FLORISTIC COMPOSITION AND ECONOMIC VALUATION OF 2-HA PLOTS OF HILL FOREST IN LANGKAWI

By

MOHD PUAT BIN DAHALAN

Thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy

March 2013

ACKNOWLEDGEMENTS

In the name of ALLAH the most gracious and the most merciful

So many people have assisted me in different ways in the development of this project that it is impossible to thank everyone by name for their contribution. Nevertheless, they all have my thanks and recognition.

My list must begin with my supervisor Prof. Mashhor bin Mansor, who inspired me to undertake this study and carry it through. His moral and practical support at all times, not to mention his unflagging optimism, helped me all the way to realize my dream.

I am indebted to my co-supervisor throughout this project, Dr. Nurul Salmi bt Abdul Latip, for giving the motivation and for her assistance, encouragement and support especially during the take-off of the study. Dr. Hj. Abd. Rahman bin Kassim, my field supervisor, provided exceptional encouragement and assistance in data collection and data analysis. His constant and enormous practical support made this study more interesting. For that, I sincerely thank him.

My appreciation also goes to the Directorate of the Forestry Department Peninsular Malaysia for allowing me to pursue my study up to this level. It begins with Y.Bhg. Dato' Dr. Hj. Abd. Rahman bin Hj. Abd. Rahim, the Director General Forestry of Peninsular Malaysia, Y.Bhg. Dato' Masran bin Md Salleh, the Deputy Director General Forestry of Peninsular Malaysia (Policy & Planning) and Y.Bhg. Dato' Nik Mohd Shah bin Nik Mustafa, the Deputy Director General Forestry of Peninsular Malaysia (Operation & Technical). My gratitude also goes to Y.Bhg. Dato' Razani bin Ujang, the former Director General Forestry of Peninsular Malaysia. Special gratitude to the Public Service Department Putrajaya for granting me with the scholarship until my completion of the study. Mr. Amir from Public Service Department Putrajaya deserved special mention.

Without the invaluable assistance and support given to me by the Kedah State Forestry Department from start to finish in my data collection, this project would not have been possible. The Kedah State Forestry Department and its staff at all levels— too numerous to mention by name went out of their way to help me.

I am also grateful to FRIM for the support given to me, in particular in the Herbarium section and the Library. Here, Mr. Kamaruddin bin Mat Salleh deserves special mention for his professional contribution in identifying and naming the voucher samples.

Thanks are also extended to Mr. Zulkifli bin Harun, Pak Razak, Pak Omar, Mr. Sofee, Ahmad Qamaruzzaman bin Mohd. Puat, Halim Khairi bin Hj. Mahfar, Mohd. Azuan bin Jaafar and Mr. Amer bin Abu Bakar for sharing with me most of the hard times collecting samples and some of their profound knowledge and stories during our camping in the forests. In particular, Mr. Zulkifli bin Harun was unfailing and untiring in his support as my field assistant for almost two and a half years during the period of data collection - the most significant period in my life study.

I am also much indebted for the professional assistance rendered by those who have taken time to look over the earlier drafts of this study: Mr. Khoo Kean Choon, Dr. Ismail bin Parlan, Ms. Juliwar bt Idrus, Mr. Syamsul bin Khamis, Tn. Hj. Zahari bin Ibrahim, Mr. Norhaidi bin Yunus, Mr.Suhaili bin Hj. Rosli, Ms. Nadia, Ms.Nazifah bt. Jainar, Ms.Syamsurina bt. Arshad and Ms.Muzzalifah bt.Abd. Hamid, who read and commented on all chapters, sometimes more than once.

This list would not be complete without mentioning my family, who have been understanding during the course of this project and helped me with their encouragement and practical support. In particular, my thanks and appreciation goes to my beloved mother, Aminah bt Mat, my wife, Che Rosnah bt Saidin, and my children, Ahmad Qamaruzzaman, Siti Shahirah, Ahmad Taufiq, Nurul Husna, Luqman Hanif, Nurshamimi Raihan and Nuraisya Mazween. Last but not least to my granddaughter Nur Sofea bt Ahmad Qamaruzzaman. It was comforting to know that they were always there for me and continuously inspiring me to meet and beat the challenge.

Finally, I always pray and give thanks to Allah SWT, the Almighty, the source of all energy for His blessings and guidance.

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LIST OF ABBREVIATIONS

AGB	=	Above-ground biomass
ANOVA	=	Analysis of variance
BA	=	Basal area
Compt	=	Compartment
DBH	=	Diameter at breast height
EPU	=	Economic Planning Unit
FAO	=	Food and Agriculture Organization
FDPM	=	Forestry Department of Peninsular Malaysia
GMFR	=	Gunung Machinchang Forest Reserve
GRFR	=	Gunung Raya Forest Reserve
HHW	=	Heavy heavy hardwood
IPCC	=	Intergovernmental Panel on Climate Change
IV*i*	=	Important Value Index
LHW	=	Light heavy hardwood
LSD	=	Least significant different
MHW	=	Medium heavy hardwood
Mt	=	Million metric tonne
MTIB	=	Malaysian Timber Industrial Board
Mtoe	=	Million tonnes oil equivalent
PRF	=	Permanent reserved forest
Rel Freq	=	Relative Frequency
SCBC	=	Secretariat Conference on Biodiversity Conservation
t/ha	=	Metric tonne per hectare
TB	=	Total biomass
Tg	=	10^6 metric tonnes
toe	=	Tonnes oil equivalent
UGB	=	Under-ground biomass
VJR	=	Virgin jungle reserve

