CHAPTER VI

· DISCUSSION

DISTRIBUTION OF SACRED GROVES IN KERALA

This study which surveyed the whole of Kerala revealed that the sacred groves are rather small, with 397 (52.17%) of them less than 200 m² in size. Only 364 groves larger than 200 m² were enumerated. Among those enumerated, 79% are small (0.02 to 0.5 ha). Only 11 (3.02%) groves exceed 0.5 ha. Only two of these sacred groves enjoy the legal status as Reserved Forests. They are Pakshipathalam (Wayanad district) and Poonkavanam (Pathanamthitta district). This situation is drastically different from the records of Veluppillai (1940) for Travancore and Logan (1887) for Malabar from where, it can be estimated that a minimum of 30,000 groves existed in Kerala in the beginning of the 19th Century. The number of groves recorded in this study is 761 (2.5% of the previous record), pointing to an enormous loss. When groves >200 m² are considered, they constitute only 1.2% of the past records.

More than 79% of the sacred groves show that they are rather small and the loss of a minimum area for the regeneration and survival of the species in them would be questionable in future. Effects of habitat isolation, fragmentation, loss of corridors and the persistent disturbances in the regeneration of the species are known to lead to decreased species viability and richness (Lovejoy et al. 1986). So, left to themselves in isolated conditions, a natural degradation is expected to set in them due to loss of endemic species as well as other climax species and also by the invasion of drier elements.

FLORA OF SACRED GROVES

Floristic analysis reveals that the sacred groves are rather rich in their species composition. Analysis of the flora of a region is normally expressed by tabulating the ten largest families in the order of the number of species encountered and comparing it with those of the adjacent regions, or of the country as a whole (Good, 1953). The family Fabaceae has a wider geographical distribution and ranks first (Table-3) in all the three areas (Cannanore, Calicut districts and study area). Flora of Madras Presidency (Gamble, 1915-35) also mentions Fabaceae as the dominant family. In the two district (Cannanore and Calicut) floras, Poaceae has the
second position, because, all the open areas in the districts are also included in them, whereas only patches covered with vegetation have been included in this study. Hence, Poaceae has been reduced to the fifth position. Rubiaceae and Euphorbiaceae are almost in similar positions in all the three. Unlike in the two district floras, Moraceae is dominant (sixth position) in the study area, mainly because of the genus *Ficus* which is common in groves. As Gadgil et al. (1996) had mentioned, *Ficus* is the most revered tree of the orient and no species of *Ficus* is traditionally felled in many parts of India.

Sacred groves are almost distributed along the entire length of the state and can be classified as Coastal evergreens, Lowland evergreens, *Myristica* swamps, Disturbed evergreens and Deciduous forests. On account of larger ecological diversity, a heterogeneous flora is conserved in them. Probably sacred groves represent the characteristic vegetation of the area. As such, they are the last surviving patches of a large network of potential vegetation of the country. Loss of these remnant patches would lead to a complete loss of characteristic vegetation in the area due to the demands of agriculture and other land-use patterns.

A flora for Kerala state has not been published yet, but regional floras are available (Manilal and Sivarajan, 1982; Subramanian et al. 1987; Manilal, 1988; Ramachandran and Nair, 1988; Mohanan and Henry, 1994; Philip and Sivarajan, 1996; Sasidaran and Sivarajan, 1996; Subramanian 1996), although they have never been synthesized into a comprehensive work for the entire state. A detailed flora for the state is lacking and the floristic inventory developed here is more detailed in ecology and could form a basis for further work on the flora of Kerala, with emphasis on local and regional variations across the State.

**TYPOLOGY OF GROVES**

Based on the classification of Champion (1936), Chandrasekharan (1962a, b and c) has grouped the forests of Kerala into Tropical Wet Evergreen, Tropical Moist Deciduous, Tropical Dry Deciduous, Montane Sub-tropical and Montane Temperate forests with Climax, Secondary and Edaphic types within each of them. But this is a broad classification and as far as the low lands are concerned, there are only two types such as Low Level Evergreen Forest and *Myristica* swamp Forest. These forests were mentioned to be spread over the entire length of the state. But such a classification does not reflect the great diversity within these types. Of late, Pascal(1982) and Ramesh et al. (1996) have prepared the vegetation maps for Kerala. Though the system used in these maps marks an improvement over the existing classifications, it is on a broader scale covering vast areas of
forests and does not reflect local variations on smaller scales so as to be of use for the survey of sacred groves. Hence, a new classification based on the association of trees has been developed using correspondence analysis, wherein identical groves are clustered. The clustering of the groves based on their floristic diversity revealed 21 associations, which are further included in different groups. Among them, Evergreen group constitutes 67% (14/21), Disturbed Evergreen 24% (5/21) and Deciduous group accounts for 10% (2/21). In each of these associations, a mean of 23.1 (+28.52, range 1-90) groves were seen in evergreen forests, 17.4 (+23.9, range 5-60) in disturbed evergreen and 6 (+0) in deciduous forest groups.

The evergreen group could further be classified into Lowland Evergreens, Coastal and Myristica swamps. Lowland Evergreen forests were found in 57% of the associations classified as Evergreen. Coastal and Myristica swamps accounted for the other 43%. Myristica swamps and coastal evergreen types are rather rare habitats and their continued preservation in the sacred groves is an important aspect that planners and conservationists should take into account when planning for protected areas.

The Disturbed Evergreen group accounts for 24% of the total associations. They mainly represent disturbed and open evergreen type of vegetation relatively drier than the Lowland Evergreen. Only two associations are deciduous. 21 associations derived in the present study reflect local variations due to edaphic conditions, disturbances, anthropic pressures, etc.

Coastal group consists of three associations. The first one, *Vatica chinensis - Holigarna arnottiana - Hydnocarpus pentandra* association, is limited to Calicut district only. Characteristic species *Vatica chinensis* is naturally found only along the coastal belt in North Kerala. This species is not reported from any Reserved Forest. The other two species have a wider distribution. Since this type is limited to nine groves, they are of high value in conservation. The second in this group is *Calophyllum inophyllum - Samadera indica - Garcinia gummi-gutta* association, extending from Trivandrum to Malappuram District along the coastal belt. Of these *Calophyllum inophyllum* and *Samadera indica* are mainly found in coastal areas. Formerly this type of vegetation was common in the lowlands of Kerala, but now it is restricted to 44 sacred groves. The third association in this group is an endangered type in Kerala. *Memecylon malabaricum- Memecylon umbellatum- Syzygium zeylanicum* association. This is present only in one grove - Chamakkavu - in Cannanore district (grove No. 268). Though characteristic species are present individually in different groves, this association is unique. Formerly this grove was 5 ha in area but since the importance of this type was not known to temple authorities, 2 ha were cleared for making football ground for a nearby high school (Plate-13).
Balance area deserves special protection. Thus all the associations in this group are of great ecological significance and should be given priority in conservation.

