Aliyar Project (Tamil Nadu) during early 1960. These are Parambikulam, Thunacadavu and Peruvaripallam. All the three dams are located in Parambikulam-Thunacadavu valley and a substantial quantity of water is diverted to the State of Tamil Nadu through tunnels and open channel systems.

Climate

Variation in altitude, aspect and precipitation results in variable climate in the Sanctuary. On an average the Sanctuary is endowed with a pleasant climate. The western parts of the Sanctuary receive higher precipitation than the eastern parts. The slopes which are covered with evergreen and mixed deciduous forests exhibit high percentage of humidity in the air than the valley covered with teak plantation.

The area gets both the south-west and north-east monsoon, south-west being the most active. About 80 per cent of the Sanctuary area lies in the windward side and therefore the Sanctuary receive heavy rainfall during the south-west monsoon. Average annual precipitation is 1723 mm.

The maximum temperature fluctuates between 24 and 33 ^{0}C and minimum between 20 and 25 ^{0}C. In the hills it would be still lower during night. February to April are the hottest months. The relative humidity is low. November and December are fairly cool in the valley during mornings and late evenings but are comfortably warm during day hours. Dry season lasts for 5-7 months.

Natural forests

Natural vegetation of the Sanctuary is a combination of Malabar and Deccan elements. Microclimatic fluctuations coupled with edaphic, topographic and biotic factors have provided the Sanctuary with a high floral diversity.

By following Chandrasekharan (1962) and Champion and Seth (1968) the natural vegetation of the Sanctuary can be classified into *west coast tropical evergreen forests, west coast tropical semi evergreen forests, southern moist mixed deciduous forests, southern dry mixed deciduous forests, low altitude marshy grasslands* (vayals), *moist bamboo brakes* and *reed brakes*. Teak is the major plantation species and covers an area of about 90 km^2.

3.2. Wayanad Wildlife Sanctuary

Location

The Sanctuary is located partly in Mananthavady and Sultan's Battery Taluks of Wayanad district between longitudes 76^o 02' and 76^o 27' East and between latitudes 11^o 35' and 11^o 51' North.

Ecophysical features

The altitude ranges from 650 m to 1150 m, the highest point being Karottimala in Kurichiat Reserve (1158 m). The major part of the Sanctuary is

a table land of Wayanad plateau to the east of the main ridge which gradually slopes down to the north and east to Karnataka. This is an undulating terrain interspersed with hillocks which are seldom steep. The sanctuary in general has a westerly aspect though all conceivable aspects can be seen due to the rugged nature of the country and innumerable hillocks.

The soil type found is mostly of forest soil and hill soil. This is characterised by a surface layer of organic matter derived from the forest. It is rich in nitrogen and base status varies depending on the degree of leaching. The soils are mostly loamy with varying proportions of sand and clay.

Drainage

Papanasini (Bavali river) forms the main drainage system in Tholpetty Range. The river originates from Thirunelli Reserve and flows through Kudirakode, Begur and drains to Kabani. Three main streamlets flow southwards from the upper part of the Range and join Bavali river. Some of these are perennial. A network of streamlets provides almost uniform water supply to Tholpetty region. Northern portion of Kurichiat Range is drained by Kannarampuzha and Kurichaiat river flowing northwards to join Kabani river. Towards the south-east, Manchalthodu and other streamlets join Nuguhole river to flow further north-east to Karnataka. Southern portion of the Sanctuary is being drained by Noolpuzha and Mavinhallathodu which combine to form Nuguhole river (Gopinanthan, 1990).

Climate

The temperature varies from 13 to 32 ^{0}C. The humidity is more in the valleys than in the hills. The plateau is comparatively drier. March to June are the hottest months. Mist is common form November to February on the plateau.

The south-west monsoon which brings the greater part of the rainfall commences during the first week of June preceded by a few showers in April and May. The heaviest rainfall occurs during July and August. The north-east monsoon brings some rain in October and November. Breaks in the monsoon are not uncommon. The average rainfall is 2000 mm per annum.

Natural forests

Much of the Sanctuary area fall under deciduous type of forests. Few patches of Semi evergreen forests are seen in Muthanga and Tholpetty Ranges.

By following Chandrasekharan (1962) and Champion and Seth (1968) the natural vegetation of the Sanctuary can be classified into *southern moist mixed deciduous forests, southern dry mixed deciduous forests, west coast semi-evergreen forests* and *moist bamboo brakes*. Teak is the major plantation

species covering an area of about 74 km^2. Plantations of *Eucalyptus*, rosewood, soft wood and sandal occupy an area of about 14 km^2.

4. MATERIALS AND METHODS

4.1. Vegetation studies

Details pertaining to the teak plantations in the sanctuaries such as year of planting, extent, silvicultural thinning operations, etc. were compiled from the management plans and relevant records available in the sanctuaries. The oldest teak plantations now in Parambikulam were raised in 1916 and youngest in 1983. In Wayanad, the oldest teak plantation now available was raised in 1904 and the youngest in 1982. The details of the plantations such as year of planting, extent of areas and Range wise location are provided (Map I, Map II.1, II.2, II.3 and II.4). In order to study regeneration pattern of the indigenous species, their succession, etc. the plantations were categorised into four broad age classes of 20 year interval. Thus, the plantations of Parambikulam Wildlife Sanctuary are grouped into the age classes 1916-1935, 1936-1955, 1956-1975, 1976 and above. The teak plantations of Wayanad Wildlife Sanctuary are grouped into the age classes viz. 1905-1924, 1925-1944, 1945-1964 and 1965-1984.

Based on the extent of area, year of planting and silvicultural operations carried out, adequate number of sample plots were laid out in these plantations. Details of sample plots laid out in plantations of different age classes are provided in Tables 1 and 2. For determining the frequency, density and dominance of trees, shrubs and herbs, sample plots of 30 m x 30 m were laid out. These sample plots were further divided into nine subplots of 10 m x 10 m. All trees greater than 10 cm gbh were enumerated from the nine subplots within 30 m x 30 m plots. Enumeration of plants below 10 cm gbh was carried out in the 10 m x 10 m subplots at the opposite ends (extremity of the diagonal line). Plants of tree species below 10 cm gbh were classified into different height classes such as <20 cm, 20-40 cm, 40-60 cm, 60-80 cm, 80-100 cm, 1-2 m, 2-3 m and >3 m. Enumeration of shrubs was carried out in 5 m x 5 m sample plots within 10 m x 10 m subplots at the opposite ends. For enumeration of grasses and low herbs 1 m x 1 m plots were laid out within the 10 m x 10 m subplots at the opposite ends of the 30 m x 30 m sample plots.

To compare the composition and the regeneration pattern in the natural forests and teak plantations, 17 sample plots of 30 m x 30 m were laid out in the natural forests adjacent to the plantations in Parambikulam and 11 sample plots in Wayanad. Enumeration of trees, seedlings, shrubs and herbs was carried out in the same way as did in the plantations.

Table 1. Sample plots laid out in the plantations and natural forests in different ranges (Parambikulam WLS)

Age class	Area (ha)	Range	Plots taken	Year	Location
1916-1935	381.1	S	4	1926	Amakundu
		S	2	1933	Anapady
		S	2	1935	Anapady
1936-1955	1087.367	S	1	1936	Seechali Chettirara
		S	1	1939	Seechali Chettirara
		S	1	1942	Kannimara Road
		S	1	1943	Kannimara Road
		S	2	1944	Yellow Board Sungam
		S	2	1946	Vattakanipalam
		S	2	1948	Anakkal Vayal Kannimara Chappath
		S	1	1950	Peruvaripallam
		S	1	1952	Manchadipallam
		S	1	1954	Thekkampara
1956-1975	7204.795	S	2	1956	Thekkampara Road
		S	2	1957	Thekkampara Road
		S	1	1960	Thekkampara Road
		O	1	1961 B. 7	Thallichal
		O	1	1961 B. 6	Thallichal
		O	1	1962 B. 9	Thallichal South vayal
		O	1	1962 B. 10	Thallichal
		P	1	1963 B.34	Randupalam
		P	1	1963 B.23	
		P	1	1963 B.24	Anthrappalam
		P	1	1963 B.21	Anakkalvayal
		P	2	1963 B.30	Kuriarkutty
		P	1	1964 B.40	
		P	1	1964 B.42	
		P	1	1964 B.43	
		O	1	1964 B.51	Karinthalpara
		O	1	1964 B.52	Kuriarkutty
		O	2	1964 B.53	Thellickal, Pulikkal
		O	1	1964 B.57	Orukombankutty
		K	1	1965 B.81	
		K	1	1965 B.79	Churukkichettumoola
		K	1	1965 B.69	
		K	1	1965 B.73	Kottala Vayal
		K	1	1965 B.83	Kothala
		K	1	1965 B.91	
		K	1	1965 B.92	
		K	2	1965 B.80	
		K	1	1966 B.106	Madutheenippara
		K	1	1966 B.105	
		K	1	1967 B.126	Gudonkukku
		K	1	1967 B.124	Nurserymudi
		K	1	1967 B.125	Nurserymudu
		K	1	1967 B.136	Poopara Wireless station
		K	1	1967 B.134	Olimedu
		S	2	1967	
		K	1	1969 B.149	way to Pooppara colony
		K	1	1969 B.151	
		K	1	1969 B.152	

Table 1. Contd...

Age class	Area (ha)	Range	Plots taken	Year	Location
1976 and above	46.1	S	2	1983	Nalayiram
Total Teak area	8719.362		67		
Natural Forest		P	1		Ponnamudithandu
		S	1		Amakkundu
		O	1		Kuriarkutty
		S	1		Karianchola
		K	1		Kothala
		P	2		Vengoli
		S	1		Seechali
		S	1		Annakkalvayal
		P	2		Velayudhankai
		S	2		Sungam colony
		S	1		Anappady
		S	1		Sungam colony
		S	1		Sungam colony
		S	1		Keerappady

S- Sungam, P- Parambikulam, O – Orukomban, K – Karimala

Table 2. Sample plots laid out in the plantations and natural forests in different ranges (Wayanad WLS)

Age class	Area (ha)	Range	Plots taken	Year	Location
1905-1924	163.809	M	1	1917	Mavinhalla
		T	1	1919	Naikaty
		K	1	1922	Chikenji
		T	1	1922	Nedumthana
		T	1	1923	Nedumthana
		K	1	1924	Chikenji
		K	1	1925	Chikenji
1925-1944	1462.535	K	1	1928	Chikenji
		T	1	1932	Aruligatta
		T	1	1933	Aruligatta
		K	1	1933	Odapallam
		T	1	1934	Aruligatta
		K	1	1935	Kurichiad
		T	1	1937	Nedumthana
		T	1	1938	Dasankatta
		T	1	1939	Theturoad
		K	1	1942	Odapallam
		M	1	1942	Edathara
		M	1	1943	Thakarapady
		M	1	1944	Ponkuzhy
		K	1	1944	Odapallam
1945-1964	2884.652	M	1	1945	Vattampara
		T	1	1945	Dasankatta
		K	1	1946	Odapallam
		K	1	1946	kurichiad
		K	1	1948	Thekkuvara

Table 2. Contd...

Age class	Area (ha)	Range	Plots taken	Year	Location
1945-1964 (Contd..)		K	1	1952	Vandikadavu
		K	1	1954	Kuppady
		K	1	1957	Pavaghatha
		T	1	1957	Valiyanaikaty
		K	1	1958	Kurichiad
		K	1	1959	Pavaghatha
		K	1	1960	Madakundu
		T	1	1960	Begur
		T	1	1961	4th mail
		M	1	1961	Edathara
		M	1	1962	Kumali
		K	1	1964	Kurichiad
		M	1	1964	Mavinhalla
1965 - 1984	3413.	K	1	1965	Kurichiad
		T	1	1966	Puthiyodu
		K	1	1967	Kurichiad
		T	1	1969	Edakode colony
		K	1	1970	Karipur
		T	1	1970	Bavali road
		S	1	1970	Rampur-north
		S	1	1971	Rampur-north
		S	1	1972	Rampur-north
		K	1	1973	Kurichiad
		K	1	1974	Checkpost
		S	1	1974	Rampur-south
		T	1	1974	Tholpetty road
		S	1	1975	Rampur-south
		T	1	1975	Tholpetty
		K	2	1976	Checkpost
		T	1	1976	Kuthirakodu
		T	1	1977	Kuthirakodu
		S	1	1977	Rampur-south
		S	4	1978	Rampur-Kallur
		S	2	1979	Rampur-north
		S	2	1980	Kallur
		T	1	1981	Kuthirakodu
		S	2	1981	Kallur
		T	1	1982	Punjavayal
		S	2	1982	Kallur
Total teak area	7924.467		73		
Natural Forest		S	1		Kallur
		T	1		Bavali
		T	1		Tholpetty
		K	1		Pavaghatha
		K	1		Kurichiad
		K	1		Pavaghatha
		K	1		Amavayal
		K	1		Teakvara
		S	1		Bathery
		S	1		Rampur
		K	1		Vandikadavu

S- Sulthan Bathery , M- Muthanga, K- Kurichiad ,T-Tholpetty.

4.1. Vegetation studies

The animal groups for monitoring were selected considering wider range of assumed habitat characteristics of species including microhabitats, moisture, temperature, food, canopy cover *etc.* The larger animals such as elephant, gaur and sambar deer were selected among the herbivores representing graziers and browsers. The number of spiders will reflect the number of shrubs, litter and also the cover. The amphibians will reflect the humidity, litter and the moisture in general. The soil fauna is an indication of the richness of the soil in terms of moisture. Thus the monitoring of a wider range of animals would reflect the health of the habitat.

For studying the habitat utilisation by animals and to make a comparison on the animal abundance and diversity of animals/animal groups in natural forests and plantations, the plantations were stratified according to the year of planting and then grouped according to the age. Thus plantations falling in groups of ten years were clubbed (Easa, 1989). Transects with a length of one kilometre were laid in all the plantations within the group for estimating the abundance of larger herbivores. The details of the transects laid are presented in Tables 3, 4, 5 and 6. The similar year plantations in Parambikulam are not confined to one area but are scattered and the positions of transects are given in the area map (Map 3). Hence the transects within a group were scattered depending on the distribution of plantation in Parambikulam. Transects were also laid in the natural forests adjacent to the plantations.

These transects were covered on foot. Attempts to monitor the population with the direct sightings as suggested by Burnham *et al.* (1980) were abandoned, both in Wayanad and Parambikulam, after the first attempt due to the low number of sightings. Subsequently, the dung count method (Barnes and Jensen, 1987) was adopted for estimating the density of elephant and gaur dung. In this method, the transects were covered on foot observing the dung of gaur and elephant on both sides and recording the perpendicular distances.

Plots of 10 m x 10 m were laid at every 100 m interval along the transects and the indirect evidences of sambar deer (hoof mark/pellet group) within the plots were recorded. The number of spiders, shrubs, and logs observed within the plots were also recorded. Litter depth was measured and visual estimation of canopy cover made. Soil samples were collected from 10 randomly selected plots in each plantation in Parambikulam Wildlife Sanctuary and six plots in Wayanad. The soil samples were collected from 10 cm x 10 cm x 10 cm plots. These were later used for soil fauna estimation using Berley's funnel.

Quadrat sampling method was used for estimating the abundance and diversity indices of amphibians. Plots of 10 m x 10 m size were laid at random in all the plantations and natural forests. These plots were thoroughly searched for amphibians (Heyer *et al.,* 1984). Amphibians thus observed were identified in the field itself.

Table 3. Details and length of transects in plantation (Parambikulam WLS)

Sl. No.	Year of plantation	Length of the transect (km)	Extent of plantation (ha)
Range: Sungam			
1	1926	1.0	101.58
2	1943	0.7	60.640
3	1946	1.0	93.080
4	1948	0.8	84.180
5	1957	1.0	49.370
6	1967	1.0	42.200
7	1935	1.0	36.850
8	1939	1.0	35.210
9	1933	1.0	8.740
10	1936	1.0	35.210
11	1942	0.8	46.400
12	1944	0.7	52.960
13	1950	1.0	49.600
14	1952	1.0	41.710
15	1954	0.7	49.410
16	1956	0.9	48.560
17	1960	0.5	48.560
18	1983	0.7	35.580
Total			919.840
Range: Parambikulam			
1	1963	1.0	1040.050
2	1964	1.0	679.317
Total			1719.367
Range: Karimala			
1	1967	1.0	622.810
2	1965	1.0	1454.656
3	1966	1.0	698.300
4	1969	1.0	165.750
Total			2941.546
Range: Orukomban			
1	1961	1	561.262
2	1962	1	366.652
3	1964	1	505.985
Total			1433.899

Table 4. Details of transects in natural forests (Parambikulam WLS)

Sl. No.	Locality	Vegetation Type	length of transect
Range: Sungam			
1	Karian Shola	Evergreen	1
2	Seechali	MDF	0.4
3	Keerapady	MDF	1
4	Amakkundu	MDF	1
5	Anappady	MDF	1
6	Anappady	MDF	1
7	Elathode	MDF	1
8	Thunakadavu	MDF	1
9	Kamathalamudi	MDF	1
10	Perivaripalam Dam	MDF	0.5

Table 4. Contd...

Sl. No.	Locality	Vegetation Type	length of transect
Range: Parambikulam			
1	Velayudhankai	MDF	1
2	Vengoli	Evergreen	1
3	Vengoli	Semi-evergreen	0.7
4	Anakkal Vayal	Grassland	1
5	Kannimara Teak	MDF	0.5
6	Belt	MDF	0.5
Range: Karimala			
1	Trek path	MDF	0.6
2	Muthuva Colony	MDF	1
3	Ponnamudithandu	MDF	1
Range: Orukomban			
1	Kothala Vayal	Grass land	1
2	Pooppara Section	Evergreen	1
3	Kuriarkkutty	MDF	0.2
4	Thellikkal	MDF	1

Table 5. Details and length of transects in plantation (Wayanad WLS)

Sl.No	Locality	Year of planting	Length of the transect (km)	Extent of plantation (ha)
Range: Muthanga				
1	Mavinhalla	1917	0.3	2.832
2	Edathara	1942	0.6	22.864
3	Mavinhalla	1943	1	29.968
4	Ponkuzhi	1944	0.3	30.148
5	Forest check post	1945	1	31.160
6	Edathara	1961	1	20.031
7	Edathara	1962	0.6	21.561
8	Mavinhalla	1964	1	70.840
			Total	229.404
Range Sulthan Bathery				
1	Edathara	1946	1	24.281
2	Vallurady	1961	1	58.072
3	Rampur. N	1970	1	50.000
4	Rampur. N	1971	1	39.230
5	Rampur. N	1972	1	50.000
6	Rampur. N	1974	1	56.430
7	Rampur. N	1975	1	55.500
8	Alathur	1977	1	84.00
9	Ottippara road	1977	1	84.000
10	Vallurady	1978 III	1	63.000
11	Mulangavu	1978 IV	1	63.000
12	Odapallam	1979	1	100.000
13	Illichuvadu	1980	1	90.000
14	Illichuvadu	1981	1	37.000
15	Illichuvadu	1982	1	34.000
			Total	888.513

Table 5. Contd...

Sl.No	Locality	Year of planting	Length of the transect (km)	Extent of plantation (ha)
Range: Kurichiat				
1	Chikenji	1922	1	20.230
2	Chikenji	1924	1	15.380
3	Chikenji	1925	1	15.380
4	Chikenji	1928	1	31.360
5	Thoddapalam	1933	1	20.350
6	Kurichiad	1935	1	23.330
7	Thoddapalam	1942	1	41.380
8	Thoddapalam	1944	1	55.030
9	Thoddapalam	1946	1	30.500
10	Kurichiad	1946	1	30.500
11	Thoddapalam	1948	1	53.430
12	Kurichiad	1952	1	32.370
13	Kuppady	1954	1	26.304
14	Pavagatha	1957	1	55.300
15	Kurichiad	1958	1	72.920
16	Pavagatha	1959	1	60.700
17	Kurichiad	1960	1	41.280
18	Kurichiad	1964	1	29.500
19	Kurichiad	1967	0.5	5.670
20	Karipur	1970	1	
21	Kurichiad	1973	1	14.000
22	Chek post	1974	1	
23	Chek post	1976	1	43.000
24	Pavagatha	1976	1	
			Total	717.614
Range: Tholpetty				
1	Naikatty	1919	0.4	3.24
2	Nedumthana	1922	0.6	8.5
3	Nedumthana	1923	0.4	6.88
4	Aruligatha	1932	1	17.6
5	Aruligatha	1933	1	24.6
6	Aruligatha	1934	1	11.4
7	Nedumthana	1937	0.5	5.06
8	Dasanakatha	1945	1	40.05
9	Theturoad	1939	1	43.2
10	Dasanakatha	1945	1	39.27
11	Valiyanaikutty	1957	1	63.64
12	Begur	1960	1	63.13
13	4th Mile	1961	1	80.13
14	Puthiyur	1966	1	43
15	Edacode colony	1969	1	39
16	Baveli road	1970	1	36
17	Tholpetty road	1974	1	36
18	Tholpetty	1975	1	65.2
19	Kuthirakode	1976	1	32
20	Kuthirakode	1977	1	27.3
21	Kuthirakode	1981	1	42
22	Punjavayal	1982	1	58
			Total	785.2

Table 6. Details of transects in natural forest (Wayanad WLS)

Sl.No	Location	Vegetation	Length of the transect (km)
Range: Muthanga			
1	Nellur vayal	MDF	1
2	Karnataka Border (Ponkuhi)	MDF	1
3	Thoddamoola	MDF	1
4	Muttappankolli	MDF	1
5	Cheeradankolli	MDF	1
Range : Sulthan Bathery			
1	Ottipara	MDF	1
2	Ellakallu	MDF	1
3	Karnataka Border (Ottipata)	MDF	1
4	Arakunji	MDF	1
5	Melamoda	MDF	1
6	Kuzhimoola (Mangamukku)	MDF	1
7	Ponkuzhi colony	MDF	1
8	Nallathanny road	MDF	1
9	Karnataka Border (Ottipata)	MDF	1
10	Nallathanny	MDF	1
11	Inbetween Nallathanny and Valluvady	MDF	1
Range : Kurichiat			
1	Ammavayal	MDF	1
2	Thoddakolachi	MDF	1
3	Thoddakolachi	MDF	1
4	Kurichiad	MDF	1
5	Pavagatha	MDF	1
6	Kuppady	SEG	0.5
Range : Tholpetty			
1	Dhasanakatta	MDF	1
2	Champalam	MDF	1
3	Undakarai	MDF	1
4	Karimaram	MDF	1
5	Karimaram	MDF	1
6	Thoddaddy	MDF	1
7	Thoddaddy	MDF	1
8	Punjavayal	MDF	1

5. ANALYSIS OF DATA

The data generated from the sample plots laid out in the plantations and natural forests were analysed to find out the number of teak trees per hectare; the number of indigenous trees per hectare, their density, frequency, relative density, relative frequency, relative basal area and importance value index (Mueller-Dombois and Ellenberg, 1974). The Maturity Index values of regeneration in different age classes were worked out for qualitative comparison (Pichi-Sermolli, 1948). The seedlings were analysed to find out the number of each species belonging to various height classes and their dominance in plantations and natural forests. The shrubs were analysed to find out their number per hectare as well as the percentage of each species. The percentage of *Eupatorium* and *Lantana*, the major exotic weeds in the plantations and natural forests was assessed. The herbs, grasses and climbers recorded from the sample plots were analysed to find out food species of animals.

The data on animals for the group of plantations and the natural forests were pooled and analysed using the computer program DISTANCE (Laake *et al.*, 1994) for density estimation within the group of plantations.

One way analysis of variance (ANOVA) was applied to test the significant difference between different age groups of teak plantations and natural forests with respect to number of shrubs, litter depth, dead logs, spiders, sambar deer evidences and soil fauna. The comparison of natural forests with that of different age groups of teak plantations was examined using Least Significant Difference (LSD) test.

The data collected for amphibians were analysed for diversity, richness and evenness indices using the computer program SPDIVERS of STATECOL. The diversity indices, the Shanon-Weiner and Simpson, the richness indices, the Margalef (R1) and the Menhenick's (R2) and evenness indices E1, E2, E3, E4 and E5 were estimated.

6. RESULTS AND DISCUSSION

6.1. Parambikulam Wildlife Sanctuary

6.1.1. Vegetation studies

Teak plantations

Composition of trees in teak plantations of different age class

Age class 1916-1935:
Average number of teak trees: 65/ha
Average number of other trees : 170/ha (belonging to 16 species)

Age class 1936-1955:
Average number of teak trees: 112/ha
Average number of other trees: 131/ha (belonging to 14 species)

Age class 1956-1975-Near moist deciduous forests:
Average number of teak trees: 258/ha
Average number of other trees: 216/ha (belonging to 43 species)

Age class 1956-1975-Near semi-evergreen forests:
Average number of teak trees: 225/ha
Average number of other trees: 368/ha (belonging to 50 species)

Age class 1976 and above:
Average number of teak trees: 260/ha
Average number of other trees: 176/ha (belonging to 7 species)

Data on density, frequency, relative density, relative frequency, relative basal area and importance value index of teak and other trees in plantations of the four age classes are provided in Tables 7, 8, 9, 10 and 11.

