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FOREST BIODIVERSITY
Importance of Species Composition Studies

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ABSTRACT

The vision of the Malaysian National Policy on Biological Diversity 1998 which states "to conserve Malaysia's biological diversity and to ensure that its components are utilised in a sustainable manner for the continued progress and socio-economic development of the nation" indicates that Malaysian forests harbour a very large portion of the nation's biodiversity and that forests have an important role to play in the country's socio-economic development and environmental stability. Thus, the degradation of the nation's biological diversity would have grave repercussions on the economy, environment and people. In the forestry sector, biological diversity not only provides timber and non-timber goods but also numerous other ecological services such as environmental stability which includes carbon sequestration, maintenance of hydrological regimes and recycling of nutrients, besides providing a habitat for wildlife. Much of the nation's biological diversity has yet to be documented and strengthened with scientific investigations. Current forestry issues include deforestation, conservation, intensity of sampling, sustainable forest management, economic valuation of goods and services, carbon sequestration, payment for ecosystem services and reducing emissions from deforestation and forest degradation. The applications of species composition studies are many, but those that are pertinent to forest biodiversity works include the determination of minimum sampling size in forest inventory as inventories are expensive and laborious in nature, the use of indices that are comparable between forests, consideration of minimum diameter for enumeration and measurement so as not to lose important information on biodiversity and estimation of biomass and carbon sequestration. The importance of predicting and enhancing forest regeneration is crucial to determine the next course of action by foresters in enriching the forests besides helping it to grow better

and faster for future yields. There is currently an underestimation on pricing of our timbers. Putting the correct timber species in the correct groups will thus help to increase revenue for the state governments. To date, some conservation works in the country have ignored the importance of some details in ensuring the success of the conservation programmes. These include re-introduction programmes of wildlife species and extension or creation of wildlife corridors. The justification for keeping conservation areas in the country, which are mainly forested areas, and the actions to be taken for its safe protection requires fundamental information such as species composition. Such information can be converted to suit many facets of understanding that deals with the current forestry and environmental issues such as economic value, carbon storage capacity and payment for ecosystem services.

INTRODUCTION

The diversity of flora observed in our forests today evolved through a very long history of life on earth. The evolution of many taxonomic groups is thought to have been due to the changes in land masses over geological time and climatic changes which created geographical isolation of groups of the same species, which over a long period of time, may have diverged and become new species. The diversity seen in our forests is due to the complexity of the forests themselves. Our Malaysian rainforests consist of up to five strata which comprise the emergent, canopy, understorey, shrubs and herbs layers constituting the ground flora. The stratified forests create many habitats and niches which may explain the plant diversity in terms of diverse habits, and also the animal diversity as plants provide habitats, shelter and food for the animals. Natural disturbances caused by storms, winds, lightning, landslides and floods usually create gaps which allow pioneer species to flourish, which are later replaced by climax species. The complexity of the structure of an ecosystem together with geographical barriers such as mountains and large rivers may cause speciation to groups of individuals of the same species. Despite the presence of different strata within these forests, light is available all year round and from different angles depending on the time of the day for the luxuriant growth of plants of different habits such as epiphytes, climbers, shrubs, herbs and trees.

There are 16 different forest types or formations in the tropics, differing in factors such as altitude, soil type, topography, inundation and pH, all of which have their own assemblages of plant species. Of these 14 types are found in Malaysia (Whitmore, 1975). The presence of specialized habitats such as peat swamps, limestone hills and mangrove swamps are also suggestted as being reasons for the high species diversity in our forests; with speciation arising through adaptation to these specialized habitats. Malaysia has an estimated 20.62 million hectares of natural forests in 2012, covering 62.5% of the country's land area. Peninsular Malaysia still has 43.9% (5.79 million hectares) of its land under forest while 4.31 million hectares and 10.52 million hectares are in Sabah and Sarawak, respectively (Transparency International Malaysia, 2014).

BOTANICAL WORKS AND NATIONAL POLICY ON BIOLOGICAL DIVERSITY

Botanical interests in Malaysia started as early as the 19th century with the coming of the British. Some of the earlier important works include those of Miquel (1855-1859) in Sumatera and Hooker (1872-1897) in India, which also include many taxa common to Malaysia. The first comprehensive documentary work on Malayan flora on a systematic basis was by King (1889-1902) and King and Gamble (1904-1909). This subsequently became the basis for later work on systematics and floristics in Malaysia. The first comprehensive documentation of flora in the country was by Ridley (1922-1925) which though now outdated remains relevant for botanical works today. The first comprehensive account of timber species in the Malay Peninsula for foresters was by Foxworthy (1921) and Symington (1943). It was about this time that Gibbs (1914), Merrill (1929) and Keith (1937), amongst others, started contributing to the documentation of the flora of Borneo; where the latter produced the first comprehensive documentation of timber species in Borneo (Faridah-Hanum & Lesmy Tipot, 1993). Later works include that by Whitmore (1972, 1973) and Ng (1978, 1989) who prepared the *Tree Flora of Malaya* (Volumes 1 to IV) and the on-going *Tree Flora of Sabah and Sarawak* (eg. Soepadmo & Saw, 2000; Soepadmo *et al.*, 2011; Soepadmo *et al.*, 2014) and *Flora of Peninsular Malaysia* (Kiew *et al.*, 2010, 2011, 2012; *Parris et* *al.*, 2010). All these works form the basis of later works related to forestry in the country, especially in forest inventory, plant species diversity and biodiversity conservation in Malaysia. The vision of the Malaysian National Policy on Biolgical Diversity 1998 which states "to conserve Malaysia's biological diversity and to ensure that its components are utilised in a sustainable manner for the continued progress and socio-economic development of the nation" indicates that Malaysian forests harbour a very large and important portion of its biodiversity and that forests have an important role in the country's socio-economic development and environmental stability.

Biological diversity is simply defined as the variety of organisms and the ecological complexes they are part of, and is usually considered at three levels, which are, species diversity, genetic diversity and ecosystem diversity. Malaysia is the 12th most megadiverse country in the world in terms of species richness and endemicity. The flora of Malaysia is exceedingly rich and conservatively estimated to encompass 12,500 species of flowering plants. There is high diversity of orchids with >3000 species and 536 species of palms, 1,167 species of ferns and fern-allies and 832 species of bryophytes. Biological diversity has important economic, environmental and social implications for the nation, especially in the forestry and environmental sectors. In the forestry sector, biological diversity not only provides timber and non-timber goods but also numerous other ecological services such as environmental stability which includes carbon sequestration, maintenance of hydrological regimes and recycling of nutrients, besides providing habitats for wildlife and microorganisms. Much of the nation's biological diversity has yet to be studied, documented and strengthened with scientific investigations. Lack of scientific based data impedes efforts to better utilise the nation's biological resources in various fields including forestry. Emerging and important forestry issues include deforestation, conservation, sampling, sustainable forest management, economic valuation of goods and services, carbon sequestration, payment for ecosystem services (PES) and Reducing Emissions from Deforestation and Forest Degradation (REDD).

SPECIES COMPOSITION

Our Malaysian forests house a trove of species of various characteristics, sizes and shapes, uses and functions. It is impossible to enumerate and quantify everything in the forests as the tropical rainforest is usually very vast and complex. Despite that, efforts have been made to sample forests for various reasons such as plant inventory, pre-felling, post-felling, conservation, forest regeneration, forest sampling intensity, monitoring the changes in vegetation, biodiversity studies and inferring forest environmental conditions, amongst others. One of the most practical parameters that can be used for these purposes is species composition. Species composition can be generally defined as how many different species make up the community in a given area, and how many individuals make up the species. The former can also mean richness while the latter is considered as abundance. Studies in species composition provide basic information on the forest bodiversity and can give a picture of the past and current forest and predict the future, besides giving answers that are scientifically based for considerations of many forestry related planning and management, policy and activities that concern the forest, and re-evaluation of some current practices pertaining to assessments of our forests' biodiversity. Prance (1977) suggested that data collected from these studies were not only useful for the study of floristics and evolution but also of vital importance for the conservation and utilization of tropical resources.