Another group is Lowland Evergreens. Eight different associations had been identified in this group. Of these, Clusters 6 and 7 are relatively drier than the other clusters, marked by the presence of *Aporusa lindleyana*, *Atalantia monophylla* and *Garcinia pictorius*. This is due to local dry conditions. Cluster 7 is found only in North Kerala. Lengthy dry season in North Kerala may be the reason for this. It appears that dryness has brought about dominance of different heliophytes in different sites. Under conditions of water stress, strong selection and hierarchy are taking place between the species. Except for the *Poeciloneuron indicum* facies, other associations in this group have only minor variations among them. Characteristic species in different associations are denoted by their names.

Three associations have been identified in *Myristica* swamp group. Of these, *Gymnacranthera farquhariana* - *Lophopetalum wightianum* - *Polyalthia fragrans* association is highly endemic to Pathanamthitta district. This association is found only in seven groves in this district. In North Kerala *Myristica malabarica* replaces *Gymnacranthera farquhariana*, which is present only in nine groves in Cannanore and Kasargod districts. Thus, *Myristica malabarica* is a geographic vicariant of *Gymnacranthera farquhariana*.

As far as the disturbed evergreen group is concerned, variations in the community are mainly brought about by man. The vegetation in disturbed evergreen and deciduous groups do not deserve any special mention from conservation point of view because, they are similar to the reserved forests and do not harbour any rare species. These groves provide ample scope for further protection in order to increase the endemic elements.

When compared, to the vegetation map of Ramesh *et al* (1996), the major low elevation evergreen forest type is *Dipterocarpus indicus*-*Kingiodendron pinnatum-*Strombosia ceylanica. The others encountered include *Hopea racophloea-Humboldtia brunonis* facies of the above type. Besides, some facies also have *Myristica* swamps. Co-occurrence of *Dipterocarpus indicus*- *Dipterocarpus bourdillonii* in the low elevation evergreen forests has not been recorded in the sacred groves. Thus, although certain small pockets of highly mosaic vegetation have been protected, major types fail to be represented. Therefore, it is ideal to have representations of the floristic types with each of its local variations, while aiming at representative conservation. Further, absence of sacred groves at high and medium elevations is a cause for concern.

The species that survive in the isolated patches of sacred groves are heliophilous and secondary species. Species that are highly sensitive to
perturbations are absent. Species like *Dipterocarpus indicus*, *Kingiodendron pinnatum*, *Humboldtia brunonis* that are characteristic of the low elevation evergreen forest of other parts of Western Ghats (Pascal, 1988) are absent or poorly represented here. An important difference between the present typology and the map referred to is the disappearance of more sensitive species. Low elevation evergreen forest type described in the above study had been replaced by 21 different associations. Floristic variations reflect that after the rapid disappearance of a sensitive species, they are replaced by different species depending upon the microclimate in each locality, availability of parent material, human interference, etc. The study on sacred groves thus provides a base for further studies and better understanding of the vegetation of Kerala.

**BIOLOGICAL SPECTRUM**

Biological spectra for Lowland Evergreen and *Myristica* swamp show Mesophanerophytic - Therophytic - Liana complexes (Fig 24 and 25). Compared to other groups, disturbance is less in these two groups and hence Mesophanerophytes are more. Maximum (34.06%) Therophytes are present in Coastal group. Biological spectra of Coastal, Disturbed Evergreen and Deciduous groups show Therophytic - Mesophanerophytic - Liana complexes. From these, it is inferred that disturbance and dryness is not favoured by most of the Mesophanerophytes, but it will attract more Therophytes *Myristica* swamp which has excessive soil moisture and minimum disturbances has the lowest percentage (21.70%) of Therophytes and highest percentage (40.57%) of Mesophanerophytes. So, with the increase in dryness and disturbance, there is an increase in Therophytes and a corresponding decrease in Mesophanerophytes. This ratio of Therophytes and Mesophanerophytes could be used as an index to compare the disturbance and dryness of different sites.

**PHYTOGEOGRAPHY**

A total of 154 (21.6%) species endemic to Western Ghats has been recorded, of which 52 (33.3 %) are trees. The endemics are represented in over 50 families and 94 genera. The following families have the largest number of endemics: Rubiaceae, Acanthaceae, Fabaceae, Lauraceae, Clusiaceae, Euphorbiaceae and Melastomataceae. This does not totally agree with the study of Ahamedullah and Nayar (1986), who mentioned Rubiaceae, Acanthaceae, Balsaminaceae, Asclepiadaceae, Lamiaceae, Poaceae and Orchidaceae as the families rich in endemism in Peninsular India. Blasco (1971) had reported that for the erstwhile
Madras Presidency 36% of the species are endemic to Peninsular India. His figures give Rubiaceae, Acanthaceae, Fabaceae, Balsaminaceae, Asteraceae, Lamiaceae, and Asclepiadaceae as dominant families among endemics. In all the three studies, Rubiaceae and Acanthaceae are dominant. However, estimates of endemism for the state of Kerala are yet to be compiled and the results of the study cannot be compared.

Analysis of endemic species in different associations conveys the detrimental effect of disturbances and deciduousness on them. Endemism is high in Myristica swamps (21%) followed by Lowland Evergreen (20%). Disturbed Evergreen(11%) and Deciduous groups(10%) support minimum endemics. Reduction of endemic elements ranging from Myristica swamp to Deciduous group clearly shows that the number of endemic plants decreases with disturbance.

