A PHYTOSOCIOLOGICAL STUDY OF *AQUILARIA MALACCENSIS* LAMK. AND ITS COMMUNITIES AT SUNGAI UDANG FOREST RESERVE, MALACCA

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ABSTRACT

A phytosociological study was done to assess the composition of *Aquilaria malaccensis* Lamk. and the ecological relationship between the species within the communities. Braun-Blanquet (1964) method was adopted in the present study. A total of 1668 individual trees with diameter at breast height (DBH) of 5 cm and above were found in the 25 plots in Sungai Udang Forest Reserve, Malacca, Peninsular Malaysia of which overall floristic composition consisted of 85 species belonging to 79 genera and 38 families. The most abundant family is the Euphorbiaceae with 224 individual trees, followed by Myrtaceae and Anacardiaceae representing 212 and 197 individuals, respectively. The phytosociological study identified a community which was *Aquilaria malaccensis* - *Artocarpus rigidus* community with two sub-communities known as *Palaquium gutta* sub-community and *Barringtonia racemosa* sub-community. Based on the calculated Importance Value Index (IV_i), *Spondias cytherea* (Anacardiaceae) was the most important species in the study area with an importance value index (IV_i) of 23.9%. The second most important species in the study area was *Syzygium* sp. (Myrtaceae) with an importance value index (IV_i) of 22.8%, followed by *Elateriospermum tapos* (Euphorbiaceae) and *Aquilaria malaccensis* (Thymelaeaceae) with an importance value index (IV_i) of 17.2% and 13.0%, respectively. As for species diversity, the Shannon-Weiner Diversity Index (H’) for the whole 25 plots of the study area (*Aquilaria malaccensis-Artocarpus rigidus* community) showed an index value of 3.67, while the Simpson’s index of diversity (1-D) for the whole 25 plots (*Aquilaria malaccensis-Artocarpus rigidus* community) showed an index value of 0.96. The H’ values and D values proved that the study plots are considered as obtaining a fairly high species diversity in comparison with many studies conducted at the tropical rainforests in Peninsular Malaysia. The floristic composition in the family level obtained in this

study with Euphorbiaceae as the dominant family is quite similar to those found in other tropical forests in Peninsular Malaysia. The fairly high species diversity and the good soil characteristics obtained from the study area shows that *Aquilaria malaccensis* Lamk. and its communities can successfully interact socially between each other and able to live healthily together in an ecosystem. The soil in the study area was acidic and dominated by clay loam which shows that the soil is suitable for the provision of nutrients to the plants. This study also concluded that high soil fertility promotes the high species diversity and richness of an area. The correlation analysis between the physico-chemical characteristics of soil at all the 25 plots in the Sungai Udang Forest Reserve concluded that the correlation between the chemical content of soil in this study was moderate. Furthermore, the Pearson's correlation analysis determined that the vegetation diversity or plant communities were significantly and positively correlated with soil parameters, particularly soil pH, CEC, available K, available P, available C and available N. Therefore, the soil characteristics of an environment should be an important criterion for species distribution. The composition and distribution of species in this study might be also influenced by other environmental factors such as natural forest gap, altitude and topography. The new information on *Aquilaria malaccensis* Lamk.and its communities obtained from this study could contribute to the future plantation work, by using all the exact species existed in the discovered new communities as a reference in planting trees.

ABSTRAK

Suatu kajian fitososiologi telah dijalankan untuk menilai komposisi *Aquilaria malaccensis* Lamk.dan hubungan ekologi di antara spesies di dalam komuniti. Kaedah Braun-Blanquet (1964) telah digunakan di dalam kajian ini. Sejumlah 1668 individu pokok dengan diameter pada paras dada 5 cm dan ke atas telah ditemui di dalam 25 plot di Hutan Simpan Sungai Udang, Melaka, Semenanjung Malaysia di mana keseluruhan komposisi flora terdiri daripada 85 spesies dalam 79 genera dan 38 famili. Famili yang paling banyak ialah Euphorbiaceae dengan 220 individu pokok, diikuti oleh Myrtaceae dan Anacardiaceae masing-masing mewakili 212 dan 197 individu. Kajian fitososiologi ini telah mengenalpasti sebuah komuniti iaitu komuniti *Aquilaria malaccensis* - *Artocarpus rigidus* dengan dua sub-komuniti dikenali sebagai sub-komuniti *Palaquium gutta* dansub-komuniti *Barringtonia racemosa*. Bagi kepelbagaian spesies, Indeks Kepelbagaian Shannon-Weiner (*H'*) bagi ke semua 25 plot di kawasan kajian (komuniti *Aquilaria malaccensis-Artocarpus rigidus*) menunjukkan nilai indeks 3.67, manakala indeks kepelbagaian Simpson (1-D) bagi ke semua 25 plot di kawasan kajian (komuniti *Aquilaria malaccensis-Artocarpus rigidus*) menunjukkan nilai indeks 0.96. Nilai *H'* dan nilai D membuktikan bahawa plot yang dikaji dianggap sebagai mempunyai kepelbagaian spesies yang agak tinggi berdasarkan perbandingan dengan pelbagai kajian yang dijalankan di pelbagai hutan di Semenanjung Malaysia. Komposisi flora di peringkat famili yang diperoleh di dalam kajian ini dengan Euphorbiceae sebagai famili dominan adalah agak serupa dengan yang dijumpai di hutan tropika lain di Semenanjung Malaysia. Kepelbagaian spesies yang agak tinggi dan ciri-ciri tanah yang baik yang diperolehi dari kawasan kajian menunjukkan bahawa *Aquilaria malaccensis* Lamk.dan komunitinya boleh berinteraksi secara sosial dengan cemerlang antara satu sama lain dan boleh hidup bersama dengan sihat di dalam sesuatu ekosistem. Tanah di kawasan kajian yang berasid dan didominasi oleh tanah liat gembur menunjukkan

bahawa tanah tersebut sesuai bagi penyediaan nutrien kepada tumbuh-tumbuhan.Kajian ini juga menyimpulkan bahawa kesuburan tanah yang tinggi menggalakkan kepelbagaian dan kekayaan spesies yang tinggi di sesuatu kawasan.Oleh itu, ciri-ciri tanah sesuatu persekitaran harus menjadi kriteria penting untuk taburan spesies. Komposisi dan taburan spesies di kajian ini mungkin juga dipengaruhi oleh faktor persekitaran lain seperti kewujudan jurang hutan secara semulajadi, ketinggian dan topografi. Informasi baru mengenai *Aquilaria malaccensis* Lamk.dan komunitinya yang diperolehi dari kajian ini boleh menyumbang kepada kerja perladangan di masa hadapan, dengan menggunakan ke semua spesies yang wujud di komuniti baru sebagai rujukan dalam penanaman pokok.

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Al	:	Aluminium
Ca	:	Calcium
CEC	:	Cation Exchange Capacity
CITES	:	The Convention on International Trade in Endangered Species of Wild Fauna and Flora
cm		Centimetre
DBH	:	Diameter at breast height
Fe	:	Iron
G	:	Gram
GIS	:	Geographical information system
GPS	:	Global positioning system
Ha	:	Hectares
H_3BO_3	:	Boric acid
HCl	:	Hydrochloric acid
$H_2 SO_4$	:	Sulfuric acid
IUFRO	:	The International Union of Forest Research Organizations
IVi		: Importance Value Index
K	:	Potassium
KH_2PO_4	:	Monopotassium phosphate
K_2SO_4	:	Potassium sulfate
L	:	Litre
M	:	Metre
M	:	Molar

m^2 : Metre square

ml : Mililiter

mm : Milimeter

Mg : Magnesium

Na : Sodium

NaOH : Sodium hydroxide

$NaPO_3$: Sodium hexametaphosphate

NH_4F : Ammonium fluoride

NH_4OAc : Ammonium acetate

P : Phosphorus

pH : Used to express the acidity or alkalinity of a solution

Sb : Sodium benzoate

ºC : Degree celsius

% : Percent

$<$: Less than

$\geq$: Greater than or equal to

µg : Microgram

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CHAPTER 1: INTRODUCTION

1.1 General Introduction

Phytosociology includes plant communities within the same environment, their floristic composition and development, and the social relationships between them. The information of the distribution of species as well as associations between species or groups of species could be achieved from a phytosociological study, which could lead to an important assessment of the vegetation (Frenedozo-Soave, 2003). Phytosociology is a data that represent integrated units in vegetation systems which provides a very useful basic data for ecology, geography, landscape science, conservation and environmental science (Fujiwara, 1987).

According to Enright and Nuñez (2013), the classification of vegetation into associations based on floristic composition and the identification of characteristics species is pioneered by Braun-Blanquet. The vegetation science community is becoming a globalized one, thus, the advantages and problems related with the phytosociological approach to vegetation analysis pioneered by Braun-Blanquet will unavoidably continue to be reviewed many times.

The restoration of forest biodiversity in degraded parts of the mountains as well as *in situ* biodiversity conservation are contributed by the understanding of plant community dynamics and species associations as influenced by varying environmental factors (Munishi *et al.*, 2007). The long term management of natural resources is contributed by the classification of natural ecosystems into potential plant communities and habitat types (Khan *et al.,* 2011). Natural plant communities and biodiversity can be protected by phytosociological studies, and the changes experienced in the past and in the future can be understood with phytosociological studies too (Saglam, 2013).

Vegetation studies are still being studied by scientists from developed countries, however, different scenarios are seen in European countries with defined vegetation maps and completed vegetation studies (Tel *et al*., 2010). Phytosociological study should not only deal with the dominant units but also should give attention to poorly understood and recorded units and local monographs, dealing with all community types (Parolly, 2004).

Many significant studies which involve the floristic composition and diversity of the tropical rainforest in Malaysia have been conducted many years ago. However, those studies did not focus on the social relationship between the plant communities in the tropical forest of Malaysia. The Braun-Blanquet method used in this study will provide detail information on the floristic composition of the forest area together with the social relationship of the plants involved.

The principal plant used in this study is *Aquilaria malaccensis* Lamk. (Thymelaeaceae) which is an agarwood (also known locally as 'gaharu') producing species. Agarwood is produced in the trunk of *Aquilaria malaccensis* when the tree sap is wounded and attacked by pathogens or insects (Mohamed *et al.,* 2010). The fungal infection, injury or non-pathological processes of some tree species would trigger the production of the resinous material called agarwood which could cause the physiological and chemical changes to the wood (Karlinasari *et al.,* 2015).

In international trading, the major producer of agarwood in Malaysia is *Aquilaria malaccensis* (Wong *et al.*, 2013). Perfume, incense, traditional medicine, and other commercial products by Muslims and Asian Buddhists are produced by *Aquilaria malaccensis* Lamk. which is known as among the most highly valuable non-timber products of the tropical forests (Turjaman *et al.*, 2006).

The unique aroma of agarwood is traditionally used to provide tranquility, healing and spiritual cleansing by many cultures (Karlinasari *et al.*, 2015). The aromatic resin produces an essential oil which is the main ingredient for perfume through distillation, meanwhile, incenses are commonly processed from distillation residues and lesser quality material. A black resinous reaction wood identified as a fine striations or pencil-shaped deposits in the branches, trunk and roots of the mature tree is known as agarwood and is produced by *Aquilaria malaccensis* (La Frankie, 1994).

Primary and secondary lowland forests of Bangladesh, Bhutan, China, Cambodia, India, Kalimantan, Malaysia, Moluccas, Myanmar, Papua New Guinea, Philippines, Singapore, Sulawesi, Sumatra, Thailand, Vietnam, and West Papua are the common places of *Aquilaria* species (Turjaman *et al.*, 2006). *Aquilaria agallocha*,*Aquilaria crassna* and *Aquilaria malaccensis* are the three species which are mostly found in Malaysia. Their geographical distributions are random throughout the Peninsular Malaysia.

Bukit Bauk in Terengganu, Gua Musang in Kelantan, Jelebu in Negeri Sembilan, Jeli in Kelantan and Sungai Udang in Malacca are some of the places well-known for their natural populations of *Aquilaria malaccensis* in Malaysia (Lee *et al.*, 2011). Other species of the genus of *Aquilaria malaccensis* are stated to be commonly rare, meanwhile, the *Aquilaria malaccensis* itself is absent from Sarawak (Tawan, 2004). The densities of *Aquilaria* species in Sumatra and Kalimantan are low due to the logging activities and continuing forest conversion (Soehartono & Newton, 2000).

According to Nor Azah *et al.*, (2013), the *Aquilaria* species or also known as the agarwood producing species is threatened from the agarwood harvesting activities in the forest. Local and overseas traders are really interested in these highly rewarding priced goods. Thus, the high grade agarwoodis demanded greatly in the global market.

Agarwood's high price is contributed by its high demand in the market (Karlinasari *et al.*, 2015). As a result, the International Union for the Conservation of Nature has classified *Aquilaria* species as'vulnerable' (IUCN, 2002). To make matter worse, the Convention on International Trade in Endangered Species of Wild Fauna and Flora has listed *Aquilaria malaccensis* in Appendix II (CITES, 2011).

According to Akter *et al.*, (2013), the international agreement such as CITES which is accepted by 169 countries is designed to ensure that the survival of *Aquilaria* species does not threatened by the trade in agarwood products from wild trees in the forest. However, the existing *Aquilaria* trees are still threatened by illegal cutting of *Aquilaria* trees for the trade of agarwood products due to high demand from unknowing consumers.

Foresters, biologists and naturalists who aim at conserving these species in the forest are worried of this endemic genus with restricted distributions (Lee *et al.*, 2011). The development of massive *ex-situ* plantations together with techniques capable to induce agarwood production on young plants are expected to decrease the over exploitation of this species in their natural environments (Faridah-Hanum *et al.,* 2009).

Mass planting the trees and collecting agarwood in non-destructive manner are some of the approaches to produce agarwood in a sustainable manner, which is also a way to conserve this valuable tree taxon (Mohamed *et al.,* 2010). Plantations or small gardens are some of the approaches to grow *Aquilaria* sp. economically (La Frankie, 1994).

According to Akter *et al.,* (2013), growing trees in plantations is one of the latest ways to produce agarwood. Some countries including Bangladesh, Bhutan, India, Indonesia, Laos, Malaysia, Myanmar, Papua New Guinea, Thailand and Vietnam have initiated the agarwood plantations. Sustainable *Aquilaria* plantation forests were a source of finest agarwood's oud oil which is highly paid by luxury brands.

Research on inoculation, genetic analysis, chemical analysis of the resin, and large-scale planting of *Aquilaria malaccensis* have been carried out in Malaysia (Wong *et al.,* 2013; Nor Azah *et al.,* 2013; Siah *et al.,* 2012; Lee *et al.,* 2011; Mohamed *et al.,* 2010; Turjaman *et al.,* 2006; Lok *et al.,* 1999). However, research on the phytosociology of *Aquilaria malaccensis* and its communities is entirely lacking in Malaysia.