KOMPOSISI FLORISTIK DAN NILAI EKONOMINYA PADA 2-HEKTAR PLOT HUTAN BUKIT DI LANGKAWI

ABSTRAK

Data mengenai komposisi floristik adalah sangat berguna untuk dimanfaatkan bagi mencapai kelestarian hutan dan pengurusan persekitaran. Sejumlah dua petak kajian kajian tetap dengan setiap satu dengan keluasan 2.0-ha (200m x 100m) yang terletak di antara 300m a.m.l. hingga 750m a.m.l. telah ditubuhkan di Hutan Simpan Gunung Matchingchang (GMFR) dan Hutan Simpan Gunung Raya (GRFR) bagi tujuan inventori kepelbagaian flora kawasan Hutan Bukit Dipterokarpa. Petak-petak kajian ini terdiri daripada 2 petak utama iaitu setiap satunya di GMFR dan GRFR yang kemudiannya dibahagikan kepada setiap satu 50 subpetak (20m x 20m). Di GMFR dan GRFR, masing-masing petak 2.0-ha mencatatkan jumlah bilangan individu pokok sebanyak 12,530 batang pokok dan 7,967 batang pokok. Spesies paling tinggi jumlahnya di GMFR telah dicatatkan oleh *Hydnocarpus filipes* (Flacoutiaceae) yang mencatatkan jumlah sebanyak 2,591 (20.68%) individu untuk 2.0 ha. Sementara di GRFR pula, *Diospyros ismailii* (Ebenaceae) telah mencatatkan jumlah paling tinggi iaitu sebanyak 799 (10.03%) individu untuk 2.0 ha. Secara keseluruhannya terdapat sejumlah 206 dan 199 spesies masing-masing direkodkan di GMFR dan GRFR di dalam kategori julat saiz kelas DBH $\geq$ 1.0 cm. Jumlah spesies serta bilangan individu semakin berkurangan apabila mengambilkira kategori julat saiz kelas DBH (1.0 cm < 5.0 cm) dan DBH ($\geq$ 5.0 cm). Indeks kepelbagaian juga telah direkodkan dengan masing-masing mencatatkan 3.897 dan 4.08 bagi GMFR dan GRFR. Indeks kepelbagaian juga telah diperolehi bagi setiap kategori julat saiz kelas DBH. Kajian juga telah merekodkan indeks kesamarataan bagi GMFR dan GRFR dengan masing-masing mencatatkan 0.731 dan 0.771. Indeks kesamarataan spesies juga telah diperolehi bagi

setiap kategori saiz kelas DBH. Lengkung spesies-kawasan untuk kedua-dua lokasi kajian di GMFR dan GRFR telah dihasilkan dengan masing-masing menghasilkan rumusan Y=36.42*ln(x)-158.4 dengan R^2=0.979 and Y=41.39*ln(x)-208.6 dengan R^2=0.990. Lengkung spesies-individu pokok untuk kedua-dua lokasi kajian di GMFR dan GRFR juga telah dihasilkan dengan masing-masing menghasilkan rumusan Y = 35.714*ln(X)-133.67 with R^2 = 0.9815, and Y = 41.899*ln(X)-174.58 with R^2 = 0.9884. Sebaran spatial juga telah diperolehi dan disertakan illustrasi grafik bagi 10 spesies pertama terbanyak bilangan individu serta 10 spesies endemik pertama terbanyak bilangan individu bagi GMFR dan GRFR. Sementara itu kajian juga merekodkan terdapat 9 spesies endemik di GMFR dan 13 spesies endemik di GRFR. Keluasan pangkal bagi GMFR dan GRFR masing-masing merekodkan 37.04 m^2/ha dan 47.65 m^2/2ha. Corak sebaran untuk 10 spesies terbanyak serta 10 spesies endemik terbanyak telah dikenalpasti dan sediakan illustrasi secara bergraf bagi GMFR dan GRFR. Jumlah biojisim bagi GMFR dan GRFR pula masing-masing telah merekodkan 513.92 t/ha dan 759.94 t/ha dengan jumlah biojisim atas tanah (AGB) bagi GMFR dan GRFR masing-masing adalah 438.53 t/ha dan 644.19 t/ha. Jumlah keseluruhan bagi nilai stumpej di GMFR dan GRFR adalah masing-masing dianggarkan sebanyak RM40,242.06/ha dan RM73,994.32/ha. Jumlah isipadu komersil keseluruhan iaitu bagi saiz kelas DBH ($\geq$ 15.0 cm) di GMFR dan GRFR masing-masing mencatatkan jumlah 204.20 m^3/ha dan 345.89 m^3/ha.

FLORISTIC COMPOSITION AND ECONOMIC VALUATION OF 2-HA PLOTS OF HILL FOREST IN LANGKAWI

ABSTRACT

Floristic composition data are a valuable tool in sustainable forest and environmental management. A 2.0-ha permanent plot (200 m x 100 m) located between 300 and 750 m a.s.l. was each established at Gunung Matchingchang Forest Reserve (GMFR) and Gunung Raya Forest Reserve (GRFR) in Langkawi for the purpose of inventoring hill floral diversity. The research sites comprised of two 2.0-ha plots each of which was located in GMFR and GRFR and was further divided into fifty 20 m x 20 m subplots. In GMFR and GRFR, there were a total of 12,530 trees and 7,967 trees respectively. All trees with abundant species, family, diameter breast height (DBH), total biomass (TB) and stumpage value were identified, assessed and recorded. The largest species in GMFR was recorded by *Hydnocarpus filipes* (Flacoutiaceae) with as many as 2,591 individuals. In GRFR, *Diospyros ismailii* (Ebenaceae) recorded the highest number with 799 individuals. A total of 206 and 199 species were recorded in GMFR and GRFR respectively in the DBH range size class $\geq$ 1.0 cm. The number of species and stems decreased corresponding to the other size classes, specifically DBH range class 1.0 < 5.0 cm and DBH range class $\geq$ 5.0 cm. Biodiversity indices were recorded at 3.90 and 4.08 in the DBH range size class $\geq$ 1.0 cm for GMFR and GRFR respectively. Biodiversity indices also were recorded in the other DBH size classes namely DBH range class 1.0 < 5.0 cm and DBH range class $\geq$ 5.0 cm. Similarity indices were also recorded for GMFR and GRFR at 0.731 and 0.771 respectively. Similarity indices were also recorded for the other DBH range size classes, viz. DBH range class 1.0 < 5.0 cm and DBH range class $\geq$ 5.0 cm. Species-area curves were established in both study areas in GMFR and GRFR which produced the equations Y