Phytogeographic elements show a predominance of Asiatic elements (227), with 113 species common to the study area and Sri Lanka. In all the vegetation groups, Asiatic elements are more than 28%. In their study on the Wet Evergreen forests of Silent Valley National Park (at 11°03' to 11°13' N Latitude) in Kerala, Basha et al. (1992) separated 80.6% Indigenous elements and 19.4% Pluri-regional elements. The present study recorded >30% of Pluri-regional elements in Coastal, Disturbed evergreen and Deciduous groups. Myristica swamp has the lowest percentage of Pluri-regional elements (20.6%) and is closer to that in the Silent Valley Evergreen Forest which is receiving maximum protection as a National Park. Thus, when there is a reduction of endemics with disturbance and deciduousness, there is an increase in Pluri-regional elements. Myristica swamps due to their special edaphic conditions, do not permit room for many pluri-regional elements. As this is a rare type of forest it should be given priority in conservation.

Based on the presence of different species in the groves, their distribution pattern was evaluated. Among the endemics, species like Holigarna arnottiana Artocarpus hirsutus, Hydnocarpus pentandra, Vateria indica, Gnetum ula, Cinnamomum malabatrum, Memecylon malabaricum, Ixora brachiata, Artocarpus heterophyllus etc., are widely distributed throughout Kerala. Their presence in different types of vegetation reflects their wide adaptability. There are a few species that are highly sensitive to ecological perturbations and their distribution had been narrowed down. Figs 12 and 15 show that Blepharistemma membranifolia and Gymnacranthera farquhariana are found within a wide range of distribution from 8° to 13° N Latitude but, their presence is now restricted only to a few localities. This implies that earlier, they had a wider distribution at least within the above range, but due to changing environmental conditions, they are now restricted to certain localities. They can be considered as 'anthropogenic endemics'. Buchanania
Lanceolata has a very narrow range of distribution from 8°44' to 9°12' N Latitude (Fig 13). Now its distribution is mostly limited within certain sacred groves of Kerala. Outside sacred groves it had been reported only by Mohanan (1986) from two localities in Quilon District. Casearia wynaadensis is found distributed from 10°21' to 11°59' (Fig 14). Although there are earlier reports of its presence in the Anamalai hills in Coimbatore district of Tamil Nadu there are no recent collections. Distribution of this species is now confined to Wyanad plateau. Although Syzygium travancoricum is distributed (Fig 16) within a wide range from 9°9' to 11°48'N Latitude, it has now been confined to five localities, of which four pertain to sacred groves. Only other locality is Mananthavady (Kerala Forest Research Institute Herbarium No. 4923). So, it could be inferred that the above five species are rare and detailed explorations in the probable habitats within the aforementioned range is necessary for precise assessment of their present status. Special conservation steps have to be taken to protect them. The groves which support these species should be declared as 'Hot Spots' for conservation and sites for "Biodiversity Conservation Prioritisation Programme".

Another endemic species, Pterospermum reticulatum reported as 'Threatened' by Nair and Mohanan (1981) is found in eighteen groves. Cleome burmannii, a species reported as 'Threatened' in the Red Data Book (Nayar and Sastry, 1987-1990) is found in five groves. The climber Kunstleria keralensis found in seven groves is not reported from any other area. Groves which support the above species are also to be declared as 'Hot Spots'. The fact that these rare species are preserved in sacred groves highlights their role in conservation.

Among the common species, 15 are found distributed in more than 100 sacred groves. This accounts for only 2.08% of the total species enumerated, indicating a great deal of diversity in the groves encountered.

**ECONOMIC IMPORTANCE**

Economic importance of different species indicated in Appendix - II, highlights the fact that sacred groves contain many plants of economic importance. With 419 medicinal plants, 163 timber species and 279 plants yielding minor forest produces (other than medicinal) sacred groves play an important role in conserving economically important plants. Appendix - III shows that 63 species are wild relatives of cultivars. As Arora and Nair (1964) had pointed out, heritable genetic wealth of economic plant species, crop plants and their wild relatives are under constant threat of severe genetic erosion due to indiscriminate habitat destruction. Since sacred groves support representative samples of relict vegetation in different localities, local varieties, strains or land race of such species can be present in them
and a detailed taxonomic study on them is warranting. Sacred groves provide ample material for further genetic experiments in Agricultural research.

Presence of such species in different groups are almost identical (Fig 29). More than 50% of the plants in all the groups is medicinal, >18% is of timber value and >32% is yielding non-wood forest produces. Thus, there is no significant difference between the groups as far as economic importance is concerned because, classification of groups had been done on ecological basis and the economic importance is not based on any ecological principles. A species is of economic importance, when man has found out its use or when man is in need for it. Still there are many species the uses of which are presently not known and economic importance of a species is just a chance.

**PHYTOSOCIOLOGICAL STUDIES**

**COMPARISONS WITH OTHER STUDIES**

Data concerning floristic richness are limited and is difficult to make comparisons among them, since the area as well as the girth limits selected for recording the trees vary. Ashton (1964) has given the species - area curve for six forests in Brunei (G >30 cm). Number of species varied from 50 (Amazon) to 227 (Malaya) per hectare. Paljmans (1970) had recorded 110 to 145 species from Papua New Guinea (over 0.8 ha and GBH > 130 cm). Halle et al (1967) had recorded 123 trees and shrubs (height >3m) in the forests of Belinga in Gabon. 244 species over 30 cm GBH were identified by Murça Pires et al.. (1953) over 5 ha in Amazon forests. Jones (1955) enumerated 170 tree species over 10 cm DBH from 18 ha area in Nigeria, and Cousens (1951) listed 183 species over 10 cm DBH from 24 ha in Malaysia. A total of 364 trees belonging to 63 species were enumerated by Oteng (1995) in Ghana from an area of 0.625 ha.

Before each plot is discussed, similar studies shall be considered to compare the information on the structure of the forests around Western Ghats. In the Wet Evergreen Forests of Western Ghats of Kerala (Silent Valley, Muthikkulam and Nelliampathy; 900 m elevation) 33 species (>10 cm gbh) from 2500 m² plots were recorded (Basha, 1987). Number of trees (per hectare) varied from 1168 (Muthikkulam) to 1532 (Silent Valley), with 1340 trees per hectare in Nelliampathy. The Simpson's Index was 0.87 (Nelliampathy), 0.93 (Muthikkulam) to 0.94 (Silent valley).