Aquilaria species are currently harvested completely from natural forests, thus, it is highly important to manage species such as *Aquilaria* species by getting more information on reproductive ecology and factors influencing reproductive success of *Aquilaria* species (Soehartono & Newton, 2001b). Artificial cultivation which is an effort to preserve agarwood resource and increase its supply has been conducted (Karlinasari *et al.,* 2015). The habitats of flora and fauna could be conserved and the loss of threatened species could be prevented largely by the establishment of protected and conservation areas such as permanent forest reserves (Syahida-Emiza *et al.,* 2013).

Most studies were done on other species of *Aquilaria* trees but specific studies on *Aquilaria malaccensis* itself are scarce. Thus, the strength of this study is on its focus on the phytosociological studies of *Aquilaria malaccensis* and its communities from a natural forest in Malaysia.Currently, research on the phytosociology of *Aquilaria malaccensis* such as detailed studies on its floristical aspects and its plant community level is literally unknown.

The unique properties of the highly valuable agarwood of *Aquilaria malaccensis* has triggered the extraordinary interest on understanding more about this valuable trees by doing phytosociological research on it. An excellent way to conserve this valuable tropical tree would be to know its composition and the ecological relationship between the species within its community. Understanding the social relationship of this profitable species could also indirectly bring benefits to the economy of the country.

Furthermore, the knowledge on biological diversity and ecological functions gained from this phytosociological study will assist in developing the mass planting of *Aquilaria malaccensis* and its plant communities and indirectly could contribute to the conservation efforts.The virtual absence of previous scientific information on the phytosociology study of *Aquilaria malaccensis* in Malaysia and obvious need for empirical botanical documentation provided a main stimulus for the present study.

1.2 Research Objectives

The aims of this study are;

1. To identify, characterize and classify the floristic composition of the naturally distributed *Aquilaria malaccensis* Lamk. and its communities
2. To provide information on species diversity of the plant communities
3. To examine the species importance of the plant communities
4. To describe the soil characteristics of the plant communities
5. To determine the relationship between the vegetation and the soil properties of the study area

CHAPTER 2: LITERATURE REVIEW

2.1 Phytosociology

Phytosociological study is very significant in the understanding of the species composition and diversity of a forest. The knowledge on newer species as well as their behaviour can be achieved by the understanding of the species composition and diversity of a particular forest (Mardan *et al.,* 2013).

Many studies have been conducted on the composition and diversity of the tropical rainforest in Malaysia since years ago (Khairil *et al.,* 2014; Lajuni & Latiff, 2013; Mardan *et al.,* 2013; Nizam *et al.,* 2012; Abdul Hayat *et al.,* 2010; Faridah-Hanum *et al.,* 2008). However, there is a lack of study on the social behavior of the plants in the tropical rainforest of Malaysia. Thus, the Braun-Blanquet method was chosen in this study with great expectation that it will assist in providing more information on the social behavior of the plant communities in the tropical rainforest of Malaysia.

According to van der Maarel (1975) on his perspective of the Braun-Blanquet approach, phytosociology uses large-scale vegetation maps so that it is suitable to agriculture, forestry, hydrology and physical planning. The Braun-Blanquet approach has been accepted as a scientific enterprise due to the role of phytosociology study. A much more detailed hierarchy of many new community types was distinguished with more emphasis on the structural uniformity of types by the refinement of the scale of observation which involved the meticulous mapping of vegetation.

Furthermore, van der Maarel (1975) stated that since the Braun-Blanquet approach was proposed, the main fundamentals of the phytosociological analysis which are the fairly detail description of structure, the rather rough but very efficient combined estimation of cover-abundance and the estimation of the sociability of all existing species, the systematical description of the superficial features of the site, have hardly changed and still form a very powerful tool in phytosociology.

Kolbek and Alves (1993) in their studies on some vicariating plant communities in Brazil, Malaysia and Singapore concluded that the studied communities occurred in ecologically related sites regardless of the geographical distances between them. The vicariant community groups physiognomical similarity are contributed by their large proportion of life forms which occurred together in space. Selection of similar life forms is promoted by the similar environmental conditions of the described communities. The mangroves around the world are a classical example of such communities. A larger diversity of both taxa and life forms of plants can be observed due to the broader ecological amplitude of the described communities. Even though the plot material was insufficient, the survey contributed to the knowledge of the described communities and was not recognized as exhaustive.

According to Sánchez-Mata (1997) on his study on the phytosociological approach, phytosociology is a modern science which uses a methodology recognized by most plant ecologists to be the most efficient and effective way to explain natural vegetation patterns in a geographic area with a variety of ecological features. This approach is widely used in Europe, Asia, and North Africa.

According to Botta-Dukát *et al.*, (2007), even though phytosociological sampling does not satisfy the formal criteria of statistical analysis, phytosociological plots can be analyzed using statistical methods if conventional criteria are fulfilled. Due to the long tradition of the Braun-Blanquet approach, many plots using this approach have been made. Although the traits of stands that are preferred or avoided by the phytosociologist during preferential sampling (which is a characteristic of the Braun-Blanquet approach) can be identified, there are no general rules that could predict the difference between the preferential and non-preferential datasets obtained for the same object.

Roleček *et al.*, (2007) stated that the clear advantage of preferential sampling (the traditional phytosociological approach) is that it tracks and samples nearly the full range of floristic variation in vegetation of the study area, including the rare types. It satisfies the requirement for the representation of maximum vegetation variability in the sample, while the survey resources are not wasted for the over-sampling of the prevailing vegetation types.

According to Podani (2006), The Braun-Blanquet abundance/dominance scores that commonly appear in phytosociological tables cannot be analysed by conventional multivariate analysis methods such as Principal Components Analysis and Correspondence Analysis. All the ordination methods that are commonly used, for example Principal Components Analysis and all variants of Correspondence Analysis as well as standard cluster analyses such as Ward's method and group average clustering, are inappropriate when using the abundance/dominance data. Therefore, the application of ordinal clustering and scaling methods to traditional phytosociological data is advocated.

Lájer (2007) added that the frequently applied statictical tests such as the t-test, ANOVA, Mann-Whitney test, Kruskal-Wallis test, chi-square test (of independence, goodness-of-fit, and homogeneity), Kolmogorov-Smirnov test, concentration analysis, tests of linear correlation and Spearman rank correlation coefficient, computer intensive methods (such as randomization and re-sampling) and others do not provide reliable support for the inferences made because non-randomness of samples violated the demand for observations to be independent, and different parts of the investigated communities did not have equal chance to be represented in the sample.

Mohd Hasmadi *et al.*, (2010) studied plant association and composition in Gunung Tahan, Malaysia using GIS and phytosociological approaches. The study stated that throughout the twentieth century, the original Braun-Blanquet method was modified and adapted to meet specific requirements of plant ecologists. Lately, plant community classification and vegetation mapping have applied the phytosociological methods extensively.

The flood of redundant names to a set of manageable units can be reduced by the revisionary account on a broad base of references in phytosociological research (Parolly, 2004). Land management, restoration and conservation involve essential tools such as the classification and assessment of vegetation patterns and species associations (Munishi *et al.*, 2007).

The sample plot which represents the composition of the forest is essential in capturing the dynamics, production and regeneration capabilities in terms of number, size and species of a particular forest (Faridah-Hanum *et al.*, 2008). Understanding the ecological processes and responses of vegetation in facing future disturbances involves the assessment of the distribution patterns of a certain species, which is essential as regional and global disturbances directly affect composition and diversity of a species (Prado Júnior *et al.*, 2014).

According to Ledo (2015), doing inventory work on forest plots as well as mapping of tropical trees is a difficult chore. Technical and economic difficulties will be faced by anyone who attempted to do the inventory work and mapping the tropical trees. The tropical forest which is consisted of a mix of hundreds of tree species can be a complicated place with limited visibility and capacity for movement, due to high density of woody plants such as trees, shrubs and lianas. Under the current global economic crisis, expensive projects such as mapping of trees which require the involvement of high level of manhours are frequently hindered.

Whereas the communities of this study occurred in the same range of geographical distances and the plots are ecologically related. The non-exhaustive phytosociological survey of this study could assist in understanding more about the social behavior of the communities and the environment, even though it involved a meticulous work of large scale vegetation mapping.

2.2 *Aquilaria malaccensis* Lamk.

Aquilaria malaccensis Lamk. (Thymelaeaceae) is a medium sized tree typically ranging around 30 m to 40 m in height. The inner bark and bark are usually cream to white in colour and dark to pale grey, respectively. There is usually no difference in colour between sapwood and heartwood of the light and soft wood of *Aquilaria* species (Chakrabarti *et al.*, 1994). The family commonly occurs in the lowland forests of the Southeast Asia region such as Borneo Island, Philippines, Malaysia, Myanmar and Sumatera (Lok *et al.*, 1999).

According to Mohamed *et al.*, (2010), fungi are the main microbial component which plays an important part in the agarwood formation. Multiple fungal taxa exist in a complex system of wounded trunks of *Aquilaria malaccensis* in the natural environment which lead to agarwood production in the wounded tree trunk. The weaken tree attacked by a pathogenic fungus caused the injury of the stem or main branches of the tree which triggered the agarwood formation.

According to Akter *et al.*, (2013) in the study on agarwood production, the infection of parasites on the trunk and roots of trees triggered the formation of agarwood. As a result, a resin high in volatile organic compounds that aids in suppressing or retarding the infection is produced by the tree and this process is called tylosis. The affected wood changed its colour from pale beige to dark brown or black and this process is caused by the resin which significantly increased the mass and density of the affected wood, while the unaffected wood of the tree is relatively light in colour. Only about 7% of the trees in the natural forest are infected by fungus.

Agarwood formation involves essential factors such as tree age, genetic background, seasonal and environmental variation (Ng *et al.*, 1997). A complex range of regulatory mechanisms is stimulated when plants are wounded and attacked by pathogen which is a way of the plants to recognize and initiate the defense responses (Wong *et al.*, 2013).

Agarwood has a unique property whereby the burnt resin of its wood will emits a wonderful fragrant. Several kilograms of the valuable dark, heavy resinous wood with the characteristic honey-like scent might be produced by a good agarwood tree (Donovan & Puri, 2004). Thus, it is used as a main ingredient in manufacturing perfumes and incenses. Recently, agarwood has been included in pharmaceutical products to treat many illnesses including coughs, acroparalysis, asthma and as an anti-histamine, and also has been known and accepted in traditional medicines over many generations (Kim *et al.,* 1997; Bhuiyan *et al.*, 2009).

Akter *et al.*, (2013) in the study on agarwood production added that the resinous wood or oil extracted is used during Buddhist and Islamic cultural activities as well as an important ingredient in many traditional medicines, thus, the agarwood is extremely valuable. It is also used in traditional Japanese incense ceremonies and regarded as an extremely important component. The use of this aromatic resinous wood as incense is mentioned several times in the bible although most people in the United States and Europe are unfamiliar with it.

La Frankie (1994) in his studies on population biology of *Aquilaria malaccensis* in a permanent plot of primary rain forest in Malaysia stated that the low density and wide spatial distribution of *Aquilaria* species are by far the most constraining features of these natural populations. This distribution must significantly hamper any effort to collect its bark and resin. Other than by making an exhaustive inventory one is very unlikely to ever come across any gaharu in practice.

Akter *et al.*, (2013) in the study on agarwood production stated that *Aquilaria* species can live in a certain range of habitats such as rocky, sandy or calcareous, well-drained slopes and ridges and land near swamps. The trees started to produce flowers and seeds as young as four years old and they will grow rapidly.

Karlinasari *et al.*, (2015) in the study of sonic and ultrasonic waves in agarwood trees stated that direct harvesting and indiscriminate felling in natural forests and among cultivated trees are common methods for collecting agarwood which use visual assessment and experience of agarwood collectors. The trunk and branches of the tree are parts that are commonly found with agarwood. The presence of agarwood is indicated by the colour and fragrance of agarwood. Higher agarwood content is recognized by the darker of the wood. Agarwood is traded as lumps, chips and powder after it is collected in the form of wood.

Agarwood has declined in the number of trees due to the hundreds years of harvested activities in the forests (Mohamed *et al.,* 2010). The attempts by inexperienced outsiders to cash in on what they perceive as a "free good" have caused unnecessary damage to *Aquilaria* stands to the extent of threatening their continued existence in some areas, thus, most of the internationally traded resinous wood is a product of a rapidly diminishing area of natural rainforest (Donovan & Puri, 2004).

Nobody yet has succeeded in producing high quality commercial gaharu from plantations despite its long trade history, the enduring interest of consumers, high prices, and several decades of research (Barden *et al.*, 2000, Soehartono & Newton 2001a, Tabata *et al.*, 2003). More detailed studies at molecular level are now emerging which involved the mechanism of agarwood biosynthesis (Siah *et al.*, 2012).

The *Aquilaria* species often grow slowly in the early growth stage compared with the fast growing high quality seedlings, thus, the fast production of those high quality seedlings in nurseries is a vital stage for refilling degraded tropical forest lands (Turjaman *et al.,* 2006). Tools for the identification of seeds and seedlings are necessary for the production and breeding of *Aquilaria* in the nursery (Lee *et al.*, 2011). Increasing the cultivation of *Aquilaria* spp. in plantations is another alternative to secure sustainable gaharu production and natural populations of trees should not be extracted and reduced beyond their capability to regenerate (Soehartono & Newton, 2001b).

La Frankie (1994) in his studies on population biology of *Aquilaria malaccensis* in Pasoh Forest Reserve in Malaysia added that the number of harvestable trees, the quantity of gaharu per tree, the quality of gaharu per tree contributed to the economic benefits of *Aquilaria* species. These three factors are sufficiently uncertain so as to preclude the formal calculation of a meaningful net present value. Nonetheless, the process of analysis, while more than a little speculative, is a useful means to examine the range of possible outcomes relative to other land-use alternatives.

Akter *et al.*, (2013) also added that first-grade agarwood has an extremely high value. A wide range of qualities and products varying with geographical location and cultural authentication is on the market. The price of a top quality oil and resinous wood can reach over 30 thousand US dollars while the lowest quality can reach as low as a few dollars per kilogram. The quantity of resin inside the agarwood chips contribute to the price of the chips. One of the most expensive natural raw materials in the world is the valuable first-grade agarwood.

According to Page and Awarau (2012) on a study of the performance of agarwood seedling transplants, the rapid decline of *Aquilaria* natural stands due to wild harvesting in its natural environment in tropical Asian and Pacific countries contributed to the increasing interest in establishing its plantings worldwide. Harvesting pressures on *Aquilaria* wild stands would be reduced and an alternative source of agarwood would be provided by the existence of such plantings.

Soehartono and Newton (2001b) stated that the results of the study on the reproductive ecology of *Aquilaria* species in Indonesia suggested that *Aquilaria* trees have a high reproductive potential and are usually extremely productive. An individual tree will produce thousands of seeds which are due to the high number of flowers borne by a mature tree, even though the proportion of flowers developing into a fruit was very low. The potential for seedling recruitment would be high if the high germination rates were reproduced under forest conditions.

