CHAPTER 6.
DISCUSSION

The extensive qualitative survey recorded more species than the intensive quantitative survey did (Table 5.1 and 5.3). This is because the extensive qualitative survey covered all species found growing in each site and additional species recorded during the intensive quantitative survey were added to the research database as part of the qualitative survey's result.

The results showed that the ground flora species composition in the forest site differed from the other sites. This was apparently due to environmental changes which occurred when the natural forest was cleared and converted to plantations. Such enviromental aspects as microclimate, temperature, humidity, precipitation and soil are the most significant factors contributing in changes species composition when the conversion of natural forest to plantations occurred. **Whitmore** (1992) asserted that at least three main reasons why some tropical rain forests are rich in species resulting from: (i) a large stable climatic history in an equiable environment, (ii) a forest canopy provides large number of spatial and temporal niches and (iii) richness results from interactions with animals, mainly as pollinators and dispersers, factors which can not be found in the plantations. In terms of soil nutrient content, especially nitrogen, such changes included a considerable reduction of nutrient reserves available to the vegetation, because of nutrient losses due to fire and cultivation, top soil losses due to heavy rain, opening of the nutrient cycle due to a loss of root-matting and subsequent high leaching rates, rapid reduction of organic matter in the soil resulting in a significant decrease in cation exchange capacity and in mineralized nutrients in erosion of the top layer of soil (**Spurr and Burton**, 1980).

Tables 5.1 and 5.3 show that herbaceous plants dominated the ground flora while shrubs were the most sparse (both in the extensive qualitative and intensive

qualitative surveys). Forest supported the highest species composition, whilst the lowest was in the eucalyptus plantation, particularly for deciduous/evergreen vines, which was significantly lower than in the evergreen forest site. Replacement of natural forest with plantations therefore reduces the capacity of an area to support high number of species.

The number of species in common between forest and young pine plantation was the highest, whilst the lowest was between mature pine and eucalyptus plantations (Table 5.2). Presumably the higher the number is, the more similar are the characteristics of the sites. This indicated that the mature pine plantation had a very different species composition compared to the eucalyptus plantation or it can be said that very few species are common between the two sites. In terms of the value of Sorensen's index, the highest similarity was 0.66, between mature and young pine plantations, while the lowest was 0.46, between mature pine and eucalyptus plantations (Figure 5.1). This simply means that mature and young pine plantations had many species in common (shared), while the regenerating gap and mature pine sites had very few common species.

Species/area curves are very useful to determine the minimum area that adequately represents a community. Increasing the number of sample plots increases the number of species recorded. Figure 5.2 shows that, particularly in the forest, mature pine and young pine, species/area curves nearly reached an upper asymptote, indicating that twenty quadrats were almost sufficient to adequately represent the whole community at each site.

The species richness index (for both the extensive qualitative and intensive quantitative surveys) was highest in the forest (Table 5.4). As mentioned **by Ludwig and Reynolds** (1988), species richness is the number of species in the community.

The forest site supported the highest number of species, while the eucalyptus plantation supported the lowest (extensive survey). **Bruenig *et al.*,** (1991) explained that species richness was mainly related to site conditions and the evenness or diversity or mortality, small-scale and medium scale catastrophes, regenerate cycles and long-term successional changes in the vegetation, soil and physiognomy and texture (architecture) of crowns and canopies were expressions of adaptations to physical and other conditions of the site.

Species diversity indices (both N1 and N2) in the forest were the highest, while the lowest were in the eucalyptus plantation which was not very different to the mature pine plantation. It is suggested that both plantations (eucalyptus and mature pine) not only absorbed a lot of water from the soil, but also exuded chemical substances which may have adverse effects on other organisms, including herbaceous plant. **Poore and Fries**, (1988) revealed that certain species of eucalyptus may produce chemicals from their leaves or litter that inhibit the germination or growth of other plant species. Known as allelopathy, this effect is quite different from direct competition for water, minerals or light. Similarly **Del Moral and Muller** (1970) noted that *Eucalyptus camaldulensis* Dehnh. (Myrtaceae) inhibits improved grassland species including *Bromus mollis* L. (Gramineae) and *Lolium multiflorum* Lam. (Gramineae). There was more vegetation under oak, in 45% sunlight, than under the eucalyptus, in 64% sunlight. **Al-Mousawi and Al-Naib** (1975) found a scarcity of herbaceous plants in plantations of *Eucalyptus microtheca* F. Muell. (Myrtaceae) in central Iraq, which was not due to lack of moisture, nutrients or shading; but leaf extracts, decaying leaves and soil inhibited germination and growth of associated species. The volatile inhibitors found were the same as those identified for *Eucalyptus globulus* Labill. (Myrtaceae) by **Del Moral and Muller** (1969). They found that the absence of vegetation beneath *Eucalyptus globulus* Labill. (Myrtaceae) could not be attributed to competition for essential resources, but phytotoxins in fog-

drip appeared to be capable of causing this. A number of annual grasses were tested with the solution coming through the canopy.