RELEVANCE TO FOREST BIODIVERSITY WORK

What Size Sampling Plots for Tropical Forest Plant Diversity Studies?

Efforts to comprehend the magnitude of the richness of forest biodiversity have been mainly done through plot sampling and species composition studies. Apart from representing the plant species composition of the forest, the sample plot is also important in capturing the dynamics, production and regeneration capabilities in terms of number, size and species of a particular forest type or forest stage of succession. In biodiversity terms, a suitable sample plot size must be big enough to be able to capture the diversity of a particular forest type at a particular time. To date however, the sample plot sizes used have been varied and this makes sampling inconsistent and comparison difficult. Examples include those of Okuda *et al.* (2003) who used a 6-ha plot in Pasoh, Negeri Sembilan, Bradford *et al.*(2014) who used a 25-ha plot in Australia and Ostertag *et al.* (2014) who used a 4-ha plot in Hawaii. As plot setting and forest inventory are costly and time consuming activities, one often encounters the question 'What sample plot size is sufficient to capture tropical forest species diversity"? Quite a number of past researches in Malaysia had been undertaken to find out how much diversity is captured in a 1-ha plot in a forest (eg. Abdul Hayat *et al.*, 2010, Faridah-Hanum, 1999; Faridah-Hanum *et al.*, 1999a; 1999b; Faridah-Hanum & Zamri Rosly, 2000; Hikmat *et al.*, 2008). Prance (1977) emphasized the importance of following a standardised inventory and hence many studies conducted in other parts of the tropics have also mainly used 1-ha plots. These include the works of Ferreira & Prance (1998), Milliken (1998), Phillips *et al.* (1994), Poulsen *et al.* (2006) and Strasberg (1996).

While results showed substantial species diversity in the 1-ha plots, we were interested to find out if a larger sample plot size would be able to capture a greater range of diversity of a forest type. To determine the size of the sample plot, we used the species accumulation curve based on the basic species composition obtained from various forests. For example, a study by Saiful *et al.* (2014) in a hill dipterocarp forest and Ghollasimood *et al.* (2011a) in a coastal hill forest showed similar discrepancies. As seen in Figures 1 and 2 the curve did not reach the asymptote at 1-ha sampling size but showed an increasing trend. For the hill dipterocarp forest at the Ulu Muda Forest in Kedah, all three species-accumulation curves showed no tendency to flatten out as new additional species continued to increase slowly within the study area (Figure 1) (Saiful *et al.*, 2007) while the species accumulation curve for a coastal hill forest on Langkawi Island also did not reach the asymptote at 1 –ha (Figure 3) (Abdul Hayat *et al.,* 2010).

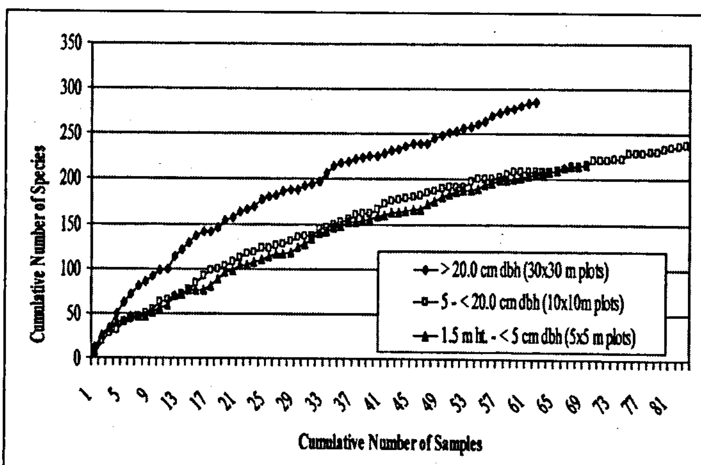

Figure 1 Species-accumulation curves for the primary hill dipterocarp forest at Ulu Muda Forest Reserve, Kedah. Note that all three curves show no tendency to flatten out at 1-ha

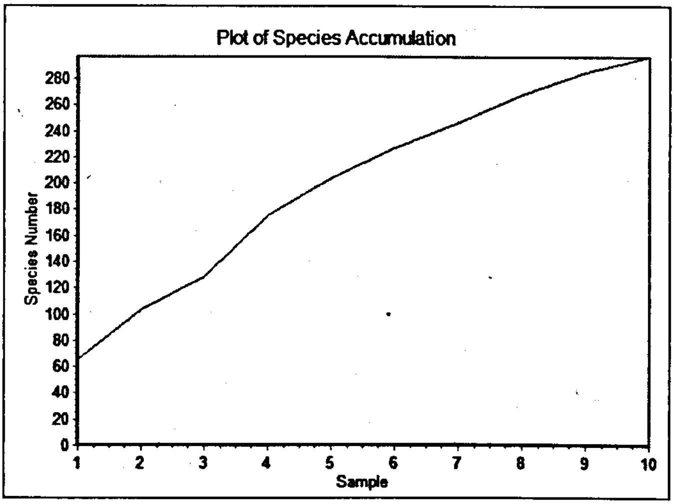

Figure 2 Species accumulation curve of 1-ha of supervised logged-over forest in Ulu Muda Forest Reserve, Kedah

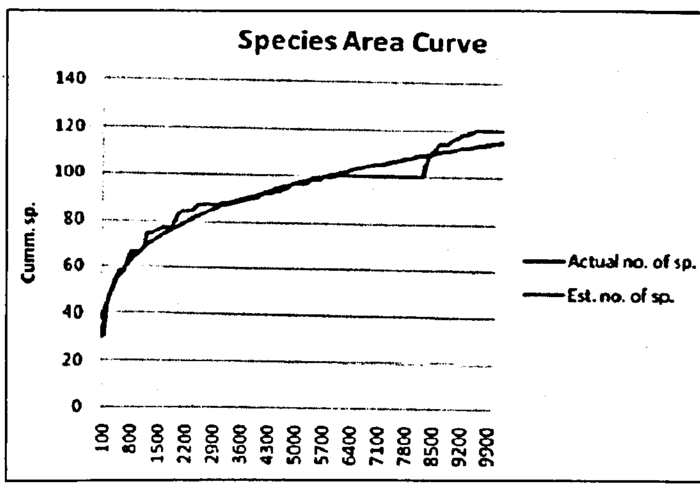

Figure 3 Species area curve for a 1-ha plot in the coastal hill forest at Pasir Tengkorak, Langkawi

However in less diverse forests such as the mangroves (Figure 4), it was found that the asympote was reached in less than a 1-ha plot (Faridah-Hanum et al., 2012). At the 17th plot (0.7 ha), the graph started to level off and it was not until the 25th plot (1 ha) that the graph showed an increment of just one species. The increment of one species is probably not worthwhile to consider increasing the sampling area when taking into account the time and cost for the establishment of the additional subplots (0.3 ha). Roberts-Pichette and Gillespie (2001) stated that sampling is sufficient when none or very few species are added with each successive quadrat that is sometime after the curve starts to flatten. Seaby and Henderson (2007) also stated that when a species accumulation curve approaches an asymptote, it shows that sampling is adequate to collect most of the species present; the asymptotic value is a measure of the total species complement. It is thus assumed here that 0.7 ha is capable of capturing the species in the mangrove forest at Marudu Bay. If sampling efforts increase, more of the species found in this forest type can be captured until eventually only the rarest species or occasional ones will remain unrecorded, thus additional efforts can increase the number of species recorded. Considering that the mangroves is a muddy and difficult place to work in, this is indeed a result that would be welcomed by many researchers of mangroves as a sampling size smaller than 1-ha is considered sufficient to capture the mangrove diversity.