Some of those mentioned studies above were not done specifically on *Aquilaria malaccensis* trees but on other species of *Aquilaria* trees. The strength of this research lies on its specific focus on the phytosociological studies of *Aquilaria malaccensis*. There have been several astounding studies on the *Aquilaria malaccensis* trees in Sungai Udang Forest Reserve particularly regarding the inoculation of the gaharu and chemical reactions of the tree species. However, lack of research regarding the phytosociology study and the social relationship of particularly *Aquilaria malaccensis* and its communities.

Due to the wonderful fragrant and unique property of the highly valuable agarwood which could be used for so many purposes and beneficial to many kinds of people, this study has been conducted in hoping that it will contribute more information on *Aquilaria malaccensis* and could help in understanding the *Aquilaria malaccensis* better. Furthermore, understanding the social behavior of *Aquilaria malaccensis* towards its communities could contribute in the planting of the highly fecund *Aquilaria malaccensis,* thus, preventing the declining of agarwood due to harvesting activities in the natural forest. In other way, it could bring benefits to the economy of the country.

2.3 Factors Influencing Floristic Composition

Previous studies have discovered that there are many important factors that could influence the floristic composition of a forest. Some of those mentioned factors are environmental gradients, anthropogenic pressure, topography and elevations, soil physical and chemical properties (Khairil *et al.,* 2014; Saiful & Latiff, 2014; Li *et al.,* 2012; Millet *et al.,* 2010; Kwan & Whitmore, 1970). The complex characteristics of floristic composition is due to several parameters of disturbance such as time, intensity and repetition could affect regeneration of the original floristic composition and soil condition (Millet *et al.,* 2010).

A study by Munishi *et al.,* (2007) on compositional gradients of plant communities in submontane rainforests stated that areas with excellent conditions to survive and reproduce are favourable to the plants. Moisture, soil physical and chemical properties and other physical characteristics of the landscape are factors that influence the growth of plants in a particular environment. Distinct plant communities are the formation of an association between plants that respond to the same environmental factors equally.

A study of the role of gap formation on the structure, function, and biodiversity of the Malaysian tropical rain forest by Sato (2009) concluded that changes in environmental conditions drastically affected the change of species composition but the whole forest structure is not affected significantly. In such situations, environmental changes might significantly impact the biodiversity of subdominant species, even though such changes do not show clear effects on dominant canopy species or whole forest structure.

According to Nizam *et al.,* (2012), floristic variation patterns between two different habitats of limestone and lowland dipterocarp forest at the Kenong Forest Park suggest that the floristic patterns are influenced by the environmental gradients. The essential formula to protect and conserve forest habitats is by identifying environmental gradients such as abiotic conditions and major soil that influences the vegetation patterns.

According to Siddiqui *et al.,* (2009), a phytosociological study of *Pinus roxburghii* in Pakistan found that a flattened structure with some fairly large trees and gaps is shown by the distribution of a low density stands. The study concluded that forests are in unstable and in degrading phase due to the anthropogenic disturbances. These ecological and economically important forests and species should be immediately saved by a prompt conservation steps.

According to Ashton (2008), in sheltered well watered sites, including on fertile soils, lack of emergent canopy disturbance can trigger the formation of widespread stands which can form a closed and continuous canopy. Their dense crowns showed that they might never have soil water shortages. The canopy gap may be caused by a windthrow or landslide which can cause some trees uprooted and the soil surface is deprived of litter or the litter might be totally removed.

Sato (2009) on the study of the role of gap formation on the structure, function, and biodiversity of the Malaysian tropical rain forest stated that tropical forests are usually distinguished with a closed and complex vertical structure. Tree regeneration strongly depends on canopy gaps, thus, the loss of dominant canopy trees and the creation of canopy gaps provide critical roles in forest dynamics of such dense forests. Those of a less abundant, shade-intolerant species group are greatly affected by the success and decay of the dominant species group that monopolized the canopy layer.

According to Mohd Hasmadi *et al.*, (2010) on a study of plant association and composition from Mount Tahan, Malaysia using GIS and phytosociological approaches, many recreation ecological studies showed a huge interest in the effect of human trampling on vegetation and soil. For instance, camping and climbing activities could contribute to the severe impacts of trees and ecosystem.

A study on the relationship between understory plant diversity and anthropogenic disturbances stated that species diversity of shrub and herb layers in urban forest is significantly affected by anthropogenic disturbances gradient such as visitor flow rate, shrub coverage, aspect and adjacent land types. Low anthropogenic disturbances might promote co-existence of wood species in suburban areas, meanwhile similar non-native herb species in urban area might be increased with the existence of severe disturbances (Li *et al.*, 2012).

The potential height of trees will reduce from 25% to 50% by the disturbances (Ng, 1983). Disturbance also severely affected the structure of the forest (Millet *et* al., 2010). Undisturbed or minimally-disturbed montane rainforest communities in isolated areas are few and scattered in Peninsular Malaysia (Asep Sumpena, 1995).

Hussain and Perveen (2015) on a study of the plant biodiversity, floristic composition and phytosociological attributes concluded that severe anthropogenic pressure such as over exploitation, habitat destruction, overgrazing and browsing, tourism and unlimited fuel wood cutting have contributed to the continuous declining of the plant diversity. The biodiversity loss of particularly the medicinal plants is due to the threats of the severe anthropogenic pressure on potentially important rare and vulnerable species.

Topography is very well known to influence the vegetation across biomes. For instance, plant communities will change by the increase of elevation. The progressive shift upward of the species composition and assemblages to alpine or boreal communities are due to a change in elevation for given latitude (Bunyan *et al.*, 2015).

Besides factor of environmental disturbances, soil pH is also considered as one of the important environmental factors that influence tree species distribution and contribute to the distribution pattern of vegetation communities. The distribution of vegetation communities of a particular forest ecosystem is largely influenced by the environmental gradient, particularly the soil gradient (Nurfazliza *et al.*, 2012).

The accumulation and subsequent slow decomposition of organic matter which releases acids can be due to the reduction in pH (Haan, 1977). Some of the significant scopes in determining the site quality are the nature of soil profile, soil pH and nutrient cycle between soil and trees (Sharma & Kumar, 1991). In order for nutrient supply to be balanced, forest soils should be slightly acidic (Leskiw, 1998). Different stands have different soil characteristics among soil depths (Son *et al.*, 2004). Two main limitations for trees growing on highly-weathered soils in the tropics are soil P deficiency and acidity (Yost & Ares, 2007).

Sollins (1998) in the study on whether soil factor influence species composition in a tropical lowland rain forest, summarized that tree species distribution is influenced by soil factors, even the chemical ones. Thus, more intensive soil sampling to understand the patterns and causes of spatial and temporal variation in soil properties is required, and to add knowledge of the physiological needs of individual plant species.

According to Son *et al.*, (2003), environmental and land-management factors influence the carbon storage and soils are the major reservoir of terrestrial carbon. A complex set of interactions that change during successional development of vegetative communities were the one which regulated soil carbon and nitrogen dynamics.

Nykvist and Sim (2009) in their study on the changes in carbon and inorganic nutrients after clear felling a rainforest in Sabah, Malaysia, stated that large amounts of nutrient in forest soils are fixed in biomass or in plant residues from earlier wood harvests, thus, the analyses of plant available nutrients usually give very low nutrient content levels. Also, in their study, they concluded that plant available phosphorus, potassium, calcium and magnesium levels are the variables that most frequently found from the assessments of soil fertility in agricultural systems and forest ecosystems.

According to Adzmi *et al.,* (2010) on their study of heterogeneity of soil morphology and hydrology on the 50 ha long-term ecological research plot at Pasoh Forest Reserve, Peninsular Malaysia, stated that soil nutrient insufficiencies and imbalances are the most extensive edaphic constraint on tropical forests due to the generally high rainfall and intensive leaching in the forest.

According to Nilus *et al.*, (2011) on their study of nutrient limitation of tree seedling growth in three soil types found at Sepilok Forest Reserve in Sabah, Malaysia, stated that it is compulsory to determine the effects of both the physical and chemical properties of the soils to understand the mechanisms that force the differentiation of forest composition on different soil types, in particular the spatial heterogeneity and temporal dynamics of plant nutrient availability. It is essential to understand which nutrients are limiting to plant growth on both soil types given that plant distribution may be closely related to site conditions and nutrient availabilities.

A study by Ibrahim *et al.,* (2012) on the physico-chemical properties of disturbed soils in South Korea stated that the disturbed and accumulated soils display a great diversity in their physico-chemical properties and they are increasing in area around the globe. Changes in the soil properties make it unpredictable for the growth of plant under specific agro ecological conditions. This is due to the fact that both of the weathering (which causes nutrient levels changes to occur) and the soil hydrological properties is affected by the development of soil and ecosystem.

A study by Kobal *et al.,* (2015) on the influence of soil properties on silver fir growth revealed that in addition to tree age and competition intensity, the factors controlling tree growth were soil parameters such as soil depth, thickness of genetic soil horizons, share of soil types around each tree and soil associations. Tree height growth and basal area increments are influenced by the important site parameter which is soil. Thus, the adaption of soils to thinning intensities to the variations in micro topography over short distances should be considered in forest management.

In a study on effects of soil conditions on the diversity of tropical forests across a successional gradient, Martins *et al.,* (2015) found that Al concentration in soil is strongly influenced by forest age. This finding also indicated that the high concentration of organic matter contributed to the increase of acid in soils and resulting in the release of Al, which will increases soil toxicity and inhibits P absorption by plants.

However, a study by Nilus *et al.,* (2011) on the nutrient limitation of tree seedling growth in three soil types found at Sepilok Forest Reserve in Sabah, Malaysia, concluded that the alluvial soils have higher concentrations of available nutrients and the experiment suggests that P is not limiting to plant growth. Growth became limited by the availability of K, in the absence of limitation by P.

Martins *et al.,* (2015) in a study on effects of soil conditions on the diversity of tropical forests across a successional gradient, suggest that forest recovery is strongly driven by soils due to the detection of consistent differences in forest structure, diversity and species composition in areas with contrasting soil characteristics.

Some of the mentioned factors that influenced the floristic composition of other tree species in previous studies such as environmental gradients, physico-chemical properties of soil and anthropogenic pressure were evaluated in this study. Furthermore, this study focused more on the influence of these factors (environmental gradients, physico-chemical properties of soil and anthropogenic pressure) specifically on *Aquilaria malaccensis* and its composition. The understanding of these significant factors could lead to a better understanding of the association of plant communities that are affected by these factors. Thus, it could contribute in the conservation efforts of forest habitats and the biodiversity loss also could be prevented.

2.4 Tropical Rainforest

Whitmore (1989) in his perspective of the state of tropical rainforest ecology in 1988 concluded that tropical rainforest scientists of the present generation should concentrate on factors which can strengthen the long term security of tropical rainforest. Nations which possess tropical rainforest can only use it wisely if scientists have provided the basic scientific understanding for them to do so. The extremely species rich tropical rain forests always arouse the curiosity of the biologists. The questions by the biologists have formed the foundation of studies on forest dynamics, seedling ecology, plant-animal interactions and biogeographic patterns.

La Frankie (1994) in his studies on population biology of *Aquilaria malaccensis* in Pasoh Forest Reserve in Malaysia concluded that the wealth of known and hidden commercial goods of tropical forests is famous among people in the world. These riches naturally lead to the idea that tropical forests might be managed like a supermarket, where rattan, fruits, nuts, latexes, resins, specialty timbers and myriad other products could be harvested on an ad hoc basis. One could at least imagine that the sum net present value would exceed current net present value for other land uses.

A study by Asep Sumpena (1995) on the phytosociological investigations of the Gunung Ledang montane forest in Peninsular Malaysia stated that the American rainforest, African rainforest and Indo-Malayan rainforest are the three great regions of tropical rainforest in the world. The physiognomy of the species and the structure of rainforest are similar throughout the three regions of the world. Regardless of this similarity, important differences are detected such as the Indo-Malayan region has a larger mountainous region compared to the other two regions. At least the development of two formations are identified which are the lowland forest and upper montane forest in all major mountains.

According to Zhu (1997) in the ecological and biogeographical studies on the tropical rain forest, the tropical rain forest occurs mostly in valleys and on lower hills below 900 m altitude with a tropical moist climate due to a particular topography. The tropical rain forest appears as patches in local habitats and consisted of a mosaic pattern with montane evergreen forests and semi evergreen forests.

According to Numata *et al.,* (2006), rapid human impacts are happening in tropical rainforests. For instance, selective logging is a common form of forest structural alteration and is an extensively employed approach for commercial timber production In South-East Asia.

The environmental conditions of tropical rainforests demonstrate high spatial variability and tropical rainforests are considered the most complex terrestrial ecosystems (Konishi *et al.*, 2006). Forest values such as the biological diversity and ecological functions of forests cannot be protected by the plantation forest, thus, is frequently criticized (Son *et al.,* 2007). Changes in environmental conditions largely influenced the growth of tropical secondary forest vegetation (Romell *et al.*, 2008). Several studies have indicated that depending on certain conditions, forest ecosystems can act as important sinks or sources of carbon (Nykvist & Sim, 2009). The lowland tropical forest plants have extreme species diversity, very complex plant mosaic and involved time constraints, thus, the study on lowland tropical forest plants is considered complicated (Mohd Hasmadi *et al.*, 2010).

According to Adekunle (2006) on a study of community diversity of tropical rainforest ecosystem, the most important characteristics of tropical rainforest ecosystem are species richness and distribution. The number of tree species is far larger in tropical rainforest than in any other forest community regardless of the size of the plot. The ecosystem that had been adversely affected and disturbed by the growing human population is indicated by any low number of trees and species encountered in the studied ecosystem.

According to Ashton (2008) on the paper discussing on the meaning of the term biodiversity and the challenge of its evaluation in Malaysian forests, stated that the service value of tropical lowland evergreen forests unequalled in any other terrestrial ecosystem is known as biological diversity or commonly abbreviated as biodiversity. The lowland evergreen tropical rain forests are known as the only place to sequester more than half of the total diversity of the planet. Additionally, the biodiversity of the Sunda Shelf, particularly Malaysia, Borneo and Sumatra, is second to the central and the Andean hinterlands of South America.

Furthermore, Ashton (2008) stated that plants are organisms that obtained solar energy and carbon from the ecosystem, thus, tree species provide a reasonable substitute of energy for overall biodiversity in tropical rainforests. All other organisms depend directly or indirectly on them for food, thus, they are known as the primary producers. Thus, an extraordinary diversity of chemical as well as physical defenses has been developed by the plants to protect themselves against pathogens, predators and herbivores.