Table 7. Composition of trees in teak plantations; Age class: 1916-1935

Species	D	F	RD	RF	RBA	IVI	IND
Tectona grandis	72.22	100	27.66	16	85.6	129.26	65
Cassia fistula	61.11	100	23.4	16	1.13	40.53	55
Catunaregam torulosa	37.5	75	14.36	12	0.13	26.49	34
Terminalia paniculata	20.83	37.5	7.98	6	5.83	19.81	19
Casearia wynaadensis	19.44	50	7.45	8	0.67	16.12	18
Diospyros montana	13.89	50	5.32	8	0.17	13.49	13
Xylia xylocarpa	11.11	50	4.25	8	1.68	13.93	10
Dalbergia latifolia	5.56	25	2.13	4	3.09	9.22	5
Tabernaemontana heyneana	5.56	25	2.13	4	0.09	6.22	5
Trewia nudiflora	2.78	25	1.06	4	0.01	5.07	3
Lagerstroemia microcarpa	2.78	12.5	1.06	2	1.14	4.2	3
Dillenia pentagyna	1.39	12.5	0.53	2	0.24	2.77	1
Syzygium cumini	1.39	12.5	0.53	2	0.13	2.66	1
Wrightia tinctoria	1.39	12.5	0.53	2	0.09	2.62	1
Antidesma acidum	1.39	12.5	0.53	2	0	2.53	1
Bauhinia malabarica	1.39	12.5	0.53	2	0	2.53	1
Grewia tiliifolia	1.39	12.5	0.53	2	0	2.53	1
Total			100	100	100	300	235

D- Density, F- Frequency, RD-Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI- Importance Value Index, IND- Individuals per hectare

Table 8. Composition of trees in teak plantations; Age class: 1936-1955

Species	D	F	RD	RF	RBA	IVI	IND
Tectona grandis	124.79	100	46.2	18.57	88.17	152.94	112
Cassia fistula	34.19	84.62	12.66	15.72	1.41	29.79	31
Diospyros montana	24.79	61.54	9.18	11.43	0.53	21.14	22
Xylia xylocarpa	22.22	38.46	8.23	7.14	2.67	18.04	20
Trewia nudiflora	14.53	38.46	5.38	7.14	0.43	12.95	13
Casearia esculenta	13.68	46.15	5.07	8.57	0.24	13.88	12
Lagerstroemia microcarpa	9.4	30.77	3.48	5.71	2.92	12.11	8
Terminalia paniculata	6.84	30.77	2.53	5.71	2.74	10.98	6
Holarrhena antidysenterica	5.13	23.08	1.9	4.29	0.11	6.3	5
Dillenia pentagyna	4.27	23.08	1.58	4.29	0.44	6.31	4
Wrightia tinctoria	3.42	23.08	1.27	4.29	0.08	5.64	3
Antidesma acidum	2.56	15.38	0.95	2.86	0.01	3.82	2
Tabernaemontana heyneana	2.56	7.69	0.95	1.43	0.05	2.43	2
Lagerstroemia reginae	0.85	7.69	0.31	1.43	0.18	1.92	1
Actinodaphne malabarica	0.85	7.69	0.31	1.43	0.01	1.75	1
Total			100	100	100	300	243

D- Density, F- Frequency, RD-Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI- Importance Value Index, IND- Individuals per hectare

Table 9. Composition of trees in teak plantations – near moist deciduous forests; Age class: 1956-1975

Species	D	F	RD	RF	RBA	IV	IND
Tectona grandis	286.83	100	55.63	14.36	82.06	152.05	258
Cassia fistula	24.69	66.67	4.79	9.57	1.06	15.42	22
Terminalia paniculata	22.22	29.63	4.31	4.26	5.48	14.05	20
Wrightia tinctoria	21.4	22.22	4.15	3.19	0.53	7.87	19
Xylia xylocarpa	18.11	40.74	3.51	5.85	2.27	11.63	16
Diospyros montana	17.28	48.15	3.35	6.92	0.35	10.62	16
Catunaregam torulosa	14.81	37.04	2.87	5.32	0.14	8.33	13
Lagerstroemia microcarpa	14.4	51.85	2.79	7.45	1.56	11.8	13
Chionanthus mala-elengi	11.93	7.41	2.31	1.06	0.32	3.69	11
Macaranga peltata	9.88	18.52	1.92	2.66	2.03	6.61	9
Trewia nudiflora	9.47	25.93	1.84	3.72	0.29	5.85	9
Ixora brachiata	9.05	7.41	1.76	1.06	0.11	2.93	8
Tabernaemontana heyneana	9.05	37.04	1.76	5.32	0.2	7.28	8
Casearia esculenta	5.76	25.93	1.12	3.72	0.07	4.91	5
Phyllanthus emblica	3.7	14.81	0.72	2.13	1.01	3.86	3
Zizyphus glabrata	3.7	11.11	0.72	1.6	0.08	2.4	3
Alangium salvifolium	3.29	7.41	0.64	1.06	0.02	1.72	3
Schleichera oleosa	3.29	11.11	0.64	1.6	0.06	2.3	3
Blepharistemma serratum	2.88	3.7	0.56	0.53	0.02	1.11	3
Mallotus philippensis	2.88	14.81	0.56	2.13	0.03	2.72	3
Dalbergia latifolia	2.47	11.11	0.48	1.6	0.93	3.01	2
Antidesma acidum	2.06	14.81	0.4	2.13	0.01	2.54	2
Bauhinia malabarica	2.06	7.41	0.4	1.06	0.21	1.67	2
Glochidion ellipticum	2.06	3.7	0.4	0.53	0.04	0.97	2
Grewia tiliifolia	1.65	7.41	0.32	1.06	0.53	1.91	1
Vitex altissima	1.65	3.7	0.32	0.53	0.05	0.9	1
Stereospermum colais	1.23	3.7	0.24	0.53	0.16	0.93	1
Casearia wynaadensis	0.82	3.7	0.16	0.53	0.04	0.73	1
Neolitsea cassia	0.82	3.7	0.16	0.53	0.02	0.71	1
Adina cordifolia	0.41	3.7	0.08	0.53	0.04	0.65	1
Aporusa lindleyana	0.41	3.7	0.08	0.53	0	0.61	1
Bridelia retusa	0.41	3.7	0.08	0.53	0.12	0.73	1
Carallia brachiata	0.41	3.7	0.08	0.53	0	0.61	1
Cordia dichotoma	0.41	3.7	0.08	0.53	0.02	0.63	1
Dillenia pentagyna	0.41	3.7	0.08	0.53	0.02	0.63	1
Litsea coriacea	0.41	3.7	0.08	0.53	0	0.61	1
Mallotus tetracoccus	0.41	3.7	0.08	0.53	0	0.61	1
Radermachera xylocarpa	0.41	3.7	0.08	0.53	0.02	0.63	1
Santalum album	0.41	3.7	0.08	0.53	0	0.61	1
Sapindus laurifolius	0.41	3.7	0.08	0.53	0	0.61	1
Spondias pinnata	0.41	3.7	0.08	0.53	0.01	0.62	1
Syzygium cumini	0.41	3.7	0.08	0.53	0	0.61	1
Terminalia bellirica	0.41	3.7	0.08	0.53	0.02	0.63	1
Terminalia crenulata	0.41	3.7	0.08	0.53	0.06	0.67	1
Total			100	100	100	300	474

D- Density, F- Frequency, RD-Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI- Importance Value Index, IND- Individuals per hectare

Table 10. Composition of trees in teak plantations – near semi-evergreen forests; Age class: 1956-1975

Species	D	F	RD	RF	RBA	IVI	IND
Tectona grandis	249.67	100	37.9	9.09	70.82	117.8	225
Trewia nudiflora	47.06	64.71	7.14	5.88	1.25	14.27	42
Diospyros montana	27.45	52.94	4.17	4.81	0.83	9.81	25
Tabernaemontana heyneana	23.53	52.94	3.57	4.81	0.58	8.96	21
Litsea coriacea	20.92	47.06	3.18	4.28	0.33	7.79	19
Macaranga peltata	20.26	52.94	3.08	4.81	4.53	12.42	18
Hydnocarpus pentandra	16.99	11.76	2.58	1.07	0.6	4.25	15
Aporusa lindleyana	16.34	29.41	2.48	2.67	0.34	5.49	15
Lagerstroemia microcarpa	16.34	58.82	2.48	5.35	2.57	10.4	15
Wrightia tinctoria	16.34	23.53	2.48	2.14	0.53	5.15	15
Pterospermum reticulatum	14.38	58.82	2.18	5.35	0.38	7.91	13
Chionanthus mala-elengi	13.73	29.41	2.08	2.67	0.33	5.08	12
Polyalthia fragrans	13.73	5.88	2.08	0.53	0.08	2.69	12
Actinodaphne malabarica	12.42	35.29	1.89	3.21	0.67	5.77	11
Grewia tiliifolia	12.42	23.53	1.89	2.14	2.5	6.53	11
Cinnamomum malabathrum	11.76	29.41	1.79	2.67	0.86	5.32	11
Mallotus philippensis	10.46	29.41	1.59	2.67	0.07	4.33	9
Xylia xylocarpa	9.8	11.76	1.49	1.07	1.18	3.74	9
Cassia fistula	9.15	35.29	1.39	3.21	0.78	5.38	8
Blepharistemma serratum	7.84	5.88	1.19	0.53	0.06	1.78	7
Terminalia paniculata	7.84	23.53	1.19	2.14	2.56	5.89	7
Cleistanthus collinus	7.19	17.65	1.09	1.6	0.31	3	6
Dalbergia latifolia	7.19	23.53	1.09	2.14	4.37	7.6	6
Alangium salvifolium	6.54	29.41	0.99	2.67	0.08	3.74	6
Dillenia pentagyna	5.23	17.65	0.79	1.6	0.39	2.78	5
Bauhinia malabarica	3.92	5.88	0.6	0.53	0.36	1.49	4
Ixora brachiata	3.92	11.76	0.6	1.07	0.03	1.7	4
Schleichera oleosa	3.92	11.76	0.6	1.07	0.17	1.84	4
Zizyphus glabrata	3.92	17.65	0.6	1.6	0.06	2.26	4
Mallotus tetracoccus	3.27	5.88	0.5	0.53	0.03	1.06	3
Olea dioica	3.27	23.53	0.5	2.14	0.26	2.9	3
Persea macrantha	3.27	17.65	0.5	1.6	0.14	2.24	3
Pterospermum rubiginosum	3.27	5.88	0.5	0.53	0.4	1.43	3
Sapindus laurifolius	3.27	17.65	0.5	1.6	0.03	2.13	3
Adina cordifolia	2.61	5.88	0.4	0.53	0.08	1.01	2
Flacourtia montana	2.61	5.88	0.4	0.53	0.23	1.16	2
Callicarpa tomentosa	1.96	11.76	0.3	1.07	0.09	1.46	2
Glochidion zeylanica	1.96	5.88	0.3	0.53	0.41	1.24	2
Baccaurea courtallensis	1.31	5.88	0.2	0.53	0.04	0.77	1
Bischofia javanica	1.31	5.88	0.2	0.53	0.18	0.91	1
Canthium travancoricum	1.31	5.88	0.2	0.53	0.06	0.79	1
Careya arborea	1.31	11.76	0.2	1.07	0.05	1.32	1
Chukrasia tabularis	1.31	5.88	0.2	0.53	0.01	0.74	1
Psidium guajava	1.31	5.88	0.2	0.53	0.01	0.74	1
Santalum album	1.31	5.88	0.2	0.53	0.06	0.79	1
Catunaregam torulosa	0.65	5.88	0.1	0.53	0.01	0.64	1
Dimocarpus longan	0.65	5.88	0.1	0.53	0.05	0.68	1

Table 10. Contd...

Species	D	F	RD	RF	RBA	IVI	IND
Drypetes oblongifolius	0.65	5.88	0.1	0.53	0	0.63	1
Syzygium cumini	0.65	5.88	0.1	0.53	0.19	0.82	1
Solenocarpus indica	0.65	5.88	0.1	0.53	0.03	0.66	1
Spondias pinnata	0.65	5.88	0.1	0.53	0.01	0.64	1
Total			100	100	100	300	593

D- Density, F- Frequency, RD-Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI- Importance Value Index, IND- Individuals per hectare

Table 11. Composition of trees in teak plantations; Age class: 1976 and above

Species	D	F	RD	RF	RBA	IVI	IND
Tectona grandis	288.89	66.67	59.54	18.18	49.92	127.64	260
Cassia fistula	129.63	66.67	26.72	18.18	36.71	81.61	117
Wrightia tinctoria	44.44	66.67	9.16	18.18	5.61	32.95	40
Syzygium cumini	3.7	33.33	0.76	9.09	5.18	15.03	3
Casearia wynaadensis	7.41	33.33	1.53	9.09	0.89	11.51	7
Cordia dichotoma	3.7	33.33	0.76	9.09	1.35	11.2	3
Psidium guajava	3.7	33.33	0.76	9.09	0.2	10.05	3
Dalbergia latifolia	3.7	33.33	0.76	9.09	0.14	9.99	3
Total			100	100	100	300	436

D- Density, F- Frequency, RD-Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI- Importance Value Index, IND- Individuals per hectare

Regeneration of tree species in teak plantations

Age class 1916-1935:
Average number of seedlings: 4213/ha (representing 30 species).
Among the seedlings 68 per cent are belonging to the height classes below one metre (Fig. 1). *Catunaregam torulosa, Tectona grandis, Syzygium cumini, Grewia tiliifolia, Bauhinia malabarica* and *Cassia fistula* are the dominant species.

Age class 1936-1955:
Average number of seedlings: 1765/ha (representing 37 species).
Among the seedlings 84 per cent are belonging to the height classes below one metre (Fig. 2). *Catunaregam torulosa, Tectona grandis, Zizyphus glabrata, Dalbergia latifolia, Grewia tiliifolia* and *Xylia xylocarpa* are the dominant species.

Age class 1956-1975-Near moist deciduous forests:
Average number of seedlings: 2982/ha (representing 53 species).
Among the seedlings 84 per cent are belonging to the height classes below one metre (Fig. 3). *Catunaregam torulosa, Tectona grandis, Zizyphus glabrata, Xylia*

xylocarpa, Bauhinia racemosa, Persea macrantha and *Grewia tiliifolia* are the dominant species.

Age class 1956-1975-Near semi-evergreen forests:
Average number of seedlings: 3859/ha (representing 66 species).
Among the seedlings 81 per cent are belonging to the height classes below one metre (Fig. 4). *Cinnamomum malabathrum, Pterospermum reticulatum, Zizyphus glabrata, Tectona grandis, Actinodaphne malabarica, Catunaregam torulosa,* and *Grewia tiliifolia* are the dominant species.

Age class 1976 and above:
Average number of seedlings: 2975/ha (representing 16 species).
Among the seedlings 72 per cent are belonging to the height classes below one metre (Fig. 5). *Catunaregam torulosa, Cassia fistula, Tectona grandis, Dalbergia latifolia* and *Tamarindus indica* are the dominant species.

The number of seedlings of different trees representing various height classes and their dominance in plantations of different age classes are provided in Tables 12, 13, 14, 15 and 16.

Table 12. Regeneration of tree species in teak plantations; Age class: 1916-1935
Plot size: 10 m x 10 m; Number of plots: 16

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	>1 m	>2 m	>3 m	Total
Catunaregam torulosa	32	50	68	45	34	93	41	46	409
Tectona grandis	1	10	9	3	5	16	5		49
Syzygium cumini		17	4	1	1	1			24
Grewia tiliifolia	3	4	7	4	4				22
Bauhinia malabarica	4	15	1						20
Cassia fistula	1	4	2	3	3	5			18
Bauhinia racemosa	5	7	1	2	1				16
Schleichera oleosa	8	7	1						16
Phyllanthus emblica	6	3	2			1			12
Diospyros montana	2	3		1	1	1	1	2	11
Lagerstroemia microcarpa	3	3	4	1					11
Sterculia urens	6	3	1						10
Casearia wynaadensis	1	2	1	2		3			9
Tamarindus indicus	3	4	1						8
Albizia odoratissima	2	5							7
Terminalia paniculata	1	1	4						6
Actinodaphne malabarica	1		2						3
Dalbergia latifolia	1	2							3
Macaranga peltata	3								3
Adina cordifolia		2							2
Bridelia retusa	1	1							2
Casearia esculenta	1		1						2

Table 12. Contd...

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	>1 m	>2 m	>3 m	Total
Cordia dichotoma			1			1			2
Melia dubia			2						2
Olea dioica	1				1				2
Antidesma acidum						1			1
Careya arborea					1				1
Pongamia pinnata				1					1
Radermachera xylocarpa					1				1
Sapindus laurifolius	1								1
Total	87	143	112	63	52	122	47	48	674

Table 13. Regeneration of tree species In teak plantations; Age class: 1936-1955
Plot size: 10 m x 10 m; Number of plots: 26

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	>1 m	>2 m	>3 m	Total
Catunaregam torulosa	16	25	44	30	25	16	9	3	168
Tectona grandis		2	6	13	16	20	4		61
Zizyphus glabrata	16	10	6	2					34
Dalbergia latifolia	19	6	2						27
Grewia tiliifolia	1	5	14	3	1	1			25
Xylia xylocarpa		10	12	1	1				24
Schleichera oleosa	3	8	2		1	1			15
Lagerstroemia microcarpa	2	8	4						14
Cassia fistula	1	4	2	1	1	2	2		13
Diospyros montana	6		2						8
Trewia nudiflora				2	2	4			8
Bridelia retusa	4	2							6
Casearia wynaadensis			2		2	1	1		6
Holarrhena antidysenterica	1		1		1	1	2		6
Terminalia paniculata	2	3					1		6
Syzygium cumini	3	1							4
Adina cordifolia		1		1		1			3
Cordia dichotoma		2		1					3
Tabernaemontana heyneana	1	1	1						3
Actinodaphne malabarica			2						2
Canthium travancoricum						2			2
Careya arborea	1	1							2
Casearia esculenta			2						2
Cinnamomum malabatrum	1	1							2
Dillenia pentagyna	1	1							2
Macaranga peltata	1		1						2
Olea dioica		1				1			2
Radermachera xylocarpa			1			1			2
Sterculia guttata		2							2
Antidesma acidum		1							1
Antidesma menasu						1			1

Table 13. Contd…

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	>1 m	>2 m	>3 m	Total
Dalbergia lanceolaria				1					1
Litsea coriacea	1								1
Persea macrantha	1								1
Sapindus laurifolius						1			1
Scolopia crenata		1							1
Terminalia bellirica			1						1
Total	81	95	104	55	50	52	19	3	459

Table 14. Regeneration of tree species in teak plantations-near moist deciduous forests; Age class: 1956-1975
Plot size: 10 m x 10 m; Number of plots: 54

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	>1 m	>2 m	>3 m	Total
Catunaregam torulosa	83	109	87	55	44	45	46	13	482
Tectona grandis	3	15	16	19	59	59	21	8	200
Zizyphus glabrata	50	88	31	5		2			176
Xylia xylocarpa	26	20	26	8	5	5			90
Bauhinia racemosa	11	36	9	2	3				61
Persea macrantha	49		1						50
Grewia tiliifolia	7	24	12	3					46
Schleichera oleosa	9	20	5	8	1	1			44
Mallotus philippensis		7	10	7	6	3	1	1	35
Olea dioica	1	17	12	1		1			32
Cassia fistula	5	1	7	2	7	6	3		31
Tabernaemontana heyneana	10	5	5	3	4	3			30
Sapindus laurifolius	6	10	7	3	1				27
Trewia nudiflora	3	6	5	3	4	2	1		24
Phyllanthus emblica	10	4	7	1	1				23
Lagerstroemia microcarpa	5	9	8					1	23
Bauhinia malabarica	8	5	6	2	1				22
Terminalia paniculata	6	4	4	1	4	2			21
Blepharistemma serratum				10		5		3	18
Naringi crenulata		6				4	5	1	16
Diospyros montana	3	3	5	1	1	1		1	15
Bridelia retusa		5	3	6					14
Careya arborea	7	3	4						14
Macaranga peltata	11	3							14
Ixora brachiata	12	1							13
Syzygium cumini		5	2				2	1	10
Antidesma acidum	1		1	2	1	1	2		8
Dillenia pentagyna		3		1	2	1			7
Wrightia tinctoria		2	1		2	2			7
Casearia wynaadensis	4	1							5
Cleistanthus collinus	4	1							5
Glochidion zeylanicum	1		4						5
Chionanthus mala-elengi		2			1			1	4
Canthium umbellatum			3						3

Table 14. Contd…

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	>1 m	>2 m	>3 m	Total
Mitragyna parvifolia	1	2							3
Radermachera xylocarpa	1	1	1						3
Spondias pinnata		2	1						3
Sterculia guttata		3							3
Sterculia urens	1	2							3
Terminalia bellirica	2	1							3
Adina cordifolia		1	1						2
Aporusa lindleyana	1			1					2
Cordia dichotoma		1		1					2
Pongamia pinnata	1	1							2
Dalbergia lanceolaria								1	1
Euodia lunu-ankenda							1		1
Glochidion ellipticum		1							1
Holarrhena antidysenterica			1						1
Pavetta indica		1							1
Syzygium cumini		1							1
Tamarindus indica			1						1
Vitex altissima						1			1
Zizyphus mauritiana			1						1
Total	342	432	287	145	147	144	82	31	1610

Table 15. Regeneration of tree species in teak plantations–near semi-evergreen forests; Age class: 1956-1975
Plot size: 10 m x 10 m; Number of plots: 34

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	>1 m	>2 m	>3 m	Total
Cinnamomum malabatrum	30	76	53	26	26	26	12		249
Pterospermum reticulatum	115	12	17	9	1	11	3	3	171
Zizyphus glabrata	27	60	21	4	2	1	1	2	118
Tectona grandis	1	12	17	3	12	28	17	9	99
Actinodaphne malabarica	7	34	24			3		1	69
Catunaregam torulosa	6	3	11	10	8	7	7	1	53
Grewia tiliifolia	7	17	11	5	2	3	3		48
Schleichera oleosa	5	28	4	4	1	3			45
Litsea coriacea	4	12	13	2	3	4	1		39
Chionanthus mala-elengi	2	1	3	2	10	7	7		32
Sapindus laurifolius	10	15	4			3			32
Tabernaemontana heyneana	6	14	5		3	3			31
Persea macrantha	12	4	8	1	2				27
Trewia nudiflora	6	8	4	1	5	3			27
Cassia fistula	1	1	2	2	2	13	4	1	26
Cleistanthus collinus	3	3	5		3	2	2	1	19
Dalbergia latifolia		16	1		1		1		19
Macaranga peltata	11	4	1						16
Mallotus philippensis	2	1	2		4	3	2	2	16
Alangium salvifolium	7		4			2	1	1	15
Xylia xylocarpa		6	2	2	5				15

Table 15. Contd…

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	>1 m	>2 m	>3 m	Total
Diospyros montana	1	1	1		1	5	3		12
Olea dioica	1	1	3	2	1	2	1		11
Blepharistemma serratum						9	1		10
Lagerstroemia microcarpa	1	1	4	1	3				10
Artocarpus hirsutus	1	6			1				8
Clausena indica			2		2	3			7
Ixora brachiata	2	1	1		1	1	1		7
Phyllanthus emblica	1	1		1	2	1			6
Hydnocarpus pentandra		1	3		1	1			6
Casearia esculenta				1		4			5
Polyalthia fragrans		1	2			1			4
Syzygium cumini	1	2	1						4
Terminalia paniculata	1	2	1						4
Aglaia barberi		1	2						3
Bauhinia racemosa		1	1	1					3
Flacourtia montana	1	2							3
Sterculia guttata		1			1			1	3
Baccaurea courtallensis		2							2
Bauhinia malabarica		1		1					2
Callicarpa tomentosa					1	1			2
Cassine glauca			2						2
Clausena dentata		1						1	2
Dysoxylum malabaricum		1				1			2
Ficus hispida				2					2
Garcinia gummi-gutta					1	1			2
Mangifera indica	1	1							2
Meiogyne pannosa				1		1			2
Polymorpha fragrans						2			2
Vitex altissima	2								2
Bombax insigne				1					1
Canthium dicoccum				1					1
Careya arborea			1						1
Caryota urens	1								1
Cordia dichotoma							1		1
Diospyros paniculata							1		1
Ehretia canarensis		1							1
Euodia lunu-ankenda			1						1
Glochidion zeylanicum						1			1
Litsea glabrata		1							1
Mallotus tetracoccus		1							1
Melia dubia		1							1
Mitragyna parvifolia	1								1
Paracroton zeylanicus				1					1
Psidium guajava							1		1
Santalum album							1		1
Total	277	359	237	84	105	156	71	23	1312

Table 16. Regeneration of tree species in teak plantations; Age class: 1976 and above
Plot size: 10 m x 10 m; Number of plots: 4

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	>1 m	>2 m	>3 m	Total
Catunaregam torulosa	9	13	2	1	12	11	4		52
Cassia fistula					14	2			16
Tectona grandis	1		3	1		6	3		14
Dalbergia latifolia	3	3	2						8
Tamarindus indicus			2		4				6
Grewia tiliifolia	1		1		1			1	4
Diospyros montana				1		1	1		3
Eucalyptus							2	1	3
Lagerstroemia microcarpa	1	1							2
Mallotus philippensis				2					2
Olea dioica		2							2
Psidium guajava	1						1		2
Syzygium cumini		2							2
Casearia esculenta		1							1
Cinnamomum malabatrum		1							1
Pongamia pinnata		1							1
Total	16	24	10	5	31	20	11	2	119

Composition of shrubs

Age class 1916-1935:
Nine species of shrubs were enumerated from the sample plots. Among these *Eupatorium odoratum* and *Helicteres isora* are the most dominant followed by *Glycosmis pentaphylla* and *Desmodium laxiflorum.*

Age class 1936-1955:
Eleven species of shrubs were enumerated from the sample plots. Among these *Eupatorium odoratum* and *Helicteres isora* are the most dominant followed by *Lantana camara* and *Flemingia strobilifera.*

Age class 1956-1975-near moist deciduous forests:
Fourteen species of shrubs were enumerated from the sample plots. Among these *Eupatorium odoratum* and *Flemingia strobilifera* are the most dominant followed by *Lantana camara* and *Helicteres isora.*

Age class 1956-1975-near semi-evergreen forests:
Thirteen species of shrubs were enumerated from the sample plots. Among these *Eupatorium odoratum* and *Lantana camara* are the most dominant followed by *Leea indica* and *Flemingia strobilifera.*

Age class 1976 and above
Five species of shrubs were enumerated from the sample plots. Among these *Eupatorium odoratum* and *Lantana camara* are the most dominant species.