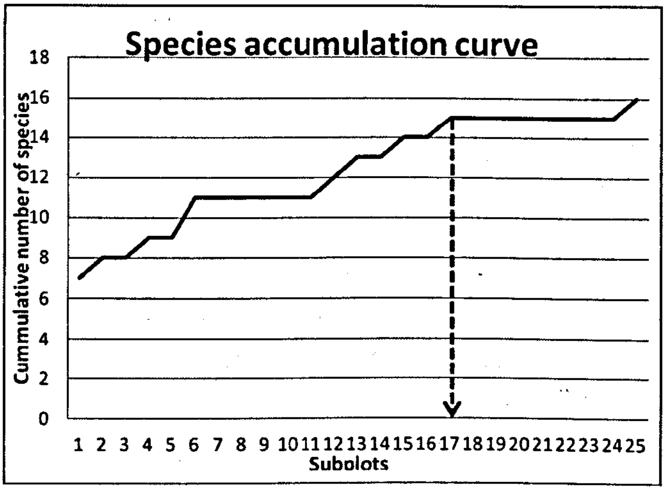

Figure 4 Species accumulation curve of a mangrove forest in Marudu Bay, Sabah

Figures 5 and 6 show the accumulative number of species with increasing hectarage within the 5-ha plot in both an inland forest (Faridah-Hanum *et al.*, 2008) and coastal hill forest (Ghollasimood *et al.*, 2011a). In Figure 5 it can be seen that the total number of species enumerated increased from the first to the fifth hectare, within a range of 9 to 35 species. However, the number of incremental species decreased with every additional hectare and only amounted to 9 species in the fifth hectare. If the size of the plot was increased to more than 5-ha the increment in the number of species would probably be less than nine and thereafter remain constant (Faridah-Hanum & Philip, 2006). Similarly, the number of genera increased from three to five with increasing hectarage but did not increase further in the fifth hectare. In terms of family, there was only one addition for each of the first four hectares and none in the fifth hectare. Hence the most ideal sample plot size would be a larger plot to capture greater species diversity, which is definitely not 1-ha but an area of 5-ha for an inland dry tropical lowland logged-over forest. Interestingly enough, an earlier study encompassing a 50-ha plot in a Virgin Jungle Reserve at Pasoh also found a contiguous area of 5-ha sufficiently large to sample and detect tree distribution by species group and class size with 95% probability of finding trees belonging to the same species group (Wan Mohd. Shukri *et al.*, 1997; Manokaran & LaFrankie, 1990).).

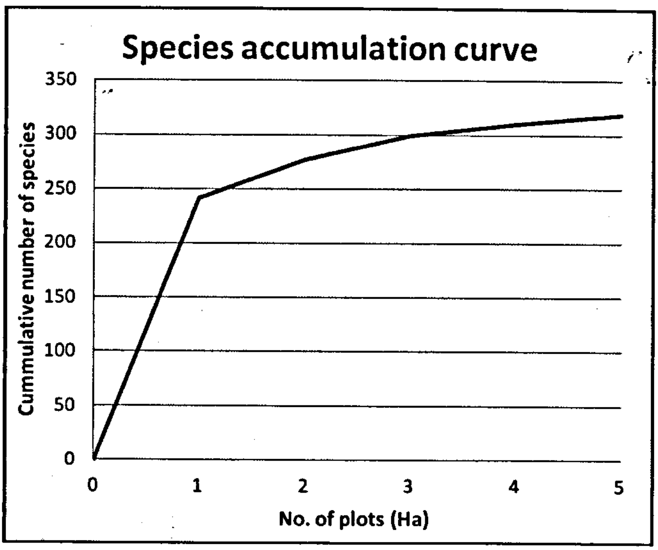

Figure 5 Species accumulation curve in a 5-ha plot of a tropical logged-over forest at Ayer Hitam, Selangor.

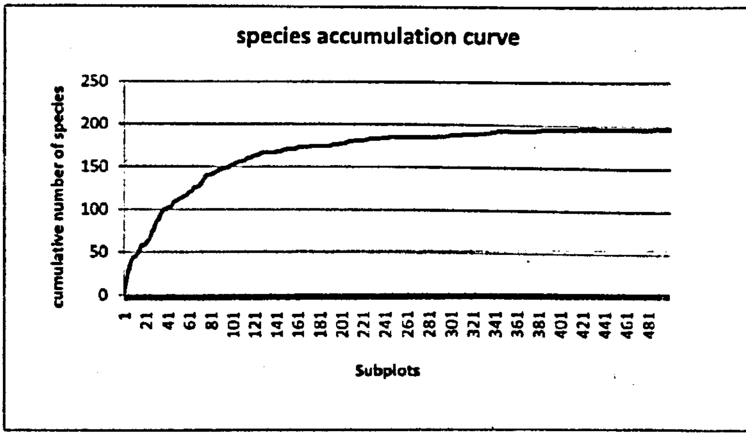

Figure 6 Species accumulation curve based on five 1-ha plots in a coastal hill forest in Pulau Pangkor, Perak

We found a plot size of 5-ha sufficient to capture family and generic diversity of a tropical lowland logged-over forest (Faridah-Hanum & Philip, 2006). A minimum size of 5-ha is recommended to capture species diversity of the same forest type elsewhere. This is supported by the richness presently captured in a 5-ha plot at Ayer Hitam, not only in terms of the tree species recorded but also the amazing list of Peninsular Malaysia endemics, such as, *Actinodaphne pruinosa, Diospyros foxworthyi* and *Sarcotheca monophylla,* as well as new records for the state of Selangor, such as, *Actinodaphne sphaerocarpa* and *Calophyllum pulcherrimum,* coupled with rare and uncommon species such as *Ptychopyxis caput-medusae.*

We also found that in the coastal hill forest at Pulau Pangkor, the species accumulation curve began to level off at the 3rd hectare (Figure 6), suggesting that it is sufficient to capture the maximum proportion of species diversity; 1-ha is not enough to do this (Figure 3).

We also recommend a minimum plot size of 1-ha to capture the species diversity of a virgin hill dipterocarp forest as exemplified by the work in the Tranum Forest Reserve, Pahang (Faridah-Hanum *et al.*, 2009). There was no tendency of an increasing number of species with increasing area (Figure 7). The cumulative species-area curve for trees > 1 cm dbh reached its asymptote at 391 to 426 species using Chao 1 species richness estimator. The point of inflection for all curves was between 0.8 and 1 ha, corresponding to 80 and 100 quadrats (size 10m x 10m), respectively.