Nykvist and Sim (2009) in their study on the changes in carbon and inorganic nutrients after clear felling a rainforest in Sabah, Malaysia, stated that the increases in atmospheric concentration and its effects on global warming has raised concerns among people. Thus, the effects of diverse forest management strategies on carbon dioxide release and the large amounts of organic carbon in forest ecosystems have largely been focused on by scientists.

Wan Razali (2012) in his article on defending the tropical forests on the environmental degradation and biodiversity loss, stated thattropical forests and tropical savannas have a high amount of carbon stored in both vegetation and soil as compared with temperate forests and temperate grasslands. This indicated that the destruction of tropical ecosystems diminishes the natural carbon sinks due to the fact that they act as an efficient carbon sinks and eventually help to mitigate the adverse impacts of climate change.

A logging cycle of 50 years is too short to keep the species composition of primary forests because 40 - 50 years is not enough time for a Malaysian tropical forest to recover its original species composition after logging (Yamada *et al.*, 2013). The forest in Malaysia has a high richness of tree flora which is due to high percentage of forest cover, thus, Malaysia is considered as fortunate (Saiful & Latiff, 2014). The tropical rain forest plants synthesize various chemicals as defence agents against pests, diseases and predators, thus, they contains assorted resources of biologically and chemically important components (Danial *et al.*, 2013).

According to Mardan *et al.*, (2013) on a study of the composition of species and species diversity in the Ulu Muda Forest Reserve, Kedah, Peninsular Malaysia, a decline in numbers of trees with increasing size is maintained, thus, natural and semi-natural tropical rainforests are considered as structurally stable. The phenomenon of available space restricts the number of trees that can be accommodated in any size class is known as forest dynamics.

A study by Oxbrough *et al.*, (2014) that discussed on a selection of papers which were first presented at the second international IUFRO conference on biodiversity in forest ecosystems and landscapes concluded that even though the forests in tropical regions are currently facing threats, and their importance to global biodiversity is well known. Furthermore, they added that it was surprising to see that there was a notable lack of research from tropical regions presented at the conference.

Putz and Ruslandi (2015) in their article on the intensification of tropical silviculture stated that whereas in many temperate and boreal forests, especially on private lands, environmentally concerned foresters are working against the trend towards increased intensity of management and the consequent forest simplification, natural forest management in the tropics is still not common. Instead, timber exploitation (log mining) is likely to continue for the foreseeable future in much of the tropics.

A study by Aisyah *et al.*, (2015) showed that agriculture and urban expansion largely triggered deforestation of the forest in Selangor, Peninsular Malaysia. The increase of population and the increasing demand for new housing areas caused these unavoidable factors. Issues such as illegal encroachment of agricultural activities, peat fires, illegal logging and measures to mitigate deforestation can also be planned.

Some of the reason why tropical rainforest was chosen in this study is because of its well-known complex terrestrial ecosystem. Malaysia has a tropical rainforest that is very rich with tree flora and biodiversity. Thus, it has a high amount of carbon stored and could act as a carbon sink which could ultimately contribute in mitigating climate change.

However, the disturbing destruction due to human impact faced by the tropical rainforest could cause the depletion of the tropical rainforest in future. This has led to an abundant of research on the tropical rainforest such as the one that has been done in this study. It is highly expected that this study could contribute more in understanding the tropical rainforest, thus, could be an advantage to the tropical forest management.

2.5 Conservation and Management

An example of an outstanding approach to conserve this valuable endangered tropical tree is by producing agarwood in a sustainable manner. It could be achieved through massive planting of the trees and using a non-destructive method to collect agarwood. An efficient monitoring of the agarwood should be done by revising the current techniques of controlling agarwood's manufacturing, harvesting and trade. The monitoring should also be synchronized due to the fact that different agencies are involved in managing similar forest.

Whitmore (1989) in his view of the state of tropical rainforest ecology stated that the management plans which are not destructive to the indigenous peoples' societies should be designed for huge areas of tropical rainforests. For instance, the selective removal of timber should be arranged once every few decades. In a way, that kind of efficient management plans can assist in maintaining the source of highly valuable forest products such as the climbing rattan palms of West Malaysia.

Asep Sumpena (1995) did a phytosociological investigation of the Gunung Ledang montane forest in Peninsular Malaysia and stated that a thorough understanding of the ecological processes involved in maintaining the existence of the forest and knowledge of the plant communities that occur at the forest, is required as a basis for the formulation of management strategies necessary for its conservation.

According to Rubio *et al.*, (1999), in order to maintain the perdurability and stability of the system, it is important to understand the interactions of distresses which are conducted by management. Thus,the species and also processes of the managed forest system which has been preserved effectively can become united.

Numerous approaches seldom focus on individual species and usually focus on the sustainable assessment of the forest ecosystems management (Soehartono & Newton, 2001a). The fast production of high quality seedlings in nurseries is a vital stage for replenishing degraded tropical forest lands because the *Aquilaria* species often grow slowly in the early growth stage compared with such fast growing species (Turjaman *et al.,* 2006). The positive act of increasing cultivation of *Aquilaria* spp. in plantations and action to make sure the extraction of its trees in the natural forests will not affect their population and the capability to regenerate, are some of the ways to secure sustainable agarwood production (Soehartono & Newton, 2001b).

Soehartono and Newton (2001b) also declared that silviculture systems which depended on the existence of advanced regeneration are relevant to *Aquilaria* species if the species has a potential to be highly productive. Provision of seed trees is the key issue in the management of populations in natural forest and is very important to *Aquilaria* species which does not reveal any seed dormancy.

Donovan and Puri (2004) stated that the failure of domesticating the *Aquilaria* spp. production is contributed by several factors such as biological and ecological. Researchers are confused with the complex ecology of resin formation which involves two or maybe more living organisms such as the tree, fungi or even an insect intermediary. A clear understanding on the connection of various elements of the natural system is required to develop a sustainable management system for this resource.

Adekunle (2006) on a study of community diversity of tropical rainforest ecosystem stated that another way to make the ecosystem sustainable is by the construction of reserve conservation through *in situ* and *ex situ* methods. The permanent sample plots, nature reserves, game reserves, forest reserves and sacred groves which are managed effectively is an achievement of *in situ* conservation. This way can hinder any difficulties in trying to conserve species outside their ecosystem and in other words the species can continue to exist in their natural habitat. Thus, the management of tropical natural forest by *in situ* and *ex situ* conservation methods should also be strengthened by forest policy makers. The destruction of the rainforest structure and biodiversity can be reduced by monitoring the intensity of tree harvesting, refining logging practice and preventing illegal felling.

Ashton (2008) in a study on the challenge of biodiversity and its sustainable management in Malaysian forests concluded that in order to generate a wildlife sustainment, the conservation of some huge areas of lowland and other forest such as Taman Negara arenecessary. However, this effort is inadequate for the conservation of biodiversity. Thus, a network of smaller forest areas known as 'virgin jungle reserves' which represent biodiverse ecosystems must compliments those huge areas. These virgin jungle reserves vary both with geographical distance apart and with physical habitat. This effort has been achieved succesfully in Peninsular Malaysia by the combination of Taman Negara and the lowland virgin jungle reserves, even though Taman Negara has a limited area of mixed dipterocarp forest and the virgin jungle reserves such as Pasoh Forest Reserve and a few other similar intact sites is minimal in reality.

Putz (2008) in the study on the irrelevance of tropical foresters and tropical forestry stated that if the potential for natural forest management to contribute to conservation and development is to be reached, then managers need to more effectively demonstrate their potential. Policy makers and forestland owners need to be convinced that there are alternatives to the options of pillaging or protecting forests, and that these alternatives are rendered viable with the input of foresters.

Mohd Hasmadi *et al.*, (2010) on a study of plant association and composition from Mount Tahan, Malaysia concluded that phytosociological study together with GIS analysis can produce a new vegetation map which could assist in making management decisions and understanding more on the natural vegetation. The potential wildlife habitat can be evaluated and the possible impacts of human activities can also be assessed with the assistance of a vegetation map.

According to Wan Razali (2012), countries with tropical forests do not, in general, contribute to the present state of environmental degradation and biodiversity loss from the forests. Nonetheless, the need for sustainable management of the forests is not denied in order to avoid further environmental degradation and biodiversity loss.

A study by Kueh *et al.*, (2013) on the above ground biomass-carbon partitioning, storage and sequestration in a rehabilitated forest concluded that the above ground biomass and carbon recovery could be assisted by forest rehabilitation which uses the accelerating natural regeneration technique. The information on the partitioning of biomass and carbon at different tree components provided a better understanding on the effect of stand management on its storage, hence their carbon credits. The study also revealed that the oldest rehabilitated forest had better recovery in terms of biomass and carbon storage compared with the natural regenerating secondary forest.

According to Saiful and Latiff (2014), to minimize biodiversity loss, there is necessity for intervention not only in the extraction operation but also in the management system that should be compatible with biodiversity conservation. In other words, sustainable forest management system necessarily includes measures for conservation and these measures must be adopted at an early stage of forestry operations.

Jamilah *et al.,* (2014) stated that considering continuous threats to forest ecosystem, mainly from fragmentation and degradation, it is highly recommended that vegetation formations outside forest reserves should be protected by law and monitored by the relevant authority possibly through in-situ conservation. This may be the only way to ensure that its biodiversity and ecosystem functions are maintained.

Oxbrough *et al.,* (2014) on a study that discussed on a selection of papers which were first presented at the second international IUFRO conference on biodiversity in forest ecosystems and landscapes, suggested that current models of funding for high level research on forest ecology and conservation are not very effective at stimulating study in some of the tropical regions where it is most needed, and tropical forest research should be an international priority for forest science and its sponsors.

According to Saiful and Latiff (2014), with regard to forest resources, Malaysia is still fortunate with high percentage of forest cover associated with high richness of tree flora. However, there is growing concern over forest depletion and degradation and many species are known to be threatened with extinction.

Understanding the relationship between ecological variables and the distribution of plant communities is of great importance in order to conserve and manage forest ecosystems (Khairil *et al.,* 2014). Afforestation and reforestation is one way to increase or maintain forest area and biodiversity will also be increased by planting multiple tree species in a forest area (Wan Razali *et al.,* 2015).

The artificial thinning can act as a dynamic process which is necessary to create variations in tree size and heterogeneity of light availability in regenerating forests, and are highly required for the healthy natural forest cycle and for the maintenance of rich forest biodiversity (Numata *et al.,* 2006). On a national and subnational scale, practicing reduced impact logging, establishing conservation and protection area and implementing intensive reforestation projects are also ways to increase the sustainability of forestry (Lam *et al.,* 2013).

The findings by Martins *et al.,* (2015) saying that soil features are an important factor influencing plant growth and distribution in different parts of the tropics, can potentially increase the predictability of successional trajectory, which in turn would help to improve restoration and management of tropical forests.

This study has been conducted in a tropical forest reserve and careful management of this forest reserve through the understanding of the plant communities by phytosocological studies, could lead to a succesfull conservation of this species and its communities. The conservation management of the forest reserve could prevent further crucial biodiversity loss. The scenario in which species is threatened with extinction due to anthropogenic disturbances and environmental degradation of the tropical rainforest could also be prevented.

CHAPTER 3: METHODOLOGY

3.1 Study Area

Phytosociological data of the tropical trees were obtained from a 135 acre of forest reserve at Sungai Udang, Malacca, Malaysia (2°19′N, 102°8'E) as shown in Figure 3.1 (a). The Sungai Udang Forest Reserve is a lowland dipterocarp forest and is home to various flora and fauna. The area has a rough topography and ranges in altitude from 10 m to 90 m.

The data were collected within the boundary of 20 hectares of forest reserve known as Compartment 4. Sungai Udang Forest Reserve was declared in 1987 to be a permanent forest reserve area comprising the remaining approximately 335 acres of land area. It is bordered by Jalan Masjid Tanah stream to the west, a military camp on the north, an estate on the east and a Rela Camp to the south of the forest reserve. About 80 acres of the forest reserve bordering the army camp have been logged and replanted. Sungai Udang Forest Reserve was devided into four compartments. Compartment 1 is for the recreational area. Compartment 2 is used for camping area. Compartment 3 is an area which is provided for the visitors to explore. Compartment 4 which is the study area is an untouched preserve forest and are protected from the logging activities.

The area has a tropical rainforest climate which is punctuated by much rainfall. The rainy seasons or heavy monsoon season occurs from October through March every year. The dry season occurs from May through July every year. The weather is warm and humid all year round with temperatures ranging from 21^{o}C to 32^{o}C. Mean annual rainfall of the study area is recorded as 2000 mm and it is considered to be one of the driest areas in Malaysia. Mean annual maximum and minimum precipitation is recorded as 74% and 35% respectively. The relative humidity typically ranges from 54% to 96% throughout the year.

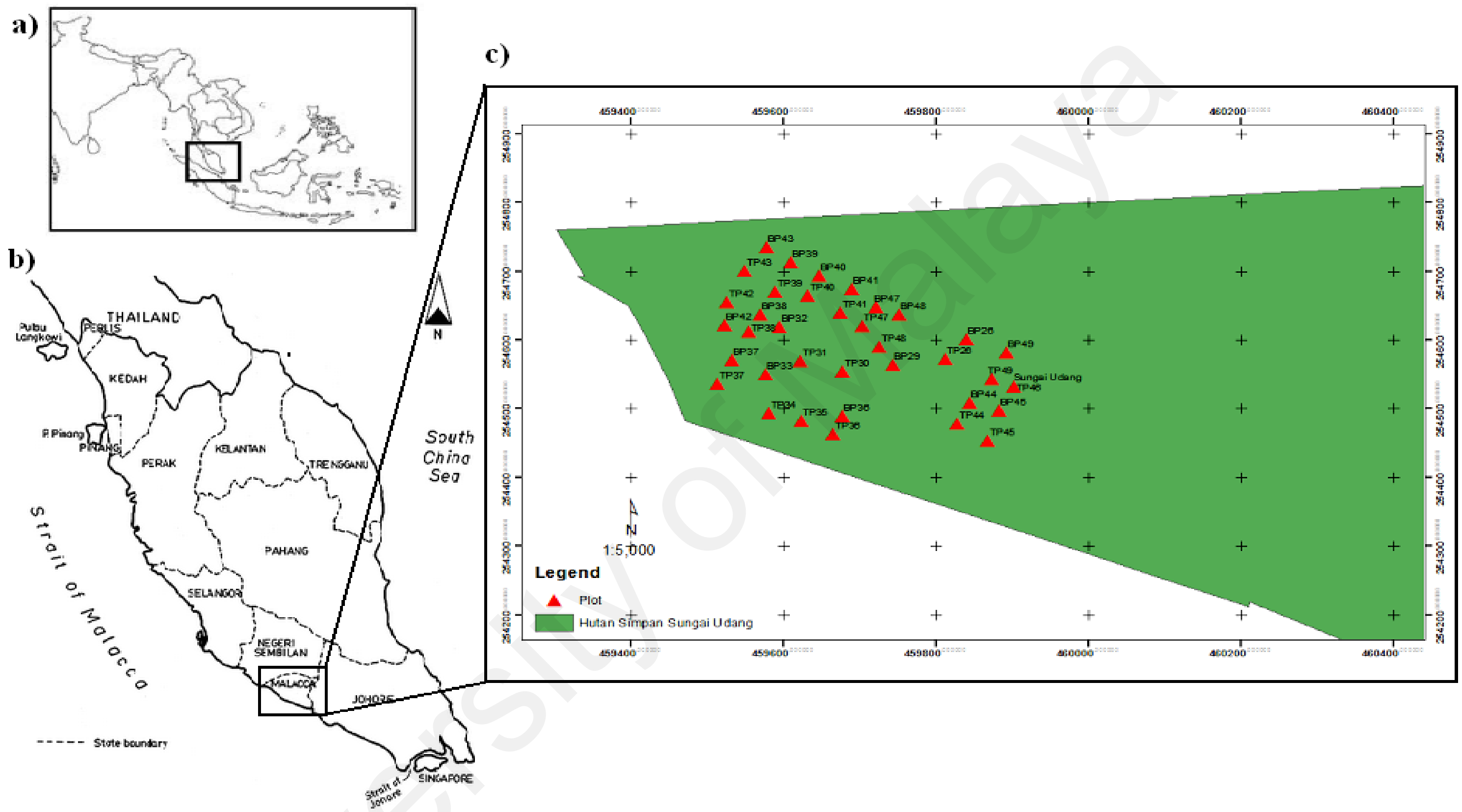


Figure 3.1: (a) Map of Southeast Asia outlining Peninsular Malaysia, (b) map of Peninsular Malaysia showing the location of the study site, and (c) map of the study site (Compartment 4) within the Sungai Udang Forest Reserve, Malacca, Malaysia. Triangles indicate the locations of sampling plots in the study site

3.2 Vegetation Sampling

Field surveys and data collection were done based on the techniques described by Braun-Blanquet (1964) and Fujiwara (1987). Fieldwork was carried out from September 2012 to April 2013.