In contrast, **Chaubey *et al.,*** (1988), conducted a study of the ground flora using quadrats in a range of teak (*Tectona grandis* L. f., (Verbenaceae) plantation in edapho-climatic regions of Madya Pradesh (Nainpur: 1-2, 4-6 and 16-17 year old plantations; and Bijawar: 2-3 and 20-23 year old plantations), and in adjoining natural forests. The importance value indices found in both the plantation sites and their adjacent natural forests were higher in the plantations than in the forest. The total number of ground flora species, total plant density and above-ground biomass were also higher in plantations than in the adjoining natural forests. The community coefficient of similarity between each plantation and its adjoining forests increased with the age of the plantation. Furthermore, **Chaubey *et al.,*** (1988) carried out a comparative studies on floristic composition, species diversity and quantitative ecological parameters (frequency, density, basal area and importance value index (IVI) for each species in teak plantations of different ages and their adjoining natural forests. No discernable differences were found in the floristic composition of tree species under teak plantations and their adjoining forests. Total density (trees/ha) and total basal area (m^2/ha) were also higher in teak plantations than in adjoining natural forests. Most of the common species which were present both in plantations and in natural forests has a higher frequency, density, basal area and IVI in plantations than in adjoining natural forests.

In line with **Chaubey, *et al.*** (1988), **Pande *et al.,*** (1988) carried out a comparative vegetative analysis of some plantation ecosystems at New Forest, Dehra Dun, Uttar Pradesh. Plantations were of *Pinus roxburghii* Sarg. (Pinaceae), *Tectona grandis* L. f. (Verbenaceae), *Shorea robusta* Gaertner f. (Dipterocarpaceae) and *Eucalyptus sp.* (Myrtaceae). Tree density and species richness were highest in the

older plantations. Total basal cover ($cm^2/100\ m^2$) was : pine>sal>teak>eucalyptus. Importance value index (IVI) was highest for eucalyptus and sal (both 300 followed by teak and pine in their prespective plantations. On the basis of both density and IVI the greatest diversity was found in the pine plantation, and the least in the eucalyptus plantation. The distribution pattern of different tree species was contagious for all plantations except pine, where it was random. The highest value of dominance concentration were found for sal (*Shorea robusta* Gaertner f., Dipterocarpaceae) and eucalyptus. This is attributed to their monoculture nature. This was apparently because there was no effect of toxic chemical substances resulting from teak trees.

Evenness index in the forest site was the highest (Table 5.4). The higher the evenness index, the more evenly distributed are individuals among species. This simply means that most of the individuals in the forest area are evenly distributed among species or species tend to be equally abundant. However, the evenness index in eucalyptus site was the lowest, indicating that most of the species were rare and few were dominant. In the eucalyptus plantation, *Pogostemon auriculatus* (L.) Hassk. (Labiatae), *Rubus blepharoneurus* Card. (Rosaceae), *Pteridium aquilinum* (L.) Kuhn ssp. *aquilinum* var. *wightianum* (Ag.) Try. (Dennstaedtiaceae), *Ettingera littoralis* (Kon.) Gise (Zingiberaceae) and *Microstegium vagans* (Nees ex Steud.) A. Camus (Gramineae) were abundant. It is suggested that those species are tolerant under eucalyptus trees which exudate chemical substances in its surroundings. However, it was very difficult to conclude that those species were able to grow in the eucalyptus plantation since there is not enough information about this.

In terms of similarities and differences, Chord distance index between young pine plantation and eucalyptus plantation site was the highest. This means that very few species in both sites are shared. However, the lowest CRD index was between the

forest site and eucalyptus sites. This means that many species of both sites are shared.

Cluster analysis and ordination showed more or less the same results. Figures 5.4, 5.5 and 5.7 show that mature and young pine plantations were clustered. This means that both sites had a similar characteristic in terms of percent cover coinciding with the similarities of species recorded. However, in the same figures it shows that forest and eucalyptus sites were clustered together. Theoretically, the forest should not be grouped in the same cluster with the eucalyptus plantation since they are different in their capacity to conserve biological diversity as mentioned before (Table 5.4).