From low elevation evergreen forests of Western Ghats of Karnataka, Pascal (1988) has recorded 22 to 35 species (>10 cm gbh) from 1600 m² plots at different locations. Number of trees/ha varied from 1314 in New Someswara to 2926 in
Kadamakal. Basal area/ha ranged from 64.9 to 69.96 m² and biomass per hectare varied from 2294.9 m³ to 3085.5 m³. Values obtained for Simpson's index was from 0.86 to 0.90 and Shannon-Wiener's index from 3.6 to 4.3.

**TABLE 48: SUMMARY OF DATA FROM PHYTOSOCIOLOGICAL STUDIES IN WESTERN GHATS.**

<table>
<thead>
<tr>
<th>State</th>
<th>Location</th>
<th>Ht. of stand m</th>
<th>Basal area m²/ha</th>
<th>Biomass m³/ha</th>
<th>Reference</th>
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<td></td>
<td>Muthikkulam</td>
<td>40</td>
<td>do</td>
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<td></td>
<td>Nelliampathy</td>
<td>39</td>
<td>do</td>
<td></td>
<td>Basha, 1987</td>
</tr>
<tr>
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<td>64.9</td>
<td>2313.3</td>
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<td></td>
<td>Naravi</td>
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<td>70.07</td>
<td>2295.0</td>
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<td>New Someswara</td>
<td>37</td>
<td>67.67</td>
<td>3085.5</td>
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<tr>
<td></td>
<td>Magod</td>
<td>35</td>
<td>67.70</td>
<td>2572.7</td>
<td>Pascal, 1988</td>
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<td>Kolani Kavu</td>
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**CASE STUDIES**

Two groups representing eight floristic associations were studied in detail. (*Myristica* swamp forest and the Lowland evergreen forest). Lowland evergreen forests harboured six associations and *Myristica* swamps the other two. All the groves selected are in low elevation areas (altitude <340 m). It is found that for certain groves the dominant vegetation in terms of IVI differs from the association to which they belong. This is because in calculating IVI, basal area is taken into consideration. Presence of a few large trees can give one species a dominant
position in IVI as a single large tree of *Holoptelea integrifolia* (in plot-3) and few
glarge trees of *Syzygium mundagam* (in plot-1) have contributed to a very large
basal area and consequently a dominant position in the community (in terms of IVI)
though in terms of their frequency and abundance they are less important in the
respective communities. Secondly, local edaphic conditions and topography are
reflected in local variations among dominant species.

(i) Dharmasastha Kavu, Cheemeni.

Based on typology, this grove comes under cluster seven that represents
*Atalantia monophylla* - *Garcinia pictorius* - *Litsea keralana* association. Based on
IVI, the vegetation is dominated by *Syzygium mundagam, Atalantia monophylla* and
*Garcinia pictorius*. But, in terms of frequency and relative density the characteristic
species *Atalantia monophylla* and *Garcinia pictorius* are standing first. Their
presence in the evergreen patch indicates that the site is relatively drier than that of
a climax evergreen site Presence of small heliophytes like *Olea dioica, Mallotus philippensis, Tabernaemontana heyneana* etc., confirms the disturbance in the
grove. A deciduous species like *Sterculia guttata* has an IVI of 16.97. Other
deciduous species like *Terminalia bellirica, Vitex altissima* and *Zanthoxylum rhetsa*
have begun to establish in the community A few large trees of *Syzygium mundagam* have contributed to the maximum basal area of the species, which is
reflected in the community too. *Atalantia monophylla* has the maximum number of
individuals (27%) With an IVI of 64.80, large trees of *Syzygium mundagam* have
secured Myrtaceae the dominant position among families also Unlike other
lowland forests of the region Dipterocarpaceae is totally absent in this plot.

Number of species recorded is 28, including the new colonisers. This is
reflected in diversity indices. Simpson's index 0.91 implies that for every 100 pair of
trees taken at random 91 are of different species and only 9 are identical. Shannon-
Wiener's index (3.89) indicates that the community is species rich. Of the 401 trees
enumerated, 68% are in the smallest girth class (<25cm gbh). Representation in
higher girth classes is negligible. Basal area is low (37.56m²) and height of the
stand is 20m. Due to the above two facts, biomass is less (851 09 m³/ha). Height is
a major factor contributing to lesser biomass.

Regeneration pattern (Table.17) indicates that *Syzygium mundagam* with
profuse regeneration is poorly represented in the fourth category even though
seedlings in younger classes are plenty. More adaptable species like *Atalantia monophylla, Garcinia pictorius, Olea dioica, Pterospermum rubiginosum* etc. have
put the species on a decline. This conveys that the present drier conditions are not
favourable for *Syzygium mundagam*. Its large trees point to the fact that earlier it
was present in good form and this species of climax vegetation has still a dominance in the community. This has caused a minor local variation for the association. This explains why the dominant community in terms of IVI is different from that of the association. In this case, the local variation reflects the climax vegetation species. Regeneration pattern of Mallotus philippensis, Tabernaemontana heyneana and Terminalia bellirica indicates that due to disturbances in the community, the species try to establish themselves opportunistically. All these points reveal that the original vegetation is under retrogression.

(ii) Edayilakkadu Kavu

This grove falls under Cluster-13 (Hopea ponga - Holigarna arnottiana - Cinnamomum malabatrum association). With an IVI of 103.55, Hopea ponga dominates in the community. Light tolerant species such as Holigarna arnottiana, Cinnamomum malabatrum and Polyalithia korinti come next. Evergreen species like Aporusa lindleyana, Mimusops elengi, Strychnos nux-vomica and Syzygium zeylanicum which are adaptable to more open conditions also show that the forest is in a degraded stage.

This grove is situated in an island, susceptible to heavy winds. Hence, tall trees are absent. Height of the stand is only 16m; Density of the stand is 1112/ha, but 60% of them are having <25 cm gdbh Girth class frequencies (Fig 34) show a stretched 'L', and larger girth classes are not proportionately represented. So the basal area is also less (40.12m²/ha). With smaller basal area and lesser height, the biomass is also proportionately less (649.30m³).

When regeneration is considered, Hopea ponga has the maximum representation and is expected to maintain its dominance further. This is followed by Aporusa lindleyana and Cinnamomum malabatrum. Regeneration pattern of Diospyros malabaricum, Mimusops elengi and Syzygium zeylanicum ensure their position in the community. Holigarna arnottiana would be pushed down a little, because higher height classes are less and its dominance among seedlings is not as much as that it has in the community. In general, regeneration pattern predicts no change in the community in the immediate future although the grove is in a degraded stage. The grove is almost isolated and lack of continuum with similar vegetations may lead to inbreeding.