= 36.42*ln(x)-158.42 with R^2 = 0.9794, and Y = 41.39*ln(x)-208.6 with R^2 = 0.9905 respectively. Species–individual relationship were established in both study areas in GMFR and GRFR which produced the equations Y = 35.714*ln(X)-133.67 with R^2 = 0.9815, and Y = 41.899*ln(X)-174.58 with R^2 = 0.9884 respectively. Distribution patterns for the first 10 most abundant species and the first 10 most dominating endemic species were determined and graphically displayed for both GMFR and GRFR. The study also recorded nine endemic species in GMFR and 13 endemic species in GRFR. The basal areas for GMFR and GRFR were registered at 37.04 m^2/ha and 47.65 m^2/ha respectively. The total biomass (TB) values for GMFR and GRFR were recorded at 513.92 t/ha and 759.94 t/ha respectively with the above-ground biomass (AGB) values for GMFR and GRFR at 438.53 t/ha and 644.19 t/ha. The total stumpage values for GMFR and GRFR were registered at RM40,242.06/ha and RM73,994.32/ha respectively. The total volumes recorded in GMFR and GRFR were 204.20 m^3/ha and 345.89 m^3/ha respectively.

CHAPTER I

INTRODUCTION

1.1 General Background

Tropical rainforests, which cover 14% of the earth's land surface (18.0 million sq. km), are exceptionally rich in biological resources. Although covering not even one fifth of the land surface, these extraordinarily rich but fragile habitats contain more than half of the earth's total biological diversity having the highest species diversity and endemism of any ecosystem type in the world (Ng *et al.*, 1990; Braatz, 1992; Soepadmo, 1998; UNEP, 2002).

Malaysia is a tropical country located north of the equator within latitudes 1°–7° North and longitudes 100°–119° East. The total land area is approximately 32.99 million ha with 13.18 million ha in Peninsular Malaysia, 7.36 million ha in Sabah, and 12.45 million ha in Sarawak (DOS, 2006a).

The climate of Malaysia is typically humid tropical and is characterized by year-round high temperature and seasonal heavy rain. The mean temperatures during the day and night are 32° C and 22° C respectively, while the average annual rainfall is about 2,540 mm with a maximum of 5,080 mm and a minimum of 1,650 mm. Humidity is always high and ranges from 70 to 98% and the sky is cloudy most of the day, especially during the monsoon months (Thang, 2003). Malaysia is covered vastly by tropical forest with extremely rich biological resources. Meffe and Carroll (1994) categorized Malaysia as a hot–spot area due to the high level of biodiversity or species richness as well as high endemism of its forests. In terms of the number of species, Malaysia is among the world's twelfth biodiversity-rich countries and in Asia she is at number four, after China, India and Indonesia (Latiff, 1997; UNEP, 2002; Mashhor *et al.*, 2006). Biodiversity, or biological diversity, encompasses all species of plants, animals and micro-organisms, and the ecosystems of which they are part (Manokaran, 1992). Biodiversity can be categorized at three different levels, 'genetic diversity', 'species diversity, and 'ecosystem diversity'. Smitinand (1995) defined biodiversity as the variety and variability among living organisms and the ecological complexes in which they occur.

Many scientific researchers have revealed in a single hectare of tropical forest the existence of many species compared to temperate forest. The World Conservation Monitoring Centre (1994) estimated Malaysia's forest to contain some 15,000 species of flowering plants, 286 species of mammals, and more than 150,000 species of invertebrates. Peninsular Malaysia alone is estimated to harbour 12,000 species of flowering plants out of which 2,830 are tree species with 890 of them reaching harvestable size of at least DBH 45.0 cm. (Faridah-Hanum & Tipot, 1993; FDPM, 2004). Of these 890 tree species, a total of 408 have been marketed in the international markets under the Malaysian Grading Rules (Soepadmo, 1998; Wong, 2002).

In addition, well over 800 species of non-flowering plants and a total of 300 species of fungi have also been recorded (Manokaran *et al.*, 1992; FDPM, 2004). Being in one of the hot-spot countries in the world, the forests are also home to many fauna species, i.e. over 4,000 species of fish, 350 species of reptiles, 300 species of amphibians, more than 100 species of snakes, 286 species of mammals (FDPM, 2004), 500–720 species of birds, over 1,000 species of butterflies and 12,000 species of moths (MOSTE, 1997; Soepadmo, 1998).

The forestry sector is one of the most important sectors in the Malaysian economy. The government gives great attention to this sector because of the significant role the forestry sector plays in forest-based industrialization, export earnings, job creation, regional development, environmental protection, and so forth. The total investment in the selected wood-based industry in Peninsular Malaysia registered an increase of 9.7% to RM1.99 billion as compared with RM1.81 billion in 2004 (FDPM, 2006a). According to the Department of Statistics Malaysia (2006a) in 2005 the total export earnings of timber products from Malaysia rose substantially by 8.5% to RM21.45 billion compared with 2004 (RM19.78 billion). This accounted for 4.0% of the total gross export receipts of Malaysia at f.o.b. RM533.8 billion (Department of Statistics Malaysia, 2006b). For Peninsular Malaysia, the export of timber and timber-based products in 2005 amounted to RM4.10 billion, registering an increase of 3.0% compared with RM3.99 billion in 2005 and at the same time providing direct employment for a total of 45,141 persons (FDPM, 2006b).

Despite their high ecological importance, the dipterocarp forests have been greatly exploited, particularly the Lowland Dipterocarp Forest. This is principally the result of large-scale agricultural development through the conversion of forested land to agriculture, mainly rubber and oil palm plantations, under various Malaysian National

Development Plans since 1961. It was estimated that some 2.0 million ha, 15.0% of the total forested area of Peninsular Malaysia, were converted over the period from 1960 to 1978 (Yong, 1996).

Under the Malaysian Constitution, forestry comes under the jurisdiction of the respective State Governments which are empowered to enact laws and formulate policies on forestry independently. The executive authority of the Federal Government only extends to the provision of advice and technical assistance, training, and the conduct of research. Hence, to facilitate a co-ordinated and common approach to forestry, the National Forestry Council was established in 1971 to discuss and resolve common problems and issues relating to forestry policy, administration and management, and to enhance co-operation between the Federal and State Governments in policies and programmes related to forestry.