A total of 25 plots (20 m × 40 m) in size were constructed according to the line transect method. The size of the plots was estimated by means of a "minimal area" which was 800 m^2 in each plot. Plots were 20 m from each other. The plots were located at various altitudes, expositions, inclinations, and relief. An effort was made to achieve a higher ecological and physiognomic homogeneity within each plot. Every plot was georeferenced with a Garmin GPS Map 60CS.

The scientific names of each vascular species in each plot were identified. All vascular plant species in each plot with a trunk diameter at breast height (DBH) ≥ 5 cm were marked and numbered, and their diameters and heights were measured and recorded. Trunk perimeter measurements were taken using a metric tape and tree heights were estimated with the aid of a clinometer.

Aerial cover was estimated for each species using a van der Maarel (1979) scale. Cover or abundance data of all vascular plant species for each plot were verified using the Braun-Blanquet (1964) method. The coverage was measured by estimating the percentage of the species covering the total areas according to the coverage table (Table 3.1). The species will be categorized from level ‘r’ (for species that occurs rarely in the vegetation sample) to level 5 which are for species that cover almost 75% to 100% of each plot area.

The sociability was measured by estimating the growing pattern of the plant either as a single group or in groups (Table 3.2). Sociability expressed the horizontal aggregation of the species. The sociability measures of the plants represent not the spatial pattern of their trunks at the ground level but rather the spatial aggregation or clustering pattern of their foliage cover or crowns of the layer in which they were recorded. The tree crown is the spatial unit. The species was valued from 1 to 5 according to the growing pattern of the species. The species will be valued as 1 if the plant grows as solitary while plants that grow in large crowd were valued as 5. Sociability level 5 will be used if the tree crown completely covers a particular layer.

The vegetation layers in the forest were divided into five layers, as shown in Table 3.3. The coverage and sociability of each plant were measured according to the layers classification. Specimens of all recorded trees were collected for the preparation of voucher specimens and for species identification. The identification of the specimens was made possible using keys in taxonomic references such as the *Tree Flora of* Malaya (Whitmore 1972). Next, the samples data collected from the field were classified in a phytosociological table according to their floristic compositions.

Table 3.1: Total estimated cover and abundance (Braun-Blanquet, 1964)

Level	Cover and Abundance
5	75 – 100% cover of the plot area, regardless of the number of individuals
4	50 – 75% cover of the plot area, regardless of the number of the individuals
3	25 – 50% cover of the plot area, regardless of the number of the individuals
2	5 – 25% cover of the plot area, or usually abundant though < 5% cover
1	Covering < 5% of the plot area but either abundance with very low cover or less abundance but with more cover
+	Few individuals, occurring sparsely and covering < 5% of the plot area
r	Only 1 or 2 individuals, occurring rarely in the plot

Table 3.2: Sociability levels of vegetation samples (Braun-Blanquet, 1964)

Level	Spatial occurrence or clustering pattern
5	Growing in large crowd, completely covering the whole plot area (mostly pure populations)
4	Growing in extensive patches (larger groups or colonies)
3	Growing in small patches, troops, or large tussocks
2	Growing in small groups of few individuals, also as small clumps
1	Growing solitary (single individual)

Table 3.3: Types of vegetation layers

Vegetation layer	**Height (m)**
Super tree (ST)	≥ 30
Canopy tree layer (T_1)	10-25
Understory tree layer (T_2)	6-9
Shrub layer (S)	2-5
Herb layer (H)	< 2

3.3 Data Analysis

3.3.1 Phytosociological Analysis

As for numerical analysis, the cover or abundance values on the scale of Braun-Blanquet were transformed into the 1 - 9 ordinal scale of van der Maarel (1979). With the goal of identifying the floristical composition of these groups, this synthetic phytosociological table was elaborated by scoring species in percentage or constancy classes, according to Braun-Blanquet's scale.

Lastly, the associations of the species were described based on all the 25 plots that were surveyed. Figure 3.2 shows the flowchart of data analyses according to the classical method of Braun-Blanquet (1964) and van der Maarel (1979). The Braun-Blanquet approach consists of two phases; (i) the field phase which consists of site reconnaissance and plot data collection, and (ii) the sorted table analysis which involves the construction of the tables.

3.3.1.1 The Braun-Blanquet Table Analysis Approach

The Braun-Blanquet's method which involves the table analysis is a critical section of the phytosociological analysis on plants classification. All vegetation descriptions in the Braun-Blanquet method involved the construction of tables which will give information on the species of the described vegetation communities. Plots will be grouped into synthesis tables known as raw table, frequency table, partial table and the differentated table.

The goal of producing those synthesis tables is to construct the differentiated table. The final outcome will show the differentiated table with a well-organized form of the plot data. Thus, this can help in the understanding of species distribution between the plots of the study area and the diagnostic or character species will become the key to identification of vegetaton units.

(a) ***Table of Raw Data***

The purpose of creating the table of raw data is to organize the data collected from the fieldwork into rows and columns. The table was organized with the rows being the species and the columns being the plots. These organized data make it easier to recognize differential species, by arranging the plots according to fixed groupings along a certain gradient (which will change at later stages of the table analysis). Then, each plot number was written with the number of species beneath it.

(b) ***Frequency Table***

The species was arranged in order of constancy in the frequency table. The relative frequency which is the number of occurrences divided by the quantity of plots × 100% of each species was calculated. Next, all the species were rearranged in descending order of highest constancy to lowest constancy.

(c) ***Partial Table***

The groups of species that described the communities of the plants were identified by the construction of partial table. Mostly, these species were known as intermediate constancy. The characteristic of the whole group of plots were represented by the species with high constancy, while those species which have very low constancy were most probably not included in the characteristic groups of plots. Usually, the range of constancy values of 10% - 60% is known as the intermediate constancy range. However, various vegetation types have a various range of intermediate constancy. When the range of constancy values has been determined, the groups of species that occurred together in several plots were also determined in the constancy table. Finally, the partial table is constructed by arranging those potential differential species based on their plot groups.

(d) ***Differentiated Table***

The floristic similarity of the plots and species were shown by constructing the differentiated table. In each plot, the number of differential species within each species group was summed beneath the partial table. Next, the ordinated partial table was constructed by rearranging the plots based on the new sequence. At the same time, the species in every group of associated species were arranged based on descending order which were from high constancy to low constancy. The second ordinated partial table might be constructed to avoid confusion due to the existence of many species from many plots. A few repetitions of partial ordinated tables might be needed to achieve a perfect ordering of the species and plots.The final differentiated table will display the plots which contain species that have been arranged according to their particular associations. The plots of the differentiated table are listed in their particular groups based on the frequency of their species in the groups of associated species. Finally, the name of the initial community type was given to each group of plots. In the differentiated table, the groups of associated species were defined with vertical lines. Meanwhile, the outlined blocks showed the associated species of the initial community type.

3.3.1.2 Unranked Plant Communities

The final conclusion of the procedures of table analysis which resulted with the construction of differentiated table might end up in a different condition. The mentioned condition is when the vegetation unitshave no relationship to the recognized pre-established units of the Braun-Blanquet's system. When this situation happened, the vegetation units should not be called associations. In fact a better term for those vegetation units is called 'community type'. This situation is due to the fact that to create a formal association name and to find the community type in a Braun-Blanquet hierarchical system involves the preparation of a summary table, that contain the summary of related information from various plots of other phytosociological studies in a single column.

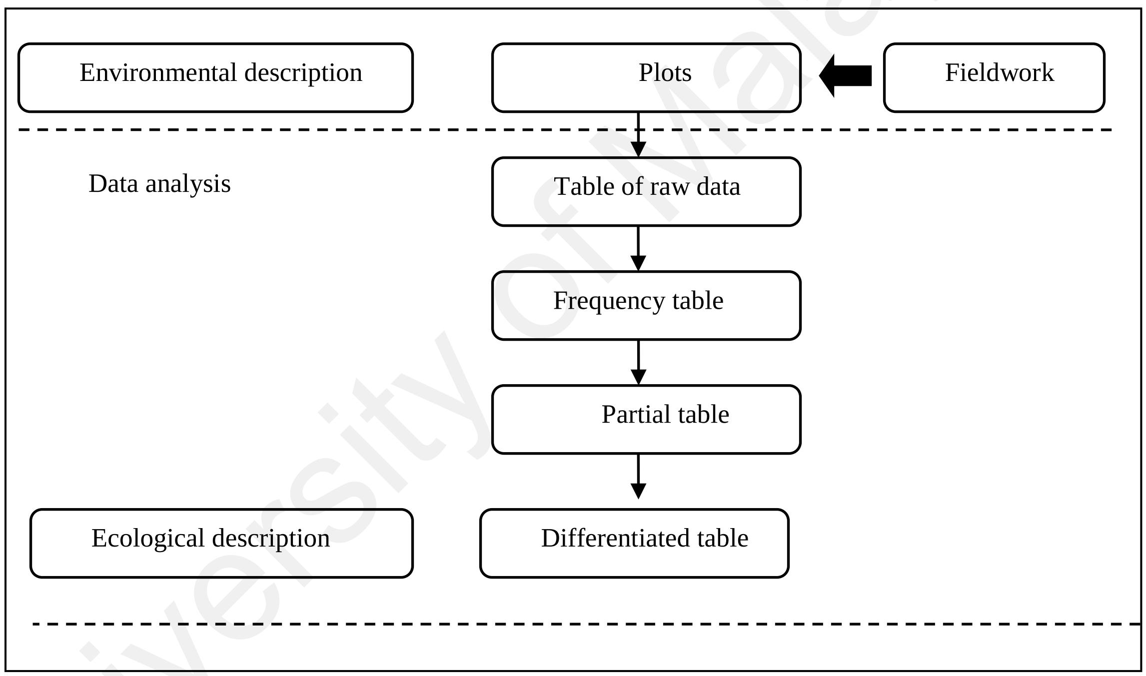


Figure 3.2: Flowchart of data analysis according to the classical method of Braun-Blanquet (1964) and van der Maarel (1979)

3.3.2 Species Diversity

3.3.2.1 Shannon-Wiener's Index

Species diversity was determined by using the Shannon-Wiener Diversity Index (*H'*) (Shannon & Weaver, 1963) as follows;

$$H' = -\sum_{i=1, 2, 3,\ldots n} (p_i)(\log_e p_i)$$

Where,

H' = Shannon index of diversity

p_i= the proportion of important value of the i^th^ species

($p_i = n_i$ / N, n_i is the number of individual of i^{th} species and N is the total number of all individual).

3.3.2.2 Simpson's Index

Species dominance was evaluated by using the Simpson (1949) index of Dominance. Simpson's index of dominance was calculated as follows;

$$D = \sum (p_i)^2$$

Where,

D = Simpson index of dominance

p_i= the proportion of important value of the i^{th} species

($p_i = n_i$ / N, n_i is the number of species and N is the total number of all individuals)

As D increases, diversity decreases and Simpson's diversity index was therefore usually expressed as 1-D or 1/D.

$$1\text{-}D = 1\text{-}\sum (p_i)^2$$

Where,

1-D = Simpson diversity index

p_i = proportion of individual from *i* species in a community

3.3.3 Species Importance

3.3.3.1 Relative frequency

Relative frequency is the degree of dispersion of individual species in an area in relation to the number of all the species occurred which is calculated as follows;

$$\text{Relative frequency} = \frac{\text{Number of occurrence of the species}}{\text{Number of occurrence of all the species}} \times 100$$

3.3.3.2 Relative density

The study of numerical strength of a species in relation to the total number of individuals of all the species and can be calculated as;

$$\text{Relative density} = \frac{\text{Number of individual of the species}}{\text{Number of individual of all the species}} \times 100$$

3.3.3.3 Relative dominance

Dominance of a species is determined by the value of the basal area. Relative dominance is the coverage value of a species with respect to the sum of coverage of the rest of the species in the area which is calculated as follows;

$$\text{Relative dominance} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all the species}} \times 100$$

The total basal area was calculated from the sum of the total diameter of immerging stems. In trees, the basal area was measured at breast height (5cm and above) and by using the formula πr^2.

3.3.3.4 Importance Value Index

This index is used to determine the overall importance of each species in the community structure of the research area. In calculating this index, the percentage values of the relative density, relative frequency, and relative dominance are summed up together and this value is designated as the Importance Value Index or IV_i of the species (Curtis, 1959) as follows;

$$IV_i = RD_i + RF_i + RB_i$$

Where,

IV_i = Importance value of species $_i$

RD_i = Relative density of species $_i$

RF_i = Relative frequency of species $_i$

RB_i = Relative dominance (basal area) of species $_i$

3.3.4 Soil Characteristics

3.3.4.1 Soil Sampling

Soil samples were collected from each 25 plots of the study sites in December 2013. The litter from the surface was removed and soil was dug out from the upper surface layers (0 - 30 cm) of the profile of the vegetation type. About 500 g of each sample from each plot was placed in polyethylene bags and sample was mixed well individually. Then samples were air dried at 20 to 25^{o}C, crushed and then passed through a 2 mm mesh sieve to remove the stone pieces and large root particles. The composite soil samples were used for detail analysis of different physiochemical characteristics in the soil laboratory.