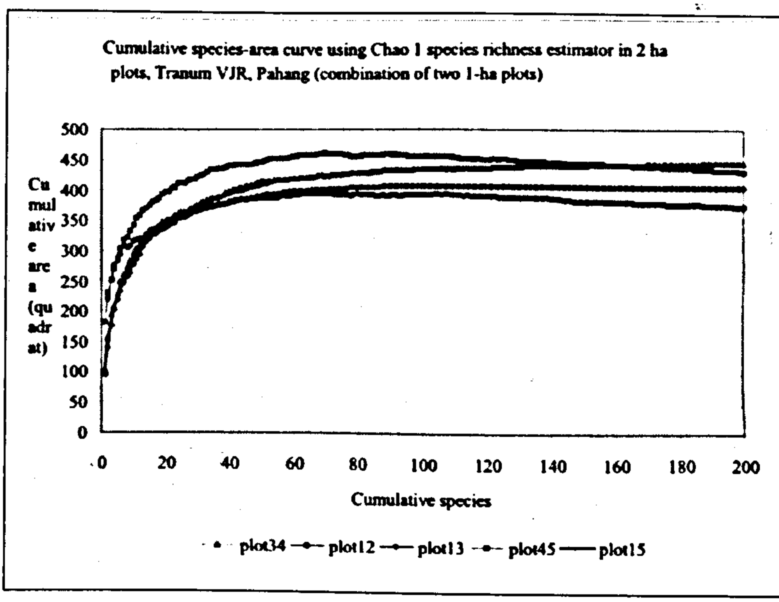

Figure 7 Cumulative species-area curve using Chao 1 species richness estimator in 2 ha plots, Tranum VJR, Pahang (combination of two 1-ha plots) (trees > 1 cm dbh)

These findings shed light on a frequently asked question on the recommended size of forest sampling plots to capture diversity 'How much is enough?' The findings also proved that the general perception of logged-over forests being poor forests is misleading. The richness of logged-over forests is often underestimated and as a result many have been given way for development. This situation is excellently exemplified by the Ayer Hitam Forest in Puchong (originally at ca. 10 000 ha) which eventually paved way for highways and housing projects. Now the remaining 1176 ha, is the only large chunk of green lung left in the Klang Valley and it houses at least 11% of the total tree species found in Peninsular Malaysia (Faridah-Hanum, 2009).

Determining Plant Species Indices Through Species Composition

The basic idea of a diversity index is to obtain a quantitative estimate of biological variability that can be used to compare biological entities, composed of direct components, in space or in time. There are several ways to estimate plant species diversity, such as, the Alpha Fisher's Index, Margalef's Index and Simpson's Diversity Index. Earlier on in our research (Saiful *et al.*, 2007) we found that there were shortcomings in some indexes, such as, the Simpson Index being heavily dependent on the most abundant species and not able to discriminate minor variations in species abundance patterns and not able to discriminate habitats while Alpha Fisher's Index increased with small samples (< 500 individuals). Since we usually deal with a large number of individuals in the forest (>1000), Shannon's index has more discriminative ability in distinguishing habitats than the Simpson Index and we also found it to be more informative when comparing between sites. An example is illustrated in Table 1. Examples of other works using Shannon's index include Banerjee & Srivasta (2010) and Amaral *et al.* (2013).

Table 1 Species diversity indices for different habitat types of the study site (Simpson index (Ds), Shannon index (H'), Hmax (= In S), Shannon Evenness). Shannon values with similar superscript are not significantly different from one another by t-test

Habitat	Species (S)	Stems (N)	Ds	H'	H max	E
Stream	129	241	0.98	4.79*	4.85	0.99
Hillside	252	772	0.99	5.07b	5.52	0.92
Ridge	269	907	0.99	5.02b	5.59	0.90
Ridgetop	178	490	0.98	4.75*	5.18	0.92
All strata	421	2410	0.99	5.61	6.04	0.93

Source: (Saiful *et al.*, 2007)

When initiating this work in the different forests around the country 15 years ago, the author found that she could not do it alone as there was too much to do as well as due to financial constaints as it involved a lot of time and field assistants. She thus decided to involve colleagues and students from both Universiti Putra Malaysia and Universiti Kebangsaan Malaysia. This strategy worked and the project is currently still on-going and there are also some results of Shannon-species diversity index for both virgin to logged-over forests of various forest types around the country, shown in Table 2.

Table 2 Comparison of Shannon index, H' between different forests

Site	Shannon Index H'	Source
Mata Ayer VJR, Perlis	3.98	Hikmat *et al.* (2008)
Bk.Bauk VJR, Terengganu	4.21	Hikmat *et al.* (2008)
G. Pulai VJR, Johor	4.52	Hikmat *et al.* (2008)
Sg. Pinang FR; Perak	3.99	Ghollasimood *et al.* (2011a)
Pasir Tengkorak, Langkawi	5.42	Abdul Hayat *et al.* (2010)
Tranum FR, Pahang	5.36	Awang Noor *et al.* (2008)
Ulu Muda, Kedah Compt. 27	3.71	Faridah-Hanum *et al.* (1999)
Ulu Muda, Kedah (Hill Dipterocarp Forest) Compt. 25, 26, 27, 28, 29	5.62	Saiful *et al.* (2007)
Ulu Muda, Kedah (12-years after logging)	5.3	Seyed *et al.* (2014)
Matchincang FR, Langkawi	4.33	Raffae (2003)
Kilim-Kisap, Langkawi	3.0	Fatheen Nabila *et al.* (2012)
Taman Negara, Merapoh, Pahang	5.44	Norziana (2003)
Lesong VJR, Pahang	4.96	Suhaili (2004)
Lepar FR, Pahang	5.05	Mohd. Ridza (2004)
Tersang FR, Pahang	5.21	Mohd. Ridza (2004)
Ayer Hitam FR, Selangor	4.74	Faridah-Hanum & Philip (2006)

Diameter Size Consideration in Plant Diversity Studies

Inventory work in the forest is labour intensive, expensive and difficult. Depending on the purpose of the inventory, whether it is for pre-felling, post-felling, plant diversity or ecological sampling, various diameters are used as a base-line. If trees are measured at larger diameters such as >30cm, then there will be less trees enumerated, measured and identified in a given area; hence it would be less costly, and involve less work and less time to complete the inventory. However, in plant diversity studies information is lost when using this standard though we do not know by how much. Thus the team embarked on a research project with the objective of finding out how much biodiversity information is gained by lowering the diameter of trees sampled in the forest. Table 3 shows the average number of taxa, across all categories, on a per hectare basis, for trees > 1 cm and for trees > 5. Except for the number of individuals per hectare, which is nearly halved when > 5 cm dbh was considered, the number of families, genera and species remained almost the same. This means that by considering only trees with a diameter of 5 cm and above, there is an underestimation of 5% in terms of family, 5.3% in terms of genera, 8.5% in terms of species find and 42% for the number of individuals. Thus, for regeneration stocking of the forest measuring trees > 1cm is worthwhile as it does not only give information on the species composition but also on abundance and the estimated value of timber in the next cycle, if in a production forest. It is also better for the much needed biodiversity information of a particular forest.

Table 3 Average taxa and stem composition per ha at Tranum VJR, Pahang

Tree Dbh	No. Family	No. Genera	No. Species	No. of Individuals
> 1 cm per ha	60	152	388	4475
> 5 cm per ha	57	144	355	2604

Species Ccomposition in Estimating Biomass and Carbon Storage

The amount of tree biomass recorded in Peninsular Malaysia depends on the forest types where the studies were conducted. These reported studies mostly use the allometric equations derived by Kato *et al.* (1978) amongst others to estimate tree biomass in their study areas. All the values depend on the species composition studies that usually measure all trees at diameter breast height (DBH) (1.3 m above ground) where the DBH is included in the equation of biomass. For instance, the tree above ground biomass in a peat swamp forest in Pekan, Pahang varied from 332.40 to 273 t/ha (Nizam *et al.*, 2006, 2009) and was contributed by large trees in the forest while Nurul-Shida *et al.* (2014) found the tree above ground biomass in a logged-over lowland dipterocarp forest at Ayer Hitam Forest to be 232.7 t/ha or 116.3 t C/ha, mainly contributed by trees in DBH class >30cm, in both the dipterocarp and non-dipterocarp groups.