1.2 Problem Statement

One of the critical environmental issues that have confronted Malaysians in recent decades is the massive transformation of the natural forests especially in the hills and mountains. Deforestation and forest degradation are threatening biodiversity, ecosystem stability and the long-term availability of forest products as well as depleting the natural resource. Transformation of land use has also brought about changes in the soil, water, vegetation and atmosphere with associated loss of pristine natural forests and their flora and fauna. UNEP (2002) alerted that, based on the latest IUCN 'Red List', about 24.0% (1,130) of mammals and 12.0% (1,183) of bird species are currently regarded as globally threatened. Thus far, there have not been enough studies done to prove or otherwise the allegation that species loss from the Malaysian natural forest was due to habitat change.

Up till now, there have been few comprehensive field studies and records of flora produced from Hill Dipterocarp Forest. Some studies of plant diversity in Peninsular Malaysia that have been carried out in different Lowland Dipterocarp Forests include: Pasoh F.R. (Kochummen *et al.*, 1990), Ayer Hitam F.R. (Lepun *et al.*, 2001), Sg. Lallang F.R. and Sg. Jeloh F.R. (Elbushari, 2002), Machinchang F.R. (Raffae, 2003), Tersang F.R. and Lepar F.R. (Mohd. Ridza, 2004), Lesong F.R. (Suhaili, 2004), Bangi F.R. (Latiff & Nais, 1990; Norashidah, 1993; Lajuni, 1996; Elbushari, 2002); and Mata Ayer, Bukit Bauk and Gunung Pulai Forest Reserves (Hikmat, 2005).

Studies of various geological aspects in Langkawi have been carried out by a number of researchers for different parts of the islands. These include Jones (1978), Fateh (1993), Wan Fuad (1997; 2000), Mohd Shafeea (1997), Ibrahim & Kadderi (1997) and the FDPM (2005a).

However, no comprehensive field studies and records of flora have been produced from Hill Dipterocarp Forests for the northern region of the Malay Peninsula, especially on the Langkawi islands. Certainly this study would enable the capture and production of detailed records of flora and subsequently the plant systematics and analysis of species diversity from the study areas.

In so doing, the country would show its concern for environmental protection, as remarked by the former Prime Minister, "We must also ensure that our valuable natural resources are not wasted. Our land must remain productive and fertile, our atmosphere clear and clean, our water unpolluted, our forest resources capable of regeneration, able to yield needs of our national development. The beauty of our land must not be desecrated for its own sake and for our economic advancement" (Mahathir, 1991).

The occurrence of some species with a very restricted local distribution may result and in future be insecure if they are exposed to uncontrolled human exploitation or commercial practices. It is desirable that numbers of endemic, scarce and uncommon species be captured and assessed from these study areas. The major interest of the study was to gather a wide range of information on the diversity of flowering plants and identify them to species level.

The main aim of the study was to conduct floristic enumerations and to compile and analyse the diversity of the flowering plants from two different geological sites, namely Gunung Machinchang Forest Reserve (GMFR) and Gunung Raya Forest Reserve (GRFR), both on the main island of Langkawi. Next was to compare and uncover some ecological aspects within and between both forest reserves as well as between the same and different forest types on the mainland Peninsular Malaysia.

The rainforests of Malaysia belong to the Malesian floristic region of archipelagic Southeast Asia extending from the Kra Isthmus in Peninsular Thailand in the northwest to Papua New Guinea and its adjacent islands in the southwest

(Soepadmo, 1998). Although Malesia is a well-defined floristic region, the vegetation is far from uniform. Three distinct floristic provinces have been duly recognized, namely West Malesia, comprising the Malay Peninsula, Sumatra, Borneo and the Philippines; South Malesia, comprising Java and Nusatenggara; and East Malesia, comprising Sulawesi, Maluku and New Guinea (Aiken & Leigh, 1992).

Geographically, the Langkawi islands are located at the periphery of the most northern tip of West Malesia floristic province bordering southern Thailand as well as Myanmar. Hence, the vegetation on these islands by some means is in the transition stage (dry monsoon/wet monsoon) whereby it could bear a unique vegetation pattern in terms of species richness, species composition and species endemicity (Bidin & Latiff, 1995; Soepadmo, 1998). Since been declared a free port in 1989, Langkawi has experienced a tremendous degree of development involving considerable terrestrial changes. Substantial hill forested areas were cleared to give way to the construction of numerous roads, a satellite communication station complex at the peak of Gunung Raya and a cable car station at the top of Gunung Machinchang, just to name a few. All these projects were carried out to cater for the tourism industry which is the main source of economic growth for the islands. At the same time, the Kedah State Government needs to always monitor the development involving the highland areas in order to avoid the adverse impact on the forest ecosystem.

1.3 Objectives of Study

The study was conducted in two Permenant Reserve Forests (PRFs) as representatives of different geological zones, namely Gunung Raya Forest Reserve (granite) and Gunung Machinchang Forest Reserve (sandstone).

The overall objective of this study was to compare and obtain an understanding of the possible influences of geological as well as geographical zones on the conservation of tree species diversity, biomass and economic value of Hill Dipterocarp Forest. The specific objectives of the study were:

1. To assess the species biodiversity of the Hill Dipterocarp Forest in two different geological zones in terms of tree species composition, species diversity/richness, stand structure and spatial distribution.
2. To estimate the biomass and carbon contents of trees of the Hill Dipterocarp Forest ecosystem.
3. To estimate the economic value of the trees in the Hill Dipterocarp Forest.
4. To identify the endemic and target species for conservation in the Hill Dipterocarp Forest of the Langkawi islands.

Information obtained from the data would include diameter class distribution, height, tree density, basal area and volume, vertical structure, species density, evenness, floristic composition, key species, floristic distribution pattern and species diversity of vascular plants in the study areas. This information would generate a better understanding of the Hill Dipterocarp Forest not only in the Langkawi islands but also Malaysia.

1.4 Hypothesis

The hypothesis underlying this study is that distinctively different geological formations will harbour different species compositions and stand structures. Variations in species composition have been related to lithology, soil type, soil characteristics and drainage.