(iii) Thavidissery Kavu
This grove of Cluster-5 (Myristica malabarica - Lophopetalum wightianum - Mastixia arborea association), shows the dominance of Strombosia ceylanica (IVI 124.10). Presence of a single, large individual has placed Holoptelea integrifolia in second position. Other dominant species are Antiaris toxicaria, Ixora brachiata and Myristica malabarica. This grove is located along the slopes of a valley and the low lying areas have been converted to agricultural fields. The change in land use pattern has decreased the water level in the grove. Hence, characteristic species like, Myristica malabarica and Lophopetalum wightianum are found to have lesser IVI than Strombosia ceylanica and Antiaris toxicaria.

Of the 467 trees enumerated, 62% are in the lowest girth class (<25cm gbh) and 21.4% in the next girth class (26-50cm gbh). Other girth classes are also reasonably well represented. The basal area (57m²/ha) and biomass (1897.6m³/ha) of the grove is comparable to some of the evergreen formations of the Western Ghats described by Pascal (1988). This grove spreads over an area of 10ha along the slope and hence gets some protection from wind, which has enabled it to grow to a height of 24m. The dominance of Strombosia ceylanica has reduced the diversity (Simpson's index 0.47 and Shannon-Wiener's index 1.67).

When the regeneration pattern is examined, Strombosia ceylanica is less represented in the smaller height classes, although it dominates the third and fourth height classes. Myristica malabarica is poorly represented, Lophopetalum wightianum is not represented in the upper height classes. Predominance of Antiaris toxicaria and Ixora brachiata ensures that they can retain their position in the community in future. Regeneration of Acronychia pedunculata, Antidesma bunius, Diospyros buxifolia etc., reveals an evolution towards a drier type of vegetation. Thus, characteristic elements like Myristica malabarica and Lophopetalum wightianum have been reduced by Strombosia ceylanica. This is mainly due to the reduction in moisture conditions of the soil brought about by human agency. Thus, anthropogenic action can cause variation in the vegetation. Change in land-use pattern in the neighbourhood can cause changes in the characteristic elements of vegetation. This also tells upon the fragility of the evergreen forest ecosystem.

(iv) Poonkottukavu

This grove also belongs to Cluster - 5 (Myristica malabarica - Lophopetalum wightianum - Mastixia arborea association). The dominance of Myristica malabarica (IVI 118.68) is evident in this grove. Holigarna armottiana, Strombosia ceylanica and Hydnocarpus pentandra occupy successively less important positions. Lophopetalum wightianum is in the sixth position (IVI 12.62). Although 26 species
are recorded, the presence of light tolerant species like, *Artocarpus hirsutus*, *Caryota urens*, *Cinnamomum malabatrum*, *Polynyliira fragrans*, *Hopea ponga*, etc, and heliophytes like, *Alstonia scholaris*, *Olea dioica*, *Vitex altissima*, *Albizia odoratissima* etc., reveal that the stand is not in a climax stage. Girth class distribution (Fig 41) depicts only 35% in <25 cm class, 25% in 26-50 cm class, and 23% in 51-75 cm class. None of the trees are above 250 cm gbh, reducing the basal area of the plot to 33.92 m²/ha and biomass to 641.71 m³/ha. Although predominated by light tolerant species, this is a rare type of forest where 42.3% of the trees enumerated are endemics, requiring special conservation (or protection) measures.

Regeneration of *Myristica malabarica* and *Hopea parviflora* represented in all stages ensures their future in this community. *Holigarna arnottiana* and *Cinnamomum malabatrum* also show promising regeneration. *Lophopetalum wightianum*, *Mastixia arborea*, *Polynyliira fragrans* and *Strombosia ceylanica* show regeneration proportionate to their representation in the canopy. However, presence of *Alstonia scholaris*, *Antidesma menasu*, *Garcinia pictorius*, *Tabernaemontana heyneana* etc., indicates a trend towards drier vegetation type. This change has caused diminution of the characteristic elements of the association and hence there is slight change in the association derived on the basis of IVI from the characteristic vegetation of its group.

(v) Muchukunnu Kottah

This grove in Cluster 14 (*Vateria indica* - *Hopea ponga* - *Strychnos nux-vomica* - *Holigarna arnottiana* association) has *Vateria indica* as the dominant species (IVI= 104.10), followed by *Hopea ponga* (36.70). The disturbed state of the forest is indicated by *Strychnos nux-vomica* and *Olea dioica* which have attained third and fourth position in the community. The above four species account for 73% of the trees enumerated. Presence of *Mallotus philippensis*, *Macaranga peltata*, *Sterculia guttata*, *Zanthoxylum rhetsa*, *Vitex altissima* etc., reveal that the vegetation is not progressively evolving into an evergreen climax; rather the trend is towards a drier type. The invasion of new deciduous species could keep up the diversity indices to match with the lowland evergreen forests. Simpson's index is 0.85 and Shannon-Wiener's is 3.29. With the increase in dryness, even though the species diversity has increased, there is a reduction in the percentage of endemic plants. It is only 14.28 (Table 48). The poor species richness has resulted in the basal area to 14.99m²/ha, with a biomass of 212.1m³. Height of the stand is only 13m.

Regeneration is very poor with relatively fewer seedlings than in the other selected groves. General regeneration pattern shows some anomaly. Younger age
classes are lesser in number than the older ones. Many of the heliophytes like, *Macaranga peltata*, *Mallotus philippensis*, *Mimusops elengi*, *Tabernaemontana heyneana*, *Vitex altissima* etc., are unrepresented in the younger height classes, but are seen in the adult stage.

A heavy storm (about fifteen years back) had created large openings through fall of some huge trees. This unprecedented loss of seed source led to an invasion by the heliophytes, which further established to form a complete cover close to the ground. Lack of sufficient micro sites and light on the forest floor could be a major factor inhibiting the recruitment of seedlings of the canopy species resulting in the reverse proportion of adults versus seedlings. Although species with wider ecological adaptations have invaded, regeneration patterns of species like Vateria indica, *Hopea ponga* and *Strychnos nux-vomica* reveal that they can continue to dominate for a few more years. No incidence of fire could be traced and the role of fire in establishment of the secondary species can thus be ruled out.