The number of individuals of each shrubby species enumerated from the sample plots and their number per hectare are provided in Tables 17, 18, 19, 20 and 21.

Table 17. Status of shrubs in teak plantations; Age class: 1916-1935
Plot size: 5 m x 5 m; Number of plots: 16

Species	No	Per Ha	% of occurrence
Eupatorium odoratum	97	2425	58.79
Helicteres isora	32	800	19.39
Glycosmis pentaphylla	12	300	7.27
Desmodium laxiflorum	11	275	6.67
Lea robusta	4	100	2.42
Flemingia grahamiana	3	75	1.82
Laportea crenulata	3	75	1.82
Lantana camara	2	50	1.21
Solanum torvum	1	25	0.61
Total	165		100.00

Table 18. Status of shrubs in teak plantations; Age class: 1936-1955
Plot size: 5 m x 5 m; Number of plots: 26

Species	No	Per Ha	% of occurrence
Eupatorium odoratum	184	2831	64.11
Helicteres isora	42	646	14.63
Lantana camara	21	323	7.32
Flemingia strobilifera	18	277	6.27
Flemingia grahamiana	5	77	1.74
Laportea crenulata	5	77	1.74
Caesalpinia mimosoides	4	62	1.40
Allophylus cobbe	3	46	1.05
Colebrookea oppositifolia	2	31	0.70
Holarrhena antidysenterica	2	31	0.70
Lea indica	1	15	0.35
Total	287		100.00

Table 19. Status of shrubs in teak plantations- near moist deciduous forests; Age class: 1956-1975
Plot size: 5 m x 5 m; Number of plots: 54

Species	No	Per Ha	% of occurrence
Eupatorium odoratum	485	3593	65.99
Flemingia strobilifera	106	785	14.42
Lantana camara	54	400	7.35
Helicteres isora	43	319	5.85
Glycosmis pentaphylla	12	89	1.63
Maesa indica	8	59	1.09
Solanum torvum	7	52	0.95
Lea indica	5	37	0.68
Caesalpinia mimosoides	4	30	0.54
Allophylus cobbe	3	22	0.41
Securinega virosa	3	22	0.41
Chassalia curviflora	2	15	0.27
Colebrookea oppositifolia	2	15	0.27
Flemingia grahamiana	1	7	0.14
Total	735		100.00

Table 20. Status of shrubs in teak plantations – near semi-evergreen forests; Age class: 1956-1975
Plot size: 5 m x 5 m; Number of plots: 34

Species	No	Per Ha	% of occurrence
Eupatorium odoratum	234	2753	59.85
Lantana camara	62	729	15.86
Leea indica	37	435	9.46
Flemingia strobilifera	23	271	5.88
Clausena austroindicum	7	82	1.79
Desmodium laxiflorum	7	82	1.79
Glycosmis pentaphylla	7	82	1.79
Caesalpinia mimosoides	4	47	1.02
Solanum torvum	4	47	1.02
Chassalia curviflora	2	24	0.51
Colebrookea oppositifolia	2	24	0.51
Flemingia grahamiana	1	12	0.26
Solanum torvum	1	12	0.26
Total	391		100.00

Table 21. Status of shrubs in teak plantations; Age class: 1976 and above
Plot size: 5 m x 5 m; Number of plots: 4

Species	No	Per Ha	% of occurrence
Eupatorium odoratum	49	4900	50.52
Lantana camara	25	2500	25.77
Cassia hirsuta	8	800	8.25
Flemingia strobilifera	8	800	8.25
Maesa indica	7	700	7.22
Total	97		100.00

Status of herbs, grasses and climbers

Age class 1916-1935:
Thirty five species of herbs and grasses were enumerated from the sample plots. Among these *Oplismenus compositus, Cyrtococcum oxyphyllum* and *Uraria hamosa* are the most common species.
Thirteen species of climbers were also recorded from the plantation.

Age class 1936-1955:
Sixty two species of herbs and grasses were enumerated from the sample plots. Among these *Cyrtococcum oxyphyllum, Globba bulbifer* and *Oplismenus compositus* are the most common species.
Twenty one species of climbers were also recorded from the plantation.

Age class 1956-1975-near moist deciduous forests:
Sixty one species of herbs and grasses were enumerated from the sample plots. Among these *Oplismenus compositus, Cyrtococcum oxyphyllum, Globba bulbifer* and *Phaulopsis imbricata* are the most common species.

Twenty three species of climbers were also recorded from the plantation.

Age class 1956-1975-near semi-evergreen forests:
Fifty one species of herbs and grasses were enumerated from the sample plots. Among these *Oplismenus compositus, Cyrtococcum oxyphyllum, Phaulopsis imbricata* and *Globba bulbifer* are the most common species.
Thirty two species of climbers were also recorded from the plantation.

Age class 1976 and above:
Twenty eight species of herbs and grasses were enumerated from the sample plots. Among these *Oplismenus compositus, Phaulopsis imbricata, Triumfetta rhomboidea* and *Cyrtococcum oxyphyllum* are the most common species.
Eleven species of climbers were also recorded from the plantation.

The number of sample plots in plantations of different age classes, the herbaceous species and their number and name of climbers ae provided in Tables 22, 23, 24, 25 and 26.

Table 22. Status of herbs, grasses and climbers in teak plantations; Age class: 1916-1935
Plot size: 1m x 1 m; Numbers of plots: 38

Species	No
Oplismenus compositus	198
Cyrtococcum oxyphyllum	152
Uraria hamosa	33
Mimosa pudica	23
Curcuma sp.	17
Pseudarthria viscida	17
Lepidagathis incurva	16
Urena lobata	16
Kyllinga sp.	15
Sida rhomboidea	14
Curculigo orchioides	11
Phaulopsis imbricata	10
Scleria rugosa	7
Sida cordata	7
Costus speciosus	6
Imperata cylindrica	5
Rungia repens	5
Desmodium gangeticum	4

Species	No
Globba bulbifer	4
Hedyotis nitida	4
Mariscus dubius	4
Achyranthes aspera	3
Cyathula prostrata	3
Oryza granulose	3
Chlorophytum orchidastrum	2
Hibiscus furcatus	2
Abutilon persicum	1
Alternanthera sessilis	1
Cassia tora	1
Dictyospermum montanum	1
Elephantopus scaber	1
Justicia simplex	1
Phyllanthus amarus	1
Sauropus quadrangularis	1
Triumfetta rhomboidea	1

Climbers

Hemidesmus indicus, Cryptolepis buchananii, Spatholobus parviflorus, Cyclea peltata, Dioscorea pentaphylla, Ichnocarpus frutescens, Centrosema pubescens, Cissus repens, Naravelia zeylanica, Zizyphus oenoplia, Acacia torta, Dioscorea hispida, Vigna radiata

Table 23. Status of herbs, grasses and climbers in teak plantations; Age class: 1936-1955
Plot size: 1m x 1 m; Numbers of plots: 102

species	No
Cyrtococcum oxyphyllum	296
Globba bulbifer	269
Oplismenus compositus	260
Mimosa pudica	94
Phaulopsis imbricata	78
Desmodium laxiflorum	68
Globba ophioglossa	56
Cyathula prostrata	55
Curculigo orchioides	44
Uraria hamosa	42
Imperata cylindrica	35
Kyllinga triceps	34
Urena lobata	26
Rungia muralis	23
Sida rhomboidea	21
Curcuma sp.	19
Pseudarthria viscida	19
Sida cordata	17
Costus speciosus	14
Schumannianthus virgatus	14
Lepidagathis incurva	14
Peperomia pellucida	14
Curculigo orchioides	11
Phyllanthus amarus	11
Desmodium gangeticum	10
Scleria rugosa	10
Commelina erecta	9
Hedyotis nitida	9
Baliospermum montanum	8
Commelina persicariifolia	8
Curcuma vamana	8

species	No
Impatiens oppositifolia	7
Leucas chinensis	7
Oryza granulosa	7
Pouzolzia indica	7
Elephantopus scaber	6
Justicia diffusa	6
Cyanotis axillaris	5
Murdannia japonica	5
Abutilon indicum	3
Achyranthes aspera	3
Sauropus quadrangularis	3
Adiantum lunulatum	2
Asclepias curassavica	2
Cassia tora	2
Chlorophytum orchidastrum	2
Commelina diffusa	2
Dictyospermum montanum	2
Gomphostemma heyneana	2
Justicia simplex	2
Micrococca mercurialis	2
Ocimum americanum	2
Stachyphrynium spicatum	2
Synedrella nudiflora	2
Abutilon crispa	1
Amorphophallus paeoniifolius	1
Bambusa bambos	1
Calanthe masuca	1
Centotheca lappacea	1
Curcuma longan	1
Hibiscus furcatus	1
Zingiber zerumbet	1

Climbers

Centrosema pubescens, Cyclea peltata, Dioscorea wallichii, Hemidesmus indicus, Spatholobus parviflorus, Dioscorea pentaphylla, Ichnocarpus frutescens, Cayratia pedata, Cryptolepis buchananii, Hewittia malabarica, Naravelia zeylanica, Argyreia sp., Cissus repens, Ipomoea cairica, Stephania wightii, Calycopteris floribunda, Cissus discolor, Dioscorea bulbifera, Merremia umbellata, Zehneria mysorensis, Zizyphus oenoplia

Table 24. Status of herbs, grasses and climbers in teak plantations–near moist deciduous forests; Age class: 1956-1975
Plot size: 1m x 1 m; Numbers of plots: 158

Species	No
Oplismenus compositus	766
Cyrtococcum oxyphyllum	498
Globba bulbifer	250
Phaulopsis imbricata	108
Mimosa pudica	83
Curculigo orchioides	55
Globba ophioglossa	54
Rungia repens	46
Urena lobata	43
Pseudarthria viscida	40
Sida cordata	31
Cyathula prostrata	30
Sida rhomboidea	29
Uraria hamosa	27
Kyllinga triceps	25
Lepidagathis incurva	18
Commelina erecta	16
Scleria rugosa	16
Baliospermum montanum	14
Hedyotis nitida	14
Curcuma zedoaria	13
Rungia muralis	13
Impatiens chinensis	11
Hibiscus furcatus	10
Asystasia gangetica	9
Imperata cylindrica	9
Leucas chinensis	9
Desmodium gangeticum	7
Amorphophallus paeoniifolius	6
Stachyphrynium spicatum	6
Adiantum lunulatum	5
Cissus discolor	5

Species	No
Costus speciosus	5
Desmodium laxiflorum	5
Murdannia japonica	5
Zingiber officinale	5
Commelina persicariifolia	4
Cynoglossum furcatum	4
Peperomia pellucida	4
Curcuma vamana	3
Desmodium triflorum	3
Elephantopus scaber	3
Pouzolzia indica	3
Acalypha indica	2
Ageratum houstonianum	2
Calanthe masuca	2
Chlorophytum orchidastrum	2
Curcuma ecalcarata	2
Gomphostemma heyneana	2
Helicteres isora	2
Rungia wightiana	2
Sauropus quadrangularis	2
Achyranthes aspera	1
Biophytum reinwardtii	1
Commelina benghalensis	1
Crotalaria juncea	1
Laportea crenulata	1
Phyllanthus amara	1
Selaginella repanda	1
Sida alnifolia	1
Typhonium bulbiferum	1
Vernonia cinerea	1
Zingiber zerumbet	1

Climbers

Centrosema pubescens, Spatholobus parviflorus, Cyclea peltata, Naravelia zeylanica, Cryptolepis buchananii, Hemidesmus indicus, Dioscorea pentaphylla, Dioscorea wallichii, Ichnocarpus frutescens, Jasminum multiflorum, Stephania wightii, Smilax zeylanica, Zizyphus oenoplia, Cissus repens, Lygodium scandens, Acacia caesia, Asparagus racemosus, Connarus monocarpus, Jasminum multiflorum, Adenia hondala, Piper argyrophyllum, Dioscorea bulbifera, Ipomoea cairica

Table 25. Status of herbs, grasses and climbers in teak plantations–near semi-evergreen forests; Age class: 1956-1975
Plot size: 1m x 1 m; Numbers of plots: 96

Species	No
Oplismenus compositus	407
Cyrtococcum oxyphyllum	258
Phaulopsis imbricata	150
Globba ophioglossa	98
Mimosa pudica	44
Curculigo orchioides	40
Selaginella repanda	40
Sida cordata	33
Pseudarthria viscida	29
Cyathula prostrata	27
Urena lobata	24
Rungia repens	22
Globba bulbifer	18
Kyllinga triceps	15
Uraria hamosa	14
Asystasia gangetica	11
Rungia muralis	11
Zingiber zerumbet	11
Rungia pectinata	9
Sida rhomboidea	9
Curcuma ecalcarata	7
Hedyotis nitida	7
Hibiscus furcatus	6
Crotalaria heyneana	5
Desmodium gangeticum	5
Lepidagathis incurva	5

Species	No
Desmodium heterophyllum	4
Phyllanthus urinaria	4
Amorphophallus paeoniifolius	3
Costus speciosus	3
Leucas chinensis	3
Pteridium aquilinum	3
Stachyphrynium spicatum	3
Vernonia cinerea	3
Cassia tora	2
Commelina erecta	2
Cyanotis axillaris	2
Floscopa scandens	2
Imperata cylindrica	2
Murdannia japonica	2
Oryza meyeriana ssp. granulosa	2
Rungia muralis	2
Scleria rugosa	2
Zingiber neesanum	2
Baliospermum montanum	1
Commelina benghalensis	1
Desmodium motorium	1
Desmodium triquetrum	1
Digitaria ciliaris	1
Justicia diffusa	1
Sauropus quadrangularis	1
Solanum xanthocarpum	1

Climbers

Centrosema pubescens, Cryptolepis buchananii, Naravelia zeylanica, Cyclea peltata, Jasminum multiflorum, Dioscorea wallichii, Hemidesmus indicus, Smilax zeylanica, Dioscorea pentaphylla, Piper hymenophyllum, Jasminum pubescens, Ichnocarpus frutescens, Ipomoea hederifolia, Argyreia elliptica, Lygodium scandens, Piper hymenophyllum, Asparagus racemosus, Cayratia pedata, Ipomoea deccana, Merremia umbellata, Rubia cordifolia, Vigna radiata, Acacia torta, Adenia hondala, Calamus thwaitesii, Cissus discolor, Dioscorea bulbifera, Dioscorea oppositifolia, Jasminum parviflorus, Stephania wightii, Zizyphus oenoplia, Holostemma ada-kodien

Table 26. Status of herbs, grasses and climbers in teak plantations; Age class: 1976 and above
Plot size: 1m x 1 m; Numbers of plots: 15

Species	No
Oplismenus compositus	51
Phaulopsis imbricata	18
Triumfetta rhomboidea	14
Cyrtococcum oxyphyllum	13
Curcuma sp.	11
Uraria hamosa	10
Alternanthera tenella	9
Zizyphus oenoplia	9
Mimosa pudica	8
Oxalis corniculata	6
Pseudarthria viscida	6
Commelina erecta	5
Justicia glabra	4
Urena lobata	4

Species	No
Baliospermum montanum	3
Curculigo orchioides	3
Digitaria ciliaris	3
Mariscus dubius	3
Phyllanthus amarus	3
Desmodium gangeticum	2
Peristrophe montana	2
Sida cordata	2
Abutilon crispum	1
Cassia tora	1
Imperata cylindrica	1
Sauropus quadrangularis	1
Sida rhomboidea	1
Tragia involucrata	1

Climbers

Ichnocarpus frutescens, Centrosema pubescens, Cryptolepis buchananii, Hemidesmus indicus, Acacia torta, Asparagus racemosa, Cyclea peltata, Ipomoea pileata, Ipomoea sp., Toddalia asiatica, Merremia umbellata

Natural forests

Moist deciduous forests

Thirty species of trees were enumerated from the sample plots. *Catunaregam torulosa, Cassia fistula, Lagerstroemia microcarpa, Terminalis paniculata, Tectona grandis* and *Xylia xylocarpa* are the dominant species (Table 27).

Table 27. Composition of trees in natural forests–near moist deciduous forests

Species	D	F	RD	RF	RBA	IVI	IND
Catunaregam spinosa	162.04	66.67	39.59	8	7.26	54.85	146
Cassia fistula	64.81	75	15.84	9	0.99	25.83	58
Lagerstroemia microcarpa	32.41	75	7.92	9	12.42	29.34	29
Terminalia paniculata	28.7	66.67	7.01	8	33.93	48.94	26
Tectona grandis	12.04	66.67	2.94	8	17.86	28.8	11
Xylia xylocarpa	12.04	33.33	2.94	4	5.07	12.01	11
Diospyros montana	9.26	25	2.26	3	1.74	7	8
Premna serratifolia	9.26	8.33	2.26	1	0.09	3.35	8
Wrightia tinctoria	9.26	33.33	2.26	4	0.2	6.46	8
Radermachera xylocarpa	8.33	41.67	2.04	5	1.83	8.87	8
Trewia nudiflora	8.33	8.33	2.04	1	0.12	3.16	8
Dillenia pentagyna	7.41	50	1.81	6	6.04	13.85	7
Butea monosperma	4.63	8.33	1.13	1	0.72	2.85	4
Casearia wynaadensis	4.63	41.67	1.13	5	0.23	6.36	4
Grewia tiliifolia	4.63	25	1.13	3	2	6.13	4
Grewia disperma	3.7	8.33	0.9	1	0.02	1.92	3
Tabernaemontana heyneana	3.7	33.33	0.9	4	0.02	4.92	3

Table 27. Contd...

Species	D	F	RD	RF	RBA	IVI	IND
Terminalia crenulata	3.7	33.33	0.9	4	3.05	7.95	3
Cordia dichotoma	2.78	16.67	0.68	2	0.12	2.8	3
Dalbergia latifolia	2.78	16.67	0.68	2	0.34	3.02	3
Givotia rottleriformis	2.78	8.33	0.68	1	0.09	1.77	3
Emblica officinalis	1.85	16.67	0.45	2	0.72	3.17	2
Mitragyna parviflora	1.85	8.33	0.45	1	2.2	3.65	2
Sapindus laurifolius	1.85	8.33	0.45	1	0.09	1.54	2
Albizia lebbeck	0.93	8.33	0.23	1	0.51	1.74	1
Haldina cordifolia	0.93	8.33	0.23	1	0.4	1.63	1
Mallotus philippensis	0.93	8.33	0.23	1	0	1.23	1
Premna tomentosa	0.93	8.33	0.23	1	0.08	1.31	1
Pterocarpus marsupium	0.93	8.33	0.23	1	0.86	2.09	1
Schleichera oleosa	0.93	8.33	0.23	1	0.64	1.87	1
Terminalia bellirica	0.93	8.33	0.23	1	0.38	1.61	1
Total			100	100	100	300	368

D- Density, F- Frequency, RD-Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI- Important Value Index, IND- Individuals per hectare

The regeneration status of trees shows that *Catunaregam torulosa, Grewia tiliifolia, Schleichera oleosa, Xylia xylocarpa, Bauhinia racemosa, Diospyros montana* and *Syzygium cumini* are the dominant species among regeneration. However, established seedlings (above 1 m height) are comparatively few (Fig. 6). *Grewia tiliifolia* (76%), *Schleichera oleosa* (100%), *Xylia xylocarpa* (97%), *Bauhinia racemosa* (93%), *Diospyros montana* (75%) and *Syzygium cumini* (100%) are represented by seedlings below one metre height classes (Table 28).

Table 28. Regeneration of tree species in moist deciduous forests
Plot size: 10 m x 10 m; Number of plots: 24

Species	<20cm	20-40cm	40-60cm	60-80cm	80-100cm	>1m	>2m	>3m	Total
Catunaregam spinosa	36	54	44	51	38	104	91	54	472
Grewia tiliifolia	10	14	20	9	8	5		1	67
Schleichera oleosa	28	14	2	1					45
Xylia xylocarpa	17	3	14	6	3	1			44
Bauhinia racemosa	7	16	2	5		2			32
Diospyros montana	3	5	9	4	1	5	2		29
Syzygium cumini	12	12	4						28
Cassia fistula	2	4	3	1	1	2	6	4	23
Tectona grandis		1	4	1	4	4	4	1	19
Aglaia anamalayana	18								18
Sapindus laurifolius	12	3	3						18
Dalbergia latifolia	5	2	4	1					12
Tabernaemontana heyneana		3		2	1	1	1		8
Olea dioica	1	2	2		2				7
Anogeissus latifolia	1	2	1		1	1			6
Bridelia retusa	5	1							6
Grewia disperma		2		2	1		1		6

Table 28. Contd...

Species	<20cm	20-40cm	40-60cm	60-80cm	80-100cm	>1m	>2m	>3m	Total
Lagerstroemia microcarpa	1	1	1		1	1			5
Bauhinia malabarica	1	3							4
Mallotus philippensis	1		1		2				4
Melia dubia	1	2	1						4
Radermachera xylocarpa	2					2			4
Terminalia paniculata		3		1					4
Wrightia tinctoria	2	1					1		4
Sterculia guttata	2			1					3
Casearia wynaadensis				1			1		2
Chionanthus mala-elengi							2		2
Dillenia pentagyna			1	1					2
Haldina cordifolia						1	1		2
Pavetta indica	2								2
Trewia nudiflora			1		1				2
Albizia odoratissima		1							1
Antidesma acidum						1			1
Canthium umbellatum					1				1
Casearia esculenta		1							1
Emblica officinalis			1						1
Flacourtia montana		1							1
Holigarna grahamii	1								1
Ixora brachiata	1								1
Lagerstroemia reginae					1				1
Macaranga peltata	1								1
Miliusa tomentosa						1			1
Strychnos nux-vomica							1		1
Total	172	151	118	87	66	131	111	60	896

Among the shrubs, *Helicteres isora, Lantana camara, Flemingia strobilifera* and *Eupatorium odoratum* are the dominant species (Table 29). Seventy eight species of grasses and herbs were enumerated from the sample plots. *Cyrtococcum oxyphyllum, Oplismenus compositus, Cyathula prostrata, Phaulopsis imbricata, Mimosa pudica, Pseudarthria viscida* and *Sida cordata* are the dominant species. Twenty three climbers were also recorded from the sample plots (Table 30).

Table 29. Status of shrubs in moist deciduous forests
Plot size: 5 m x 5 m; Number of plots: 24

Species	No	Per Ha	% of occurrence
Helicteres isora	78	1300	30.12
Lantana camara	73	1216	28.19
Flemingia strobilifera	25	417	9.65
Eupatorium odoratum	20	340	7.72
Ocimum gratissimum	15	250	5.79
Grewia obtusa	14	233	5.41

Table 29. Contd...