1.4.1 Thesis Statement

In the Hill Dipterocarp Forest, different geological formation should exhibit different types of stand structure and other vegetation attributes even though the areas are under more or less the same physical and microclimatic environments.

Therefore the postulation of this study is that the stand structure, species composition, biomass and economic valuation of Hill Dipterocarp Forest of two different sites in close proximity are different due to disparities in geological characteristics.

Findings should show significant differences in terms of diameter class distribution, tree density, basal area and volume, species density, evenness, floristic composition, key species, floristic distribution pattern, regeneration pattern and species diversity of higher plants in the same forest type of different study areas.

1.5 Organization of the Thesis

The thesis is organized into eight chapters. The Introduction is given in Chapter I. The Literature Review is presented in Chapter II. Chapter III provides the Methodology of this study. Results and Discussion are presented in Chapter IV. General Discussion is presented in Chapter V. Finally, Chapter VI provides the Conclusion and Recommendations of the study. References and appendices are presented at the end of the thesis.

CHAPTER II

LITERATURE REVIEW

2.1 TROPICAL FOREST

2.1.1 Introduction

In developing tropical countries, forest degradation is occurring at an alarming rate (Rudel & Roper, 1997; Laurence, 1999). Since the last few decades of the 20th century, spatial and temporal changes of land utilization by human activities have become more prominent as a proximate factor that catalyses forest degradation in the region (McMorrow & Talip, 2001). Rapid economic development as well as pressure of development from increasing human population is the major underlying factor that creates these circumstances (Tole, 1998; Koop & Tole, 2001).

In tropical regions, many studies have shown that human intervention in land utilization has changed forest cover over time (Kammerbauer & Ardon, 1999; Milington *et al.*, 2003). Malaysia is one of the developing tropical countries where both proximate and underlying causes of land use play a major role in promoting forest exploitation. From the 1950s to the 1970s, most of the natural forests were converted into agricultural land, mainly for rubber and oil palm plantations (Wong, 1974). Therefore, the environmental and biodiversity impact due to forest utilization is a growing concern in tropical regions (1998; Laurence, 1999; Sodhi, 2002). For this reason, forest biological indices are useful tools for measuring the level of health of the forests.

Malaysia is one of the mega-diversity countries of the world. Keng (1970), as cited by Hikmat (2005), estimated that the flora of Peninsular Malaysia consists of about 8,000–8,500 species in 1,400 genera and 200 families. However, records of the Langkawi flora are scarce as not many comprehensive studies have been carried out on the islands. Raffae (2003) reported that a few botanists have visited the Langkawi islands since the early nineteenth century. Among them were Maxwell (1887), Charles Curtis (1898) and later followed by a few others. It was also reported that H.N.Ridley, who was at that time the Director of the Singapore Botanical Garden, visited the Langkawi islands between 1890 and 1911 and collected a series of samples of the Langkawi flora.

2.1.2 Forest Types

Forests form the dominant natural ecosystem in Malaysia. There are several classification schemes for the forest ecosystem, which vary according to substrate (i.e. dry or wet soil type), the structure and floristic composition, altitude and many other features. Wyatt-Smith (1995) briefly mentioned that some examples of widely used forest classification systems which are applicable, particularly to Peninsular Malaysia's forests, are provided by Foxworthy, Symington and Whitmore.

However, Wyatt-Smith (1995), in the Manual of Malayan Silviculture for Inland Forest (2nd edition), further refined and classified forests in Peninsular Malaysia into six main groups and fifteen subgroups. Among the main groups, Lowland Evergreen Rainforest is the most extensive. Upper Hill, Hill and Lowland

Dipterocarp Forests that fall under the group of Lowland Evergreen Rainforests are the most extensive forest formations which constitute the major subgroups in Peninsular Malaysia as they cover approximately 87.0% of the total forested area in Peninsular Malaysia (Symington, 1943; Whitmore, 1984; Wan Razali, 1997). Lowland, Hill and Upper Hill Dipterocarp Forests cover areas with altitudinal limits of < 300 m, 300 m–$<$ 700 m and $\geq$ 700 m–$<$ 1,200 m a.s.l. respectively. The trees in these types of forests are usually tall, the canopy being some 21.0–30.0 m above ground with staight clear boles to considerable heights (Wyatt Smith, 1963).

Many areas of hill forests in Peninsular Malaysia are characterized by stands of *Shorea curtisii* (seraya) growing along the ridges, and other species of *Shorea* such as *S. laevis* and *S. glauca* are frequently encountered (Symington, 1943; Wyatt Smith, 1963). Nevertheless, stand structure and floristic patterns of hill forests in Peninsular Malaysia do change with elevation giving rise to separate types of forest (Symington, 1943).

Wyatt-Smith (1995) classified the forests according to several main groupings and subgroupings (Table 2.1).

Table 2.1 Groupings of the Malaysian rainforests (Wyatt-Smith, 1995)

Swamp and low-lying forests	
1	Marine Alluvial (mangrove) Swamp Forests
2	Peat Swamp Forests
3	Freshwater Alluvial Swamp Forests
4	Riparian Fringes
Lowland evergreen rainforests	
5	Lowland Dipterocarp Forests
6	White Meranti-Gerutu (seasonal) Forests
7	'Heath" Forests
8	Hill Dipterocarp Forests
9	Upper Hill Dipterocarp Forests
Lower montane forests	
10	Montane Oak Forests
Upper montane forests	
11	Montane Ericaceous Forests
Miscellaneous forests on sites with severe drainage and those deficient in available moisture due to violent winds or too low temperature	
12	Beach (strand) Forests
13	Limestone Vegetation
14	Vegetation of quartz dyks, quartzite ridges and other sterile Habitats With Severe Drainage Or Lacking Available Moisture
Regenerated forests	
15	Regenerated Forests

In terms of vegetations, Whitmore (1984) pointed out that neither Lowland nor Hill Dipterocarp Forest is floristically uniform. He broadly categorized forests in Peninsular Malaysia into three categories: 1) Lowland (0–750 m); 2) Lower Montane (750–1,500 m) and 3) Upper Montane (1,500–2,100 m). Symington (1943), Wyatt-Smith (1963) and Kitayama (1991) further subdivided these categories into seven floristic zones, namely, 1) Lowland Dipterocarp (1–300 m); 2) Hill Dipterocarp (300–750); 3) Upper Dipterocarp (750 – 1,200 m); 4) Oak-laurel (1,200 – 1,500 m); 5) Montane Ericaceous (1,500–3,500 m); 6) Subalpine (3,000–4,000 m); and 7) Alpine (> 4,000 m).