3.3.4.2 Physico-chemical Analysis of Soil

The following measurements such as pH (saturation slush, pH meter), electrical conductivity (saturation slush, electrical conductivity meter), carbonate (calcimeter), organic matter, and P were taken and determined by standard methods. Exchangeable cations (Na, K, Ca, and Mg) analyses were also done in the soil laboratory.

(a) *Physical properties of soil*

i Soil moisture content

The moisture content of soil was determined by Gravimetric method or oven dry method (Allen *et al.*, 1974). The gravimetric method is the simplest method to directly determine soil water content. The given soil samples were oven dried at 105 °C and 110°C for 24 hours, and the amount of water lost was measured by weighing the given soil samples before and after the samples were oven dried.

ii Soil texture

Soil texture is defined as the proportion of sand, silt, and clay. Soil texture is an important property that affects soil drainage conditions, soil water-holding capacity, amount and size of pores, and plant root development. As a result, the rate of water intake, water supplying ability, aeration, and soil fertility are all affected by soil texture. The soil textures were determined both in the field and laboratory.

For the field or rapid method, wet and moist soil samples were squeezed between fingers. If the soil contains clay, the soil feels sticky when wet and the moist sample slicks out to form a thin ribbon. For sand, its presence is felt when the soil sample is gritty. In the case of silt, its presence in the soil sample is felt when it produces a slick, a soapy feeling.

In the laboratory, the soil texture was determined using the pipette method. The pipette method is an alternative method for soil texture determination and is laborious and time consuming. However, the accuracy of this method compares quite well with the hydrometer and centrifuge methods.

The laboratory method is an indirect method which is carried out through the quantitative determination of soil separates (sand, silt, and clay). Now referred to as particle size distribution or particle size analysis (former called mechanical analysis), is a procedure that separates the inorganic soil particles into the sand, silt, and clay fractions. The two important steps in this method were the particle size analysis method commonly called dispersion and sedimentation.

The soil texture determination involved the dispersion process which involved the broken down of the soil aggregates into the individual particles and suspending water. The dispersion must be strong enough to drastically crush the individual particles. The NaOH or $NaPO_3$ (sodium metaphosphate or calgon) is added to enhance the dispersion. Samples are also shaken or mixed mechanically with a blender to ensure effective dispersion,.

The process of sorting out the different particle size fractions (based on weight difference) after the soil sample has been dispersed the pipette method is called sedimentation. A pipette is used to withdraw an aliquot of the soil suspension at a specified time. The sample is dried and the weight determined. For a quantitative collection of the various size fractions, the suspended material was siphoned off at a fixed time period and dried.

(b) *Chemical properties of soil*

iii Soil pH

Soil pH indicates the degree of acidity or alkalinity of soils. There are various ways to determine soil pH but in this study only the potentiometric method is used. Soil pH for every sample was measured by mixing 10 g of air-dried soil in a 25 ml of distilled water and stirred for 15 minutes in a beaker using magnetic stirrer. The soil-water mixture was leaved to stand overnight or for 24 hours. Prior to use, the pH meter was calibrated with two buffer solutions namely pH 4.0 and pH 7.0. Then, the electrode was rinsed again with distilled water and was placed in the soil suspension above.

iv Soil organic carbon

Soil organic carbon was determined by rapid dichromate oxidation technique. The organic matters in the soil were oxidized by chromic acid (Potassium dichromate plus conc. H_2SO_4) utilizing the heat of dilution of H_2SO_4. The unreacted dichromate was determined by back titration with ferrous sulfate.

v Total nitrogen

Total nitrogen (N) determination was a complicated process due to the presence of various forms of N such as ammonium, nitrate, nitrite, ammonia, organic etc. The two methods commonly used for total N determination were the Dumas method (dry combustion method) and the Kjeldahl method (wet oxidation method). The Kjeldahl is the most common method for total N determination and was used in this study. The advantages of using Kjeldahl method were because it was easy to run multiple analyses and it was applicable to samples low in N.

The Kjeldahl method entails digestion and distillation. The sample was digested in concentrated sulphuric acid with a catalyst mixture to raise the boiling temperature and to promote the conversion of organic-N to ammonium-N. The ammonium-N from the digested sample was obtained by steam distillation, using excess NaOH to raise the pH. The distillate was collected in saturated boric acid, and then titrated with dilute sulphuric acid to pH 5.0. The Kjeldahl method determines ammonium-N, most of the organic-N forms, and a variable fraction of nitrate-N in soils in particular. Thus, this method is a good estimate of total soil N content. When necessary, nitrate-N can be included through the reduced iron or salicylic acid modifications of the Kjeldahl method.

The extraction and analysis of total nitrogen involved weighing 0.5 g soil (sieved to pass 0.5 mm) into 50 mL Kjeldhal digestion tubes. About 0.4 g salicylic acid was added. The soil was wet with few drops of water and 5 mL concentrated sulphuric acid was added. 1 tablet of Kjeldhal catalyst was added before the samples were shaken and allowed to equilibrate for 30 minutes. The samples in a digestion block at 180°C were heated for 1 hour and then at 320°C for 4 to 5 hours until samples became colourless. The samples were allowed to cool down before 30 mL distilled water was added on cooling. It was made up to volume when the solution was cool. 10 mL of the sample was pipetted into distillation apparatus. 10 mL of 40% NaOH (e.g. 30% NaOH = (400 g NaOH/1L distilled water) x 100) was added. Distillate in 10 mL of 2% boric acid-indicator solution was collected. The colour changed from purple to green during distillation.

A 2% boric acid was prepared by weighing 80 g of pure boric acid (H_3BO_3) in a 5 L flask marked to indicate a volume of 4 L. About 3500 ml of water was added. The solution was heated and swirled until the boric acid dissolved and then allowed to cool. 80 mL of mixed indicator (0.099 g bromocresolgreen + 0.066 g methyl red in 100 mL of ethanol) was added. 0.1 M NaOH was added until the solution becomes reddish purple (pH 5.0). The solution was made up to 4 L with distilled water. The 50 mL conical flask containing the distillate was removed when twice of the original volume (20 mL) is obtained. The solution was titrated against 0.01 M HCl or 0.01 M H_2SO_4 until the colour changed from green to purple.

vi Cation exchange capacity (CEC)

Cation exchange capacity of a soil is the capacity of a soil to hold and exchange cations. Cation exchange capacity is a quantitative measure of all the cations adsorbed on the surface of the soil colloids. The cation exchange capacity was analyzed using the ammonium acetate method (leaching method) and distillation method.

1 M ammonium acetate (NH_4OAc) solution was prepared with pH of 7.0. The base of leaching tube (20 cm long and 2 cm diameter) was filled with broth and covered with Whatman filter paper No. 2. 10 g soil was weighed and placed in the tube and the soil was covered with Whatman filter paper No. 2. The soil was leached with 100 mL of 1 M NH_4OAc for 5 to 6 hours. The soil was not allowed to dry during the leaching process.

Next, the soil was washed with 95% ethanol. 1 M K_2SO_4 and the leachate were collected in a 100 mL volumetric flask and made up to volume. 10 mL of the sample was pipetted into distillation apparatus. 10 mL of 40% NaOH was added. The distillate was collected in a 10 mL of 2% boric acid-indicator solution. The colour changed from purple to green during distillation. The 50 mL conical flask containing the distillate was removed when twice of the original volume (20 mL) is obtained. Next, it was titrated against 0.01 M HCl or 0.01 M H_2SO_4 until the colour changes from green to purple. This directly gives the CEC in meq/100 g of soil or cmol (+)/kg of soil.

vii Available phosphorus (P)

Available P is the fraction of P in soils that is available for plant growth. There are as many as seven methods in soil available P determination but only one of them was used in this study which was the Bray 1 method. This method of soil available P extraction is successful for acid soils. The method extracted acid-soluble P coming from Ca-phosphates and Al-phosphates and Fe-phosphates from soils. NH_4F chelates Al and Fe, and in this way, dissolved the phosphate mineral.

5 g of soil was weighed in a 250 mL Erlenmeyer flask. 50 mL of extracting solution mixture was added and mechanically shaken at 180 rpm for 10 minutes. The supernatant was filtered (using Whatman filter paper No. 2) into a plastic vial. 25 g [(NH_4)6Mo7O_{24}. H_2O)] was weighed in a beaker, and 200 mL distilled water was added. Then, it was heated at 60°C to dissolve under constant stirring. 275 mL concentrated H_2SO_4 was diluted with distilled water to 750 mL, and the solution was allowed to cool. The molybdate solution was poured slowly into the H_2SO_4 solution.

Next, the 667.0 mg of potassium antimony tartrate, KSbO.$C_4H_4O_6$, was dissolved in 250 mL distilled water. 10 g of ascorbic acid in a 100 mL volumetric flask was weighed. 80 mL distilled water was added to dissolve, and diluted to the mark. The reagent was stored in a cold room at 2°C. Equal volumes of the ascorbic acid and Sb solution were mixed before use. 219.4 g of KH_2PO_4 in a 1 L volumetric flask was weighed, and dissolved with 500 mL distilled water. 25 mL 7 M H_2SO_4 was added, and diluted to mark with distilled water. This stock solution contained 50 mg P/L. 20 mL of this stock solution was pipetted into a 500 mL volumetric flask, and diluted to the mark with distilled water. This was the working solution, which contained 2 µg P/mL.

2 mL (depending on the intensity of the blue colour to be developed or P concentration) of the extract was pipetted into 50 mL volumetric flask. 10 mL of the

ammonium molybdate solution containing H_2SO_4 was added and the flask was swirled to mix the solution. 4 mL of the antimony-ascorbic acid mixture was added, and diluted with distilled water to the mark. Maximum colour intensity developed within 10 minutes and remained stable for several hours. The absorbance was measured at 840 nm. A standard curve was prepared by pipetting 0, 1, 4, 5, and 10 mL of the KH_2PO_4 working solution into series of 50 mL volumetric flasks. Samples including standards were then read by spectrophotometry.

viii Available potassium (K)

Available potassium is the amount of potassium (K) soluble in water. Plant available K also includes exchangeable K. The ammonium acetate method (leaching method) was used in the plant available K extraction. 1 M ammonium acetate (NH_4OAc) solution with pH of 7.0 was prepared in the laboratory. The base of leaching tube (20 cm long and 2 cm diameter) was filled with broth and covered with Whatman filter paper No. 2. 10 g soil was weighed and placed in the tube, the soil was covered with Whatman filter paper No. 2. The soil was leached with 100 mL of 1 M NH_4OAc for 5 to 6 hours into 250 mL conical flask. The leachate was analyzed for K, Ca, Mg, Na, and most micro-elements. The soil was not allowed to dry during the leaching process. The atomic absorption spectrophotometer (AAS) was calibrated, provided with a hollow cathode K tube, with the prepared standard. The extract was aspirated into the AAS and the absorbance was recorded.

ix Available sodium (Na)

As for the determination of available sodium (Na), the ammonium acetate method (leaching method) was also used. 10 g soil was weighed and placed in the 250 mL Erlenmeyer flask. 100 mL of 1 M NH_4OAc was added for 5 to 6 hours into 250 mL Erlenmeyer flask and the rest of the procedures were done the same as the plant available K determination. The extract could also be used for other major cations and micro-elements.

x Available calcium (Ca)

As for the determination of available calcium (Ca), the ammonium acetate method (leaching method) was also used. 10 g soil was weighed and placed in the 250 mL Erlenmeyer flask. 100 mL of 1 M NH_4OAc was added for 5 to 6 hours into 250 mL Erlenmeyer flask and the rest of the procedures were done the same as the plant available K determination. The extract obtained by the ammonium acetate procedure of K could also be used for the determination of dilute acid extractable Ca.

xi Available magnesium (Mg)

As for the determination of available magnesium (Mg), the ammonium acetate method (leaching method) was also used. 10 g soil was weighed and placed in the 250 mL Erlenmeyer flask. 100 mL of 1 M NH_4OAc was added for 5 to 6 hours into 250 mL

Erlenmeyer flask and the rest of the procedures were done the same as the plant available K determination. The extract obtained by the ammonium acetate procedure of K could also be used for the determination of exchangeable Mg.

3.3.4.3 Pearson Correlation Analysis

Correlation analysis was used to determine the correlation among the soil parameters. The formula for the correlation (*r*) was as follows;

$$r = \frac{1}{n-1}\left(\frac{\sum_{x}\sum_{y}\left(x-\bar{x}\right)\left(y-\bar{y}\right)}{s_x s_y}\right)$$

Where,

n = the number of pairs of data

$\bar{x}$ and $\bar{y}$ = the sample means of all the x-values and all the y-values, respectively

s_x and s_y = the sample standard deviations of all the x- and y-values, respectively

CHAPTER 4: RESULTS

4.1 Floristic Composition

A total of 1668 individual trees with diameter at breast height (DBH) of 5 cm and above were found in the 25 plots in Sungai Udang Forest Reserve, of which overall floristic composition consisted of 85 species belonging to 79 genera and 38 families (Table 4.1).

The most abundant family was Euphorbiaceae with 224 individual trees, and represented by 9 species in 9 genera namely; *Antidesma* sp., *Baccaurea parviflora, Blumeodendron subcaudatum, Drypetes* sp., *Elateriospermum tapos, Endospermum diadenum, Macaranga gigantia* and *Sapium baccatum.* Myrtaceae was the second most abundant family, with 2 genera and 2 species (212 individual trees) namely; *Rhodamnia cinerea* and *Syzygium* sp. It was followed by Anacardiaceae with 4 genera and 6 species (197 individual trees) namely; *Bouea macrophylla, Bouea oppositifolia, Buchanania subobovata, Spondias cytherea, Swintonia penangiana* and *Swintonia schwenkii.*

In addition, there was one family that was represented with only one species and one individual in the study plots, namely, Combretaceae. With the least number of species and individual, this family is considered as the most uncommon family within the study plots.

The most abundant species was *Syzygium* sp. (Myrtaceae) with 210 individuals followed by *Spondias cytherea*(Anacardiaceae) with 144 individuals and *Elateriospermum tapos* (Euphorbiaceae) with 129 individuals, respectively (Table 4.2).

The DBH distribution of trees in this study is summarized in Table 4.3. Majority of the trees in this study area (875 individuals) fall into Class One which was the group of trees with a diameter of breast height between 5 cm to 14.90 cm. Class Seven which was the group of trees with a diameter of breast height of more than 65.00 cm had the lowest number of individuals in this study which was 27 individuals.

. Table 4.4 shows the largest ten individual trees in the plots of the study area. The study area showed an existence of several large trees ranged from 55 m to 45 m in height which were tall enough to form the emergent canopy. Both *Artocarpus rigidus* (Moraceae) and *Ixonanthes reticulata* (Ixonanthaceae) was the largests tree in the study area and stated a similar diameter at breast height which was 110 cm and 55 cm in height, followed by *Paratocarpus bracteatus* with 94 cm in diameter at breast height and 53 cm in height.