Species	No	Per Ha	% of occurrence
Jatropha glandulifera	6	102	2.32
Desmodium laxiflorum	4	68	1.54
Flemingia grahamiana	4	68	1.54
Grewia hirsuta	4	68	1.54
Glycosmis pentaphylla	3	51	1.16
Caesalpinia mimosoides	2	34	0.77
Kirganelia reticulata	2	34	0.77
Pavetta indica	2	34	0.77
Tarenna asiatica	2	34	0.77
Thottea siliquosa	2	34	0.77
Hibiscus furcatus	1	17	0.39
Opuntia dillenii	1	17	0.39
Polygonum chinense	1	17	0.39
Total	259		100.00

Table 30. Status of herbs, grasses and climbers in moist deciduous forests
Plot size: 1 m x 1 m; Numbers of plots: 54

Species	No
Cyrtococcum oxyphyllum	203
Oplismenus compositus	157
Cyathula prostrata	68
Phaulopsis imbricata	64
Mimosa pudica	42
Pseudarthria viscida	38
Sida cordata	37
Imperata cylindrica	29
Justicia diffusa	27
Achyranthes aspera	24
Justicia glabra	23
Globba bulbifer	22
Urena lobata	18
Curculigo orchioides	15
Costus speciosus	14
Desmodium laxiflorum	14
Schumannianthus virgatus	14
Sida rhombifolia	14
Stachyphrynium spicatum	14
Floscopa scandens	12
Uraria hamosa	12
Leucas chinensis	11
Elephantopus scaber	11
Desmodium gangeticum	10
Adiantum lunulatum	10
Piper hymenophyllum	10
Sida alnifolia	10

Species	No
Desmodium gangeticum	8
Pupalia lappacea	8
Cynoglossum furcatum	6
Baliospermum montanum	6
Acalypha indica	6
Ageratum conyzoides	5
Apluda mutica	5
Sauropus quadrangularis	4
Asystasia gangetica	4
Cyathula prostrata	4
Lepidagathis incurva	4
Abutilon hirtum	4
Rungia repens	3
Kyllinga triceps	3
Oryza meyeriana ssp. granulosa	3
Smilax zeylanica	3
Rungia muralis	3
Amorphophallus paeoniifolius	2
Catharanthus roseus	2
Chlorophytum orchidastrum	2
Eragrostis unioloides	2
Hedyotis nitida	2
Pouzolzia indica	2
Rungia pectinata	2
Crotalaria juncea	1
Hibiscus furcatus	1
Pennisetum hohenackeri	1

Climbers

Centrosema pubescens, Hemidesmus indicus, Cyclea peltata, Zizyphus oenoplia, Argyreia elliptica, Combretum ovalifolium, Cryptolepis buchananii, Calamus thwaitesii, Ancistrocladus heyneanus, Ichnocarpus frutescens, Piper argyrophyllum, Calamus hookerianus, Naravelia zeylanica, Pterolobium hexapetalum, Myxopyrum smilacifolium, Calycopteris floribunda, Olax imbricata, Opilia amentacea, Spatholobus parviflorus, Croton caudatus, Dioscorea pentaphylla, Dioscorea wallichii, Ventilago bombaiensis

Semi-evergreen forests

Sixty six species of trees were enumerated from the sample plots. *Polyalthia fragrans, Aglaia barberi, Drypetes oblongifolia, Aglaia anamallayana, Baccaurea courtallensis* and *Mesua ferrea* are the dominant species (Table 31).

Table 31. Composition of trees in natural forests – near semi-evergreen forests

Species	D	F	RD	RF	RBA	IVI	IND	Per Ha
Polyalthia fragrans	88.89	60	10.5	2.65	1.39	14.54	40	80
Aglaia barberi	82.22	80	9.71	3.54	3.02	16.27	37	74
Drypetes oblongifolia	55.56	80	6.56	3.54	2.49	12.59	25	50
Aglaia anamalayana	53.33	40	6.3	1.77	1.01	9.08	24	48
Baccaurea courtallensis	40	40	4.72	1.77	0.53	7.02	18	36
Mesua ferrea	33.33	40	3.94	1.77	2.17	7.88	15	30
Dimorphocalyx lawianus	31.11	60	3.67	2.65	1.45	7.77	14	28
Acronychia pedunculata	28.89	60	3.41	2.65	1.63	7.69	13	26
Chukrasia tabularis	28.89	40	3.41	1.77	3.84	9.02	13	26
Croton malabaricus	28.89	60	3.41	2.65	1.22	7.28	13	26
Calophyllum polyanthum	24.44	40	2.89	1.77	2.82	7.48	11	22
Vepris bilocularis	20	60	2.36	2.65	3.04	8.05	9	18
Alangium salvifolium	17.78	40	2.1	1.77	0.26	4.13	8	16
Mallotus philippensis	15.56	60	1.84	2.65	0.12	4.61	7	14
Paracroton zeylanicus	15.56	40	1.84	1.77	1.23	4.84	7	14
Neolitsea scrobiculata	13.33	40	1.57	1.77	0.14	3.48	6	12
Palaquium ellipticum	13.33	60	1.57	2.65	8	12.22	6	12
Firmiana colorata	11.11	20	1.31	0.88	0.65	2.84	5	10
Hydnocarpus pentandra	11.11	40	1.31	1.77	0.46	3.54	5	10
Myristica dactyloides	11.11	60	1.31	2.65	0.99	4.95	5	10
Schleichera oleosa	11.11	60	1.31	2.65	0.66	4.62	5	10
Trewia nudiflora	11.11	40	1.31	1.77	0.52	3.6	5	10
Aphanamixis polystachya	8.89	20	1.05	0.88	0.16	2.09	4	8
Otonephelium stipulaceum	8.89	20	1.05	0.88	0.09	2.02	4	8
Diospyros paniculata	8.89	60	1.05	2.65	1.84	5.54	4	8
Grewia tiliifolia	8.89	20	1.05	0.88	4.02	5.95	4	8
Actinodaphne malabarica	6.67	40	0.79	1.77	0.84	3.4	3	6
Casearia esculenta	6.67	40	0.79	1.77	0.08	2.64	3	6
Cassine paniculata	6.67	40	0.79	1.77	1.17	3.73	3	6
Cleidion javanicum	6.67	20	0.79	0.88	1.57	3.24	3	6
Diospyros buxifolia	6.67	20	0.79	0.88	6.8	8.47	3	6
Diospyros candolleana	6.67	40	0.79	1.77	0.21	2.77	3	6
Dipterocarpus indicus	6.67	20	0.79	0.88	5.73	7.4	3	6

Table 31. Contd...

Species	D	F	RD	RF	RBA	IVI	IND	Per Ha
Harpullia arborea	6.67	20	0.79	0.88	1.09	2.76	3	6
Ixora brachiata	6.67	60	0.79	2.65	0.6	4.04	3	6
Nothopegia colebrookeana	6.67	40	0.79	1.77	0.27	2.83	3	6
Aglaia elengioides	4.44	20	0.52	0.88	0.08	1.48	2	4
Aporusa lindleyana	4.44	20	0.52	0.88	0.15	1.55	2	4
Cinnamomum malabatrum	4.44	20	0.52	0.88	0.09	1.49	2	4
Dillenia pentagyna	4.44	20	0.52	0.88	0.11	1.51	2	4
Elaeocarpus serratus	4.44	40	0.52	1.77	4.43	6.72	2	4
Flacourtia montana	4.44	20	0.52	0.88	1.91	3.31	2	4
Hunteria corymbosa	4.44	40	0.52	1.77	0.02	2.31	2	4
Litsea coriacea	4.44	20	0.52	0.88	0.06	1.46	2	4
Mesua thwaitesii	4.44	20	0.52	0.88	0.15	1.55	2	4
Olea dioica	4.44	20	0.52	0.88	0.02	1.42	2	4
Persea macrantha	4.44	40	0.52	1.77	23.7	25.99	2	4
Pterospermum reticulatum	4.44	20	0.52	0.88	0.03	1.43	2	4
Tectona grandis	4.44	20	0.52	0.88	1.87	3.27	2	4
Canthium umbellatum	2.22	20	0.26	0.88	0.01	1.15	1	2
Cassia fistula	2.22	20	0.26	0.88	0.01	1.15	1	2
Dimocarpus longan	2.22	20	0.26	0.88	0.04	1.18	1	2
Diospyros montana	2.22	20	0.26	0.88	0.01	1.15	1	2
Drypetes wightii	2.22	20	0.26	0.88	0.04	1.18	1	2
Emblica officinalis	2.22	20	0.26	0.88	0.23	1.37	1	2
Ficus travancorica	2.22	20	0.26	0.88	0.03	1.17	1	2
Garcinia morella	2.22	20	0.26	0.88	0.01	1.15	1	2
Hydnocarpus alpina	2.22	20	0.26	0.88	0.02	1.16	1	2
Macaranga peltata	2.22	20	0.26	0.88	1.5	2.64	1	2
Mallotus tetracoccus	2.22	20	0.26	0.88	1.6	2.74	1	2
Mangifera indica	2.22	20	0.26	0.88	0.09	1.23	1	2
Meiogyne pannosa	2.22	20	0.26	0.88	0.01	1.15	1	2
Syzygium laetum	2.22	20	0.26	0.88	0.07	1.21	1	2
Syzygium mundagam	2.22	20	0.26	0.88	0.09	1.23	1	2
Tabernaemontana heyneana	2.22	20	0.26	0.88	0.01	1.15	1	2
Bischofia javanica	2.22	20	0.26	0.88	1.5	2.64	1	2
Zanthoxylum rhetsa	2.22	20	0.26	0.88	0.03	1.17	1	2
Total			100	100	100	300	381	762

D- Density, F- Frequency, RD-Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI- Important Value Index, IND- Individuals per hectare

The regeneration status of trees shows that *Aglaia anamallayana, Aglaia barberi, Polyalthia fragrans, Pterospermum reticulatum, Myristica dactyloides* and *Chukrasia tabularis* are the dominant species among regeneration. However, established seedlings (above 1 m height) are comparatively more (Fig. 7) for species like *Aglaia anamallayana* (56%) and *Aglaia barberi* (56%). For other species, seedlings below one metre are more than established seedlings (Table 32). Thirty two species growing in the semi-evergreen/evergreen forests and eight species in moist deciduous forests have not regenerated in the plantations (Table 33).

Figure 1-7. Regeneration of tree species in teak plantations of different age classes and natural forests

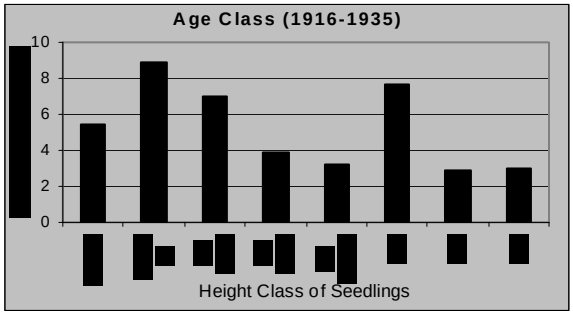


Figure 1

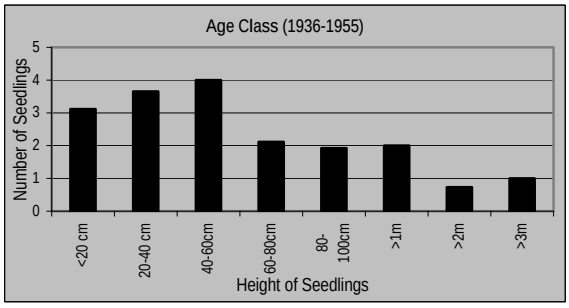


Figure 2

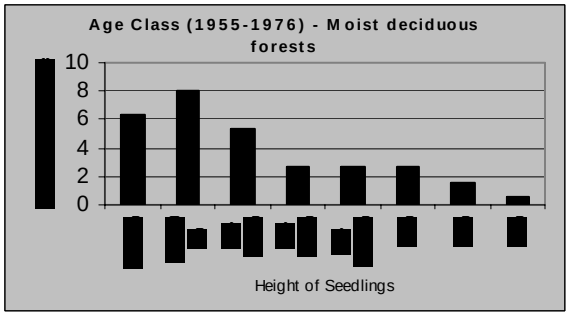


Figure 3

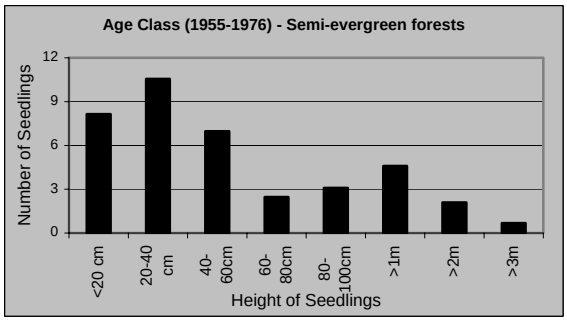


Figure 4

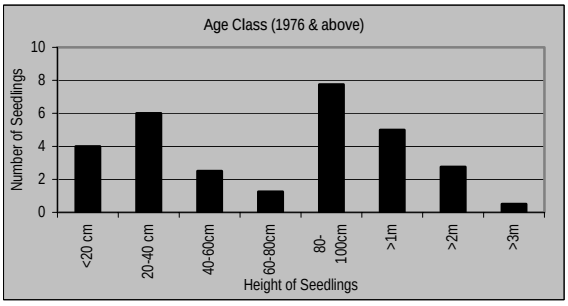


Figure 5

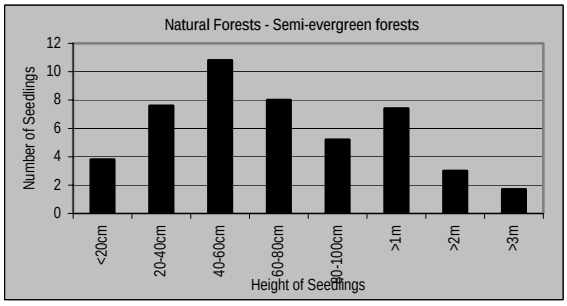


Figure 6

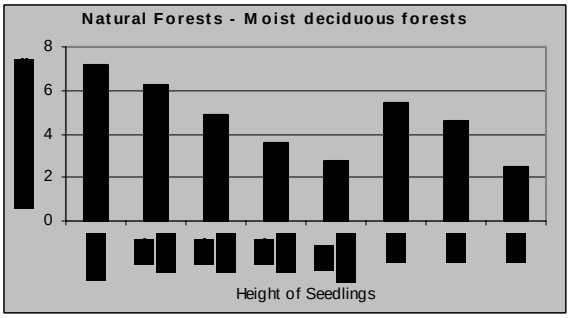


Figure 7

Table 32. Regeneration of tree species in semi-evergreen forests
Plot size: 10 m x 10 m; Number of plots:10

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	>1 m	>2 m	>3 m	Total
Aglaia anamalayana	5		30	7		6	15	12	75
Aglaia barberi			4	10	17	31	10		72
Polyalthia fragrans	6	10	26	6	2				50
Pterospermum reticulatum	5	16	2	3	1	4			31
Myristica dactyloides		1		4	11	5			21
Chukrasia tabularis				11	9				20
Neolitsea scrobiculata	2	9	5	2		1			19
Dipterocarpus indicus		7	11						18
Acronychia pedunculata		1	1	1		11		2	16
Hopea parvifolia				13					13
Knema attenuata		6	4						10
Paracroton zeylanicus	1		6				1		8
Catunaregam torulosa			2	4		1			7
Dimorphocalyx lawianus	1		1	3	2				7
Drypetes oblongifolius	1	1	5						7
Litsea ligustrina				2	1	3	1		7
Mallotus philippensis		5			1			1	7
Litsea coriacea	2			3		1			6
Sapindus laurifolius	6								6
Croton malabaricus		3				1		1	5
Vepris bilocularis			1	1		2	1		5
Vitex altissima				2	2	1			5
Chionanthus mala-elengi		2					2		4
Mangifera indica		1	3						4
Meiogyne pannosa			1		1	1		1	4
Schleichera oleosa	1			3					4
Tabernaemontana heyneana			1	2	1				4
Alangium salvifolium		1	2						3
Casearia esculenta					1	2			3
Mesua ferrea		3							3
Prunus zeylanicus		1	2						3
Baccaurea courtallensis	2								2
Caryota urens	2								2
Harpullia arborea		2							2
Hydnocarpus pentandra		1			1				2
Ixora brachiata		1		1					2
Olea dioica						2			2
Sterculia guttata	1	1							2
Syzygium munronii			1	1					2
Tectona grandis					1	1			2
Xanthophyllum flavescens		2							2
Actinodaphne malabarica	1								1
Calophyllum polyanthum	1								1
Cassine paniculata					1				1
Cleistanthus colais	1								1
Dillenia pentagyna		1							1
Dimocarpus longan						1			1
Diospyros buxifolia				1					1
Terminalia bellirica		1							1
Total	38	76	108	80	52	74	30	17	475

Table 33. Tree species in the natural forests not regenerated in the plantations

Moist deciduous forests	Semi-evergreen/evergreen forests		
Albizia lebbeck	*Acronychia pedunculata*	*Aglaia anamalayana*	*Aglaia elaeagnoidea*
Butea monosperma	*Aphanamixis polystachya*	*Calophyllum polyanthum*	*Canthium umbellatum*
Givotia rottleriformis	*Cassine paniculata*	*Cleidion javanicum*	*Croton malabaricus*
Grewia disperma	*Dimorphocalyx lawianus*	*Diospyros buxifolia*	*Diospyros candolleana*
Haldina cordifolia	*Dipterocarpus indicus*	*Drypetes oblongifolia*	*Drypetes wightii*
Premna serratifolia	*Elaeocarpus serratus*	*Firmiana colorata*	*Ficus travancorica*
Premna tomentosa	*Garcinia morella*	*Harpullia arborea*	*Hunteria corymbosa*
Pterocarpus marsupium	*Hydnocarpus alpinia*	*Mesua ferrea*	*Mesua thwaitesii*
	Myristica dactyloides	*Neolitsea scrobiculata*	*Nothopegia colebrookeana*
	Otonephelium stipulaceum	*Palaquium ellipticum*	*Syzygium laetum*
	Syzygium mundagam	*Vepris bilocularis*	

Among the shrubs, *Glycosmis macrocarpa, Helicteres isora, Ixora nigricans* and *Flemingia strobilifera* are the dominant species (Table 34). Twenty two species of grasses and herbs were enumerated from the sample plots. *Oplismenus compositus, Elatostema acuminatum, Stachyphrynium spicatum, Adiantum lunulatum, Smilax zeylanica* and *Phaulopsis imbricata* are the dominant species. Fourteen climbers were also recorded from the sample plots (Table 35).

Table 34. Status of shrubs in semi-evergreen forests
Plot size: 5 m x 5 m; Number of plots: 10

Species	No	Per Ha	% of occurrence
Glycosmis macrocarpa	11	440	25.58
Helicteres isora	8	320	18.60
Ixora nigricans	5	200	11.63
Flemingia strobilifera	4	160	9.30
Dracaena terniflora	3	120	6.98
Lantana camara	3	120	6.98
Dichapetalum gelonioides	2	80	4.65
Flemingia grahamiana	2	80	4.65
Nilgirianthus ciliatus	2	80	4.65
Desmodium laxiflorum	1	40	2.33
Thottea siliquosa	1	40	2.33
Zizyphus oenoplia	1	40	2.33
Total	43		100.00

Table 35. Status of herbs, grasses and climbers in semi-evergreen forests
Plot size: 1 m x 1 m; Numbers of plots: 20

Species	No
Oplismenus compositus	37
Elatostema acuminatum	20
Stachyphrynium spicatum	18
Adiantum lunulatum	9
Elatostema lineolatum	6
Phaulopsis imbricata	6
Smilax zeylanica	6
Alpinia smithiae	4
Curcuma vamana	3
Ophiopogon intermedia	3
Pseudarthria viscida	3

Species	No
Globba bulbifer	2
Amomum cannicarpum	2
Geophila repens	2
Pogostemon paniculatus	2
Cyathula prostrata	1
Desmodium gangeticum	1
Dracaena terniflora	1
Pteridium aquilinum	1
Malaxis rheedii	1
Peliosanthes teta	1
Urena lobata	1

Climbers

Piper hymenophyllum, Ancistrocladus heyneanus, Centrosema pubescens, Calamus thwaitesii, Cryptolepis buchananii, Desmos lawii, Jasminum multiflorum, Acacia torta, Naravelia zeylanica, Piper argyrophyllum, Coscinium fenestratum, Croton caudatus, Elaeagnus indica, Merremia umbellata

Discussion

In the teak plantations of all age classes the number of naturally regenerated trees per hectare is more than the number of existing teak trees. In Orukomban and Karimala Ranges in the age class 1956-1975 near semi-evergreen forests the average number of indigenous trees (50 species) per hectare is 368 and near moist deciduous forests 216 trees per hectare belonging to 43 species. However, their total basal area is very low when compared with the basal area of teak. The average number of seedlings of tree species per hectare in the plantations this age class near semi-evergreen forests is 2982 (53 species) and 3859 (66 species) near moist deciduous forests. Thirty two tree species growing in the neighbouring semi-evergreen forests and 8 in the moist deciduous forests have not regenerated in the plantation.

Mutual comparison of dominant tree species based on importance value index (IVI), species with high 'ecological efficiency' with varying conditions for the period of 67 years (*ie*, 1916-1983) are *Tectona grandis, Cassia fistula, Casearia esculenta* and *Catunaregam torulosa*. The qualitative similarity of 60 per cent was observed with the oldest age class of 1916-1935 to that of 1936-1955 and 1956-1975, whereas only 40 per cent similarity was observed when compared to the youngest age class 1976 and above. It is also observed that high weed growth of *Lantana* and *Eupatorium* in 1976 and above plantations. The low similarity value between high age group (1916-1935) and lowest age group (1976 and above) may due to the high weed growth, affecting the tree regeneration. The quantitative similarity studies in terms of number of

individual species per unit area reveals that the difference between the oldest plantation in Parambikulam (*ie*, 1916-1935) and forest plantation (*ie*, 1976 above) is of 1.9 times. The respective values in 1936-1955 and 1956-1975 age class are 16.8 and 28.6 per cent respectively (Table 36). The Maturity Index studies (Pichi-Sermolli, 1948) based on 10 dominant species in different age classes reveals that oldest age group is having the Maturity Index of 53.5 (Table 37) indicating more stable status of succession when compared to the youngest plantations.

Table 36. Percentage of seedlings of different height classes in the plantations

Height class (cm)	Age class (per cent)			
	1916-1935	1936-1955	1956-1975	1976 and above
<20	12.9	17.6	21.2	13.4
20-40	21.2	20.7	26.8	20.2
40-60	16.6	22.7	17.8	8.4
60-80	9.3	12.0	9.0	4.2
80-100	7.7	10.9	9.1	26.1
> 100 (established seedlings)	32.2	16.1	16.0	27.7

Table 37. Maturity Index value of four age classes

No	Age class	Maturity Index (%)
1.	1916-1935	53.5
2.	1936-1955	47.7
3.	1956-1975	42.2
4.	1976 and above	45.8

Comparison of regeneration status of tree species in the four age classes reveals that species like *Catunaregam torulosa, Tectona grandis, Grewia tiliifolia, Xylia xylocarpa* along with habitat specific species like *Diospyros montana, Persea macrantha* and *Tamarindus indica* comprises the 'Character Species' covering major seedlings population of the classes (79 per cent of class: 1916-1935; 74 per cent of class: 1936-1955; 69 per cent of class: 1956-1975 and 84 per cent of class: 1976 and above). The structural manipulation of more desired species among the species mentioned above may enhance the qualitative status of vegetation in term of economic viability. The dominance of seedlings and samplings of *Catunaregam torulosa* among regeneration indicates fire incidence in the plantations.

Lantana is not a major weed in the plantations except in the age class 1976 and above where it forms 25 per cent among shrubs. However, percentage of *Eupatorium* is high and varies from 67 per cent to 51 per cent among shrubs in the plantations of all age classes.

6.1.2. Animal studies

The estimated elephant and gaur dung density in various age group of plantations in Parambikulam are summarised in Tables 38 and 39 and in natural forests in Table 40. These are also presented in Figure 8. The dung density of elephants in teak plantations in Parambikulam follows a pattern where the younger age plantations are utilized more compared to the older plantations, though the results indicate a deviation from the pattern in the age group of 51-60 and 71-80. The younger plantations are highly preferred. Almost a similar pattern is followed by gaur in teak plantations in Parambikulam. The comparison with pooled data from the natural forests however indicates that the natural forests are comparatively better utilized as indicated by the higher dung density. Gaur in Parambikulam also follows the same pattern with higher dung density in natural forests.