> 4,000 m	Alpine Forest: G. Kinabalu (4,101 m)	Rocky desert *Centrolepis philipinnensis, Trachymene* spp. ,*Rhododendron spp., Vaccinium* spp., *Styphelia* spp.
3,500 – 4,000 m	Subalpine	*Dacrucarpus kinabaluensis, Phyllocládos* spp., *Leptospermum* spp., *Polyosma* spp., *Symplocos* spp.
1,500 – 3,500 m	Upper Montane Forest: G. Murud (2,425 m) G.Tahan (2,187 m) G.Ledang (2,187 m)	Dominated by *Pieris ovalifolia, Rhododendron* spp., *and Vaccinium* spp. Other species*: Arthrophyllum montanum, Anneslea crassipes, Buxus spp., Elaeocarpus mastersii, Syzygium* spp., *Garcinia* spp., *Ilex* spp., *Myrsine porteriana, Pentaphylax arborea, Phoebe declinata, Rhodamnia cinerea, Symplocos spp., Ternstroemia japonica, Tetractomia tetrandra, Tristania merguensis, Argostemma* spp., *Burmannia* spp.
1,200 – 1,500 m	Lower Montane Forest: Bkt. Fraser (1,448 m) Bukt. Larut (1,410 m)	Family of Fagaceae*: Quercus* spp., *Lithocarpus spp. and Castanopsis spp. and family of Lauraceae.* Other typical species*: Acer niveum, Adinandra* spp., *Agathis alba, Calophyllum* spp., *Canarium* spp., *Dacrydium* spp., *Engelhardia spp., Syzygium* spp., *Garcinia* spp., *Gordonia* spp., *Podocarpus imbricatus, P. neriifolius, Santiria laevigata, Toona serrata, T. sureni.*
750 – 1,200 m	Upper Hill Dipterocarp Forest	Key species: *Shorea platyclados, Agathis alba, Calophyllum* spp., *Dipterocarpus costatus, D. retusus, Melanorrhoea* spp., *Shorea ovata, S. submontana.*
300 – 750 m	Hill Dipterocarp Forest	Seraya-ridge forest, *Balau kumus-Damar hitam forest, Balau laut forest, Merpauh forest, Keruing-Resak-Mengkulang forest.*
< 300 m	Lowland Dipterocarp Forest	Meranti-Keruing forest, *Balau forest, Kempas-Kedondong forest, Merbau-Kekatong forest, Keruing forest, Chengal forest, Nemesu forest. Other common species: Lithocarpus* spp., *Palaquium* spp., *Nephelium* spp.
± Mean sea level	Mangrove Forest Peat Swamp Forest Fresh Water Forest Beach Forest Limestone Hill Forest	Mangrove forest: *Rhizophora* spp., *Avicennia* spp., *Bruguiera* spp., *Sonneratia* spp., *Xylocarpus* spp., *Ceriops* spp., *Kandelia* spp. *Peat swamp forest: Blumeodendron tokbrai, Myristica lowiana, Xylopia fusca, Ganua motleyana, Tetramerista glabra.* Other dominant species: *Amoora* spp., *Anisoptera* spp., *Calophyllum* spp., *Cratoxylum* spp., *Ctenolophon* spp., *Dialium* spp., *Durio* spp., *Syzygium* spp., *Ganua* spp., *Gonystylus* spp., *Hopea* spp., *Koompasia* spp., *Litsea* spp., *Myristica* spp., *Neesia* spp., *Polyalthia* spp., *Shorea* spp., *Stemonurus* spp. Fresh water forest*: Alstonia* spp., *Artocarpus* spp., *Calophyllum* spp., *Campnospermum* spp., *Castanopsis* spp., *Coccocerus* spp., *Dialium* spp., *Dillenia* spp., *Syzygium* spp., *Hopea* spp., *Ilex* spp., *Intsia* spp., *Koompasia* spp., *Lophopetalum* spp., *Madhuca* spp., *Melanorrhoea* spp., *Parastemon* spp., *Pometia* spp., *Shorea* spp., *Sindora* spp., *Vatica* spp.

Figure 2.1 Forest classification based on altitude, edaphic climax and climate (Symington, 1943; Wyatt-Smith, 1963 and Kitayama, 1991)

As this research focused on Dipterocarp Forest, only the first three forest types will be considered and described here. The descriptions of these three forest types are extracts based on the classification by Wyatt-Smith (1995). With the exception of Peat Swamp and Mangrove Forests, the other forest types are all 'non-productive' and are designated as protection forest as briefly described in Figure 2.1.

1. Lowland Dipterocarp Forests

The Lowland Dipterocarp Forests include all well-drained forests of the plains, undulating land and foothills up to the elevation of about 300 m above mean sea level. The forests are usually dense and comprised many thousands of tree species as well as shrubs, herbs and woody climbers. The upper or emergent storey is usually about 30 to 45 m high. This storey is usually characterized by a high occurrence of the family Dipterocarpaceae with many of the species of the genera *Anisoptera, Dipterocarpus, Dryobalanops, Hopea, Shorea* and *Parashorea*. Other common large trees in this storey include *Dyera costulata*, *Gluta* spp., *Intsia palembanica*, *Koompassia malaccensis*, *Melanorrhoea* spp., *Palaquium* spp., *Sindora* spp. and *Tarrietia* spp.

The main storey or second tree layer, which occupies a region of about 20 to 30 m from the ground, forms a continuous canopy except immediately below the large emergent storey trees. This storey consists of young trees of the normally upperstorey species together, predominantly, with members of the families Burseraceae, Clusiaceae, Myristicaceae, Myrtaceae and Sapotaceae. Meanwhile, the understorey or third tree layer consists of saplings of the upper two storeys together, mainly with members of such families as Annonaceae, Euphorbiaceae, Flacourtiaceae and Rubiaceae.