(vi) Mukkola

This is the only grove in Cluster - 20 (*Poeciloneuron indicum* consociation). The community is dominated by *Poeciloneuron indicum* (\( \text{IVI} = 114.13 \)), followed by *Aglaia eleagnoida* and *Antiaris toxicara*. Presence of species like, *Alstonia scholaris*, *Artocarpus hirsutus*, *Mimusops elengi*, *Olea dioica*, *Mallotus philippensis* etc., indicates that it is not a progressive vegetation. However, this is the only sacred grove in Kerala with dominance of *Poeciloneuron indicum*. It was observed during my study that there were no trees of *Poeciloneuron indicum* within a radius of about 20 km outside the grove. There are no water bodies near the grove also. The soil is lateritic too. This consociation is due to some edaphic constraints and is analogous to *Poeciloneuron* facies in *Dipterocarpus indicus-Humboldtia brunonis-Poeciloneuron indicum* type recorded from 350m to 1250m altitude in Karnataka portion of Western Ghats by *Pascal* (1988). He recorded 35 species and 302 individuals above 10 cm gbb with a basal area of 69.96 m\(^2\)/ha and biomass 2294.9 m\(^3\)/ha from a 1600 m\(^2\) plot (at Naravi). The present plot on a 2500 m\(^2\) area contained only 19 species and 200 individuals above 10 cm gbb. Basal area of 25 m\(^2\)/ha and the biomass of 467.52 m\(^3\)/ha are quite low. Hence, this is quite inferior to that facies, but probably represents the southernmost limit of the facies and the forest type. The representation of *Poeciloneuron indicum* is 25.8% at Naravi, but 41% in this plot. According to *Kadambi* (1942) greater dominance of *Poeciloneuron indicum* indicates more unfavourable conditions and gradual loss of its characteristic climax associates. This may be the reason for the presence of new associates of *Poeciloneuron indicum* in this community.
Regeneration shows dominance of *Poeciloneuron indicum* and *Aglaia eleagnoidea*. When all seedlings are considered, a normal pattern with more number of seedlings in the smallest height class and progressive decrease towards the larger height classes are seen. Bell shaped distribution of *Macaranga peltata*, *Mallotus philippensis*, *Olea dioica* and *Vitex altissima* are characteristic of the heliophytes (Rollet 1974) and their presence also shows ecological disturbances in the community. Even though this grove comes under Lowland Evergreen group as per typology, the variation in characteristic elements is due to special edaphic conditions.

(vii) Vallikkattu Kavu

This is the only grove in Cluster - 21 with *Hopea ponga* - *Xanthophyllum arnottianum* - *Vateria indica* association. This cluster falls under *Myristica* swamp group. Characteristic elements of this group like, *Myristica malabarica* and *Lophopetalum wightianum* are gradually reduced due to local edaphic changes. The dominance of *Hopea ponga*, *Xanthophyllum arnottianum* and *Vateria indica* are observed. *Myristica malabarica* and *Lophopetalum wightianum* are present in small numbers. Light tolerant species like *Hopea ponga* and *Xanthophyllum arnottianum* are dominant. Other species like, *Alstonia scholaris*, *Aporusa lindleyana*, *Ficus benghalensis* and *Mimusops elengi* indicate that this is not the characteristic climax vegetation. Density of the stand at 1532/ha is good when compared to low elevation evergreen forests, but 64% of the density is represented in the lowest girth class and 21% in girth class 26 - 50 cm gbh. Only 6.5% of individuals have >100 cm gbh. Basal area is only 313 m²/ha, with a biomass of 453.20 m³/ha. Height of the canopy is 15m Dominance of any species is considerably low accounting for a moderate species diversity, although lower than that of a climax forest.

Regeneration is comparatively poor with less number of seedlings. *Hopea ponga* has maximum number of seedlings *Adenanthera pavonina*, a light tolerant evergreen species has some seedlings in the first height class. *Aporusa lindleyana* has good representation in the adult stage. In comparison, *Vateria indica* seems to lose with no representation in the first two stages. Although characteristic species of the type like, *Myristica malabarica*, *Lophopetalum wightianum* and *Mastixia arborea* are represented, the recruitment of light tolerant species is more and the trend shows a shift from *Myristica* swamp towards a disturbed evergreen. This is an isolated grove and changing land-use pattern in the surroundings has caused changes in the water table, followed by substantial changes in the community, with decreasing dominance of characteristic species.
(viii) Iringole Kavu

This grove is selected from Cluster 11 (Vateria indica - Hopea parviflora - Hopea ponga association). Vateria indica (IVI = 128.01) is the dominant species, followed by Hopea ponga (46.19) and Strombosia ceylanica (43.28). Representation of heliophytes is negligible with single individual of Mallotus philippensis, Strychnos nux-vomica, Zanthoxylum rhetsa etc., showing small pockets of disturbances in the grove. Average height of the forest is 25m. With more seedlings in shorter height class, decreasing towards higher height classes, girth class distribution is almost normal. Trees in smallest girth class (<25cm gh1) account for 51% whereas 13% have gh1 more than 100 cm. Density of the stand (1180/ha) and biomass (1280.86 m3/ha) are little less than similar formations referred to, though better than those of the other groves discussed earlier. There is only one species with IVI more than 100 and more than 50 individuals. Hence, diversity indices are low, as it is centred on one species - Vateria indica.

Vateria indica shows good regeneration. Other species like, Cinnamomum malabatrum, Hopea parviflora, Polyalthia fragrans and Strombosia ceylanica have enough representation to assure their position in the community. Macaranga peltata, Mallotus philippensis and Terminalia bellirica make use of the available opportunities. Recruitment of Garcinia gummi-gutta and Myristica dactylodes shows that if conditions return to a favourable phase, the stand can progress towards climax. Existence of light tolerant dominant species, point to the vegetation being in a secondary successional stage rather than a climax.