Table 38. Elephant dung density (number/km^2) in teak plantations

Plantation year class	Density	LCL	UCL	CV
1971-1980	3467.2	2145.9	5602.2	23.6
1961-1970	1933.4	1390.1	2689.1	16.7
1951-1960	1124.9	744.44	1699.9	20.7
1941-1950	1836.6	1311.6	2571.9	16.9
1931-1940	716.5	492.06	1043.3	18.8
1921-1930	1000.1	144.87	6904.2	66.8

LCL – Lower Confidence Limit; UCL – Upper Confidence Limit; CV – Coefficient of Variation

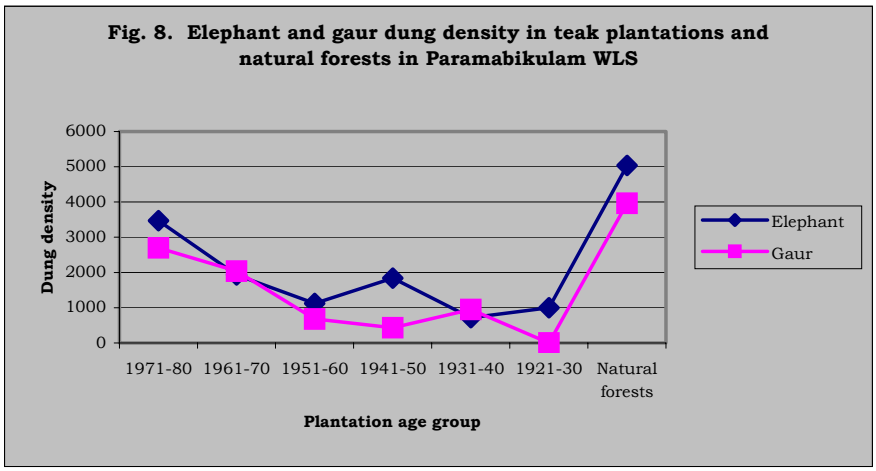
Table 39. Gaur dung density (number/km^2) in teak plantations

Plantation year class	Density	LCL	UCL	CV
1971-1980	2699.9	1329.6	5482.3	33.4
1961-1970	2035.8	1467.7	2823.7	16.5
1951-1960	676.44	441.34	1036.8	21.4
1941-1950	432.98	254.34	737.1	25.7
1931-1940	948.12	611.12	1471	21.9
1921-1930	0	0	0	0

Table 40. Elephant and gaur dung density (number/km^2) in natural forests

Animal	Density	LCL	UCL	CV
Elephant	5038.300	4523.900	5611.200	05.5
Gaur	3960.500	3480.600	4506.600	06.6

The comparison of various parameters in teak plantations with that of natural forests in Parambikulam also indicate significant differences (Table 41) except in the case of litter depth and the indirect evidences of sambar deer. However, the comparison with different age group of plantations have shown significant difference in all parameters (Table 42). The LSD test does not show any



significant difference in all parameters in a particular age group (Table 43). The difference in the number of spiders and the sambar deer evidences were comparably different in the case of 1971-80 year class teak plantations. Further, the occurrence of sambar deer in higher numbers in plantations of 1971-80 and 1931-40 and natural forests in Parambikulam is the special characteristic feature of the area. This is also evident in the case of litter depth and number of spiders.

Table 41. Comparison of various parameters in teak plantation with natural forests

Vegetation Type	No. of plots	Mean	Std. Deviation	F Value	Significance
Number of shrubs					
Teak plantation	248	16.20	14.290	27.992	0.000
Natural Forest	194	24.67	19.351		
Litter depth					
Teak plantation	248	5.68	3.053	0.159	0.690
Natural Forest	194	5.58	2.105		
Number of logs					
Teak plantation	248	10.79	7.510	15.621	0.000
Natural Forest	194	14.08	9.973		
Number of spiders					
Teak plantation	248	6.21	6.567	9.998	0.002
Natural Forest	194	4.20	6.675		
Sambar deer indirect evidences					
Teak plantation	248	12.77	16.926	1.377	0.188
Natural Forest	194	14.73	13.622		

Table 42. Comparison of various parameters in different teak plantation age groups with natural forests

Vegetation Type	No. of plots	Mean	Std. Deviation	F Value	Significance
No. of Shrub				8.813	0.000
Teak Plantation 1971-1980	7	19.29	10.750		
Teak Plantation 1961-1970	80	12.04	9.674		
Teak Plantation 1951-1960	51	24.43	20.612		
Teak Plantation 1941-1950	52	14.71	13.355		
Teak Plantation 1931-1940	48	17.83	10.830		
Teak Plantation 1921-1930	10	5.30	4.191		
Natural Forest	194	24.67	19.351		

Table 42. Contd...

Vegetation Type	No. of plots	Mean	Std. Deviation	F Value	Significance
Litter depth					
Teak Plantation 1971-1980	7	4.14	1.345	14.318	0.000
Teak Plantation 1961-1970	80	3.80	1.247		
Teak Plantation 1951-1960	51	6.80	3.027		
Teak Plantation 1941-1950	52	6.73	4.150		
Teak Plantation 1931-1940	48	6.99	2.563		
Teak Plantation 1921-1930	10	4.40	0.699		
Natural Forest	194	5.58	2.105		
No. of Logs					
Teak Plantation 1971-1980	7	18.43	4.353	5.136	0.000
Teak Plantation 1961-1970	80	10.79	4.944		
Teak Plantation 1951-1960	51	12.69	7.814		
Teak Plantation 1941-1950	52	7.85	5.613		
Teak Plantation 1931-1940	48	11.27	11.369		
Teak Plantation 1921-1930	10	8.80	2.530		
Natural Forest	194	14.08	9.973		
No. of spider					
Teak Plantation 1971-1980	7	10.14	11.452	3.901	0.001
Teak Plantation 1961-1970	80	5.73	3.952		
Teak Plantation 1951-1960	51	8.27	8.474		
Teak Plantation 1941-1950	52	6.19	7.736		
Teak Plantation 1931-1940	48	4.08	5.331		
Teak Plantation 1921-1930	10	7.00	3.055		
Natural Forest	194	4.20	6.675		
Sambar deer indirect evidences					
Teak Plantation 1971-1980	7	28.86	14.690	12.885	0.000
Teak Plantation 1961-1970	80	4.11	5.287		
Teak Plantation 1951-1960	51	11.94	15.109		
Teak Plantation 1941-1950	52	17.13	21.597		
Teak Plantation 1931-1940	48	23.46	18.638		
Teak Plantation 1921-1930	10	0.90	0.738		
Natural Forest	194	14.73	13.622		

Table 43. Comparison of various parameters in natural forests with different age group plantations (Using LSD Test)

Age group of Teak Plantation	Mean Difference between Plantation and Natural Forest				
	No. of shrubs	Litter depth	No. of logs	No. of spiders	Sambar deer indirect evidences
Teak Plantation 1971-1980	5.38	1.44	-4.35	-5.94*	-14.13*
Teak Plantation 1961-1970	12.63*	1.78*	3.29*	-1.52	10.62*
Teak Plantation 1951-1960	0.24	-1.22*	1.39	-4.07*	2.71
Teak Plantation 1941-1950	9.96*	-1.15*	6.23*	-1.99	-2.40
Teak Plantation 1931-1940	6.84*	-1.41*	2.81*	0.12	-8.73*
Teak Plantation 1921-1930	19.37*	1.18	5.28	-2.80	13.83*

The number of soil fauna in the plantations and natural forests in Parambikulam was not significantly different (Tables 44 and 45).

Table 44. Comparison of soil fauna in plantations with natural forests

Vegetation Type	No. of plots	Mean	Std. Deviation	F Value	Significance
Teak Plantations	270	19.93	15.704		
Natural Forest	180	25.56	26.919	0.786	0.380

Table 45. Comparison of soil fauna in different age group plantations with natural forests

Vegetation Type	No. of plots	Mean	Std. Deviation	F Value	Significance
Teak Plantation11-20	10	50.00	-		
Teak Plantation31-40	80	29.63	17.402		
Teak Plantation41-50	60	17.83	12.703	1.103	0.378
Teak Plantation51-60	60	13.83	12.432		
Teak Plantation61-70	50	9.60	7.503		
Teak Plantation71-80	10	13.00	-		
Natural Forest	180	25.56	26.919		

The richness indices for amphibians in different habitats in Parambikulam indicate that 31 to 40 year old plantations are rich in species (Table 46). The diversity values also indicate the similar trend with higher diversity in 31 to 40 year old plantation (Table 47). Evenness indices of amphibians in plantations and natural forests are given in Table 48.

Table 46. Species richness of amphibians in different age group of plantations and natural forests

Vegetation	R1	R2
Teak Plantation 1981-1990	1.477077	1.290994
Teak Plantation 1961-1970	3.069277	2.157278
Teak Plantation 1941-1950	1.207289	1.154701
Teak Plantation1930-1940	1.674332	1.632993
Natural forests	1.517065	1.154701

Table 47. Diversity indices of amphibians of different age group plantations and natural forests

Vegetation	Lamda	H'
Teak Plantation 1981-1990	0.982143	1.899187
Teak Plantation 1961-1970	9.48E-02	2.18466
Teak Plantation 1941-1950	0.265734	1.198849
Teak Plantation 1931-1940	0.114286	1.329661
Natural forests	0.225275	1.520015

Table 48. Evenness indices of amphibians in different age groups plantations and natural forests

Vegetation	E1	E2	E3	E4	E5
Teak plantation 1981-1990	1.180031	1.336092	1.420116	0.152412	3.20E-03
Teak plantation 1961-1970	0.911074	0.807966	0.788763	1.186691	1.21036
Teak plantation 1941-1950	0.864787	0.829075	0.7721	1.134746	1.19292
Teak plantation 1931-1940	0.959148	0.944941	0.926588	2.31496	2.788007
Natural forests	0.848337	0.762049	0.714459	0.970853	0.962693

Discussion

Significant influence of habitat type on gaur dung density was reported in Parambikulam in an earlier study by Easa (1998). Grasslands were observed to be the most preferred habitat for gaur, the contribution of grass being the highest in the diet. This was followed by moist deciduous forests with higher grass availability and number of principal food next to grasslands. There was also a significant effect of habitat on food availability where natural forests have the significant influence with highest percentage. The Habitat Suitability Index developed for gaur in Parambikulam also indicated higher values for the natural forests. The study has also confirmed the influence of grasslands and deciduous forests in the seasonal distribution of gaur in Parambikulam.

However, the largest animals like Elephant and gaur may not indicate the adverse effects of plantations, if any. The amphibians, spiders and soil fauna could give better indications due to their specific microhabitat characteristics. The earlier study in Parambikulam by Nair and Jayson (1988) has also concluded that the damage, if any due to monoculture plantations have been ameliorated due to the presence of natural forests. The marshy swamps (vayals) and the natural forests around plantations give a mosaic nature to the vegetation in Parambikulam thereby compensating for the presence of plantations.

6.1.3. Conclusions

The regeneration status of indigenous trees shows that older plantations (above 40 years old) in the Sungam and Parambikulam Ranges do not have enough established seedlings and saplings for attaining their status similar to the neighbouring moist deciduous forests through succession. Eight indigenous tree species found in the moist deciduous forests were not observed in the adjacent plantations. Therefore, enrichment planting with indigenous species may be taken up in older plantations. The number of seedlings per hectare may be between 250-500 depending on the gaps in the plantations. The number of undesired *Catunaregam* may be reduced to its number per hectare in the neighbouring forests.

Regarding species selection for enrichment planting, emphasis may be given to species which are component of the original vegetation, preferably found in the neighbouring forests and also species beneficial to animals (Easa, 1989; 1998). For planting the seedlings no special method is suggested. However, the standard practice of planting in 30 cm x 30 cm size pits and providing a hill ward slopping platform of 60 cm x 60 cm may be followed. Fencing the planted area as already done in Wayanad Sanctuary may be followed.

The main objective of the project is to suggest measures for promoting succession of indigenous species in the plantations. The ideal situation is to have a species composition similar to the neighbouring natural forests where the number of teak trees is only eleven. However, it is not advisable to fell teak trees to reduce their number in the plantations considering the likely damages to the seedling and saplings as well as to the habitats of lower group of animals due to felling, logging and transportation.

Lantana is not a major weed in the plantations except in the plantations of 1976 and above where it forms 25 per cent among shrubs. However, percentage of *Eupatorium* is high and varies from 67 per cent to 51 per cent among shrubs in the plantations of all age classes.

Weed management may be carried out in the plantations of 1976 and above where weeds are affecting the establishment of indigenous species. No weeding is needed in the plantations of 1956-1975 near semi-evergreen forests in Karimala and Orukomban Ranges. In Sungam and Parambikulam Ranges, where enrichment planting is recommended, weeding around the planted seedling may be carried out. It is found that lower group of animal such as amphibians and spiders prefer plantations where there is dense shrub growth and thick litter. *Eupatorium* is a major component of shrubs in the plantations.

The analysis of regeneration indicates heavy mortality to the newly recruited seedlings, every year. The plantations near moist deciduous forests are more prone to fire. Therefore, strict fire control is essential for the survival of seedlings. All combustible materials may be removed to a width of 10 m on either side of the roads along the plantations and also engage fire watchers during the fire season (January-May).

6.2. Wayanad Wildlife Sanctuary

6.2.1. Vegetation studies

Teak plantations

Composition of trees in teak plantations of different age class

Age class 1905-1924:
Average number of teak trees: 90/ha
Average number of other trees: 172/ha (belonging to 19 species)

Age class 1925-1944:
Average number of teak trees: 169/ha
Average number of other trees: 176/ha (belonging to 21 species)

Age class 1945-1964:
Average number of teak trees: 248/ha
Average number of other trees: 196/ha (belonging to 28 species)

Age class 1965-1984:
Average number of teak trees: 436/ha
Average number of other trees: 117/ha (belonging to 39 species)

Data on density, frequency, relative density, relative frequency, relative basal area and importance value index of teak and other trees in plantations of the four age classes are provided in Tables 49, 50, 51 and 52.

Table 49. Composition of trees in teak plantations; Age class: 1905-1924

Species	D	F	RD	RF	RBA	IVI	IND
Tectona grandis	100.00	100.00	34.39	13.64	72.96	120.99	90
Cassia fistula	70.37	83.33	24.20	11.36	1.07	36.63	63
Dalbergia latifolia	14.81	83.33	5.09	11.36	5.55	22.00	13
Lagerstroemia microcarpa	14.81	50.00	5.09	6.82	3.36	15.27	13
Phyllanthus emblica	12.96	50.00	4.46	6.82	1.36	12.64	12
Careya arborea	11.11	33.33	3.82	4.55	0.19	8.56	10
Terminalia crenulata	11.11	33.33	3.82	4.55	2.02	10.39	10
Pterocarpus marsupium	9.26	16.67	3.18	2.27	0.45	5.90	8
Terminalia paniculata	9.26	33.33	3.18	4.55	4.12	11.85	8
Anogeissus latifolia	7.41	33.33	2.55	4.55	0.68	7.78	7
Syzygium cumini	5.56	33.33	1.91	4.55	1.81	8.27	5
Grewia tiliifolia	3.70	16.67	1.27	2.27	1.03	4.57	3
Kydia calycina	3.70	33.33	1.27	4.55	1.07	6.89	3
Schleichera oleosa	3.70	33.33	1.27	4.55	0.41	6.23	3
Stereospermum marsupium	3.70	16.67	1.27	2.27	0.24	3.78	3
Bombax ceiba	1.85	16.67	0.64	2.27	2.57	5.48	2
Bridelia retusa	1.85	16.67	0.64	2.27	0.55	3.46	2
Diospyros ovalifolia	1.85	16.67	0.64	2.27	0.02	2.93	2
Gmelina arborea	1.85	16.67	0.64	2.27	0.09	3.00	2
Mitragyna parviflora	1.85	16.67	0.64	2.27	0.45	3.36	2
TOTAL			100.00	100.00	100.00	300.00	262

D- Density, F- Frequency, RD-Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI- Importance Value Index, IND- Individuals per hectare

Table 50. Composition of trees in teak plantations; Age class: 1925-1944

Species	D	F	RD	RF	RBA	IVI	IND
Tectona grandis	187.41	100.00	48.94	20.83	89.69	159.46	169
Cassia fistula	83.70	86.67	21.86	18.06	1.60	41.52	75
Dalbergia latifolia	60.74	66.67	15.86	13.89	4.10	33.85	55
Terminalia crenulata	9.63	20.00	2.51	4.17	0.81	7.49	9
Catunaregam torulosa	8.89	26.67	2.32	5.56	0.34	8.22	8
Lagerstroemia microcarpa	4.44	20.00	1.16	4.17	0.82	6.15	4
Phyllanthus emblica	4.44	20.00	1.16	4.17	0.38	5.71	4
Butea monosperma	3.70	6.67	0.97	1.39	0.29	2.65	3
Anogeissus latifolia	2.22	20.00	0.58	4.17	0.19	4.94	2
Diospyros montana	2.22	13.33	0.58	2.78	0.02	3.38	2
Grewia tiliifolia	2.22	6.67	0.58	1.39	0.40	2.37	2
Tabernaemontana heyneana	2.22	13.33	0.58	2.78	0.02	3.38	2
Trewia polycarpa	2.22	6.67	0.58	1.39	0.01	1.98	2
Diospyros ovalifolia	1.48	13.33	0.39	2.78	0.01	3.18	1
Gmelina arborea	1.48	13.33	0.39	2.78	0.04	3.21	1
Miliusa tomentosa	1.48	6.67	0.39	1.39	0.01	1.79	1
Albizia odoratissima	0.74	6.67	0.19	1.39	0.99	2.57	1
Bauhinia racemosa	0.74	6.67	0.19	1.39	0.01	1.59	1
Dalbergia lanceolaria	0.74	6.67	0.19	1.39	0.08	1.66	1
Radermachera xylocarpa	0.74	6.67	0.19	1.39	0.03	1.61	1
Syzygium cumini	0.74	6.67	0.19	1.39	0.07	1.65	1
Terminalia bellirica	0.74	6.67	0.19	1.39	0.09	1.67	1
TOTAL			100.00	100.00	100.00	300.00	345

D- Density, F- Frequency, RD-Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI- Importance Value Index, IND- Individuals per hectare

Table 51. Composition of trees in teak plantations; Age class: 1945-1964

Species	D	F	RD	RF	RBA	IVI	IND
Tectona grandis	275.93	100.00	55.88	15.93	79.67	151.48	248
Cassia fistula	48.77	77.78	9.88	12.39	1.02	23.29	44
Grewia tiliifolia	40.12	50.00	8.12	7.96	7.13	23.21	36
Dalbergia latifolia	21.60	55.56	4.37	8.85	2.37	15.59	19
Terminalia crenulata	18.52	44.44	3.75	7.08	1.76	12.59	17
Lagerstroemia microcarpa	16.67	38.89	3.38	6.19	3.96	13.53	15
Tabernaemontana heyneana	15.43	11.11	3.12	1.77	0.22	5.11	14
Catunaregam torulosa	12.96	22.22	2.62	3.54	0.14	6.30	12
Kydia calycina	7.41	27.78	1.50	4.43	1.47	7.40	7
Anogeissus latifolia	6.79	16.67	1.37	2.66	0.46	4.49	6
Pterocarpus marsupium	4.94	27.78	1.00	4.43	0.43	5.86	4
Dalbergia lanceolata	3.70	16.67	0.75	2.66	0.17	3.58	3
Phyllanthus emblica	3.09	5.56	0.63	0.89	0.10	1.62	3
Bauhinia racemosa	2.47	16.67	0.50	2.66	0.11	3.27	2
Gmelina arborea	2.47	11.11	0.50	1.77	0.17	2.44	2
Careya arborea	1.85	16.67	0.37	2.66	0.03	3.06	2
Terminalia paniculata	1.85	11.11	0.37	1.77	0.04	2.18	2
Butea monosperma	1.23	11.11	0.25	1.77	0.06	2.08	1
Diospyros ovalifolia	1.23	11.11	0.25	1.77	0.01	2.03	1
Trewia polycarpa	1.23	5.56	0.25	0.89	0.01	1.15	1
Bombax ceiba	0.62	5.56	0.13	0.89	0.03	1.05	1
Bridelia retusa	0.62	5.56	0.13	0.89	0.01	1.03	1
Erythrina stricta	0.62	5.56	0.13	0.89	0.02	1.04	1
Euodia lunu-ankenda	0.62	5.56	0.13	0.89	0.02	1.04	1
Flacourtia montana	0.62	5.56	0.13	0.89	0.01	1.03	1

Table 51. Contd…

Species	D	F	RD	RF	RBA	IVI	IND
Olea dioica	0.62	5.56	0.13	0.89	0.02	1.04	1
Terminalia bellirica	0.62	5.56	0.13	0.89	0.56	1.58	1
Zizyphus jujuba	0.62	5.56	0.13	0.89	0.01	1.03	1
Zizyphus xylopyrus	0.62	5.56	0.13	0.89	0.00	1.02	1
TOTAL			100.00	100.00	100.00	300.00	444

D- Density, F- Frequency, RD-Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI- Importance Value Index, IND- Individuals per hectare

Table 52. Composition of trees in teak plantations; Age class: 1965-1984

Species	D	F	RD	RF	RBA	IVI	IND
Tectona grandis	484.72	100.00	79.77	21.62	86.53	187.92	436
Anogeissus latifolia	24.65	25.00	4.06	5.41	1.16	10.63	22
Cassia fistula	20.14	46.88	3.31	10.14	0.80	14.25	18
Grewia tiliifolia	10.76	15.63	1.77	3.38	2.51	7.66	10
Lagerstroemia microcarpa	10.07	31.25	1.66	6.76	1.62	10.04	9
Dalbergia latifolia	7.29	31.25	1.20	6.76	1.33	9.29	7
Terminalia crenulata	6.25	18.75	1.03	4.05	0.62	5.70	6
Catunaregam torulosa	5.21	15.63	0.86	3.38	0.07	4.31	5
Kydia calycina	4.51	6.25	0.74	1.35	0.58	2.67	4
Butea monosperma	3.47	15.63	0.57	3.38	0.35	4.30	3
Diospyros montana	2.78	6.25	0.46	1.35	0.09	1.90	3
Pterospermum diversifolia	2.78	6.25	0.46	1.35	1.54	3.35	3
Syzygium cumini	2.43	15.63	0.40	3.38	0.30	4.08	2
Terminalia paniculata	2.08	3.13	0.34	0.68	0.26	1.28	2
Miliusa tomentosa	1.74	6.25	0.29	1.35	0.37	2.01	2
Phyllanthus emblica	1.74	3.13	0.29	0.68	0.04	1.01	2
Terminalia ballerina	1.74	9.38	0.29	2.03	0.24	2.56	2
Pterocarpus marsupium	1.39	12.50	0.23	2.70	0.38	3.31	1
Aporusa lindleyana	1.04	6.25	0.17	1.35	0.05	1.57	1
Bauhinia racemosa	1.04	3.13	0.17	0.68	0.02	0.87	1
Erythrina stricta	1.04	3.13	0.17	0.68	0.50	1.35	1
Gmelina arborea	1.04	9.38	0.17	2.03	0.11	2.31	1
Randia uliginosa	1.04	3.13	0.17	0.68	0.04	0.89	1
Careya arborea	0.69	6.25	0.11	1.35	0.02	1.48	1
Chionanthus mala-elengi	0.69	3.13	0.11	0.68	0.09	0.88	1
Dalbergia lanceolata	0.69	6.25	0.11	1.35	0.01	1.47	1
Diospyros ovalifolia	0.69	6.25	0.11	1.35	0.01	1.47	1
Macaranga indica	0.69	3.13	0.11	0.68	0.14	0.93	1
Naringi crenulata	0.69	3.13	0.11	0.68	0.01	0.80	1
Olea dioica	0.69	6.25	0.11	1.35	0.03	1.49	1
Tabernaemontana heyneana	0.69	6.25	0.11	1.35	0.01	1.47	1
Bombax ceiba	0.35	3.13	0.06	0.68	0.06	0.80	1
Bridelia retusa	0.35	3.13	0.06	0.68	0.02	0.76	1
Canthium dicoccum	0.35	3.13	0.06	0.68	0.01	0.75	1
Dillenia pentagyna	0.35	3.13	0.06	0.68	0.01	0.75	1
Flacourtia montana	0.35	3.13	0.06	0.68	0.01	0.75	1
Mallotus philippensis	0.35	3.13	0.06	0.68	0.00	0.74	1
Radermachera xylocarpa	0.35	3.13	0.06	0.68	0.01	0.75	1
Schleichera oleosa	0.35	3.13	0.06	0.68	0.05	0.79	1
Stereospermum colais	0.35	3.13	0.06	0.68	0.00	0.74	1
TOTAL			100.00	100.00	100.00	300.00	553

D- Density, F- Frequency, RD-Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI- Importance Value Index, IND- Individuals per hectare

Regeneration status of tree species in teak plantations

Age class 1905-1924:
Average number of seedlings: 5941/ha representing 33 species
Among the seedlings 97 per cent are belonging to the height classes below one metre (Fig. 9). *Croton roxburghii, Catunaregam torulosa, Cassia fistula, Grewia tiliifolia* and are the dominant species.