Ordination method using mean absolute distance showed that the lowest mean absolute distance was 1.24, between mature and young pine plantations. This value was the same as between forest and eucalyptus sites. This simply means that both sites had similar characteristics in terms of percentage cover and species involved. The highest mean absolute distance was 1.82, between eucalyptus and mature pine plantations (Figure 5.5). This simply means that both sites had no influence or similar characteristics in the effects on the percent cover species recorded.

Table 5.7 shows the relative growth rate (RGR), mortality and density of tree seedlings in all five sites. The RGR in the regenerating gap was the highest, followed by the forest was and the lowest was in the mature pine plantation. Species which grow in the gap were mostly pioneer species. They are able to grow fast under high light intensity, resulting in maximum rate of photosythesis. **Whitmore** (1992) and **Grime** (1979) revealed that early successional species are shade-intolerant (i.e. light demanding) and are photosythetically efficient by virtue of their multilayer foliage canopy which is suitable for high illumination. Such canopies are also selected to be

water conservative and, for this reason, early succesion species may persist on shallow or arid soil. **Bazzaz** (1979) reviews evidence for the water efficiency and high maximum photosythesis of early succession herbs and trees.

The highest mortality occurred in the mature pine plantation, while the lowest occurred in the forest site. The characteristic of ground layer in the mature pine was open the canopy sparse so that results in high light intensity passing through to the ground flora. Drought mortality is distictly different from heat injury and can take place after the succulent stage. It will not occur if seedling roots extend themselves rapidly enough to maintain contact with portions of the soil where water is available. This is one reason why shaded seedlings are more likely to die of drought than those growing in the open since seedlings in shaded place have a less extensive/deep root system that exposed one (**Smith**, 1986). In addition, new seedlings are most vulnerable during the first few weeks of their existence, while their stems are still green and succulent. Heat injury resulting from extremely high temperature on surfaces exposed to direct solar radiation takes a heavy toll, particularly among conifers. Cutworms and other insect larvae are particularly active during the beginning of cool season. This was one reason why some of herbs and seedlings died. It was noted that caterpilars and adult insects damaged the leaves of herbs and stems of seedlings, particularly in the young pine plantation, there were a few seedlings of *Schima wallichii* (DC.) Korth (Theaceae) and *Styrax benzoides* Craib (Styracaceae) eaten by caterpillars. In the forest site, *Aerva sanguinolenta* (L.) Bl. (Amaranthaceae), *Thunbergia similis* Craib (Acanthaceae) and *Impatiens violaeflora* Hk. f. (Balsaminaceae) were some herbs that were eaten by caterpillars and insects.

The growth of ground flora species, including tree seedlings in the pine plantation may have been inhibited by the chemicals in pine leaves. The leaves of pine trees in both young and old pine plantations suppress the development of ground flora. The

thickness of fallen young pine and old pine leaves was 3-4 cm and 9-11 cm; respectively. In addition, pine leaves take a long time to decompose, exude chemical substances which are able to inhibit the growth of the understorey communities. Besides that, frequent fires in eucalyptus and both pine plantations have resulted in the reduction of the ground cover of ground flora which is even barren in some areas. The same thing may have been happening in the eucalyptus plantation, where very few ground flora and tree seedlings were recorded. Similarly **Bernhard-Reversat** (1982) made a laboratory study of the decomposition of *Eucalyptus camaldulensis* litter. He found that there was abundant litter fall, but that the proportion of the fine material in the surface soil was small; the disappearance and mineralisation of the litter was relatively slow, but mineralisation of carbon continued in old litter; the litter was retained in the soil if there was sufficient clay in it, and there was a reduction of organic matter in the silty-clay fraction of the soil.

Table 5.8 shows that organic matter content in the evergreen forest was the highest and the lowest was in the young pine plantation. The nutrient content, especially percent nitrogen in the evergreen forest was the highest and significantly higher compared to the other sites, eventhough phosphorus and potassium (ppm exchangeable) in the plantations were higher. In plantation site, there was a secondary product from either pine or eucalyptus tree which has a negative impact that even may kill other organisms, whereas in the forest site it was not. It is also the fact that in plantation seed predator and dispersal are absence, resulting in lacking of seed in the soil so that even though in plantation it contains higher phosphorus and potassium (ppm exchangeble), those nutrients will remain in the soil since very few plants may absorb them. This could be explained that the forest site to have the highest species diversity is due to the high nutrient content, especially percent nitrogen in the soil and the absence of toxic substances in its surroundings. However, it is very difficult to conclude since the higher species diversity in some cases,

especially in tropical rain forest, can be found on nutrient-poor soil. **Whitmore** (1992) revealed that the most species-rich community is that at an intermediate stage in recovery from disturbance since it contains both pioneer and climax species eventhough it is under the scarcity of nutrients.