(ix) Kolani Kavu

This grove also belongs to Cluster 11 (Vateria indica - Hopea parviflora - Hopea ponga association). Dominance of light tolerant species like, Strombosia ceylanica and Hopea parviflora is followed by Diospyros sylvestica, Aglaia eleagnoidea and Syzygium cumini. Presence of species like, Zanthoxylum rhetsa, Trema orientalis, Premna coriacea, Tabernaemontana heyneana etc., show that it is not progressing towards a climax. This grove is surrounded by rubber plantations and is protected from wind. The stand is 30m tall. This grove incidentally supports the tallest vegetation. Density of the stand is only 1064/ha, but 17% of the woody species are having >100cm gh1. Only 56% is in the first girth class (<25 cm gh1). This greater representation of the higher girth class leads to increased basal area (96.62 m2/ha), which is slightly higher than that of the lowland evergreen forests referred to, for comparison. This is also the grove with maximum number (8) of trees
having >300 cm gbh. Biomass of the forest is 2948.11m$^3$/ha and can be compared with other lowland evergreen forests of Western Ghats. It shows that if proper protection from wind is provided, other groves can also grow to maximum height. Therefore, strong wind appears to be a limiting factor, responsible for the short stature of many groves.

Regeneration shows maximum seedlings of Aglaia eleagnoides and Hopea parviiflora, followed by Holigarna arnotitiana. Profuse regeneration of Artocarpus hirsutus shows favourable conditions for light tolerant species. Irregular regeneration pattern of Caryota urens, Cinnamomum malabaricum, Mallotus philippensis and Olea dioica shows that they had made use of the chances to establish whenever there have been disturbances. This grove does not seem to be progressing towards a climax. But disturbances are minimum in this grove and 33% of the trees enumerated are endemic.

(x) Elanjimel Vallikavu

This grove belongs to cluster 13 (Hopea ponga - Holigarna arnotitiana - Cinnamomum malabaricum association) Based on phytosociological studies Hopea ponga dominates this community with 80% of the trees (LVI =163.45). Five other species constitute 18.5% of the trees and balance of 1.5% is contributed by 6 species. Species other than Hopea ponga are negligible in the community. Majority of the dominant species are represented in the lower girth classes indicating that the stand is not very old. The area was drastically clear felled about two decades back by the owners of the grove. Some protection has resulted in the regeneration and establishment of light tolerant species like, Hopea ponga, Xanthophyllum arnotitianum, Olea dioica, Cinnamomum malabaricum, Strychnos nux-vomica etc. Thus, human interference has left a mark of long lasting effects on the vegetation community. Such single species dominance with the elimination of other characteristic elements shows unfavourable conditions for the eliminated constituents.

This is a forest in the secondary succession phase with poor species richness. Since the community is centred on one species, diversity indices are quite low. This is an isolated patch of forest and the canopy height is only 13m, with basal area of 20.07m$^2$/ha. Biomass is too low to be compared with the lowland evergreen formations. The density of the stand is very high (4060/ha). Space available for each tree is only 2.46m$^2$. Hence, there is poor light in the forest floor This has led to poor regeneration in the plot. Clear-felling done earlier has caused some detrimental effects on the parent material of sciophytes and hence their regeneration is also not seen. Fig 59 depicts an abnormal regeneration pattern with
more number of seedlings in the upper height class and decreasing towards the lower. *Strombosia ceylanica* requires less light than *Hopea ponga* and hence its seedlings are more in number than the latter. There is rather a need for natural elimination of some of the pole crop for the proper development of the forest. Therefore, in the present set up poor regeneration is not a problem.

(xii) *Paekkavu*

This grove is selected from Cluster 6 (*Aporusa lindleyana* - *Hopea parviflora* - *Strombosia ceylanica* association). Phytosociological study gives an association of *Aporusa lindleyana*, *Hopea parviflora* and *Terminalia paniculata* on the basis of IVI. The characteristic elements are usually replaced by other species, depending upon the environmental conditions. Local dryness (as is reflected from other constituent dry elements in the community) has made the environment favourable for *Terminalia paniculata* replacing *Strombosia ceylanica*. Floristic composition reveals that this vegetation is evolving towards a semi-evergreen type. *Terminalia paniculata* itself has become the third dominant species. Deciduous elements like, *Bombax ceiba*, *Bridelia airy-shawii*, *Lagerstroemia microcarpa*, *Schleichera oleosa*, *Stereospermum chelonoides*, *Tetrameles nudiflora* etc., confirm this fact. Invading species have inflated the species richness of the forest (30), but with low presence of endemics (23.3%), confirming that endemism reduces with dryness. Density of the stand is less (768/ha), but available trees are distributed in different girth classes along the pattern of a normal forest. Only 22% of them are in the first girth class (<25 cm gbh) and 23% in the second (26-50 cm gbh). The girth class above 100 cm have 30.7% of the trees. This grove is also surrounded by large extent of teak and rubber plantations, which has helped it to grow to a height of 28m. Normal distribution of girth classes has contributed to a basal area of 66.08 m²/ha. Biomass is also good, but second to that of Kolani Kavu discussed earlier (plot-9). This is the only grove where there are no species with IVI more than 50 and hence the community is not concentrated in one or two species. So the diversity indices are the highest for this grove and this is what is expected of a forest during transition from evergreen to semi-evergreen.

Regeneration shows a dominance of *Hopea parviflora*, followed by *Cinnamomum malabatrum*. Presence of *Elaeocarpus tuberculatus*, *Myristica malabarica*, *Persea macarantlia*, *Syzygium gardneri* etc., reveals that the microclimate is not completely lost for the evergreen species or rather the change to semi-evergreen is not rapid. Bell shaped regeneration pattern of *Artocarpus hirsutus*, *Macaranga peltata* and *Tabernaemontana heynana* conveys that the disturbances in the community have helped establishment of other species. This
relative increase of biodiversity due to increase in heliophytes and invasion of deciduous species will have an adverse effect on the endemic elements. Many of such drier elements are not endemic to this part of the country and their invasion will only result in the elimination or suppression of the endemics.

CASE STUDIES IN GENERAL

Abstract of the phytosociological studies in eleven plots is presented in Table-48. The data for different plots are presented in the decreasing order of their biomass, separately for Lowland Evergreen and *Myristica* swamp types. Percentage of endemic elements for the *Myristica* swamp shows that they have a high percentage (42.3) in Poonkottukavu (Plot-4), but in other two groves (Plots 3 and 7) where the association has changed due to change in edaphic conditions, it has been considerably reduced to 26%. So, these are not only the drier elements that reduce the endemic elements in a forest, but also the invasion of any species other than the characteristic ones into that community.