Age class 1925-1944:
Average number of seedlings: 5993/ha representing 35 species
Among the seedlings 74 per cent are belonging to the height classes below one metre (Fig. 10). *Catunaregam torulosa, Dalbergia latifolia, Tectona grandis, Croton roxburghii, Grewia tiliifolia* and *Cassia fistula* are the dominant species.

Age class 1945-1964:
Average number of seedlings: 8622/ha representing 52 species
Among the seedlings 78 per cent are belonging to the height classes below one metre (Fig. 11). *Catunaregam torulosa, Dalbergia latifolia, Tectona grandis, Cassia fistula, Kydia calycina, Olea dioica* and *Grewia tiliifolia* are the dominant species.

Age class 1965-1984:
Average number of seedlings: 5289/ha representing 38 species
Among the seedlings 58 per cent are belonging to the height classes below one metre (Fig. 12). *Tectona grandis, Catunaregam torulosa, Dalbergia latifolia, Cassia fistula, Olea dioica, Kydia calycina* and *Grewia tiliifolia* are the dominant species.

The number of seedlings of different trees representing various height classes and their dominance in plantations of different age classes are provided in Tables 53, 54, 55 and 56.

Table 53. Regeneration of tree species in teak plantations; Age class: 1905-1924
Plot size: 10 m x 10 m; Numbers of plots: 12

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	>1 m	>2 m	>3 m	Total
Croton roxburghii	4	30	27	18	9	6			94
Catunaregam torulosa	16	21	16	20	11	3			87
Cassia fistula	11	20	16	12	14	5			78
Grewia tiliifolia	10	16	22	6	7				61
Lagerstroemia microcarpa	7	13	11	6	4				41
Dalbergia latifolia	8	10	12	5	1				36
Schleichera oleosa	8	10	7	8	1	1			35
Diospyros ovalifolia	7	12	5	5	3	1	1		34
Kydia calycina	2	13	8	6	4				33
Syzygium cumini	5	10	7	6	3	2			33
Olea dioica	7	8	5	8	4				32
Zizyphus xylopyrus	5	8	5	2					20

Table 53. Contd...

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	>1 m	>2 m	>3 m	Total
Pterocarpus marsupium	5	6	4	4					19
Bauhinia racemosa	5	5	2	2	1			1	15
Persea macrantha	2	5	3						10
Tabernaemontana heyneana	3	3	2	2					10
Radermachera xylocarpa	1	3	2	2	1				9
Pongamia pinnata	2	2	3	1					8
Stereospermum colais	1	3	2	2					8
Tectona grandis		4	3	1					8
Naringi crenulata	1		3	3					7
Haldina cordifolia	3	1	1						5
Canthium dicoccum		2	2						4
Flacourtia montana	2		2						4
Albizia odoratissima	1	1		1					3
Careya arborea	1	2							3
Mitragyna parvifolia	1	2							3
Terminalia bellirica		1	2						3
Terminalia crenulata		2	1						3
Artocarpus hirsutus				2					2
Dalbergia lanceolaria		2							2
Ficus hispida			2						2
Mangifera indica	1								1
Total	119	215	175	122	63	18	1	1	713

Table 54. Regeneration of tree species in teak plantations; Age class: 1925-1944
Plot size: 10 m x 10 m; Numbers of plots: 30

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 m	>1 m	>2 m	>3 m	Total
Catunaregam torulosa	104	90	95	71	53	37	11	5	466
Dalbergia latifolia	63	80	81	40	26	14	3	1	308
Tectona grandis	29	33	28	30	17	15	10		163
Croton roxburghii	25	21	17	41	29	17			152
Grewia tiliifolia	36	25	29	22	11	3			126
Cassia fistula	23	28	19	21	11	3	3	3	111
Diospyros ovalifolia	31	33	15	9	2	3	1		94
Schleichera oleosa	11	15	14	7	2	2			51
Olea dioica	8	15	7	8					38
Tabernaemontana heyneana	7	7	6	4	1	2			27
Kydia calycina	4	8	4	4	4	1	1		26
Lagerstroemia microcarpa	8	9	4	1					22
Zizyphus xylopyrus	7	3	8	3					21
Phyllanthus emblica	5	5	4	2	4				20
Terminalia bellirica	7	6	3	1					17
Antidesma menasu	2	4	3	4	2	1			16
Dalbergia lanceolaria	4	5	2	1	1				13
Persea macrantha	3	6	1	1	1	1			13
Zizyphus jujuba	5	3	2	2					12
Flacourtia montana	5	2	3	1					11

Table 54. Contd...

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 m	>1 m	>2 m	>3 m	Total
Naringi crenulata	3	3	3	1	1				11
Albizia odoratissima	4	4	1		1				10
Bauhinia racemosa	6	4							10
Syzygium cumini	5	4	1						10
Chionanthus mala-elengi	3	3	2						8
Trema orientalis		2	3		2				7
Pterocarpus marsupium	2	2	2						6
Trewia polycarpa	2	2	1	1					6
Gmelina arborea	2	2	1						5
Mallotus philippensis		2	1	2					5
Sterculia villosa	1	2	1						4
Miliusa tomentosa		2	1						3
Sterculia guttata	2	1							3
Haldina cordifolia	1	1							2
Mangifera indica		1							1
Total	418	433	362	277	168	99	29	9	1798

Table 55. Regeneration of trees species in teak plantations; Age class: 1945-1964
Plot size: 10 m x10 m; Numbers of plots: 36

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	>1 m	>2 m	>3 m	Total
Catunaregam torulosa	128	155	158	117	82	41	22	5	708
Dalbergia latifolia	71	152	111	86	59	34	11	2	526
Tectona grandis	31	55	61	41	34	20	13	3	258
Cassia fistula	36	49	49	37	37	20	8	1	237
Kydia calycina	42	73	60	32	13	3			223
Olea dioica	21	36	31	25	10	2			124
Grewia tiliifolia	17	37	39	12	3	1			109
Diospyros ovalifolia	16	25	18	7	10	8	3		87
Schleichera oleosa	12	25	18	12	5	2			74
Terminalia bellirica	12	31	9	5					57
Zizyphus xylopyrus	12	21	11	8	1	3	1		57
Dalbergia lanceolata	9	15	13	8	4	2			51
Syzygium cumini	9	19	16	5	1				50
Lagerstroemia microcarpa	8	18	17	5					48
Tabernaemontana heyneana		8	14	11	8	4	5		48
Phyllanthus emblica	9	13	14	8	1	1			46
Croton malabaricus	10	12	10	5	3	3	1		44
Flacourtia montana	7	15	8	5	2				37
Naringi crenulata	7	14	6	2		1			30
Persea macrantha	5	10	8	3		1	1		28
Pterocarpus marsupium	7	13	6	1					27
Zizyphus jujuba	7	8	8	3		1			27
Anogeissus latifolia	2	6	8	5					21
Chionanthus mala-elengi	2	7	7	2	1				19
Aporusa lindleyana	1	8	4	2		2	1		18
Bauhinia racemosa	2	7	5	3	1				18

Table 55. Contd…

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	>1 m	>2 m	>3 m	Total
Albizia odoratissima	3	10	2	1					16
Canthium dicoccum	4	6	1	1					12
Stereospermum colais	1	7	3						11
Gmelina arborea		5	5						10
Bridelia retusa		6	2						8
Sterculia villosa	1	4	2		1				8
Terminalia paniculata	1	3	2	1					7
Butea monosperma	2	1	2	1					6
Radermachera xylocarpa	2		2			1			5
Sterculia guttata		4	1						5
Trewia polycarpa	1	2	1	1					5
Antidesma acidum		3	1						4
Euodia lunu-ankenda		2	1	1					4
Antidesma menasu		2	1						3
Bombax ceiba		2	1						3
Careya arborea	1		1			1			3
Ficus hispida		1	2						3
Hydnocarpus pentandra		1	2						3
Lannea coromandelica	1	2							3
Terminalia crenulata		1	2						3
Artocarpus hirsutus		2							2
Cinnamomum malabatrum		1	1						2
Holigarna arnottiana			2						2
Spondias pinnata	1	1							2
Santalum album					1				1
Vitex altissima		1							1
Total	501	899	746	456	277	151	66	11	3104

Table 56. Regeneration of tree species in teak plantations; Age class: 1965-1984
Plot size: 10 m x10m; No of plots: 48

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	>1 m	>2 m	>3 m	Total
Catunaregam torulosa	94	98	90	71	45	28	14	1	441
Tectona grandis	60	73	75	77	63	50	25	6	429
Dalbergia latifolia	51	67	44	32	22	10	5	1	232
Cassia fistula	37	50	41	29	18	6	2	1	185
Olea dioica	30	44	46	20	12	3	1		156
Kydia calycina	24	37	29	16	18	9	1		134
Grewia tiliifolia	30	39	24	20	10	3	1		127
Anogeissus latifolia	19	22	27	11	6	4	2		91
Flacourtia montana	13	33	24	11	6				87
Phyllanthus emblica	12	18	13	9	4	6	1		63
Zizyphus xylopyrus	14	21	17	7					59
Terminalia paniculata	16	18	16	1					51
Bauhinia malabarica	14	16	12	5	3				50
Dalbergia lanceolata	14	9	6	6	6	2			43
Schleichera oleosa	8	13	14	4	1				40

Table 56. Contd...

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	>1 m	>2 m	>3 m	Total
Pterocarpus marsupium	6	19	8			2		1	38
Tabernaemontana heyneana	5	15	9	4	3	1			37
Terminalia bellirica	6	18	8	3					35
Diospyros ovalifolia	9	15	7	1	1				33
Syzygium cumini	7	10	7	5		2			31
Naringi crenulata	4	12	9	1	1				27
Lagerstroemia microcarpa	6	6	7	2	1				21
Cinnamomum malabatrum	7	9	4	0					20
Miliusa tomentosa	5	5	3	2					15
Euodia lunu-ankenda	5	3	2	2					12
Randia uliginosa		2	4	4	1				11
Aporusa lindleyana		4	3	2					9
Gmelina arborea	4	2	2	1					9
Zizyphus jujuba	4	2	1	1	1				9
Chionanthus mala-elengi		3	3	1	1				8
Vitex altissima	3	2	1	2					8
Dillenia pentagyna	2	3	2						7
Albizia odoratissima		3	2						5
Wrightia tinctoria		2	1	1					4
Butea monosperma		2	1						3
Diospyros montana		3							3
Bridelia racemosa	1		1						2
Litsea sp.		2							2
Mitragyna parvifolia		1	1						2
Total	510	701	564	351	223	126	54	10	2539

Composition of shrubs

Age class 1905-1924:

Thirteen species of shrubs were enumerated from the sample plots. Among these *Eupatorium odoratum, Lantana camara* are the most dominant followed by *Helicteres isora, Cipadessa baccifera* and *Glycosmis pentaphylla.*

Age class 1925-1944:

Seventeen species were enumerated from the sample plots. Among these *Eupatorium odoratum* is the most dominant followed by *Glycosmis pentaphylla, Lantana camara, Cipadessa baccifera* and *Helicteres isora.*

Age class 1945-1964:

Fourteen species were enumerated from the sample plots. Among these *Eupatorium odoratum* is the most dominant followed by *Lantana camara, Cipadessa baccifera, Glycosmis pentaphylla* and *Helicteres isora.*

Age class 1965-1984:

Fourteen species were enumerated from the sample plots. Among these *Eupatorium odoratum* is the most dominant followed by *Glycosmis pentaphylla, Helicteres isora, Lantana camara* and *Cipadessa baccifera*.

The number of individuals of each shrubby species enumerated from the sample plots and their number per hectare are provided in Tables 57, 58, 59 and 60.

Table 57. Status of shrubs in teak plantations; Age class: 1905-1924
Plot size: 5 m x 5 m; Numbers of plots: 12

Species	No	Per Ha	% of occurrence
Eupatorium odoratum	234	7800	34.91
Lantana camara	159	5300	23.72
Helicteres isora	72	2400	10.74
Cipadessa baccifera	62	2066	9.24
Glycosmis pentaphylla	57	1900	8.50
Solanum torvum	35	1167	5.21
Crotalaria sp.	22	733	3.27
Leea indica	12	400	1.78
Zizyphus oenoplia	7	233	1.04
Securinega virosa	6	200	0.89
Plectranthus sp.	2	67	0.28
Embelia tsjeriam-cottam	2	67	0.28
Flemingia bracteata	1	33	0.14
Total	671		100.00

Table 58. Status of shrubs in teak plantations; Age class: 1925-1944
Plot size: 5 m x 5 m; Numbers of plots: 30

Species	No	Per Ha	% of occurrence
Eupatorium odoratum	459	6557	33.50
Glycosmis pentaphylla	241	3213	17.59
Lantana camara	229	3053	16.71
Cipadessa baccifera	202	2703	14.74
Helicteres isora	80	1066	5.84
Urena lobata	54	720	3.94
Crotalaria sp.	29	386	2.12
Flemingia bracteata	18	240	1.31
Desmodium velutinum	15	200	1.09
Embelia tsjeriam-cottam	12	160	0.88
Securinega virosa	9	120	0.66
Leea indica	7	94	0.51
Solanum torvum	5	66	0.36
Desmodium pulchellum	5	66	0.36
Ocimum gratissimum	3	40	0.22
Rauvolfia serpentina	2	26	0.15
Total	1368		100.00

Table 59. Status of shrubs in teak plantations; Age class: 1945-1964
Plot size: 5 m x 5 m; Numbers of plots: 36

Species	No	Per Ha	% of occurrence
Eupatorium odoratum	723	8033	53.40
Lantana camara	247	2744	18.24
Urena lobata	110	1222	8.13
Cipadessa baccifera	101	1114	7.46
Glycosmis pentaphylla	55	611	4.06
Helicteres isora	47	519	3.48
Flemingia bracteata	19	211	1.40
Embelia tsjeriam-cottam	17	188	1.25
Leea indica	13	144	0.96
Crotalaria sp.	9	100	0.66
Zizyphus oenoplia	4	44	0.29
Securinega virosa	4	44	0.29
Plectranthus sp.	3	33	0.22
Solanum torvum	2	22	0.15
Total	1354		99.99

Table 60. Status of shrubs in teak plantations; Age class: 1965-1984
Plot size: 5 m x 5 m; No of plots: 48

Species	No	Per Ha	% of occurrence
Eupatorium odoratum	359	7180	33.27
Glycosmis pentaphylla	266	5320	24.65
Helicteres isora	120	2400	11.12
Lantana camara	115	2300	10.65
Cipadessa baccifera	63	1260	5.84
Urena lobata	46	920	4.26
Solanum torvum	26	520	2.40
Desmodium velutinum	21	175	1.95
Zizyphus oenoplia	21	175	1.95
Embelia tsjeriam-cottam	14	116	1.30
Leea indica	13	108	1.20
Plectranthus sp.	8	66	0.74
Flemingia bracteata	4	33	0.37
Rauvolfia serpentina	3	25	0.28
Total	1079		100.00

Status of herbs, grasses and climbers

Age class 1905-1924:

Thirty species of herbs and grasses were enumerated from the sample plots. Among these *Oplismenus compositus, Desmodium triflorum, Mimosa pudica* and *Cyrtococcum oxyphyllum* are the most common species.

Eleven species of climbers were also recorded from the plantations.

Age class 1925-1944:
Thirty-three species of herbs and grasses were enumerated from the sample plots. Among these *Oplismenus compositus, Cyrtococcum oxyphyllum, Mimosa pudica* and *Desmodium triflorum* are the most common species.
Fourteen species of climbers were also recorded from the plantations.

Age class 1945-1964:
Thirty-seven species of herbs and grasses were enumerated from the sample plots. Among these *Oplismenus compositus, Cyrtococcum oxyphyllum, Globba ophioglossa* and *Mimosa pudica* are the most common species.
Fourteen species of climbers were also recorded from the plantations.

Age class 1965-1984:
Twenty-nine species of herbs and grasses were enumerated from the sample plots. *Oplismenus compositus*, Cyrtococcum *oxyphyllum, Globba ophioglossa* and *Mimosa pudica* are the most common species.
Fourteen species of climbers were also recorded from the plantations.

The number of sample plots in plantations of different age classes, the herbaceous species and their number and name of climbers are provided in Tables 61, 62, 63 and 64.

Table 61. Status of herbs, grasses and climbers in teak plantations; Age class: 1905-1924
Plot size: 1 m x 1 m; Numbers of plots: 12

Species	No
Oplismenus compositus	86
Desmodium triflorum	51
Mimosa pudica	46
Cyrtococcum oxyphyllum	40
Carex sp.	25
Murdannia glabra	21
Uraria rufescens	18
Cyrtococcum oxyphyllum	14
Ageratum conyzoides	12
Justicia sp.	12
Kyllinga sp.	12
Elephantopus scaber	12
Costus speciosus	9
Globba ophioglossa	9
Justicia simplex	8
Zingiber zerumbet	7

Species	No
Cyperus sp.	6
Uraria rufescens	6
Curculigo orchioides	5
Scleria sp.	5
Sida rhomboidea	5
Triumfetta rhomboidea	5
Biophytum sensitivum	4
Leucas aspera.	4
Achyranthes aspera	3
Curcuma ecalcarata	3
Impatiens sp.	3
Pseudarthria viscida	3
Vernonia cinerea	2
Sida acuta	2
Desmodium laxiflorum	2

Climbers

Cyclea peltata, Dioscorea pentaphylla, Ichnocarpus frutescens, Rubia cordifolia, Vigna pilosa, Zizyphus rugosa, Asparagus racemosus. Jasminum sp., Hemidesmus indicus, Acacia caesia, Cryptolepis buchananii, Thunbergia mysorensis.

Table 62. Status of herbs, grasses and climbers in teak plantations; Age class: 1925-1944
Plot size: 1 m x 1 m; Numbers of plots: 30

Species	No
Oplismenus compositus	266
Cyrtococcum oxyphyllum	214
Mimosa pudica	102
Desmodium triflorum	94
Globba ophioglossa	72
Zingiber zerumbet	61
Curculigo orchioides	57
Costus speciosus	56
Justicia simplex	47
Kyllinga triceps	39
Cyperus sp.	38
Murdannia glabra	38
Curcuma ecalcarata	37
Carex sp.	32
Uraria rufescens	30
Biophytum sensitivum	27
Scleria parvula	25

Species	No
Ageratum conyzoides	22
Leucas chinensis	14
Themeda sp.	11
Spermacoce pusilla	10
Imperata cylindrica	7
Fimbristylis sp.	6
Mitracarpus verticillatus	6
Achyranthes aspera	3
Vernonia cinerea	3
Triumfetta rhomboidea	3
Desmodium laxiflorum	3
Asclepias curassavica	2
Sida rhomboidea	2
Gomphostemma heyneana	2
Leucas sp.	2
Sauropus quadrangularis	1

Climbers

Cyclea peltata, Dioscorea pentaphylla, Smilax ceylanica, Zizyphus rugosa, Jasminum sp., Acacia caesia, Hemidesmus indicus, Asparagus racemosus, Vigna pilosa, Thunbergia mysorensis, Naravelia zeylanica, Ichnocarpus frutescence, Cryptolepis buchananii, Rubia cordifolia.

Table 63. Status of herbs, grasses and climbers in teak plantations; Age class: 1945-1964
Plot size: 1 m x 1 m; Numbers of plots: 36

Species	No
Oplismenus compositus	273
Cyrtococcum oxyphyllum	214
Globba ophioglossa	100
Mimosa pudica	98
Desmodium triflorum	74
Zingiber zerumbet	63
Murdannia baccifera	60
Justicia simplex	54
Uraria rufescens	48
Costus specious	46
Cyprus sp.	42
Curculigo orchioides	41
Kyllinga sp.	41
Elephantopus scaber	38
Scleria parvula	33
Biophytum sensitivum	28
Carex sp.	24
Curcuma ecalcarata	24

Themeda sp.	14
Spermacoce pusilla	13
Fimbristylis sp.	12
Ageratum conyzoides	10
Vernonia cinerea	8
Desmodium velutinum	6
Pseudarthria viscida	6
Cyanotis sp.	5
Lucas chinensis	4
Imperata cylindrica	4
Triumfetta rhomboidea	4
Sida rhomboidea	3
Sida alnifolia	3
Lucas aspera	3
Impatiens sp.	2
Mitracarpus verticillatus	2
Phyllanthus sp.	2
Sauropus quadrangularis	2
Gomphostemma heyneana	2

Climbers

Cyclea peltata, Dioscorea pentaphylla, Smilax ceylanica, Zizyphus rugosa, Jasminum sp Acacia caesia, Hemidesmus indicus, Asparagus racemosus, Vigna pilosa, Thunbergia mysorensis, Naravelia zeylanica, Ichnocarpus frutescence, Cryptolepis buchananii, Rubia cordifolia

Table 64. Status of herbs, grasses and climbers in teak plantations; Age class: 1965-1984
Plot size: 1 m x 1 m; Numbers of plots: 48

Species	No
Oplismenus compositus	364
Cyrtococcum oxyphyllum	285
Mimosa pudica	148
Globba ophioglossa	120
Desmodium triflorum	98
Murdannia glabra	85
Zingiber zerumbet	79
Uraria rufescens	78
Justicia simplex	69
Curculigo orchioides	62
Elephantopus scaber	60
Costus speciosus	55
Kyllinga triceps	48
Cyperus sp.	46
Scleria parvula	35

Species	No
Carex sp.	32
Biophytum sensitivum	30
Curcuma ecalcarata	28
Themeda sp.	22
Spermacoce pusilla	18
Ageratum conyzoides	13
Vernonia cinerea	9
Triumfetta rhomboidea	7
Achyranthes aspera	5
Sida rhomboidea	4
Sida acuta	3
Gomphostemma heyneana	3
Sauropus quadrangularis	3
Lucas aspera	2

Climbers

Cyclea peltata, Dioscorea pentaphylla, Smilax ceylanica, Zizyphus rugosa, Jasminum sp, Acacia caesia, Hemidesmus indicus, Asparagus racemosus, Vigna pilosa, Thunbergia mysorensis, Naravelia zeylanica, Ichnocarpus frutescence, Cryptolepis buchananii, Rubia cordifolia.

Natural forests

Thirty-eight species of trees were enumerated from the sample plots. *Terminalia crenulata, Anogeissus latifolia, Kydia calycina, Lagerstroemia microcarpa, Grewia tiliifolia, Catunaregam torulosa* and *Tectona grandis* are the dominant species (Table 65).

Table 65. Composition of trees in moist deciduous forests-Natural forests

Species	D	F	RD	RF	RBA	IVI	IND
Terminalia crenulata	61.62	90.91	13.90	7.19	21.46	42.55	55
Anogeissus latifolia	42.42	54.55	9.57	4.32	5.56	19.45	38
Kydia calycina	39.39	45.45	8.88	3.60	1.60	14.08	35
Lagerstroemia microcarpa	28.28	63.64	6.38	5.04	7.95	19.37	25
Grewia tiliifolia	27.27	81.82	6.15	6.47	9.23	21.85	25
Catunaregam torulosa	21.21	72.73	4.78	5.76	1.67	12.21	19
Tectona grandis	21.21	54.55	4.78	4.32	16.01	25.11	19
Olea dioica	20.20	36.36	4.56	2.88	2.66	10.10	18
Cassia fistula	18.18	54.55	4.10	4.32	0.51	8.93	16
Dalbergia latifolia	18.18	72.73	4.10	5.76	3.77	13.63	16
Haldina cordifolia	15.15	45.45	3.42	3.60	2.66	9.68	14

Table 65. Contd...