Tree above ground biomass value can also give an estimate of the carbon being sequestered. This estimation can be obtained by assuming that 50% of the estimated biomass is carbon sequestered by the forests (Brown & Lugo 1982). We estimated the above ground biomass for the mangrove forest in Marudu Bay in Sabah, through species composition study, (Table 4) to be 98.4 t/ha (Table

5) and thus the carbon sequestered by the mangroves was estimated at ca. 49.2 t C/ha (Faridah-Hanum *et al.*, 2012). A similar study using species composition estimated the tree above ground biomass of Pulau Langkawi to be 115.07 t/ha (Norhayati & Latiff, 2001). Hence, the estimation of carbon sequestered by the mangroves of Pulau Langkawi was ca. 57.53 t C/ha. Pidgeon (2009) stated that mangrove forests sequester as much as 50 times the amount of carbon in their soil per hectare as a tropical forest. Thus, the long-term sequestration of carbon by one square kilometer of mangrove forest is equivalent to that in fifty square kilometres of an inland tropical forest.

Table 4 Stand density in 1-ha plot at Marudu Bay mangroves, Sabah

Species	Stand density (no. stems./ha)
Rhizophora apiculata	757
Rhizophora mucronata	511
Xylocarpus granatum	449
Bruguiera parviflora	348
Avicennia alba	175
Ceriops decandra	84
Heritiera littoralis	13
Sonneratia alba	11
Avicennia marina	10
Excoecaria agallocha	7
Bruguiera gymnorrhiza	1
Intsia bijuga	1
Xylocarpus moluccensis	1
Total	**2368**

Table 5 Above-ground biomass of trees by species in 1-ha plot of a mangrove forest at Marudu Bay, Sabah

Species	Biomass t/ha
Rhizophora mucronata	46.7
Rhizophora apiculata	28.8
Avicennia alba	11.4
Bruguiera parviflora	6.6
Xylocarpus granatum	2.8
Sonneratia alba	0.8
Excoecaria agallocha	0.3
Ceriops decandra	0.3
Avicennia marina	0.3
Heritiera littoralis	0.1
Xylocarpus moluccensis	0.1
Intsia bijuga	0.1
Bruguiera gymnorrhiza	0.1
Total	**98.4**

Other documented biomass works include those of Raffae (2003) who reported the total above ground biomass of another inland forest in Langkawi to be about 529 t/ha or 264.5 t C/ha. Mat-Salleh *et al.* (2003), who conducted a similar study at a beach forest in Cape Rachado, Negeri Sembilan, estimated the total above ground biomass of trees at 233.4 t/ha or carbon storage of 116.7 t C/ha, while the biomass of a montane forest in Fraser's Hill was estimated at 218.7 t/ha or carbon storage of 109.3 t C/ha (Petol 1994). Hikmat *et al.* (2009) who estimated the above ground biomass of three Virgin Jungle Reserves (VJR) found them to be 402.6 t/ha at Mata Ayer VJR, 551.2 t/ha at Bukit Bauk VJR and 320.6 t/ha at Gunung Pulai VJR, hence the carbon storage was estimated at 201.3 t C/ha, 275.6 t C/ha and 160.3 t C/ha for the individual VJRs, respectively. Here, the carbon storage capacity of these forests was estimated from the biomass values obtained using the species composition information.

Predicting and Enhancing Forest Regeneration Through Species Composition Studies

Species composition can also show the structure and regeneration status of the forest. When a forest is severely disturbed by harvesting or natural forces, it will undergo succession where the pioneer species will make up the new forest composition. These early successional species are generally light demanding. Species composition also shows whether the forest is young, mature or climaxed. The stage of regeneration of the logged-over forest stands can also be determined through recovery assessment (Mohd Zaki *et al.,* 2004) and is deemed important to support sustainable forest management efforts in ensuring sustainable timber production for the country. A large number of stems of species from the family Dipterocarpaceae are also an important indicator of the logged-over forests' regeneration potential, and this can be obtained through species composition work. The dipterocarps are often the most affected during logging as they are sought after for their volume due to their large sized boles. It was shown to be necessary for forest stands to be planted with some dipterocarp species to assist in quicker recovery in the Pasoh (Mohd Zaki *et al.*, 2006) and Senaling Inas Forests (Ashari *et al.*, 1992). If forests had been left to recover naturally after the Malayan Uniform System (MUS), it was shown that it would have taken approximately 40 years for the forests to reach their original state (Mohd Zaki *et al.*, 2004). Wyatt-Smith (1995) showed that the presence of dipterocarp species in recovering forests is crucial in determining the rate of species dominance recovery. Having good knowledge of the species composition after past harvestings would help in considering forest recovery procedures and planning forest management activities. If most stands were dominated by many non-dipterocarp species after harvest, there is also a need to replant with dipterocarp species for enrichment purposes. The rehabilitation project carried out in an area can be viewed as a way for quicker recovery of the stands (Mohd Zaki *et al.*, 2006). Samsudin *et al.* (2010) showed that the stocking and species composition of two second growth forests in Peninsular Malaysia were not as predicted and still able to produce an economic harvest in terms of total timber yield within the specified rotation cycle. These forests have not fully recovered in terms of stocking of commercial species and species composition has been altered favouring higher dominance of non-dipterocarp species. Such information is essential to improve planning and management of this resource, with the aim of enhancing future productivity. Another study by Okuda *et al.* (2003) showed that despite the number of stems per hectare and the basal areas of medium-sized trees (10-30cm DBH) being higher in the regenerating forest that was logged 41 years earlier than the primary forest in Pasoh, the diversity in tree species, estimated through species composition studies, was shown to be affected by logging in the regenerating forest.

In another study at the Ayer Hitam Forest, it was found that the family Dipterocarpaceae contributed about 8.5% of the trees recorded in the study plot. The work of Faridah-Hanum (1999), Faridah-Hanum and Philip (2006) and Nurul-Shida *et al.* (2014) showed that while the Ayer Hitam Forest is regenerating slowly it still has good regeneration potential although it lacks large sized trees, mainly the dipterocarps as shown in the vertical stratification (Figures 8,9 and 10). Ayer Hitam was last logged 60 years ago in 1955 under the Malayan Uniform System (MUS) where all mature trees of commercial species above 45 cm diameter at breast height (DBH) were removed in one single harvesting. This was followed by poison girdling and climber cutting (GCL) of defective relics (old-growth) and non-commercial species. A quicker recovery for the Ayer Hitam Forest would be through enrichment planting with the dipterocarp species and appropriate forest management practices.

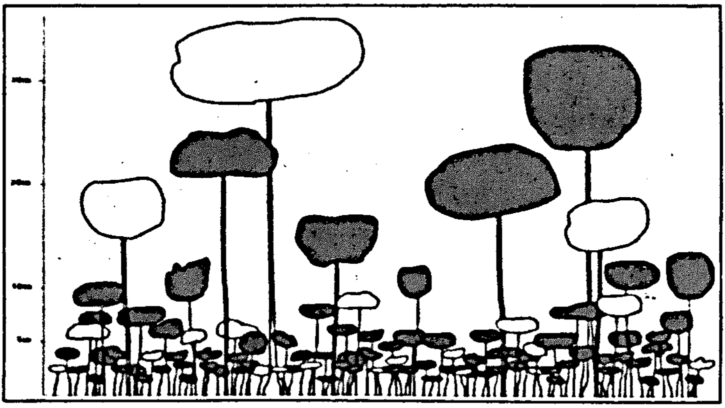

Figure 8 Profile diagram of the Ayer Hitam Forest Reserve. The diagram represents community structure of two tree groups: a) white crown — Dipterocarp group; and b) grey crown — Non-Dipterocarp group. Note that only trees over 2 metres are shown