The case studies have helped to understand the ecological status of the groves. In many cases the characteristic species have been replaced by some other species and this replacement depends on many factors such as edaphic conditions, land-use pattern in the neighbouring areas, history of human activities in the site, local climatic changes and major climatic incidences, openings in the canopy and fragmentation of the habitat. Hence, local variations are reflective of the above factors. On the basis of correspondence analysis certain associations had been identified. Case studies of groves from these associations had revealed that the names of such associations are quite suitable for them. There are minor variations in the dominance of certain species (reasons for which are very clear) None of them today support climax vegetation. They are in isolated conditions, surrounded by agricultural lands (Plate-14) and this island effect has played a major role in their structure and composition. Most obvious is the levelling of tall trees to withstand strong winds (especially groves in plains). Hence, height of the groves varies from 13m to 20m. Wherever it is more than 20m it had been protected by some other vegetation or topography (e.g. hill slopes) as already discussed. The groves are subjected to seasonal monsoon winds. Since the evergreen trees have a shallow root system, the tall trees fall rather easily, because the wind force is doubled by the bole length. Such tree-falls create large openings to affect the process of regeneration. Most of the seedlings and saplings of sciophytic species which could not survive have made room for light tolerant evergreens. Thus the light tolerant evergreens like *Aporusa lindleyana*, *Hopea parviflora*, *Hopea ponga*, *Strychnos nux-vomica*, *Strombosia ceylanica*, *Vateria indica* etc., gain dominance in the
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Plate 13 Part of the grove converted into playground (Chamakkavu grove N°268)

Plate 14 A Grove surrounded by agricultural field
community. This also explains for the absence of characteristic species of the low elevations like, *Baccaurea courtallensis*, *Canarium strictum*, *Diospyros bourdillonii*, *Dipterocarpus bourdillonii*, *Dipterocarpus indicus*, *Drypetes malabarica*, *Humboldtia brunonis*, *Kingiodendron pinnatum*, etc.

The fact that the structure and composition are susceptible to change proves the fragility of the ecosystem. Little protection from wind provided by the surrounding plantations has helped the groves at Kolani kavu, Iringole Kavu and Paekkavu to attain height of 24 to 30m. Wherever the grove could grow in height (as in the case of plots 3, 8, and 9), the biomass is almost equal to, or sometimes even greater than that of the evergreen formations described by Pascal (1988). This also reflects upon the potentiality of the soil to support superior vegetation, only if it is large or properly protected. If the groves cannot be expanded (spiralling land cost and land-hunger being the limiting factors in the State), this method of raising plantations of cash crops or some intensive agroforestry practices in the adjacent lands can be thought of, to enhance the ecological utility of sacred groves. Changes in the species composition of the edaphic evergreens at Thavidisserykavu and Vallikkattukavu (plots 3 and 7) reveal that small alterations in land-use pattern will have detrimental effects on the original vegetation in the neighbouring areas.

Family dominance showed two sets of plots. The first, where Dipterocarpaceae dominated (Plots 2, 5, 7, 8, 9 and 10) and the second, where non-Dipterocarpaceae dominated (Plots 1, 3, 4, 6 and 11). Among the Dipterocarpaceae dominated groves, the average percentage of basal area is 62% (ranging from 41 to 81 %). When number of trees are considered, on an average 45% of the stems are of Dipterocarpaceae (ranging from 13 to 81 %). When all the eleven groves are considered 25% by number and 33% by basal area constituted this family. On a Malaysian lowland dipterocarp forest, Appanah and Weinland (1993) and Manokaran et al. (1992) reported that Dipterocarpaceae constituted 9.2% of the total stems (>1cm dbh in a 50 ha plot), whereas Kochummen et al. (1990) reported 9.3 %. When basal area is considered, Appanah and Weinland (1993) reported 28% for the family. Laumonier (1991) has stated that 9% of the stems and 25% of the basal area in a lowland forest of Sumatra are constituted by Dipterocarpaceae. In terms of basal area and number, Dipterocarpaceae is as dominant or rather more dominant in their community in sacred groves, than any other lowland dipterocarp forests of the Southeast Asian region. Therefore the sacred groves of Kerala in their physiognomic shape of lowland evergreen forests may be representing the remnants of the original low elevation evergreen forests and can be considered as Indian Lowland Dipterocarp Forests.
Dominance of Dipterocarpaceae is well recognised, but the reason for its exceptional dominance is not fully understood. Several explanations have been provided. They include flowering and fruiting behaviour, high seeding populations, mycorrhizal associations, high resin contents and aseasonal climate (Ashton, 1988). As per the "random walk" theory of Hubbel (1979), the species observed within a formation are the result of a random assemblage of plants, through immigration, extinction, and in situ species formation. However, Ashton (1969 and 1976) has suggested that edaphic determinism is strongly expressed, at least in the case of Bruneiian forests of East Malaysia. Observations in the study plots support this hypothesis. When the non-dipterocarp plots are considered, their floristic composition reveals that they are either drier than the dipterocarp plots (Plot 1 and 11) or contain more moisture (Plots 3, 4 and 7 with high water table supporting Myristica swamp). Plot No.6 (Mukkola Kavu) having Poeciloneuron indicum facies is an exception and is not considered. It may be noted that even though plot 7 (Vallikkattu kavu), belongs to Myristica type, wherever water table has gone down in some places, Dipterocarpaceae has dominated such patches instead of Myristicaceae. In Kerala, moisture regime appears to determine the population of Dipterocarpaceae in the low lands. If other factors are favourable, excessive moisture or inundation will induce Myristica swamp Forests, poor/meagre moisture will causes development of forests with species adaptable to dry localities and adequate water with good drainage will lead to Lowland Dipterocarp Forests. Of course, more detailed research about the actual moisture regime and influence of other micro elements needs to be carried out.

Among the non-Dipterocarp groves average basal area was 5% and average number was 2% for Dipterocarpaceae. Thus, there is a striking difference in the basal area and number of stems between the Dipterocarpaceae and non Dipterocarpaceae in each of the plots. This fully supports the observation of Appanah and Weinland (1993) that where dipterocarps predominated, the non dipterocarps were poor and vice-versa. This also gives a clue to the forest managers that it is possible to manipulate the stands to increase Dipterocarp elements over non-Dipterocarp elements upto the allowable limits of Dipterocarps.