Table 4.1: Number of genera and species for all families present in all 25 plots

No.	Family	No. of genera	No. of species	No. of individuals
1	Anacardiaceae	4	6	197
2	Annonaceae	3	3	27
3	Arecaceae	1	1	9
4	Bombacaceae	2	2	20
5	Burseraceae	1	1	2
6	Clusiaceae	3	3	45
7	Combretaceae	1	1	1
8	Dilleniaceae	1	1	4
9	Dipterocarpaceae	2	2	29
10	Ebenaceae	1	2	37
11	Elaeocarpaceae	1	1	18
12	Euphorbiaceae	9	9	224
13	Fabaceae	8	8	58
14	Fagaceae	1	1	41
15	Flacourtiaceae	2	2	6
16	Hypericaceae	1	1	7
17	Ixonanthaceae	1	2	37
18	Lauraceae	1	1	78
19	Lecythidaceae	1	1	26
20	Melastomataceae	2	2	27
21	Meliaceae	5	5	34
22	Moraceae	4	6	75
23	Myristicaceae	1	1	53
24	Myrsinaceae	1	1	5
25	Myrtaceae	2	2	212
26	Olacaceae	1	1	39
27	Oxalidaceae	1	1	22
28	Pandanaceae	1	1	2
29	Rhizophoraceae	2	2	17
30	Rubiaceae	5	5	109
31	Rutaceae	1	1	12
32	Sapindaceae	1	1	6
33	Sapotaceae	1	1	33
34	Simaroubaceae	1	1	9
35	Sterculiaceae	2	2	5
36	Theaceae	2	2	17
37	Thymelaeaceae	1	1	56
38	Ulmaceae	1	1	69
	Total	79	85	1668

Table 4.2: List of indigenuous species found at all the 25 plots in the study area

Family	Species	Vernacular Name	No. of individuals
Anacardiaceae	*Bouea macrophylla*	Kundang hutan	5
Anacardiaceae	*Bouea oppositifolia*	Kundang rumania	1
Anacardiaceae	*Buchanania subobovata*	Otak udang	2
Anacardiaceae	*Spondias cytherea*	Kedondong	144
Anacardiaceae	*Swintonia penangiana*	Merpauh daun runcing	6
Anacardiaceae	*Swintonia schwenkii*	Merpauh periang	39
Annonaceae	*Cyathocalyx* sp.	Antoi	6
Annonaceae	*Polyalthia* sp.	Mempisang	20
Annonaceae	*Xylopia fusca*	Jangkang paya	1
Arecaceae	*Oncosperma tigillarium*	Nibung	9
Bombacaceae	*Durio griffithii*	Durian tupai	19
Bombacaceae	*Neesia altissima*	Bengang	1
Burseraceae	*Dacryodes rugosa*	Kedondong matahari	2
Clusiaceae	*Calophyllum marcocarpum*	Bintangor	19
Clusiaceae	*Garcinia* sp.	Kandis	21
Clusiaceae	*Mesua ferrea*	Penaga	5
Combretaceae	*Terminalia* sp.	Jelawai	1
Dilleniaceae	*Dillenia* sp.	Simpoh	4
Dipterocarpaceae	*Hopea* sp.	Merawan	14
Dipterocarpaceae	*Shorea leprosula*	Meranti tembaga	15
Ebenaceae	*Diospyros argentea*	Bedil lalat	15
Ebenaceae	*Diospyros rigida*	Kayu arang	22
Elaeocarpaceae	*Elaeocarpus nitidus*	Mending	18
Euphorbiaceae	*Antidesma bunius*	Buni	3
Euphorbiaceae	*Baccaurea macrocarpa*	Tampoi	4
Euphorbiaceae	*Baccaurea parviflora*	Setambun merah	46
Euphorbiaceae	*Blumeodendron subcaudatum*	Gaham badak	3
Euphorbiaceae	*Drypetes* sp.	Lidah lidah	4
Euphorbiaceae	*Elateriospermum tapos*	Perah	129
Euphorbiaceae	*Endospermum diadenum*	Sesenduk	15
Euphorbiaceae	*Macaranga gigantia*	Mahang gajah	13
Euphorbiaceae	*Sapium baccatum*	Ludai	3

Table 4.2, continued.

Family	Species	Vernacular Name	No. of individuals
Fabaceae	*Adenanthera pavonina*	Saga	9
Fabaceae	*Callerya atropurpurea*	Tulang daing	7
Fabaceae	*Dialium kingii*	Keranji bulu	18
Fabaceae	*Koompassia malaccensis*	Kempas	9
Fabaceae	*Parkia javanica*	Petai kerayung	1
Fabaceae	*Pithecellobium splendens*	Kungkur	10
Fabaceae	*Saraca* sp.	Gapis	2
Fabaceae	*Sindora* sp.	Sepetir	2
Fagaceae	*Lithocarpus* sp.	Mempening	41
Flacourtiaceae	*Flacourtia rukam*	Rukam	2
Flacourtiaceae	*Hydnocarpus elmeri*	Setumpol	4
Hypericaceae	*Cratoxylum arborescens*	Geronggang	7
Ixonanthaceae	*Ixonanthes icosandra*	Pagar anak	30
Ixonanthaceae	*Ixonanthes reticulate*	Inggir burung	7
Lauraceae	*Litsea firma*	Medang	78
Lecythidaceae	*Barringtonia racemosa*	Putat	26
Melastomataceae	*Memecylon* sp.	Nipis kulit	12
Melastomataceae	*Pternandra echinata*	Sial menahun	15
Meliaceae	*Aglaia* sp.	Medang	5
Meliaceae	*Azadirachta excels*	Sentang	14
Meliaceae	*Dysoxylumcauliflorum*	Dedali	1
Meliaceae	*Lansium* sp.	Dokong	2
Meliaceae	*Sandoricum koetjape*	Sentul	12
Moraceae	*Artocarpus elasticus*	Terap nasi	11
Moraceae	*Artocarpus rigidus*	Keledang/temponek	27
Moraceae	*Artocarpus scortechinii*	Terap hitam	5
Moraceae	*Ficus* sp.	Ara	4
Moraceae	*Paratocarpus bracteatus*	Ara bertih bukit	5
Moraceae	*Streblus elongates*	Tempinis	23
Myristicaceae	*Knema* sp.	Penarahan	53
Myrsinaceae	*Ardisia* sp.	Kedondong	5

Table 4.2, continued.

Family	**Species**	**Vernacular Name**	**No. of individuals**
Myrtaceae	*Rhodamnia cinerea*	Mempoyan	6
Myrtaceae	*Syzygium* sp.	Kelat	210
Olacaceae	*Ochanostachys amentaceae*	Petaling	39
Oxalidaceae	*Sarcotheca monophylla*	Asam pupoi	22
Pandanaceae	*Pandanus* sp.	Mengkuang	2
Rhizophoraceae	*Gynotroches axillaris*	Mata keli	8
Rhizophoraceae	*Pellacalyx* sp.	Membuluh	9
Rubiaceae	*Adina rubescens*	Meraga	27
Rubiaceae	*Ixora* sp.	Siantan/jejarum	7
Rubiaceae	*Pertusadina eurhyncha*	Empopor	1
Rubiaceae	*Porterandia anisophylla*	Tinjau belukar	72
Rubiaceae	*Urophyllum glabrum*	Kayu basak	2
Rutaceae	*Xanthophyllum* sp.	Minyak beruk	12
Sapindaceae	*Xerospermum noronhianum*	Rambutan pachat	6
Sapotaceae	*Palaquium* sp.	Nyatoh	33
Simaroubaceae	*Eurycoma longifolia*	Tongkat ali	9
Sterculiaceae	*Heritiera* sp.	Mengkulang	3
Sterculiaceae	*Scaphium macropodum*	Kembang semangkuk	2
Theaceae	*Adinandra* sp.	Tetiup	1
Theaceae	*Gordonia concentricicatrix*	Samak pulut	16
Thymelaeaceae	*Aquilaria malaccensis*	Karas	56
Ulmaceae	*Gironniera nervosa*	Hampas tebu	69

Table 4.3: DBH distribution of this study area in Sungai Udang Forest Reserve

Diameter class	Number of trees
CLASS 1: 05.00 - 14.90 cm	875
CLASS 2: 15.00 – 24.90 cm	400
CLASS 3: 25.00 – 34.90 cm	190
CLASS 4: 35.00 – 44.90 cm	90
CLASS 5: 45.00 – 54.90 cm	37
CLASS 6: 55.00 – 64.90 cm	49
CLASS 7: Above 65.00 cm	27

Table 4.4: The 10 largest trees found in this study

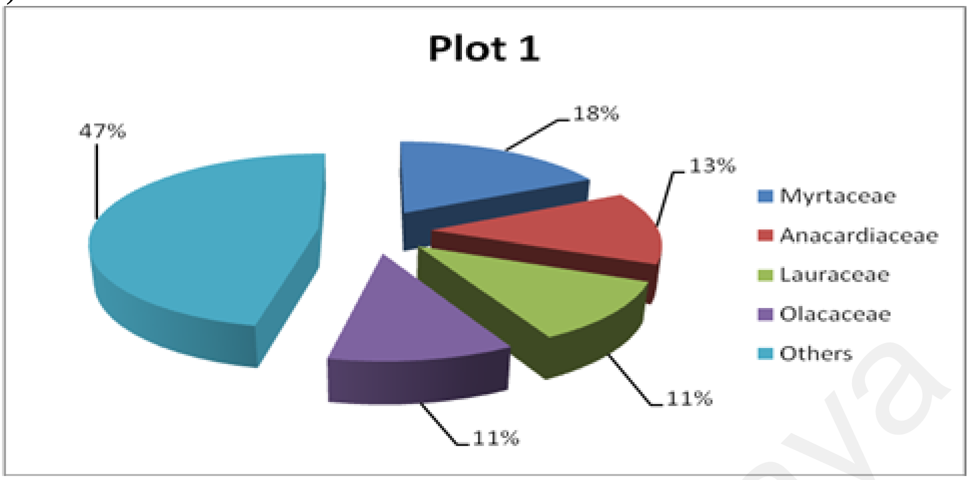
Species	Vernacular name	Family	DBH (cm)	Height (m)
Artocarpus rigidus	Keledang	Moraceae	110	55
Ixonanthes reticulata	Inggir burung	Ixonanthaceae	110	55
Paratocarpus bracteatus	Ara bertih bukit	Moraceae	94	53
Artocarpus rigidus	Keledang	Moraceae	92	51
Endospermum diadenum	Sesenduk	Euphorbiaceae	87	50
Callerya atropurpurea	Tulang daing	Fabaceae	85	50
Parkia javanica	Petai kerayung	Fabaceae	85	50
Shorea leprosula	Meranti tembaga	Dipterocarpaceae	84	50
Dacryodes rugosa	Kedondong matahari	Burseraceae	82	45
Aglaia sp.	Medang	Meliaceae	82	45

At plot 1, 45 individuals were collected and represented 20 species from 18 families. The dominant family, Myrtaceae, accounted for 18% (8 individuals) of the total number of trees sampled in plot 1. The second dominant family was Anacardiaceae with 13% (6 individuals) followed by both Lauraceae and Olacaceae each with 11% (5 individuals) (Figure 4.1a). Plot 1 was dominated by *Syzygium* sp. (8 individuals), followed by *Spondias cytherea* (6 individuals), and both *Litsea firma* and *Ochanostachys amentaceae* with (5 individuals) each (Figure 4.2a).

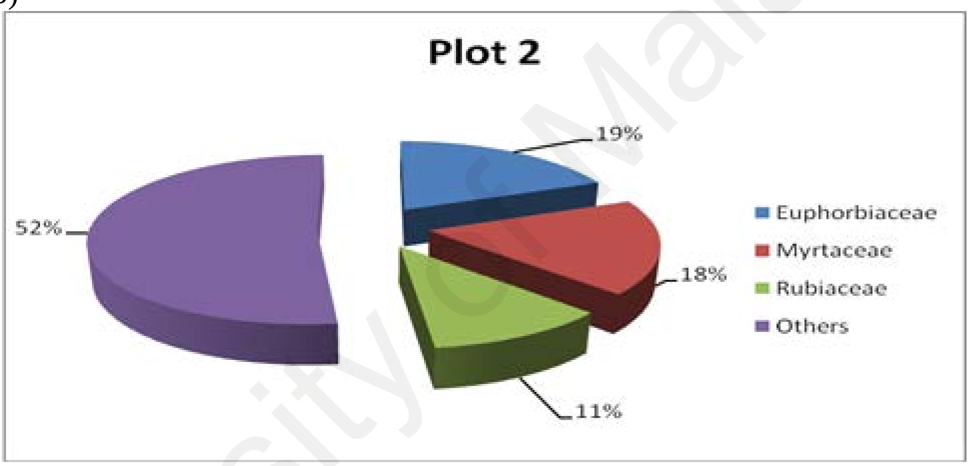
At plot 2, a total of 63 trees were sampled and were classified into 27 species from 20 families. The dominant family was Euphorbiaceae 19% (12 individuals), followed by Myrtaceae 18% (11 individuals) and Rubiaceae 11% (7 individuals) (Figure 4.1b). The dominant species, *Syzygium* sp., accounted for 11 individuals of the trees sampled from plot 2, and the second dominant species were *Baccaurea parviflora* (7 individuals), followed by *Porterandia anisophylla* (6 individuals) (Figure 4.2b).