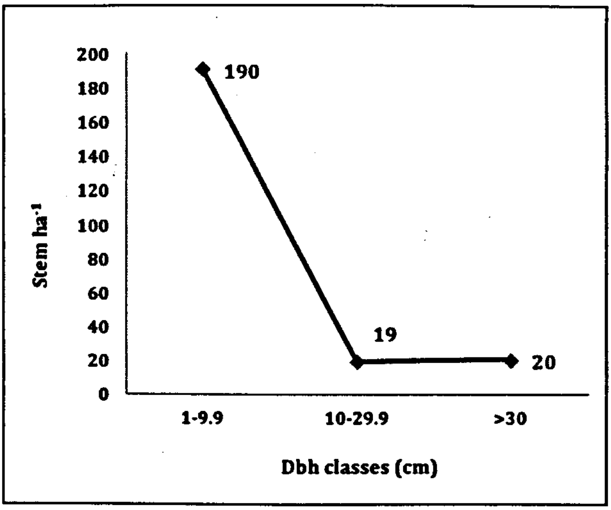

Figure 9 Stem density distribution by DBH classes of Dipterocarp trees

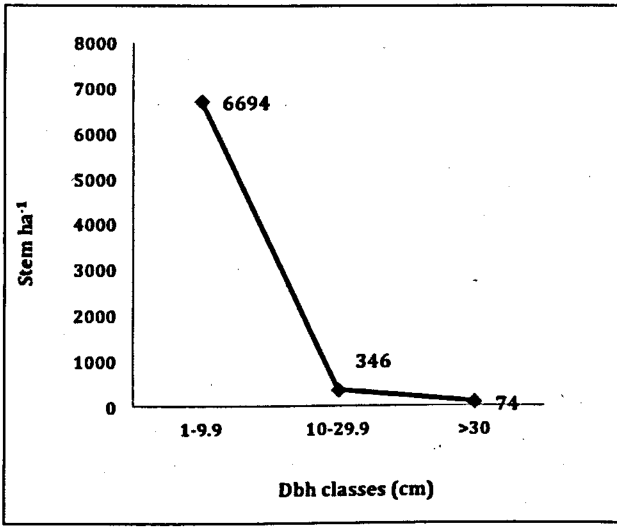

Figure 10 Stem density distribution by DBH classes of Non-Dipterocarp trees

Species Composition and Monetary Value of Forest

Before any reasonable monetory value can be put on a forest, we believe that the species composition of the forest must first be well studied. The question we hoped to answer was whether knowing the detailed composition of tree species can give a better monetary estimate of a forest to be harvested? To do this, the stumpage value i.e. the value of standing trees at the stump was used and compared between several forests.

The total stumpage value for all trees > 15 cm dbh in Ulu Muda Forest, Kedah was RM 41,445.30 per ha (Faridah-Hanum *et al.*, 1999a). The stumpage value obtained from this study was higher as compared to the Ayer Hitam Forest at RM 14,500.36 per ha (Timin, 1997), despite the species composition at Ulu Muda Forest Reserve being lower with 77 species per ha (Faridah-Hanum *et al.*, 1999a) as compared to the Ayer Hitam Forest Reserve which had

177 species per ha (Faridah-Hanum *et al.*, 1999b, 1999c). Most of the stumpage value obtained in Ulu Muda was contributed by only 4.3% of the total number of trees present per ha which were all in diameter classes > 45 cm dbh. The total stumpage value obtained in Ulu Muda was almost double the value obtained by the conventional pre-felling inventories done in the same study area (Awang Noor & Mohd. Shahwahid 1995). This difference in stumpage value can only be explained by the use of different inventory methods, where in the Ayer Hitam case, 10 % pre-felling inventory sampling was employed but in Ulu Muda, all trees > 15 cm dbh were sampled. The loss of revenue to the state government which is usually caused by the undervaluation of forest resources in forest concessions can actually be overcome if the Forestry Department insists on a 100% pre-felling inventory for all trees >15 cm dbh.

The next question asked is whether a species composition study is necessary to improve the monetary value estimation of a forest or if it would suffice to just measure larger diameter trees? Higher species composition does not necessarily fetch higher monetary value for the forest and this is further supported by another study at Tranum Forest Reserve, a hill dipterocarp forest in Pahang (Awang Noor *et al.*, 2008) Present evidences undoubtedly give the following answers viz., it will help to place the species in the correct groups and thus better assessment of the right pricing, which would not result in over-estimation or under-estimation of the monetary value of the forest, it will show the stocking of the forest, and also show which dbh classes and species groups are contributing the most stumpage. There is no doubt that many a time a forest is under estimated in terms of its monetary value because of the constraints in sampling and the high costs incurred, amongst others. However, if the government desires to increase its net revenue from forests it is recommended that a detailed study on the species composition be carried out. It is hoped that this will help in getting optimum monetary benefits from our forests.

Species Composition Studies for Conservation Work

For reintroduction of wildlife species

The work at Ayer Hitam FR has shown how plant species composition study is fundamental for the assessment of habitat suitability prior to the release of wildlife (Ebil & Faridah-Hanum, 2008; Lepun *et al.*, 2001). It included not just the evaluation of the flora that would be suitable as their food and their predictable productivity index but also the population size that the forest could handle for the long term survival and reproduction of gibbons (*Hylobates lar*) if reintroduction were to be done. The population of gibbons is very small in the Ayer Hitam Forest (Shahidin, 2006) and vital components of survival for reintroduction need to take into consideration food sources which are from plants, water, shelter and space simultaneously (Ebil, 1982).

For wildlife corridor establishment

The fundamentals established through many works such as that of Faridah-Hanum (1999), Faridah-Hanum and Philip (2006), Mohd Zaki *et al.* (2006) and Lepun *et al.* (2001) have shown the importance of tree species composition study for the establishment of a wildlife corridor and rehabilitation works, as that in Ayer Hitam and elsewhere. In 2003, a wildlife corridor established with planting of selected fruit trees in a highly degraded area of the Ayer Hitam Forest, through an international grant secured from the Forest and Forest Products Research Institute, Tsukuba, Japan, has shown tremendous increase in the number of wildlife species habituating and visiting the forest, especially birds. There were 180 species of birds from 38 families, mainly fruit and insect eaters, recorded. The diversity of birds recorded is comparable to other primary forest areas (Mohamed Zakaria & Abdul Rahim, 1999) with 24 species categorized as Protected and Totally Protected. This success story has been repeated many times with tree planting activities in the Ayer Hitam Forest until today.

Through Floristic Studies

Whenever detailed studies were conducted in a tropical rainforest, an extraordinarily large proportion of species have been found to be rare, in the sense that they exist in very low population densities (Ng & Low, 1982). The investigation of endemism and the conservation status of such species is getting increasingly important with issues of plant conservation to be dealt with under current forest management practices. Our studies in the Ayer Hitam Forest over the past 15 years produced a high number of new records of endemic species showing that this area needs to be studied further and that it should be fully conserved for research and conservation purposes (Faridah-Hanum 1999; Faridah-Hanum & Philip, 2006). The 5-ha plot also recorded 33 endemic tree species for Peninsular Malaysia and 30 new records (or recorded for the first time) for the state of Selangor. Six rare tree species in Peninsular Malaysia were also found in this plot together with one uncommon species, *Artocarpus lowii* (Faridah-Hanum *et al.*, 2001a, 2001b; Turner, 1995; Corner. 1952). The results also showed the Ayer Hitam Forest to house 11% species, 28% genera and 51% families of the total tree taxa found in Peninsular Malaysia.