One of the paradoxes of tropical rain forest is that however luxuriant rain forest vegetation may appear its presence is not an indication of great fertility of the soil. Rain forest exists on a very small nutrient budget and it survives only by maintaining an almost closed nutrient cycle. The conversion of natural forests to plantations completely disrupted nutrient cycles, especially uptake by plants and from decomposition. In a recent study at Yurimaguas in the Peruvian Amazon it has been found that the biomass of decomposers dropped from 54 to 3 g m^{-1} in the conversion from natural forest to arable agriculture and plantations (**Whitten *et al.*,** 1987). In addition, **Smith** (1986) revealed that if organic materials were allowed to decay naturally, most of the nutrients are ultimately returned to the soil and living organisms. In the meantime, they remain unavailable to the vegetation. Substantial amounts of nitrogen remain bound away in the body proteins of the microorganisms responsible for the final decay. If this kind of dead organic decay takes place, some of the energy stored in them goes to nourish the large and small organisms that churn it and are chiefly responsible for maintaining its good physical properties. The concomitant incorporation of organic matter in the mineral soil is important in maintaining the capacity of the soil to hold water, oxygen and nutrients. Unfortunately, I did not find any references about a direct relationship between organic matter content and species diversity. However, **Chiras** (1991) explained that by increasing human desires, natural forests converted to other land uses, cultivation and plantations for example, brought the reduction up to 50% or even more of the soil capacity to support biological diversity. This is because most of the plantations are open ground so if the rain does come, water falls down on through the soil surface

and soil nutrients are washed away and the land gradually become useless. Therefore, the capacity of the soil to conserve various species in the area goes down dramatically, the only plants that can grow are ones which are tolerant to poor soil content.

In the pine plantation site there was evidence of frequent fires. Fire can directly or indirectly influence the growth of the ground flora and seedling communities. If fire occurs the ground flora, including tree seedlings and soil organisms are often killed. **Smith** (1986) explained that if dead organic matter is burnt, its stored energy goes mostly to heat the air and stored chemical nutrients are released. Some nitrogen compounds are volatilized and lost into the atmosphere. Most of the nutrient elements that are of essentially mineral origin are returned to the soil in a more readily available form than before. It is possible for some chemical nutrients, especially nitrates, nitrogen and potassium, to be made mobile enough by burning to accelerate loss by leaching and surface runoff.

Figure 5.6 shows that in the young pine plantation, forest and the regenerating gap regeneration was progressing where the number of young tree seedlings were higher than adult tree seedlings. However, in the fourth class-age, there were few tree seedlings present. It was, therefore, assumed that fire had occurred in the area, including the forest site. In contrast, in the mature pine and eucalypt plantations, it indicated that degeneration was occuring since the number of young tree seedlings was lower than adult tree seedlings. **Smith** (1986) explained that the profile of a stand is a good criterion of age distribution because trees of the same age grow in height at roughly the same rate, provided site condition are uniform; those that do not keep pace are suppressed and disappear. An uneven-aged stand is usually distinctly irregular in height; the greater the number of age classes, the more uneven the canopy. A stand is a contiguous group of trees sufficiently uniform in species composition,

arrangements of age classes, and condition to be a distinguishable unit. The internal structure of stands varies mainly with respect to the degree that different species and age classes are intermingled. The simplest kind of structure in exemplified by that of the pure, even-aged plantation consisting of trees of single species. The range of complexity can extend to a wide variety of combinations of age classes and species in various vertical and horizontal arrangements.

The fluctuation of the number of tree seedlings for each age-class structure is affected by many factors. True regeneration cuttings and natural lethal disturbances of similar magnitude determine the times when new trees appear or start active development on any given unit of ground area. Each new aggregation of tree seedlings so produced is an age class of trees all of essentially the same age. Differences in timing of regenerative events create various spatial patterns of age classes. The area occupied by a given age class can be of any size, provided that it is large enough that some new trees can continue to grow in height without being arrested by the expansion of the crowns of older adjacent trees.

Variation of soil moisture mainly depends on rainfall. The higher, the rainfall is, the higher, the soil moisture content is. All monthly soil moisture records showed that the forest site had the highest soil moisture content, significantly higher than those of the other sites (Figure 5.8). **Suwannaratana** (1994) asserted that soil moisture content is one of the most important factors affecting the structure and species composition of forests.