Species	D	F	RD	RF	RBA	IVI	IND
Terminalia paniculata	13.13	27.27	2.96	2.16	2.51	7.63	12
Euodia lunu-ankenda	10.10	18.18	2.28	1.44	1.14	4.86	9
Phyllanthus emblica	10.10	63.64	2.28	5.04	0.28	7.60	9
Miliusa tomentosa	9.09	27.27	2.05	2.16	2.21	6.42	8
Pterocarpus marsupium	9.09	27.27	2.05	2.16	3.13	7.34	8
Gmelina arborea	7.07	45.45	1.59	3.60	1.34	6.53	6
Callicarpa lanata	6.06	9.09	1.37	0.72	0.18	2.27	5
Diospyros ovalifolia	6.06	18.18	1.37	1.44	0.02	2.83	5
Schleichera oleosa	6.06	27.27	1.37	2.16	1.20	4.73	5
Bauhinia racemosa	5.05	36.36	1.14	2.88	0.35	4.37	5
Careya arborea	5.05	36.36	1.14	2.88	0.70	4.72	5
Casearia wynaadensis	5.05	27.27	1.14	2.16	0.30	3.60	5
Terminalia bellirica	5.05	27.27	1.14	2.16	3.68	6.98	5
Zizyphus jujuba	5.05	18.18	1.14	1.44	0.15	2.73	5
Radermachera xylocarpa	4.04	18.18	0.91	1.44	0.62	2.97	4
Mitragyna parvifolia	3.03	18.18	0.68	1.44	0.50	2.62	3
Stereospermum chelonoides	3.03	18.18	0.68	1.44	3.70	5.82	3
Syzygium cumini	3.03	18.18	0.68	1.44	1.33	3.45	3
Bridelia retusa	2.02	18.18	0.46	1.44	0.13	2.03	2
Butea monosperma	2.02	18.18	0.46	1.44	0.18	2.08	2
Cinnamomum malabatrum	2.02	9.09	0.46	0.72	0.02	1.20	2
Dillenia pentagyna	2.02	9.09	0.46	0.72	0.58	1.76	2
Schrebera swietenioides	2.02	9.09	0.46	0.72	0.59	1.77	2
Albizia odoratissima	1.01	9.09	0.23	0.72	0.49	1.44	1
Alstonia scholaris	1.01	9.09	0.23	0.72	1.51	2.46	1
Persea macrantha	1.01	9.09	0.23	0.72	0.05	1.00	1
Terminalia heyneana	1.01	9.09	0.23	0.72	0.01	0.96	1
Zizyphus xylopyrus	1.01	9.09	0.23	0.72	0.03	0.98	1
TOTAL			100.00	100.00	100.00	300.00	399

D- Density, F- Frequency, RD-Relative Density, RF- Relative Frequency, RBA- Relative Basal Area, IVI- Importance Value Index, IND- Individuals per hectare

The regeneration status of trees shows that *Dalbergia latifolia, Grewia tiliifolia, Cassia fistula, Kydia calycina, Catunaregam torulosa, Schleichera oleosa* and *Olea dioica* are regenerating quite well. However, established seedlings (above 1 m height) are comparatively few (Fig. 13). *Dalbergia latifolia* (93%), *Grewia tiliifolia* (94%), *Cassia fistula* (97%) and *Kydia calycina* (95%) are represented by seedlings below one metre height classes (Table 66). Eight species in the natural forests have not regenerated in the plantations (Table 67).

Table 66. Regeneration of tree species in moist deciduous forests-Natural Forests
Plot size: 10 m x 10 m; Numbers of plots: 22

Species	<20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	>1 m	>2 m	>3 m	Total
Dalbergia latifolia	45	40	40	26	17	8	4		180
Grewia tiliifolia	34	49	36	17	7	4	4	1	152
Cassia fistula	39	45	33	23	9	1	1	1	149
Kydia calycina	39	35	35	23	10	5	1		148
Catunaregam torulosa	38	27	30	19	17	9	2	1	143
Schleichera oleosa	36	33	22	15	8	4			117
Olea dioica	31	32	24	12	10	5	2		115
Phyllanthus emblica	27	26	24	9	6	3	1		96
Miliusa tomentosa	17	18	13	8	2	1			59
Terminalia crenulata	16	13	12	6	5	2	1		55
Persea macrantha	14	14	11	4	1				44
Flacourtia montana	5	13	8	8	3	1			38
Pterocarpus marsupium	9	13	6	3	1				32
Gmelina arborea	5	9	5	6	1				26
Radermachera xylocarpa	10	2	7	2	2	1			25
Bauhinia racemosa	7	7	5	1	3	1			24
Lagerstroemia microcarpa	7	5	7	3					22
Terminalia bellirica	3	11	8						22
Naringi crenulata	6	7	1	1					15
Zizyphus Xylopyrus	3	6	3	2	1				15
Anogeissus latifolia	7	4	4	2					14
Chionanthus mala-elengi	3	6	4						13
Tabernaemontana heyneana	5	4	2	2					13
Diospyros ovalifolia	5	3	2	1					11
Tectona grandis	3	4	2			1			10
Terminalia paniculata	4	2	1	2			1		10
Bridelia retusa	4	3	1		1				9
Syzygium cumini	4	3	1						8
Zizyphus jujuba	6		2						8
Sterculia villosa	3	2	1	1					7
Wrightia tinctoria	3	3							6
Albizia odoratissima	3	2							5
Antidesma menasu	2	2							4
Careya arborea	1	2	1						4
Sterculia guttata	2	1							4
Stereospermum colais	1	3							4
Cinnamomum malabatrum	1	2							3
Aporusa lindleyana	1	1							2
Total	449	452	351	196	104	46	17	3	1612

Table 67. Tree species in the natural forests not regenerated in the plantations

Species	
Alstonia scholaris	*Antidesma menasu*
Callicarpa lanata	*Casearia wynaadensis*
Cinnamomum sp.	*Haldina cordifolia*
Persea macrantha	*Schrebera swietenioides*

Figure 9-13. Regeneration of tree species in teak plantations of different age classes and natural forests

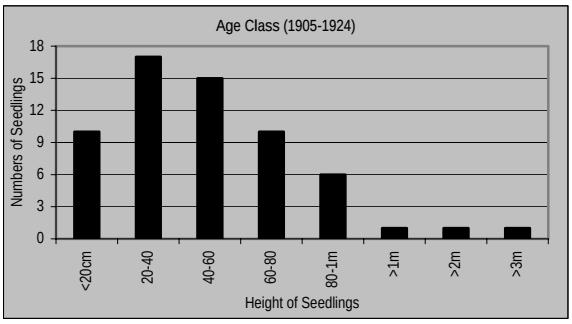


Figure 9

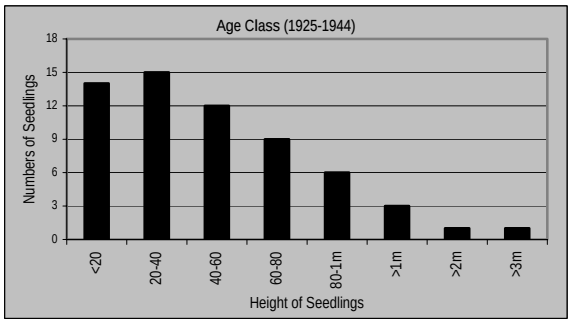


Figure 10

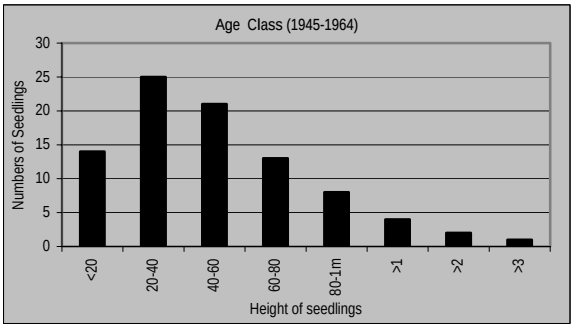


Figure 11

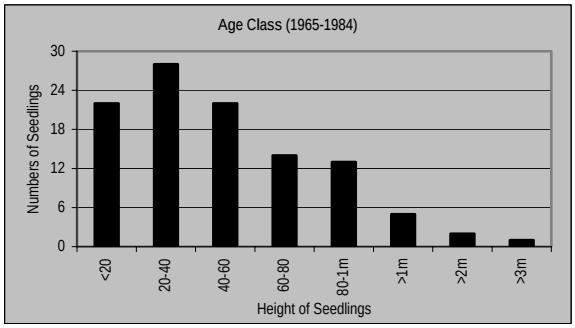


Figure 12

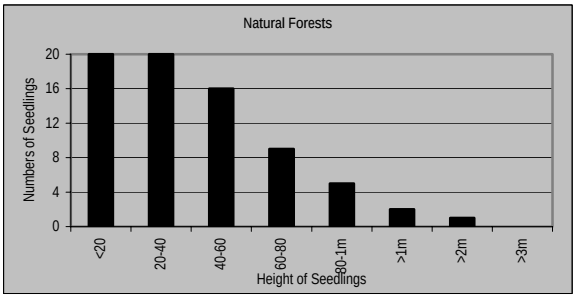


Figure 13

Among the shrubs, *Eupatorium odoratum, Lantana camara, Helicteres isora, Cipadessa baccifera* and *Leea indica* are the dominant species (Table 68). Twenty-three species of grasses and herbs were enumerated from the sample plots. *Oplismenus compositus, Cyrtococcum oxyphyllum, Elephantopus scaber, Globba ophioglossa* and *Mimosa pudica* are the dominant species. Fourteen climbers were also recorded from the sample plots (Table 69).

Table 68. Status of shrubs in moist deciduous forests-Natural Forests
Plot size: 5 m x 5 m; Numbers of plots: 22

Species	No	Per Ha	% of occurrence
Eupatorium odoratum	143	2600	26.33
Lantana camara	98	1781	18.04
Helicteres isora	77	1400	14.18
Cipadessa baccifera	50	909	9.21
Leea indica	49	890	9.02
Urena lobata	36	654	6.63
Zizyphus oenoplia	21	381	3.87
Embelia tsjeriam-cottam	17	309	3.13
Desmodium pulchellum	15	272	2.76
Glycosmis pentaphylla	13	236	2.39
Flemingia bracteata	9	163	1.66
Plectranthus	7	127	1.29
Desmodium velutinum	4	73	0.74
Crotalaria sp.	2	36	0.37
Securinega virosa	2	36	0.37
Total	543		99.99

Table 69. Status of herbs, grasses and climbers in moist deciduous forests-Natural forests
Plot size: 1 m x 1 m; Numbers of plots: 11

Species	No
Oplismenus compositus	138
Cyrtococcum oxyphyllum	96
Elephantopus scaber	48
Globba ophioglossa	39
Mimosa pudica	38
Desmodium triflorum	33
Justicia simplex	32
Zingiber zerumbet	28
Murdannia glabra	28
Uraria rufescens	23
Curculigo orchioides	21
Scleria sp.	18
Costus speciosus	17
Biophytum sensitivum	17
Curcuma ecalcarata	11
Kyllinga triceps	8

Species	No
Ageratum conyzoides	6
Cyperus sp.	5
Carex sp.	5
Triumfetta rhomboidea	5
Desmodium laxiflorum	4
Sida alnifolia	4
Themeda sp.	3
Spermacoce pusilla	3
Vernonia cinerea	3
Sida rhomboidea	3
Sauropus quadrangularis	3
Leucas aspera	3
Gomphostemma heyneana	3
Imperata cylindrica	2
Achyranthes aspera	2

Climbers

Cyclea peltata, Dioscorea pentaphylla, Smilax ceylanica, Zizyphus rugosa, Jasminum sps, Acacia caesia, Hemidesmus indicus, Asparagus racemosus, Vigna pilosa, Thunbergia mysorensis, Naravelia zeylanica, Ichnocarpus frutescence, Cryptolepis buchananii, Rubia cordifolia.

Discussion

Mutual comparison of dominant tree species based on importance value index (IVI), species with high 'ecological efficiency' with varying conditions for the period of 80 years (1905-1984) are *Tectona grandis, Dalbergia latifolia, Cassia fistula, Lagerstroemia microcarpa* and *Terminalia crenulata*. Even though, the qualitative similarity of 60 per cent was observed in most cases with respect to the quantitative aspect in terms of number of individual species per unit area, it is notable that the difference between the oldest plantation class (1905-1924) and youngest group (1965-1984) is of 2.3 times. That is, among the 1634 numbers of individuals estimated per hectare in all four classes together; only 15.97 per cent was from oldest plantation group and 36.68 per cent from youngest plantation group. The percentage of species in terms of numbers are 20.56 per cent and 27.78 per cent respectively in group 1925-1944 and 1945-1864. This may be due to stabilisation processes of vegetation leading to the more 'mature community' as evidenced by the Maturity Index values of the four different classes (Table 70). This again indicate the unidirectional successional status in the plantations of Wayanad area.

Table 70. Maturity Index value of four age classes

No	Age class	Maturity Index (%)
1.	1905-1924	36.6
2.	1925-1944	21.5
3.	1945-1964	22.4
4.	1965-1984	11.4

On comparison of regeneration status of tree species in four age classes, it is noted that species like *Catunaregam torulosa, Cassia fistula, Tectona grandis, Grewia tiliifolia, Lagerstroemia microcarpa, Dalbergia latifolia* and *Croton roxburghii* are the 'Character Species' in all four classes, constituting the maximum numbers of seedlings (51 per cent of the total seedlings of plantation class 1905-1924; 68 per cent of the class 1925-1944; 63 per cent of the class 1945-1964 and 57 per cent of the 1965-1984 plantations). Thus, in the dominant community formation during the successional stage, in different plantation age groups, the above mentioned tree seedlings play a key role. On critical examination of the 'character species' it is noted profuse regeneration and establishment of species like *Catunaregam torulosa* and in some locations *Kydia calycina* may also due to the incidence of fire in the plantations. Hence, structural manipulation of the above mentioned species in Wayanad area may enhance the quantitative status of plantations especially to that of older plantation.

The regeneration status of indigenous trees shows a similar trend to that of Parambikulam where older plantations in Wyanad do not have enough

established seedlings (Table 71). The established seedlings in older plantations (*ie*, seedlings more than 1 m height) is of 2.8 per cent of the total seedlings enumerated. The established seedlings in other age classes (viz. 1925-1944; 1945-1964 and 1965-1984 are about 7 per cent of the total. In general, more than 93 per cent of regenerated seedlings are not establishing due to the adverse habitat conditions in the area.

In the plantations subjected to treatment for converted to 'natural forests' the survival of the planted seedlings after 3 years is 52 per cent in the fenced area and 33 per cent in the unfenced area. In the treatment areas 21 tree species are also naturally regenerating (Table 89).

Table 71. Percentage of seedlings of different height classes in the plantations

Height class (cm)	Age class (per cent)			
	1905-1924	1925-1944	1945-1964	1965-1984
<20	16.7	23.2	16.1	20.1
20-40	30.0	24.1	29.0	27.6
40-60	24.5	20.1	24.0	22.2
60-80	17.1	15.4	14.7	13.8
80-100	8.8	9.3	8.9	8.7
> 100 (established seedlings)	2.8	7.6	7.3	7.5

The percentage of survival and establishment of tree seedlings in the plantations of the age class 1905-1924 are *Croton roxburghii* (16 per cent), *Catunaregam torulosa* (16 per cent) and *Cassia fistula* (24 per cent); in the age class 1925-1944 *Tectona grandis* (26 per cent), *Dalbergia latifolia* (15 per cent), *Catunaregam torulosa* (23 per cent), *Croton roxburghii* (30 per cent); in the age class 1945-1964 *Catunaregam torulosa* (21 per cent), *Dalbergia latifolia* (20 per cent), *Tectona grandis* (27 per cent), *Cassia fistula* (28 per cent) and in the age 1965-1984 *Catunaregam torulosa* (20 per cent), *Tectona grandis* (34 per cent), *Dalbergia latifolia* (16 per cent), *Cassia fistula* (15 per cent). The above mentioned species comprises 58-78 per cent of the total established seedlings in all age classes.

With respect to the weed status, *Eupatorium odoratum* along with *Lantana camara* form the major ground vegetation. On an average more than 30 per cent of weed coverage is by *Eupatorium odoratum* in all age classes and 15-20 per cent is covered by *Lantana camara.* In the plantations subjected to treatment in Muthanga Range *Imperata cylindrica* and *Lantana camara* are affecting the growth of planted seedlings. In Tholpetty Range *Lantana and Eupatorium* are the major weeds.

6.2.2. Animal studies

The elephant and gaur dung density in Wayanad Wildlife Sanctuary follows a pattern with increased utilization of the age groups 61-70 (Tables 72 and 73). The utilization of natural forests also is comparable with that of age group 61-70 (Table 74 and Fig. 14).

Table 72. Elephant dung density (number/km^2) in teak plantations

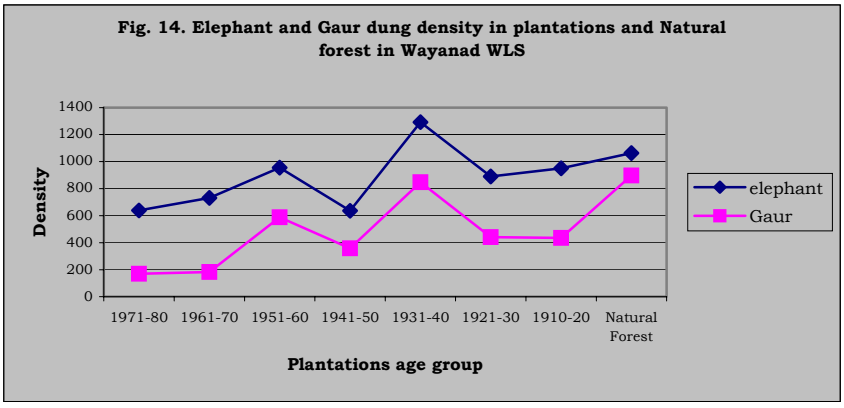
Age Class	Density	LCL	UCL	CV
1971-1980	638.17	478.66	850.84	14.6
1961-1970	732.06	540.67	991.19	15.4
1951-1960	955.14	598.95	1523.2	23.9
1941-1950	635.61	370.27	1091.1	27.7
1931-1940	1292.2	992.4	1682.6	13.4
1921-1930	889.9	607.44	1303.7	19.2
1911-19s20	951.15	542.04	1669.1	28.1

Table 73. Gaur dung density (number/km^2) in teak plantations

Age class	Density	LCL	UCL	CV
1971-1980	170.05	104.79	275.97	24.3
1961-1970	182.93	99.476	336.4	29.7
1951-1960	587.84	404.28	854.74	18.9
1941-1950	357.73	213.82	598.5	25.6
1931-1940	848.25	395.13	1821	39.6
1921-1930	441.51	226.4	861.01	32.7
1911-1920	434.83	165.53	1142.2	46.1

Table 74. Elephant and gaur dung density (number/km^2) in natural forests

Animal	Density	LCL	UCL	CV
Elephant	1063.500	829.720	1363.000	12.7
Gaur	897.160	765.510	1051.500	08.1s



The comparison of teak plantations with natural forests in southern part of Wayanad for various monitored parameters is made in Table 75. There is a significant difference between the two habitats in the case of shrubs, litter depth, number of logs, number of spiders and the sambar deer indirect evidences. The Table 76 indicates a significant difference in various parameters in different age group of teak plantation and natural forest in southern part of Wayanad. The LSD test, however shows that the difference in the case of shrubs in teak plantations is significant with that of natural forests in all the age groups of plantations except 81-90 (Table 77). The litter depth was significantly different only in certain age group and does not follow any pattern. The number of logs was evidently higher in the case of 41-50 and 51-60 age group. The number of spiders does not follow any specific pattern but was higher in 21-30,31-40, 51-60 and 71-80 age group plantations. The sambar deer indirect evidences indicate that there was clear significant difference between the natural forests and plantations especially in 21-30, 31-40,71-80 and 81-90 ages groups (Table 77). The natural forests in Wayanad were the most preferred habitat of sambar deer. The comparison in Tholpetty also indicated almost a similar pattern (Tables 78, 79 and 80). However, there was no considerable difference in the case of number of spiders. There was of course a minor difference in the significance of difference in various age group of plantations.

Table 75. Comparison of various parameters in teak plantation with natural forests in southern part

Vegetation Type	No. of plots	Mean	Std. deviation	F Value	Significance
Number of shrub					
Teak plantation	448	10.383	13.198	47.318	0.000
Natural forest	205	3.75	5.920		
Litter depth					
Teak plantation	448	1.82	2.403	18.985	0.000
Natural forest	205	1.00	1.793		
Number of logs					
Teak plantation	448	0.29	0.618	9.469	0.002
Natural forest	205	0.34	0.699		
Number of spiders					
Teak plantation	448	1.18	1.625	50.409	0.000
Natural forest	205	0.34	0.699		
Sambar deer indirect evidences					
Teak plantation	448	1.78	2.534	85.458	0.000
Natural forest	205	3.93	3.1712		

Table 76. Comparison of various parameters in different teak plantation age groups with natural forests in southern part

Vegetation type	No. of plots	Mean	Std. deviation	F Value	Significance
Number of shrubs					
Teak plantation 1971-1980	136	10.13	11.261	13.186	0.000
Teak plantation 1961-1970	75	17.09	17.278		
Teak plantation 1951-1960	77	7.29	12.530		
Teak plantation 1941-1950	82	9.66	12.895		
Teak plantation 1931-1940	36	8.31	9.386		

Table 76. Contd...

Vegetation type	No. of plots	Mean	Std. deviation	F Value	Significance
Teak plantation 1921-1930	30	10.63	12.590		
Teak plantation 1911-1920	12	1.67	5.466		
Natural forest	205	3.75	5.920		
Litter depth					
Teak plantation 1971-1980	136	2.90	2.847		
Teak plantation 1961-1970	75	1.52	2.238		
Teak plantation 1951-1960	77	1.04	1.681	11.713	0.000
Teak plantation 1941-1950	82	1.68	2.210		
Teak plantation 1931-1940	36	1.83	2.184		
Teak plantation 1921-1930	30	0.50	1.042		
Teak plantation 1911-1920	12	0.67	1.497		
Natural forest	205	1.00	1.793		
Number of logs					
Teak plantation 1971-1980	136	0.26	0.658		
Teak plantation 1961-1970	75	0.29	0.632		
Teak plantation 1951-1960	77	0.35	0.739	1.629	0.124
Teak plantation 1941-1950	82	0.29	0.533		
Teak plantation 1931-1940	36	0.33	0.535		
Teak plantation 1921-1930	30	0.27	0.450		
Teak plantation 1911-1920	12	0.17	0.389		
Natural forest	205	0.15	0.418		
Number of spiders					
Teak plantation 1971-1980	136	1.31	1.238		
Teak plantation 1961-1970	75	1.55	1.613		
Teak plantation 1951-1960	77	0.51.	0.898	15.071	0.000
Teak plantation 1941-1950	82	1.29	1.461		
Teak plantation 1931-1940	36	0.69	0.889		
Teak plantation 1921-1930	30	2.07	3.823		
Teak plantation 1921-1930	12	0.08	0.289		
Natural forest	205	0.34	0.699		
Sambar deer indirect evidences					
Teak plantation1971-1980	136	0.94	2.197		
Teak plantation1961-1970	75	1.15	1.964		
Teak plantation1951-1960	77	3.38	3.121	20.251	0.000
Teak plantation 1941-1950	82	1.98	2.419		
Teak plantation 1931-1940	36	2.69	2.352		
Teak plantation 1921-1930	30	1.57	2.096		
Teak plantation 1911-1920	12	1.58	1.929		
Natural forest	205	3.93	3.171		

Table 77. Comparison of various parameters in natural forests with different age group plantations in southern part (Using LSD Test)

Age group of Teak plantation	Mean difference between plantation and natural forests				
	No. of shrubs	Litter depth	No. of logs	No. of spiders	Sambar deer indirect evidences
1971-1980	-6.37*	-1.90*	-0.12	-0.97*	2.99*
1961-1970	-13.34*	-0.52	-0.15	-1.21*	2.78*
1951-1960	-3.53*	-0.04	-0.20*	-0.17	0.55
1941-1950	-5.91*	-0.68*	-0.15*	-0.96*	1.95*
1931-1940	-4.55*	-0.83*	-0.19	-0.36	1.23*
1921-1930	-6.88*	0.50	-0.12	-1.73*	2.36*
1911-1920	2.08	0.33	-0.02	0.25	2.34*

Table 78. Comparison of various parameters in teak plantation with natural forests in Tholpetty

Vegetation type	No. of plots	Mean	Std. deviation	F Value	Significance
No. of shrub					
Teak plantation	199	3.58	4.684	39.734	0.000
Natural forest	80	8.23	7.331		
Litter depth					
Teak plantation	199	2.56	2.512	2.066	0.152
Natural forest	80	3.01	2.053		
Number of logs					
Teak plantation	199	0.47	0.839	4.798	0.029
Natural forest	80	0.24	0.661		
Number of spiders					
Teak plantation	199	0.85	0.961	0.128	0.721
Natural forest	80	0.90	0.976		
Sambar deer indirect evidences					
Teak plantation	199	2.13	2.327	62.604	0.000
Natural forest	80	4.84	3.152		

Table 79. Comparison of various parameters in different teak plantation age groups with natural forests in Tholpetty

Vegetation type	No. of plots	Mean	Std. deviation	F Value	Significance
Number of shrubs					
Teak plantation1971-1980	60	4.43	4.451	13.985	0.000
Teak plantation1961-1970	30	1.70	2.277		
Teak plantation1951-1960	31	1.52	2.096		
Teak plantation 1941-1950	10	13.4	4.222		
Teak plantation 1931-1940	44	2.91	4.136		
Teak plantation 1921-1930	14	1.79	3.355		
Teak plantation 1911-1920	10	6.10	7.279		
Natural forest	80	8.23	7.331		
Litter depth					
Teak plantation 1971-1980	60	1.25	2.055	17.825	0.000
Teak plantation 1961-1970	30	1.17	1.744		
Teak plantation 1951-1960	31	5.03	1.197		
Teak plantation 1941-1950	10	.00	000		
Teak plantation 1931-1940	44	3.45	2.367		
Teak plantation 1921-1930	14	3.50	2.849		
Teak plantation 1911-1920	10	4.20	1.874		
Natural forest	80	3.01	2.053		
Number of logs					
Teak plantation1971-1980	60	0.88	1.027	6.383	0.000
Teak plantation1961-1970	30	0.00	0.000		
Teak plantation1951-1960	31	.39	.844		
Teak plantation 1941-1950	10	0.90	0.876		
Teak plantation 1931-1940	44	0.27	0.499		
Teak plantation 1921-1930	14	0.43	1.089		
Teak plantation 1911-1920	10	0.10	0.316		
Natural forest	80	0.24	0.661		
Number of spiders					
Teak plantation1971-1980	60	0.93	1.071	2.603	0.013
Teak plantation1961-1970	30	0.33	0.606		
Teak plantation1951-1960	31	1.06	0.998		
Teak plantation 1941-1950	10	1.00	0.943		

Table 79. Contd...