The diversity captured in a logged-over forest, as exemplified by the Ayer Hitam Forest, is sufficient to display the arrays of plant diversity which not only constitute the green lung of the Klang Valley but also display patterns of distribution which are interesting from the botanical point of view (Faridah-Hanum, 2008). Apart from housing 7% of the endemic tree species of the peninsula (i.e. species that grow in a specific area and has restricted distribution), the Ayer Hitam Forest is also interesting floristically as Selangor seems to be the focal point of plant taxa distribution in Peninsular Malaysia. It contains montane elements, such as, *Elaeocarpus pseudopaniculatus,* which occurs in Fraser's Hill and Gunung Tahan, and *Exbucklandia populnea,* which are species known to occur on the mountains of Peninsular Malaysia; southern floristic elements, such as, *Parinari elmeri*, *Terminalia foetidissima* and *Ardisia crassa,* which are species occurring south of Selangor, i.e. Negeri Sembilan, Melaka and Johor; and northern floristic elements, such as, *Alphonsea cylindrica* and *Terminalia calamansanai,* which are species found north of Selangor to beyond Perlis i.e. Thailand and Burma (Faridah-Hanum *et al.*, 2001a, 2001b; Faridah-Hanum, 2009). The presence of endemic species shows the biological uniqueness of an area (Peterson & Watson, 1998). Endemism is high in both Peninsular Malaysia and Malaysian Borneo due to the high variability of the microclimate, physiography and edaphic types. Endemic species exist because of extinction or because certain groups of plants are produced (or evolving) as localized distinct species in order to survive. It was estimated that Peninsular Malaysia has about 2,500 endemic species, of which, 746 are tree species (Ng & Low, 1982). In Sabah and Sarawak, the current number of endemic trees recorded in the "Tree Flora of Sabah and Sarawak" project stands at 1,750 species (Soepadmo & Wong, 1995). In the Ayer Hitam Forest, forest fragmentation has had severe implications on the survival of these endemic species. With AHFR possessing this kind of diversity, the charisma of AHFR in garnering support for its conservation into perpetuity remains the immediate challenge.

Another example of how the findings of floristic studies carried out could be useful to the Kedah Forestry Department for the justification of a proposed double gazettement of all the five forest compartments studied in Ulu Muda Forest Reserve as a research forest class besides a forest reserve is detailed out in Sayed *et al.* (2014). An assessment of the first ha of a 5-ha plot in Ulu Muda Forest showed the presence of 296 species and one variety in 158 genera and 56 families, of which 27 are endemic species, two are rare species, which are *Symplocos calycodactylos* (Symplocaceae) and *Alseodaphne garciniicarpa* (Lauraceae), and one is a very rare species, *Cleistanthus major* (Phyllanthaceae). *Diospyros argentea* (Ebenaceae) was also found which was a new record for Kedah.

Through Scientific Expeditions

With the initiation of a series of scientific expeditions with the Forestry Department Peninsular Malaysia and Forestry Department Perlis, which began with the state of Perlis, it became almost certain that conservation of certain forested areas can be proposed to the state governments as a state park if backed by good biodiversity data. As a result of the first three scientific expeditions carried out in Perlis, the first state park biodiversity conservation model was proposed, which was to become the model for state park establishment for the country (Faridah-Hanum, 2002; Roslan *et al.*, 2007). An additional class of forest functions called 'State Park' was later added to the existing National Forestry Act (1984) in 2004. This became the precursor of several other state parks established in Peninsular Malaysia in the past decade, such as, Gunung Stong State Park in Kelantan, and Royal Belum State Park in Perak. Species composition of plants has become one of the major studies to be undertaken in any scientific expedition organised. Many plant checklists have been produced over the last 15 years to allow considerations for conservation of forested areas to be made by the different state governments in Peninsular Malaysia and/or management of the forests by state forestry departments. Details of conservation work through scientific expeditions throughout Peninsular Malaysia are found in many publications such as Faridah-Hanum *et al.* (2014), Latiff and Faridah-Hanum (2014), Faridah-Hanum *et al.* (2012), Faridah-Hanum *et al.* (2011a,b), Rusea *et al.* (2010), Latiff and Faridah-Hanum (2009), Faridah-Hanum *et al.* (2007), Faridah-Hanum and Latiff (2007), Faridah-Hanum and Shamsul (2006), Faridah-Hanum *et al.* (2005), Shamsul *et al.* (2005), Razali Jaman *et al.* (2005), Shamsul *et al.* (2004), Latiff and Faridah-Hanum (2004), Faridah-Hanum *et al.* (2002), Latiff *et al.* (2002), Faridah-Hanum *et al.* (2001) and Latiff *et al.* (2001).

For Conservation of Specific Habitats

Wetlands, especially the mangroves and peat swamp forests, are crucial for maintaining the stability of the environment in many aspects and is confined to specific kinds of soil substratum and water pH. Mangrove forests are found in saline environments by the estuaries and sea while peat swamp forests are found somewhat inland and are acidic and water-logged. Both contain many resilient species which can tolerate harsh conditions. The mangrove flora is well researched but documentation of the peat swamp flora is rather limited. A study on the species compostion of the peat swamps in Peninsular Malaysia recorded a total of 238 plant taxa (Faridah-Hanum & Shamsul Khamis, 2005). Some of the peat swamp specific species found here include *Durio carinatus* (Durian paya) (Figure 11), *Gonystylus bancanus* (Ramin) (Figure 12) and *Tetramerista glabra* (Punah).(Figure 13). *Gonystylus bancanus* is an important source of ramin timber and has been put in the

IUCN category (Vulnerable). It is not threatened with extinction in the Malaysian peat swamp forest although regeneration in overexploited forests may be a cause of grave concern and it is also included in CITES Appendix 2. Working together with the UNDP/GEF team of experts, the South-East Pahang peat swamp forest was later designated as a high conservation value forest (HCVF). HCVF is globally accepted and included in Principle 9 in the Malaysia Criteria and Indicators for Forest Management Certification (MC&I). A forest is considered an HCVF when it has one of the following attributes: 1) it contains global, regional or national conservation values such as species, endangered species and refugia; 2) it is a rare, threatened or endangered ecosystem; 3) it provides basic services of nature in critical situations such as flood mitigation, erosion control and watershed protection; and 4) it is fundamental in meeting the basic needs of local communities and critical to the cultural, traditional identity and religious significance of the community, such as, the indigenous Jakun Tribe in South-East Pahang peat swamp forest.

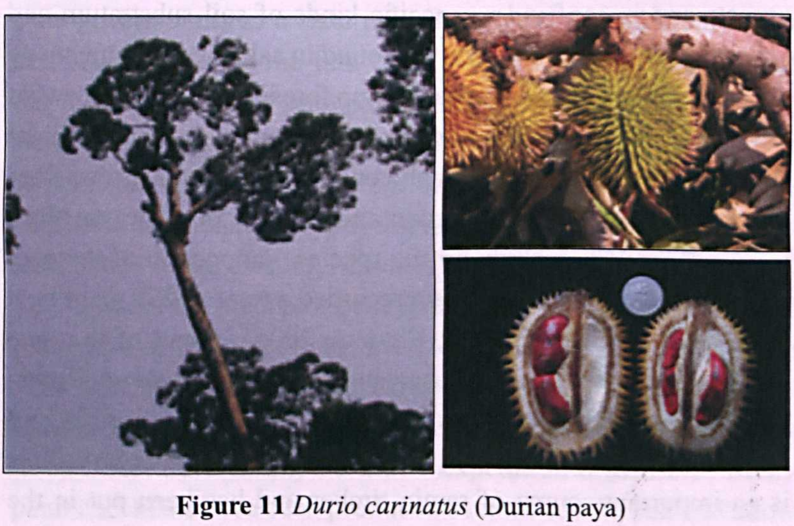

Figure 11 *Durio carinatus* (Durian paya)