In this study, most soil properties were significantly different among sites, except silt content. The soil texture is mainly a sandy loam, except in the young pine plantation which was a sandy clay loam. Field capacity in the evergreen forest was the highest and significantly higher compared to the other sites. However, the

potassium content of soil in the regenerating gap was the highest while the lowest was in the mature pine plantation (Table 5.8). **Jammet** (1975) made a comparison between pine and eucalypt plantation (*Eucalyptus camaldulensis* Dehnh., *E. saligna* Sm. and *E. platyphylla* sp. (Mystaceae) and a unnamed species of pine) on sandy soils at Pointe Noire on the coastal plain of the People's Republic of Congo. The soils were weakly acid with a low clay fraction and poor in organic matter. There was better humification under the eucalyptus plantation a reduction of calcium and weak acidification under both, but especially under the pines where there was also a tendency of podzolisation.

Extensive plantations of fast growing tree species, including eucalyptus and pines will reduce the water yield in a region. By growing quickly, they consume much ground water and they may affect soil fertility under certain circumtances (**FAO**, 1988). Pine and eucalypt plantations have a high water usage per unit time, and this is consistent with their high rate of growth. One interesting observation made during the study was the changes in abundance for a perennial fern, *Pteridium aquilinum* (L.) Kuhn ssp. *aquilinum* var. *wightianum* (Ag.) Try. (Dennstaedtiaceae) in the regenerating gap and in the young pine plantation. This species is abundant in the beginning of the cool season and died off at the middle of cool season, after that they grew up again near the end of cool season. It was assumed that the fluctuation of percent cover was due to the availability of water in the soil.

Another interesting observation was of *Clitoria mariana* L. (Leguminosae, Papilionoideae) growing in the mature pine plantation. This was abundant from August to October 1994, but in December 1994, it died off completely. After fruiting, it completed it's cycle since it is a deciduous herb. At the same site, *Piloselloides hirsuta* (Forssk.) C. Jeff. (Compositae) was herb which found on June 1994. This herb has a tap-root which was able to regrow, especially after fire occurred. In the regenerating gap, *Shuteria involucrata* (Wall.) Wight & Arn. (Leguminosae,

Papilionoideae) and *Eupatorium adenophorum* Spreng. (Compositae) were abundant during the study.

Melastoma normale D. Don var. *normale* (Melastomataceae), an evergreen treelt, was found at all five sites and it was abundant in the regenerating gap. This species can be used for indicator of forest after disturbance. The fact that this species is commonly found in the area after the forest was cleared. This is partly because the soil has lost nutrients and becomes more acid and compacted. (**Whitmore**, 1992). It was found in the Philippines that *Trema orientalis* (L.) Bl. (Ulmaceae) restores phosphorus and *Melastoma cf. polyanthum* (Melastomataceae), restores potassium to the above ground biomass. This is presumably one reason that in the regenerating gap, it contains higher potassium in the soil.

Pine seedlings were few in the middle of the cool season but most of them died off at the end of this season because of environmental factors, e.g. pathogen and insect damage. In the young pine plantation, many young seedlings of *Styrax benzoides* Craib (Styracaceae) and *Schima wallichii* (DC.) Korth. (Theaceae) were common in the beginning of the cool season, and up to the end of this study a few seedlings can still be found. In the regenerating gap and forest, there were a few seedlings growing such as *Engelhardia serrata* Bl. and *E. spicata* Lechen. ex Bl. var. *colekrookeana* (Ldl. ex Wall.) O.K. (Juglandaceae), *Castanopsis tribuloides* (Sm.) A. DC. (Fagaceae), *Helicia nilagirica* Bedd. (Proteaceae), *Albizia odoratissima* (L. f.) Bth. (Leguminosae, Mimosoideae), *Vaccinium sprengelii* (D. Don.) Sleum. (Ericaceae), and *Wendlandia tinctoria* (Roxb.) DC. ssp. *floribunda* (Craib) Cowan (Rubiaceae). Most of them were found under the shade of *Eupatorium adenophorum* Spreng. (Compositae), especially in the regenerating gap. Figure 5.9 shows the seedling of *Engelhardia serrata* Bl. (Juglandaceae) growing healthy under the shade of *Eupatorium adenophorum* Spreng. (Compositae) which was found in the

regenerating gap. The density of seedlings was quite low, even though in general the relative growth rate (RGR) was higher compared to other sites. I would recommend that these species be used for reforestation project.

Figure 5.9. Seedling of *Engelhadia serrata* Bl. (Juglandaceae) growing under the shade of *Eupatorium adenophorum* Spreng. (Compositae) in the regenerating gap site.