Vegetation type	No. of plots	Mean	Std. deviation	F Value	Significance
Teak plantation 1931-1940	44	0.75	0.811		
Teak plantation 1921-1930	14	0.86	0.770		
Teak plantation 1911-1920	10	1.60	1.265		
Natural forest	80	0.90	0.976		
Sambar deer indirect evidences					
Teak plantation1971-1980	60	1.70	2.353		
Teak plantation1961-1970	30	0.23	0.626		
Teak plantation1951-1960	31	2.87	2.349	15.205	0.000
Teak plantation 1941-1950	10	1.40	1.075		
Teak plantation 1931-1940	44	2.84	2.372		
Teak plantation 1921-1930	14	4.07	2.433		
Teak plantation 1911-1920	10	2.90	1.370		
Natural forest	80	4.84	3.152		

Table 80. Comparison of various parameters in natural forests with different age group plantations in Tholpetty Range (Using LSD Test)

Age group of teak plantation	Mean difference between plantation and natural forests				
	No. of shrubs	Litter depth	No. of logs	No. of spiders	Sambar deer indirect evidences
1971-1980	3.79*	1.76*	-0.65*	-0.03	3.14*
1961-1970	6.53*	1.85*	0.24	0.57	4.60*
1951-1960	6.71*	-2.02*	-0.15	-0.16	1.97*
1941-1950	-5.18*	3.01*	0.66*	-0.10	3.44*
1931-1940	5.32*	-0.44	0.04	0.15	2.00*
1921-1930	6.44*	-0.49	0.19	0.04	0.77
1911-1920	2.13	-1.19	0.14	-0.70*	1.94*

There was not much significant difference in the number of soil fauna in teak plantations and natural forests (Tables 81, 82, 83 and 84). This is true in all places.

Table 81. Comparison of soil fauna in plantation with natural forests in southern part of Wayanad WLS

Vegetation type	No. of plots	Mean	Std. deviation	F Value	Significance
Teak plantation	294	4.37	4.147		
Natural forest	138	3.17	2.605	1.601	0.210

Table 82. Comparison of soil fauna in different age group teak plantations and natural forests in southern part

Vegetation type	No. of plots	Mean	Std. deviation	F Value	Significance
Teak plantation1971-1980	84	4.36	6.935		
Teak plantation1961-1970	48	3.75	1.909		
Teak plantation1951-1960	48	3.88	1.885	0.510	0.824
Teak plantation 1941-1950	60	5.40	2.797		
Teak plantation 1931-1940	24	3.50	3.109		
Teak plantation 1921-1930	18	6.00	3.000		
Teak plantation 1911-1920	12	3.00	1.414		
Natural forest	138	3.17	2.605		

Table 83. Comparison of soil fauna in different age group teak plantations and natural forests in Tholpetty

Vegetation type	No. of plots	Mean	Std. deviation	F Value	Significance
Teak plantation1971-1980	36	3.00	1.897	0.493	0.829
Teak plantation1961-1970	18	5.67	8.083		
Teak plantation1951-1960	18	1.00	0.000		
Teak plantation 1941-1950	6	2.00	-		
Teak plantation 1931-1940	30	1.60	1.817		
Teak plantation 1921-1930	12	3.00	1.414		
Teak plantation 1911-1920	12	5.50	2.121		
Natural forest	48	14.50	27.192		

Table 84. Comparison of soil fauna in plantations and natural forests in Tholpetty

Vegetation type	No. of plots	Mean	Std. deviation	F Value	Significance
Teak plantation	132	2.95	3.273	4.054	0.054
Natural forest	48	14.50	27.192		

The richness indices of amphibians in Wayanad is given in Table 85. The richness indices for amphibians in different habitats show that 61-70 year old plantations are rich in amphibians followed by natural forests.

Table 85. Richness indices of amphibians in different age group plantations and natural forests

Vegetation type	R1	R2
Teak plantation 1911-1920	1.674332	1.632993
Teak plantation 1921-1930	1.674332	1.632993
Teak plantation 1931-1940	1.970753	1.527525
Teak plantation 1941-1950	1.761412+38	1
Teak plantation 1951-1960	1.559485	1.386751
Teak plantation 1961-1970	0	0.7071068
Teak plantation 1971-1980	1.609719	1.443376
Natural forests	1.803369	1.5

Diversity indices of amphibians in Wayanad are presented in Table 86. The diversity values indicate that both plantations and natural forests are equally diverse. The study also indicate high percentage of litter depth and shrub cover in these areas.

Table 86. Diversity indices of amphibians in different age group plantations and natural forests

Vegetation type	Lamda	H'
Teak plantation 1911-1920	0.133	1.329661
Teak plantation 1921-1930	0.2	1.242454
Teak plantation 1931-1940	0.1809524	1.682616
Teak plantation 1941-1950	1.7E	0
Teak plantation 1951-1960	0.1923077	1.479133
Teak plantation 1961-1970	1	0
Teak plantation 1971-1980	0.2424243	1.35221
Natural forests	0.1916667	1.580819

The amphibian distribution in Wayanad was even (Table 87). However, dominance of certain species was observed in plantations where as in all other habitats the amphibians were more or less equally distributed.

Table 87. Evenness indices of amphibians in different age group plantations and natural forests

Vegetation type	E1	E2	E3	E4	E5
Teak plantation 1911-1920	0.9591479	0.9449408	0.9265878	1.984251	2.33829
Teak plantation1921-1930	0.8962407	0.768516	0.7299354	1.02727	1.033497
Teak plantation1931-1940	0.4646936	0.768516	0.7299354	1.02727	1.033497
Teak plantation 1941-1950	1.70E+38	1	1.70E+38	1.70E+38	-1.70E+38
Teak plantation 1951-1960	0.9190369	0.8778275	0.8472844	1.184743	1.239253
Teak plantation 1961-1970	1.70E+38	1	1.70E+38	1	1.70E+38
Teak plantation 1971-1980	0.8401751	0.7731916	0.7164895	1.067006	1.090386
Natural forests	0.8822716	0.8098219	0.7717862	1.073774	1.092891

Discussion

The herbivores in Wayanad had shown seasonal difference in the utilization of habitats (Easa, 1999). However, the study had also indicated the preference of observed herbivores for natural forests. Chital showed a preference for natural forests with the highest density of evidences in dry deciduous and moist deciduous forests and the plantations being the lowest. This was true of gaur and sambar deer to a large extent with minor seasonal variations. The distribution of elephants clearly followed a seasonal pattern.

In the present study, the directionality with respect to parameters was not consistent across the study areas as evident from the summary of the results in Table 88. Moreover, the lack of information on the logging and other works carried out in different plantations make it all the more difficult to conclude whether the observed variations are due to such activities. The observations and the results from earlier studies indicate that the plantations in both the areas could be protected from fire and other interventions to bring it to the state of natural forests in due course.

Table 88. Summary of comparison of natural forest with plantations

Parameters	Locations		
	Wayanad	Tholpetty	Parambikulam
Elephant dung density	NF > Plant.		NF > Plant
Gaur dung density	NF > Plant		NF > Plant.
Mean No. of shrubs	Plant. > NF	NF > Plant.	NF > Plant.
Mean Litter depth	Plant. > NF	NF = Plant.	NF = Plant.
Mean No. of logs	Plant > NF	Plant > NF	NF > Plant.
Mean No. of spiders	NF > Plant.	NF = Plant.	Plant > NF
Mean indirect evidences of sambar	NF > Plant.	NF > Plant.	NF = Plant.
Mean soil fauna	Plant. > NF	NF > Plant.	NF = Plant.

NF-Natural forests, Plant -Teak plantations

6.2.3. Regeneration status of indigenous tree species in plantations subjected to treatment for conversion into natural forests

In Wayanad Sanctuary the *Eucalyptus* plantations raised in the past were clear-felled and planted with seedlings of indigenous species. The clear-felled *Eucalyptus* plantations in Tholpetty Range the were raised during 1971, 1972 and 1974 and in Muthanga Range raised during 1973 to 1983. The treatment areas were fenced except an area of 4 hectare in the Tholpetty Range. While weeding was carried before planting, natural growth of species like *Dalbergia latifolia, Cassia fistula,* etc. were retained.

In order to assess the survival of the planted seedlings, regeneration status of indigenous trees and weed growth in the treatment areas, sample plots of 20 m x 20 m were laid out and enumerated the planted as well as regenerated species. The height measurements of seedlings were taken.

The details of treatment area like locality, extent, year of planting, species planted, sample plots laid out, etc. are provided below.

Tholpetty Range

Total converted area	120 ha
Fenced area	116 ha
Non-fenced area	4 ha
Converted Plantations	*Eucalyptus* ,1971,1972,1974,
Year of planting	1999
No. of plots taken in fenced area	5
No. of plots taken in non-fenced area	3
No. of seedlings planted /ha	2500
Species planted *Acrocarpus fraxinifolius, Albizia odoratissima, Bauhinia malabarica, Careya arborea, Cassia fistula, Dalbergia latifolia, Grewia tiliifolia, Kydia calycina, Lagerstroemia microcarpa, Mangifera indica, Miliusa tomentosa, Olea dioica, Persea macrantha, Phyllanthus emblica Pongamia pinnata, Pterocarpus marsupium, Schleichera oleosa, Stereospermum chelonoides, Syzygium cumini, Tamarindus indica, Terminalia bellirica, Terminalia crenulata Terminalia paniculata, Bambusa bambos*	

Muthanga Range

Total converted area	600.65
Fenced area	600.65
Converted Plantations	*Eucalyptus* ,1973,74,75,80,81,82,83
Year of planting	1999
No. of plots taken in fenced area	7
Species planted *Acrocarpus fraxinifolius, Albizia odoratissima, Tamarindus indica, Mangifera indica, Cassia fistula, Dalbergia latifolia, Grewia tiliifolia, Lagerstroemia microcarpa, Mangifera indica, Pongamia pinnata, Persea macrantha, Phyllanthus emblica, Pterocarpus marsupium, Schleichera oleosa, Syzygium cumini, Terminalia bellirica, Terminalia crenulata, Terminalia paniculata, Bambusa bambos.*	

In the Tholpetty Range, the enumeration was carried out in December 2001. The survival percentage of seedlings is 52 in the fenced areas and 33 in the non-fenced areas. The average height of seedlings is 80 cm. The major weeds are *Lantana* and *Eupatorium*. These weeds are profusely growing and smothering the seedlings.

In Muthanga Range, the enumeration was carried out in December 2001. The percentage of survival of seedlings varies from 55 to 65. The average height of seedlings is 85 cm. The major weeds are *Imperata cylindric, Lantana camara* and *Eupatorium odoratum. Imperata cylindrica* is profusely growing and smothering the seedlings.

Among the 24 species selected for planting in treatment area, except *Tamarindus indica* and *Acrocarpus fraxinifolius*, all the species are naturally growing in the sanctuary. Some species have established well and attained tree size in the teak plantations through natural regeneration. Others were in the seedling stage.

In the treatment areas *Dalbergia latifolia, Cassia fistula, Grewia tiliifolia, Albizia odoratissima, Bambusa bambos, Pongamia pinnata, Phyllanthus emblica, Terminalia crenulata,* etc. are the dominant trees regenerating. The list of naturally regenerated species enumerated from the sample plots in the treatment areas is provided based on the order of dominance (Table 89).

Table 89. Regeneration of indigenous species in treatment areas
No of plots taken-15; Plot size: 20 m x 20 m

Species	No
Dalbergia latifolia	42
Cassia fistula	35
Grewia tiliifolia	25
Albizia odoratissima	22
Bambusa bambos	21
Pongamia pinnata	19
Phyllanthus emblica	16
Terminalia crenulata	14
Kydia calycina	13
Olea dioica	11
Persea macrantha	10
Schleichera oleosa	9
Aporusa lindleyana	9
Lagerstroemia microcarpa	8
Pterocarpus marsupium	8
Terminalia bellirica	7
Tectona grandis	7
Bauhinia malabarica	7
Terminalia paniculata	6
Stereospermum colais	4
Miliusa tomentosa	3

6.2.4. Conclusions

The regeneration status of indigenous trees in the plantations shows a trend more or less similar to that in Parambikulam Sanctuary. The status of established seedlings/saplings are very low in the older plantations and natural forests. Though the average number of seedlings is 5974 per hectare in the age class 1905-1924, 97 per cent of the seedlings are below one metre height indicating heavy mortality of the young seedlings every year. In the plantations of the age class 1965-1984, however 48 per cent of seedlings are above one metre height. On an average only 7-8 per cent of seedlings overcome the adverse conditions in the plantations. The dominance of *Catunaregam torulosa* and *Croton roxburghii* among the established seedlings also indicate fire incidence in the plantations. Eight species growing in the natural forests were not observed in the plantations.

Eupatorium odoratum and *Lantana camara* are the major weeds in the plantations as well as natural forests. On an average more than 30 per cent of weed coverage is by *Eupatorium odoratum* in all age classes of plantations and 15-20 per cent by *Lantana camara.* In the plantations subjected to treatment for converting to natural forests in Muthanga Range, *Imperata cylindrica* and *Lantana camara* are affecting the growth of planted seedlings. In Tholpetty Range *Lantana and Eupatorium* are the major weeds. The profuse growth of *Imperata* in the treatment areas is due to the high sunlight intensity. Once the seedlings grow and canopy develops, the growth of *Imperata* subsides. Therefore, introduction of shade crops will be more appropriate to control growth of *Imperata.* Weeding around the planted seedlings may also be carried out.

For promoting succession of indigenous species enrich planting may be taken up in older plantations (1905-1924) considering the poor regeneration status and low animal utilisation. Emphasis may be given to species which are found in the neighbouring forests and also species beneficial to animals (Easa, 1999). The number of seedlings per hectare may be between 250-500 depending on the gaps in the plantations. The excess growth of *Catunaregam torulosa* and *Croton roxburghii* may be weeded out. Standard planting method may be followed as suggested for the Parambikulam Wildlife Sanctuary. The number of teaks in the plantations need not be reduced considering the likely damages due to felling, logging and transportation. Strict fire control measures may be ensured.

The animal studies indicate that natural forests are the most preferred habitats in the Sanctuary. However, the density of elephants and gaur was more or less similar to that in natural forests in the 61-70 year old plantation. The richness and density of amphibians in the natural forests and 61-70 year old plantation were more less the same. There was no significant difference in the soil fauna in the teak plantations and natural forests. Therefore, for maximising biological diversity enrichment planting in the older plantations will be appropriate.

7. WEED MANAGEMENT

Exotic weeds are recognized as the second largest threat to biodiversity (Singh, 2001). *Lantana camara* (Verbenaceae) and *Eupatorium odoratum* (Compositae), native of tropical America, are the most menacing weeds in the teak plantations and deciduous forests. *Lantana camara* is more prevalent in the drier areas and *Eupatorium* in moist localities. Considering the adverse impact on the biodiversity, affecting productivity of plantation, reducing food plants for wildlife, fire hazard, etc. attempts were made to eradicate these weeds from pasture lands and plantations since their establishment during the early 1930s in Asian countries. For management of weeds, mechanical weeding, use of chemical weedicides, and biological control methods were adopted from time to time. Effective application of chemical weedicides and biocontrol agents in a forest ecosystem is neither feasible nor economical (Singh, 2001). Attempts to control *Lantana camara* through the introduction of insect biocontrol agents have been unsuccessful (Julian and Griffith, 1998). But, biocontrol of *Eupatorium odoratum* has been effective in small Islands (Muniappan *et al.*, 1988). Efforts are continuing to control *Eupatorium* with a variety of insects from Neotropics in Papua New Guinea and Indonesia (McFadyen, 1998).

In the Parambikulam Sanctuary the major weed is *Eupatorium odoratum*. Frequency of *Lantana camara,* though present in the plantations and natural forests, is less when compared with that of *Eupatorium*. In the teak plantations of the age class 1916-1935, *Eupatorium* forms 51.32 per cent and *Lantana* 1.06 per cent among the shrubs. In the age class 1936-1955, *Eupatorium* forms 53.24 per cent and *Lantana* 6.08 per cent. In the age class 1956-1975, *Eupatorium* forms 67. 70 per cent and *Lantana* 25 per cent among the shrubs.

In Wayanad Wildlife Sanctuary, plantations and natural forests are invaded by *Eupatorium odoratum* and *Lantana camara*. In teak plantations of different age classes, *Eupatorium* constitutes 34.91 per cent and *Lantana camara* 23.72 per cent of shrubby undergrowth in the age class 1905-1924. Together there form 58.63 per cent of the shrubs. In the age class 1925-1944, *Eupatorium* forms 33.5 per cent and *Lantana* 16.71 per cent and in the age class 1945-1964, *Eupatorium* forms 53.4 per cent and *Lantana* 18.24 per cent (total 71.64%). In the younger plantations (age class 1965-1984) *Eupatorium* forms 33.27 per cent and *Lantana* 10.65 per cent among the shrubs. Thus teak plantations of the age class 1945-64 are heavily infested by these weeds. Both *Eupatorium* and *Lantana* prefer more sunlight; opening of canopy promotes the growth of these species.

In the natural forests adjoining teak plantations also *Eupatorium* and *Lantana* have established; the former forms 18.71 per cent and the latter 12.82 per

cent among the shrubs. When compared with the plantations their frequency is low.

In the areas undergoing treatments in the Wayanad Sanctuary also there is profuse growth of weeds. In Tholpetty Range, *Eupatorium* is dominating while in Muthanga *Imperata cylindrica* has established well and is covering the planted seedlings. Tender leaves of *Imperata* are eaten by herbivores.

Considering the control measures available, biocontrol appears to be promising but introduction of biocontrol agents in Wildlife Sanctuaries cannot be recommended before carrying out trials and assessing possible impacts on indigenous flora. Weeds need to be controlled for promoting growth of indigenous species. Eradication of *Imperata* is rather difficult due to its habit, having subterranean perennial rhizomatous rootstock. The species is capable of withstanding annual fire. In the areas planted with seedlings, the profuse growth of *Imperata* is due to the high sunlight. Once the seedlings grow and canopy develops, the growth of *Imperata* subsides. *Imperata,* though present in the neighbouring natural forests, is not growing profusely due to tree cover. Weeding in the areas undergoing treatments is essential during the initial years. Weeding by cutting/uprooting may be carried out wherever these weeds are smothering seedlings of indigenous species.

Introduction of shade crops for suppressing the growth of weeds as well as use of non-residual weedicides are other options for controlling weeds. Trials are needed for selection of suitable shade crops and standardising the application of weedicides.

8. GENERAL CONCLUSIONS AND SUGGESTIONS FOR PROMOTING SUCCESSION OF INDIGENOUS SPECIES IN THE TEAK PLANTATIONS

Moist deciduous forest is the major vegetation type in Wayanad as well as Parambikulam Wildlife Sanctuaries. Teak is the seventh dominant species among the 38 species in the natural forests of Wayanad Wildlife Sanctuary with 19 trees per hectare. In the moist deciduous forests of Parambikulam, teak is the fifth dominant species (11 trees per hectare) among the 28 trees; 49th species (4 trees per hectare) among the 67 trees in semi-evergreen forests. Thus teak is a major component of the trees in the moist deciduous forests in both the Sanctuaries.

The analysis of the composition of trees in teak plantations shows that almost all tree species in the natural forests adjoining teak plantations are regenerating and some have attained the status of trees. In Parambikulam, the number of teak trees/ha is 65 and miscellaneous trees (16 species) 170/ha in the 1916-1935 plantations; in the 1936-1955 plantations teak 112/ha and miscellaneous trees (14 species) 131/ha; in the 1956-1975 plantations teak 258/ha and miscellaneous trees (43 species) 216/ha (near moist deciduous forests) and teak 225/ha and miscellaneous trees (50 species) 368/ha (near semi-evergreen forests).

In Wayanad, the average number of teak trees is 90/ha and miscellaneous trees (19 species) is 172/ha in the 1905-1924 plantations; in the age class 1925-1944, teak 169/ha and miscellaneous trees (21) 176/ha; in the age class 1945-1964, teak 248/ha and miscellaneous (28 species) trees 196/ha. Thus natural regeneration is progressing in the teak plantations. The number of seedlings/ha in teak plantations varies from 1700 to 8600. However, most of the seedlings were below 1 m indicating heavy mortality among the newly recruited seedlings, the major reason being fire. Grazing also causes damage to the seedlings.

Though quite a few indigenous species have established in the plantations, their total basal area is very low when compared to the total basal area of teak trees. In natural forests the basal area of teak is 17.8 per cent (moist deciduous forests) and 1.8 per cent (semi-evergreen forests) in Parambikulam and in Wayanad 16 per cent (moist deciduous forests) of the total basal area of all the trees. This shows that the plantations with poor regeneration can be selected for enrichment planting with indigenous species to attain the species composition similar to the neighbouring natural forests.

Lantana camara and *Eupatorium odoratum* have already infested the plantations. Their percentage varies from 50 to 71 among shrubs in the plantations of different age classes. In the treatment areas also, there is heavy infestation of *Lantana* and *Eupatorium*. In Muthanga Range the most menacing species hampering the growth of seedling is *Imperata cylindrica*.

Introduction of shade crops and application of non-residual weedicides (non toxic to animals) can be tried for controlling weed growth. Amphibians and spiders were found to be abundant in the plantations with good shrub growth. Further, new leaves of *Imperata* is a good fodder for herbivores.

The observations in Wayanad and Parambikulam on the fauna do not follow any particular pattern and trend. The plantations in general have a better value in terms of mean number of shrubs, litter depth, number of logs and soil fauna in southern part of Wayanad compared to higher value for natural forests for most of the parameters in Parambikulam. The variables/parameters taken for comparison could be influenced by several environmental factors in addition to number of shrubs, litter depth and logs. Further, the observed results could also be due to the management practices followed till date along with the various environmental factors such as fire. Unfortunately, there is no proper record available to interpret the present observations in relation to the frequency of fire and silvicultural operations.

The locations of plantations in both these areas also pose problems while attempting for management prescriptions. The plantations in both these areas are adjacent to natural forests and more often with marshy areas in between. The richness/diversity/abundance of most of the animal species including the larger animals in plantations and natural forests need not follow a similar pattern because of the obvious reasons of the habitat/micro habitat requirements and preferences. Since the differences in the observed parameters do not follow a pattern or trend, it is suggested that the plantations shall be maintained and protected from fire and other degradation factors (Plates 1, 2 and 3) to maximize biological diversity.

During the study period, no planting work or weed control trials were carried out. Only after generating essential baseline data and analysis of factors like regeneration pattern and status of indigenous species in the plantations of different age classes, structure and composition of trees in the neighbouring natural forests, the species for enrichment planting can be selected. Utilisation of the plantations by various animals is also to be assessed. The animal study suggests that the plantations shall be maintained and protected from fire and other degradation factors to maximise biological diversity. However, for promoting succession of indigenous species in the plantations all the required baseline data have been generated and analysed during the study period. Considering the factors such as extent of area under plantations, their long history, regeneration status of indigenous species, utilisation pattern by different animals, etc., it is suggested that plantations with poor regeneration and less shrubs may be selected for promoting succession of indigenous species. Weed control may be restricted to areas undergoing treatment for conversion to natural forests.

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