Figure 12 *Gonystylus bancanus* (Ramin)

Figure 13 *Tetramerista glabra* (Punah)

CONCLUSION

This account attempts to highlight the usefulness of species composition for many facets of forestry and biodiversity activities, in relation to current issues. It is also my thesis that these different facets of species composition not only improve scientific knowledge of our natural resources from the forests but further that the relevant authorities can also strengthen and integrate such knowledge in their existing activities and programmes, such as, biodiversity conservation, sustainable forest management, rehabilitation, enrichment planting, both pre-felling and post-felling forest inventory, payment for ecosystem services (PES), economic valuation of both timber and non-timber resources, estimation of carbon stocks and its pricing, and reducing emissions from deforestation and forest degradation (REDD). With her National Policy on Biological Diversity in place, Malaysia's vision of transforming the country into a centre of excellence in conservation, research and utilisation of tropical biodiversity by the year 2020 could be through the outlined 11 principles and 14 strategies for effective management of her biodiversity. These will have to include the improvement of scientific knowledge on biodiversity even at the most fundamental level, such as, enumeration and identification of biodiversity through species composition studies which can be useful for considerations in conservation programmes, and improving forest biodiversity management at the species, genes and forest ecosystem levels, amongst others.

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BIOGRAPHY

Faridah Hanum Ibrahim was born on 8 January 1960 in Kota Bharu, Kelantan. The eldest of five siblings, she received her primary education at Zainab Primary School in Kota Bharu and later, her secondary education at Maktab Rendah Sains Mara (MRSM) Seremban in 1973. She completed the Universiti Kebangsaan Malaysia Matriculation in MRSM Seremban before pursuing her Bachelor's degree in Botany in Universiti Kebangsaan Malaysia (UKM), Bangi.

Upon graduation from UKM in 1984, she joined the Faculty of Forestry, Universiti Putra (then Pertanian) Malaysia. Soon after, she received a Public Service Department scholarship to pursue further studies and graduated with a PhD in Botany from the University of Reading, England in 1989. She was promoted to Associate Professor in 1999 and Professor in 2009. She is currently a Professor of Forest Botany at the Faculty of Forestry, Universiti Putra Malaysia (UPM) where she teaches Forest Botany and Dendrology.

Professor Faridah was Dean, Faculty of Forestry (UPM) from 2011-2014, Head of Department of Forest Production, Faculty of Forestry, UPM twice in 1999 and 2009, and Deputy Director of UPM Research Management Centre (RMC) in 2010. Currently she is a university Senate member and heads the UPM Research Cluster on Forestry and Biodiversity. She is also a Fellow of the Academy Science Malaysia.

Professor Faridah Hanum has many years of experience in conducting research in the Malaysian forests. Her specialization is forest botany and major research interests lie in the area of plant diversity and conservation. She also initiated a series of scientific expeditions in 1999 for the Forestry Department Peninsular Malaysia and Forestry Department Perlis that began with the Wang Kelian expedition in Perlis, led and participated in more than 35 expeditions botanizing the Malaysian forests, besides editing numerous chapters of the expedition findings. Together with the involvement of DANIDA and WWF, this later led to the proposed Perlis State Park which became a model for the establishment of several other state parks, such as, the Gunung Stong State Park in Kelantan and Royal Belum State Park in Perak. The National Forestry Act (1984) was amended in 2004 to have an additional class of forest functions called 'State Park'.

To date Professor Faridah Hanum has received a total of 20 research grants from both local and international organizations such as the International Foundation of Science (Sweden), United Nations Development Programme (UNDP), Tsukuba Forest and Forest Products Research Institute (FFPRI), and the Centre of International Forestry Research (CIFOR). She has written, edited and published 280 papers, chapters, abstracts and reports in journals, books, proceedings and other popular contributions. She has twelve copyrights for books authored in her area of specialization. One of the books entitled *Plant Resources of South-East Asia (PROSEA): Auxiliary Plants* has been translated into eight languages (Japanese, Chinese, Vietnamese, French, Spanish, Filipino, Indonesia and Thai) and has been extensively referred to in forestry and agriculture for over two decades now. She also wrote the *Handbook on the Peat Swamp Flora of Peninsular Malaysia* for United Nations Development Programme (UNDP) which was the only publication on peat swamp plants in Southeast Asia in 2000s and has been used by research workers in other countries for a long time now. *Ayer Hitam Forest: the Green Lung of Klang Valley* which she wrote for UPM has played an important role in educating the public and policy makers about its conservation importance. One of her key contributions to science was the book edited entitled *Mangrove Ecosystems of Asia – Status, Challenges and Management Strategies* published by Springer.

She has supervised and co-supervised more than 40 postgraduate students and 80 undergraduate students, and has been external examiner for many Masters and PhD theses besides being reviewer of many journals and books. She is also the Chief Editor of the 75-year old journal, *The Malaysian Forester* and Editor for both the *Pakistan Journal of Botany* and the *Japan Society of Tropical Ecology Journal* (*TROPICS*).

Professor Faridah Hanum has also been consultant and advisor in flora related work for several international organizations such as DANIDA, WWF, UNESCO, UNEP, UNDP, CABI and ITTO. She has received fellowships from SEAMEO-BIOTROP, ASEAN Regional Centre on Biodiversity Conservation, FFPRI Tsukuba and Islamic Development Bank. She is also consulted frequently for the flora section of many EIA studies in the country, a consultant to Dewan Bahasa dan Pustaka for Kamus Pokok/ Kamus Besar Dewan (2004- 2009),and both consultant and advisor to DANIDA and WWF Malaysia for Biodiversity and Conservation of Perlis State Park (2000 – 2002).

Professor Dr. Faridah also sits on many plant and biodiversity related committees at both the university, national and international levels. Amongst them are the Steering Committee for International Society for Environment: Survival and Sustainability, United Nations Environmental Programme (UNEP) in preparing Biodiversity Country Study for Malaysia (1995-1997), Asia Pacific Trees for UNESCO (1994), Japan Society of Tropical Ecology Journal (2002 – 2005), ASEAN Regional Centre on Biodiversity Conservation (ARCBC) based in Los Banos, Philippines (2000), CABI Asia Pacific Project on Electronic Forestry Compendium of Forest Species (1997 – 1998), Steering Committee for Asia-Pacific Forestry Deans (2011-2014), Asia Pacific Forestry Research Institute (APAFRI) (2011-2014), ITTO Technical Working Group for Sustainable Forestry Projects in Malaysia (2006 – 2008) and CITES Plants Committee Malaysia (2000-2002). At the national level, she is on the Advisory Board for Majlis Bandaraya Shah Alam (2012-2015), member of the Jawatankuasa Pakar Pendaftaran Warisan Semulajadi under Jabatan Warisan Negara since 2010, Institute of Environment and Development (LESTARI) (1997-2000), National Plant Strategy Committee under Ministry of Natural Resources and Environment (2007-2008), National Steering Committee on Biodiversity Inventory under the Ministry of Natural Resources and Environment (2006- 2008) and Technical Working Group on Biodiversity for RM 9 under the Ministry of Natural Resources and Environment (2004-2005).

At UPM, being passionate about the Ayer Hitam Forest, she began her research on this forest in 1995 and strategised to provide information on plant diversity of the largest remaining green lung in the Klang Valley, hence its conservation, besides aiming to place a permanent research plot in the Ayer Hitam Forest in the international network to understand forest dynamics and resilience to disturbance, effects of past logging activities on biodiversity and carbon storage in a logged-over. This is hoped to materialize soon with the inclusion of Ayer Hitam Forest in the Tropical Managed Forests Observatory Network (TmFO).

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