2. Hill Dipterocarp Forests

The Hill Dipterocarp Forests occur on the inland ranges between the altitudinal limits of 300 and 750 m above mean sea level. Aspect and site, however, are important factors and the forests have a tendency to be found at lower limits on exposed ridges, and at higher limits in the more sheltered valleys. On isolated mountains and on coastal ranges, the forests can be found at very low elevations and occur almost at sea level. The main difference between the Lowland Dipterocarp and Hill Dipterocarp Forests is a shift in the floristic composition of the dominants in the emergent and main storeys. The most common large tree species of this forest is *Shorea curtisii* which tends to be gregarious and shows a distinct preference for ridge tops. The density of trees on ridge tops is greater than that in the lowland forest, and there are correspondingly fewer trees in the understorey and in the lower part of main storey. The vegetation of hill slopes, particularly steep slopes, is often poorly stocked with woody species. In valley bottoms, large woody species are also poorly represented and the forest is characterized by the richness of the ground flora and shrub layer where *Alocasia* spp., *Colocasia* spp., *Donax grandis* and many other ground ferns are commonly found.

3. Upper Hill Dipterocarp Forests

The Upper Hill Dipterocarp Forests are found on the higher hills between the approximate altitudinal limits of 750 and 1,200 m above mean sea level. As in the case of the Hill Dipterocarp Forest, they may also be found in a narrower and much lower belt on coastal ranges or on isolated mountains. The species are very different from those found in the Hill Dipterocarp Forests. Although the forest structure is much the same, namely three-layered, the upper layer is less tall and varies between 25 and 30 m in height, with a more even upper canopy level. The second and emergent tree layers are frequently less distinct as separate entities. The family Dipterocarpaceae is only represented by a few species and this forest is often characterized by the presence of *Shorea platyclados*.

2.1.3 Extent of the Forest Resource in Malaysia

At the end of 2009, the total area of forests in Malaysia was estimated to be 19.15 million ha or 58.27% of the total land area of 32.86 million ha. Out of this, 5.92 million ha are located in Peninsular Malaysia, while 4.34 million ha and 8.70 million ha are found in Sabah and Sarawak respectively (Table 2.2). Recognizing that the crucial role of forests is not only in the production of timber, but more importantly, in the conservation of soil, water and wildlife, as well as in the protection of the environment. Malaysia has a total of 14.44 million ha of forested land designated as Permanent Reserved Forests (PRFs) which are under sustainable management. Approximately 10.63 million ha of the PRFs are production forests with the remaining 3.81 million ha being protection forests. The status of the PRFs in Malaysia is summarized in Table 2.3.

Table 2.2 Distribution and extents of major forest types in Malaysia, 2009 (million ha) (FDPM, 2010)

Region	Land area	Natural forest			Plantation forest	Total forested land	% Total of forested land
		Dry inland forest	Swamp forest	Mangrove forest			
Peninsular Malaysia	13.16	5.92	0.30	0.07	0.07	5.99	45.52
Sabah	7.37	4.34	0.12	0.11	0.15	4.45	60.37
Sarawak	12.33	8.70	1.04	0.01	0.03	8.71	70.64
Malaysia	32.86	18.96	1.46	0.19	0.25	19.15	58.27

Table 2.3 Permanent Reserved Forests in Malaysia, 2009 (million ha) (FDFM, 2010)

Region	Protection forest	Production forest	Total land area under PRFs	% Total land area
Peninsular Malaysia	1.90	2.94	4.84	36.78
Sabah	0.91	2.69	3.60	48.85
Sarawak	1.00	5.00	6.00	48.66
Malaysia	3.81	10.63	14.44	43.94

In 1992, the National Forestry Policy 1978 was revised to include the importance of biological diversity conservation and the sustainable utilization of forest genetic resources, as well as the role of local communities in forest development.

In managing the natural tropical forests of Malaysia, the Dipterocarp and Peat Swamp Forests are selectively harvested which are based on prescribed minimum cutting limits with cutting cycles varying from 25 to 55 years, while matured trees in the Mangrove Forest are clear-felled. In this context, all forest harvesting operations have to be carried out in accordance with the adopted Forestry

Departments' specifications, rules and guidelines, particularly those pertaining to road construction, alignment, gradient, drainage, tree marking, direction of felling and the setting up of log-yards (FDPM, 2005b: Forestry Manual).

Of the logged-over forests in the PRFs in Malaysia, a total of 2.04 million ha had been silviculturally treated at the end of 2006, while an area of 44,548 ha had been enriched with indigenous tree species. Annually, 47,000 ha of logged-over forests have been targeted to be silviculturally treated while an area of 7,000 ha will be enriched with indigenous species (Thang, 2003).

2.1.4 Diversity of the Tropical Forest Resource

Tropical rainforests are of great ecological value as perceived by their high rate of vegetation growth and biological diversity. They are the most diverse terrestrial ecosystems, and the richness of these forests in terms of the number of species content is one of the main reasons why they have continuously attracted great attention amongst reseachers (Latiff, 1997). Without exception, Malaysia, which is vastly covered by tropical forest, is extremely rich in biological resources. Meffe and Carroll (1994) categorized Malaysia as a hot spot area due to the high level of biodiversity or species richness as well as the high endemism of its forest.

This forest type has the richest variety of species, with members of the Dipterocarpaceae prominent. In Sumatra, the Malay Peninsula, Borneo and Mindanao, this forest dominates the overstorey. Such dominance by a single family (although one that includes more than 500 species) can be said to be characteristic of

Southeast Asia. The following other families are comparatively well represented in this forest: Anacardiaceae, Annonaceae, Burseraceae, Caesalpineaceae, Celastraceae, Combretaceae, Connaraceae, Dilleniaceae, Ebenaceae, Euphorbiaceae, Clusiaceae, Icacinaceae, Lauraceae, Meliaceae, Mimosaceae, Moraceae, Myristicaceae, Myrtaceae, Ochnaceae, Olacaceae, Palmae, Papilionaceae, Rutaceae, Sapindaceae, Sapotaceae, Sterculiaceae, Thymelaeaceae and Tiliaceae. (Van Steenis, 1958; Whitmore, 1984; Latiff, 1994; Ashton, 2001a).

Considering the vast magnitude of the genetic resources, it is very important to continuously assess our forest in terms of species richness or biodiversity. Many botanists through their continuous research efforts have discovered new records. For instance, Kiew *et al.* (1993) have published 20 new records as well as three new species for limestone hill forests of Perlis. Subsequently, during the scientific expedition of 1999 to the Perlis State Park at Wang Kelian, Faridah-Hanum *et al.* (1999) added another 20 new records to the botanical list including one new record for Malaysia, *Tetrastigma obectum* (Vitaceae).

Many Lowland Tropical Forests contain easily more than 100 species among the trees of 10.0 cm DBH per ha and in some even more than 200 species may be found (Turner, 2001). The high diversity of species within a particular forest frequently involves the coexistence of species of different genera. For instance, 781 species of trees over 1.0 cm DBH were recorded in a 25–ha plot of Pasoh (Manokaran *et al.*, 1992). Ashton (2001b) and Condit *et al.* (2004) reported the highest records— somewhat more than 1,000 species of trees over 1.0 cm DBH each in a 25–ha plot of Lambir, Sarawak, and Yasuni, in the Ecuadorian Amazon respectively. However, in Barro Colorado Island only 275 species of trees were recorded in a 25–ha plot (Condit *et al.*, 2004).

The 50-ha plot in Pasoh harboured 338,360 trees of 1.0 cm DBH and above (mean = 6,767 trees/ha), comprising 81 families, 295 genera, and 818 species. The total basal area for all trees in the 50-ha plot was 1,658.73 m^2 (mean = 33.17 m^2/ha). Almost 80.0% of the trees were of < 5.0 cm DBH, and only 721 trees (26 trees/ha) were of > 60.0 cm DBH (Appanah & Weinland, 1993).

The most common genera found in the tropical regions are *Eugenia* and *Ficus*, with more than 500 species; however, the following genera are also represented: *Aglaia, Ardisia, Calophyllum, Daemonorops, Diospyros, Dipterocarpus, Dysoxylum, Elaeocarpus, Garcinia, Litsea, Quercus, Schefflera* and *Shorea* (Yamada, 1997).

Dipterocarpaceae disappears at altitudes between 1,000 and 1,500 m; above 1,500 m, Montane Forest appears, in which the principal flora consists of Fagaceae (Whitmore, 1984; Yamada, 1997). Montane Forest is characterized primarily by the abundance of epiphytes and climbers. Tree trunks are clothed in mosses and lichens, and wrapped around by epiphytic climbers. Except for the lack of emergents, Montane Forest at lower altitudes has the same stratification as mixed dipterocarp forest. Tree heights decrease with altitude, and around 3,000 m, the forest consists of a single layer of trees about 10 m tall. The main groups seen here are Lauraceae, Fagaceae, Cunoniaceae, Monimiaceae, Magnoliaceae, Hamamelidaceae and Ericaceae (Yamada, 1997; Richards, 1996; Barnes *et al.*, 1998).

2.1.5 Conservation Strategy

Forests are critically important for maintaining biological diversity. Forest fragmentation exacerbates the impacts of overall deforestation and forest degradation on biodiversity by blocking migration routes and making access easier for further exploitation by humans and entry by invasive and/or weed species (UNEP, 2002). Environmental degradation has led to loss of biodiversity worldwide. So far there is no accurate account of the loss of species and this loss may even occur before species are discovered. Apparently, the loss of biological diversity through the extinction of species, the conversion and degradation of natural habitats, and the disruption of ecological processes is occurring throughout the world at unprecedented rate (Anon. 2004; Anon. 2010b).

In Asia, as elsewhere, the most important direct cause of biodiversity loss is habitat destruction from clearing and burning forests, draining and filling wetlands, destroying coastal areas for development, and converting natural ecosystem for agriculture, industry and human settlement (Braatz, 1992). Figures frequently quoted are theoretical ones derived from species–area curves. Making use of the model, Reid (1992) quoted lower estimates for the rate of extinction for closed tropical forest in Asia at 2.0–5.0% of species and higher rates at 8.0–18.0%. For the flora of Peninsular Malaysia, estimated to comprised about 7,660 species (Turner, 1995), the lower rate would translate into between 153 and 383 species and higher rate into between 613 and 1,379 species.

The 1997 Red List of Threatened Plants (Walter & Gillet, 1997) lists for the whole Malaysia with at least 15,500 species, just 3 species as extinct, 3 critically endangered, 84 as endangered, 146 as vulnerable, 144 as scarce and 113 as intermediate. According to Kiew (2001), Ridley had reported dated back to the turn of the century several species to be extremely scarce and known from a single small population, which had been wiped out by forest clearance. One such species was *Echinodorus ridleyi* (*Ranalisma rostrata*) and another one was *Begonia eiromischa* Ridl. Further extinctions also reportedly occurred during the era of widespread development of plantations on the west coast of Peninsular Malaysia whereby 8 of the 12 extinct species of the Annonaceae were known only from early collections from Malacca, Penang or Perak and have not been recollected since the 1920s (Kiew, 2001).

Forest protected areas are one of the keys to the conservation of biological diversity globally (SCBD, 2010b). An estimated 12.0% of the world's forests are under protected area status (as defined by IUCN Categories I to IV) (United Nations Development Programme (Anon. 2010c). Meeting the challenge, in line with the concept of sustainable forest management, development and conservation, over the years, Malaysia has been establishing a network of protected areas for the conservation of biological diversity. Some of these national parks, wildlife reserves, nature parks, bird sanctuaries and marine parks have been established since the 1930s. Malaysia's largest national park, covering 434,351 ha, which was gazetted as early as 1939, comprises mainly virgin forests of various forest types according to altitudes and soil conditions. Currently, Malaysia has 2.15 million ha of conservation areas which are totally protected by legislation as shown in Table 2.4.