At plot 3, 131 individuals were collected and represented 32 species from 23 families. The dominant family, Myrtaceae, accounted for 16% (21 individuals) of the total number of trees sampled in plot 3. The second dominant family was Euphorbiaceae with 15% (20 individuals) followed by Ulmaceae with 12% (16 individuals) (Figure 4.1c). Plot 3 was dominated by *Syzygium* sp. (21 individuals), followed by *Gironniera nervosa* (16 individuals), with both *Knema* sp.and *Spondias cytherea*having 10 individuals each (Figure 4.2c).

a)



b)



c)

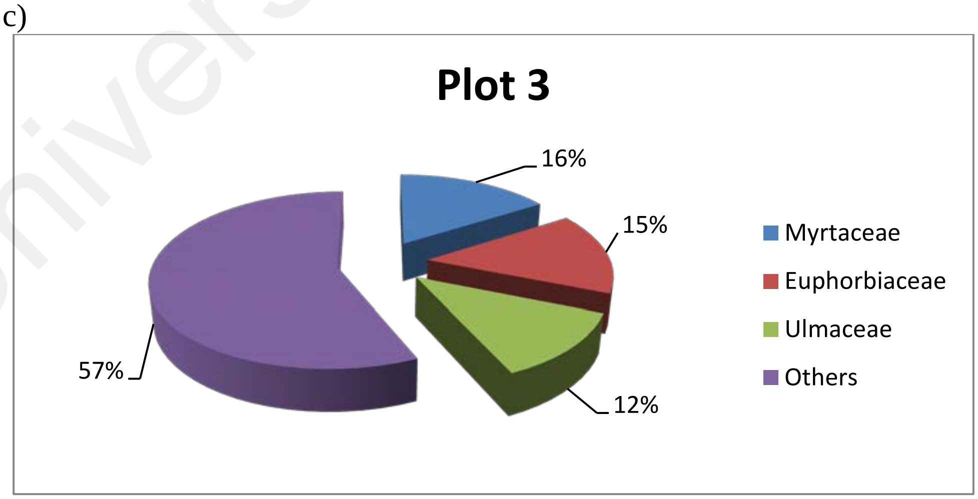


Figure 4.1: Species composition according to families (percent) of a) plot 1, b) plot 2, and c) plot 3 at the study area

a)

b)

c)

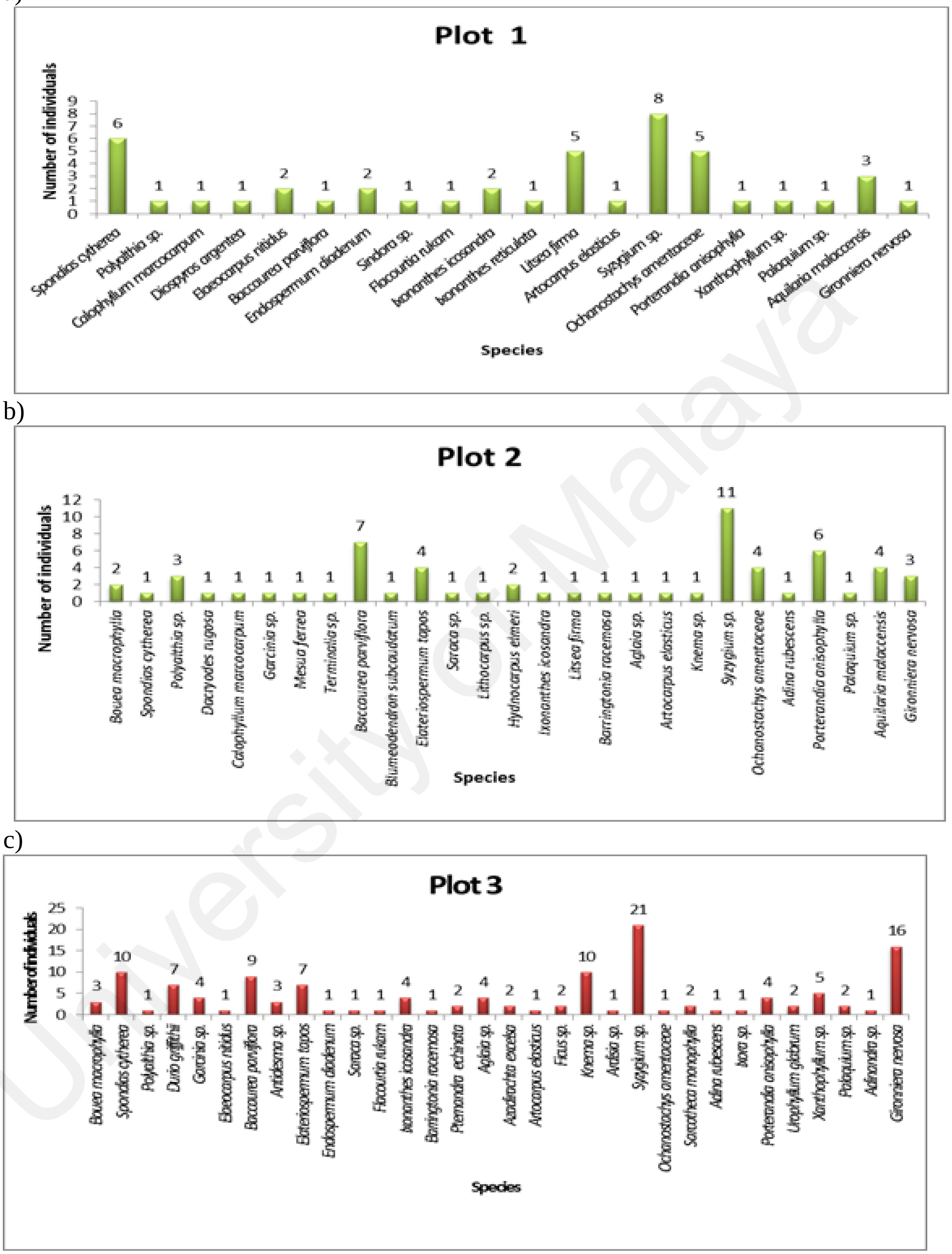


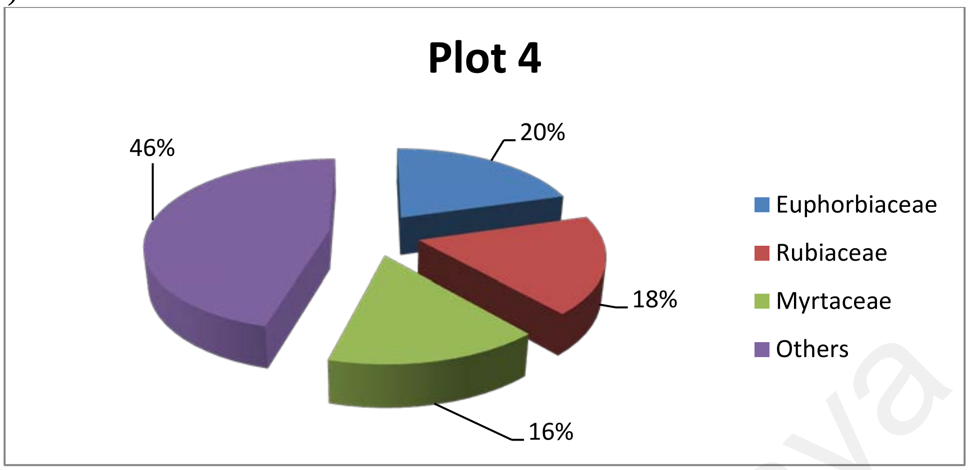
Figure 4.2: **Number of individuals according to species collected from a) plot 1, b) plot 2, and c) plot 3 at the study area**

At plot 4, a total of 83 trees were sampled and were classified into 25 species from 18 families. The dominant family was Euphorbiaceae 20% (17 individuals), followed by Rubiaceae 18% (15 individuals) and Myrtaceae 16% (13 individuals) (Figure 4.3a). *Porterandia anisophylla* was the most abundant tree species in plot 4 (15 individuals), while the second dominant species was *Syzygium* sp. (12 individuals) followed by *Elateriospermum tapos* (8 individuals) (Figure 4.4a).

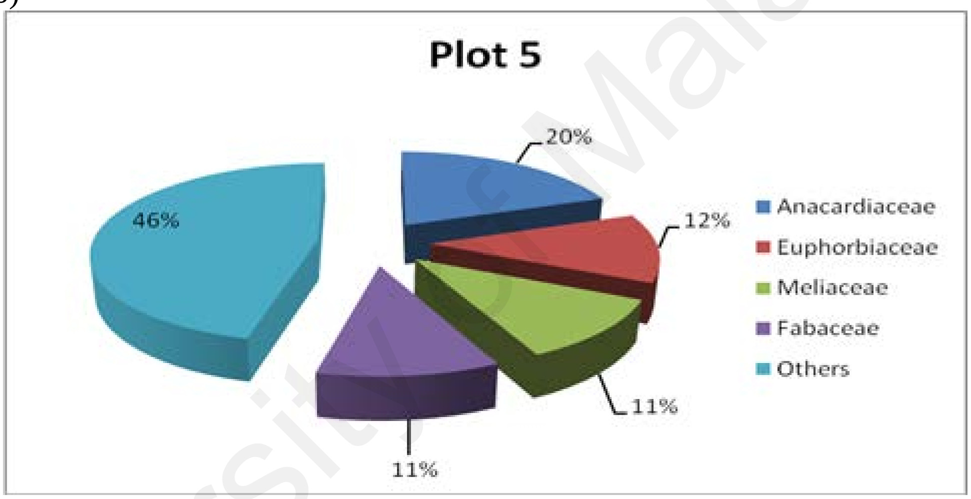
At plot 5, 82 individuals were collected and represented 36 species from 24 families. The dominant family, Anacardiaceae, accounted for 20% (16 individuals) of the total number of trees sampled in plot 5. The second dominant family was Euphorbiaceae with 12% (10 individuals) followed by both Meliaceae and Fabaceae with 11% (9 individuals) each (Figure 4.3b). Plot 5 is dominated by *Spondias cytherea* (15 individuals), followed by both *Azadirachta excelsa* and *Dialium kingii* with 5 individuals each (Figure 4.4b).

At plot 6, a total of 81 trees were sampled and were classified into 26 species from 20 families. The dominant family was Myrtaceae 21% (17 individuals) and the second dominant family was Anacardiaceae 12% (10 individuals) followed by both Moraceae and Myristicaceae with 9% (7 individuals) each (Figure 4.3c). The dominant species, *Syzygium* sp., accounted for 15 individuals of the trees sampled from plot 6, and the second dominant species were *Knema* sp. (7 individuals), followed by *Elateriospermum tapos, Spondias cytherea*, *Streblus elongatus* and *Swintonia penangiana* with 5 individuals each (Figure 4.4c).

a)



b)



c)

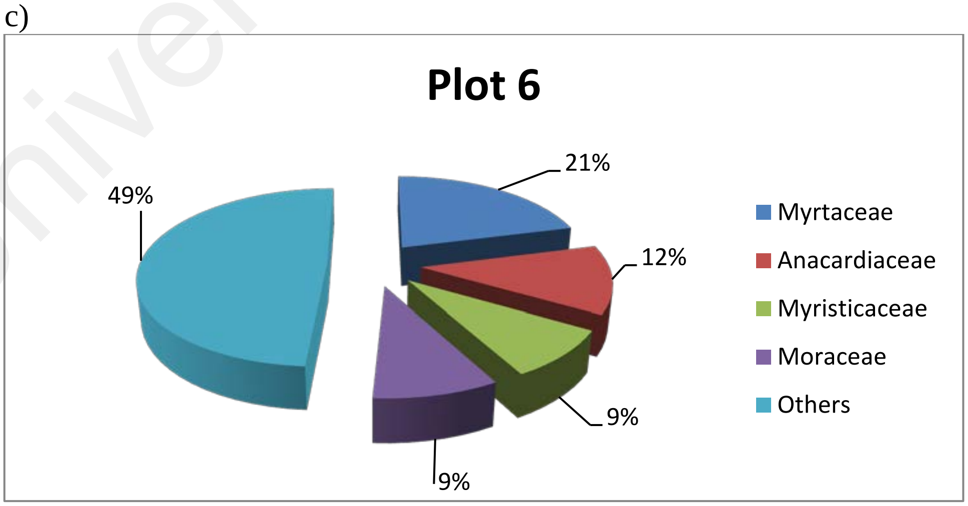
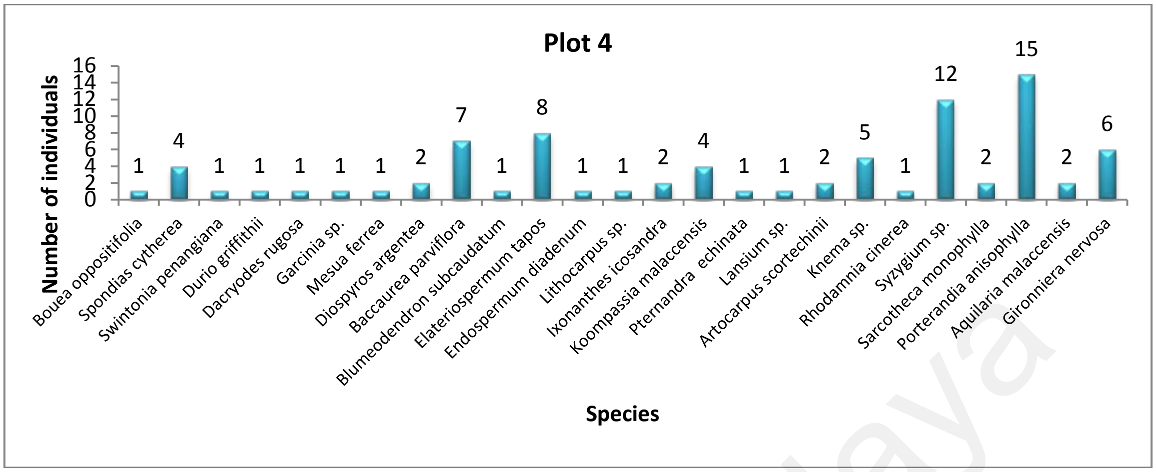
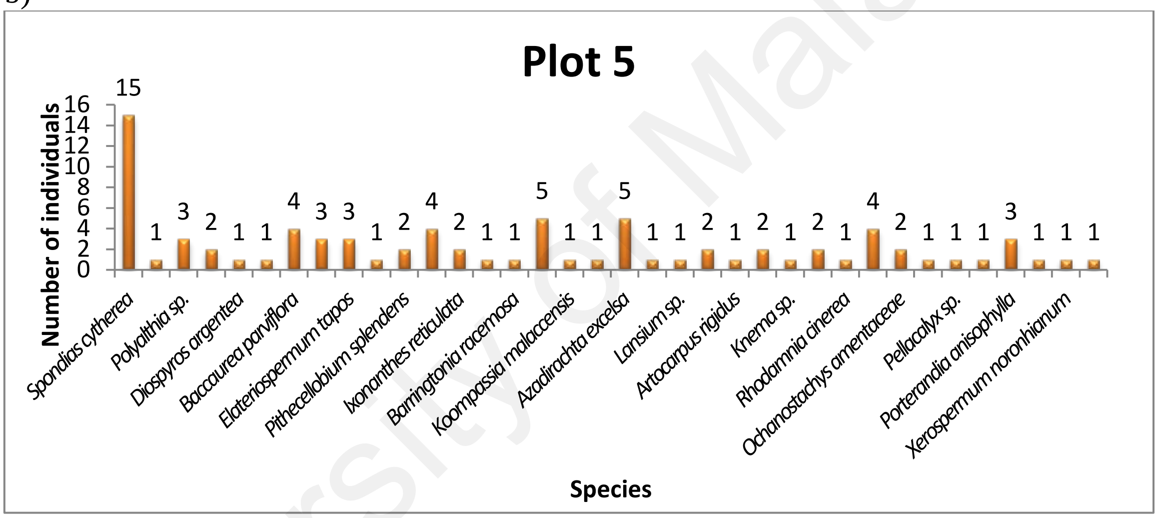


Figure 4.3: Species composition according to families (percent) of a) plot 4, b) plot 5, and c) plot 6 at the study area

a)



b)



c)

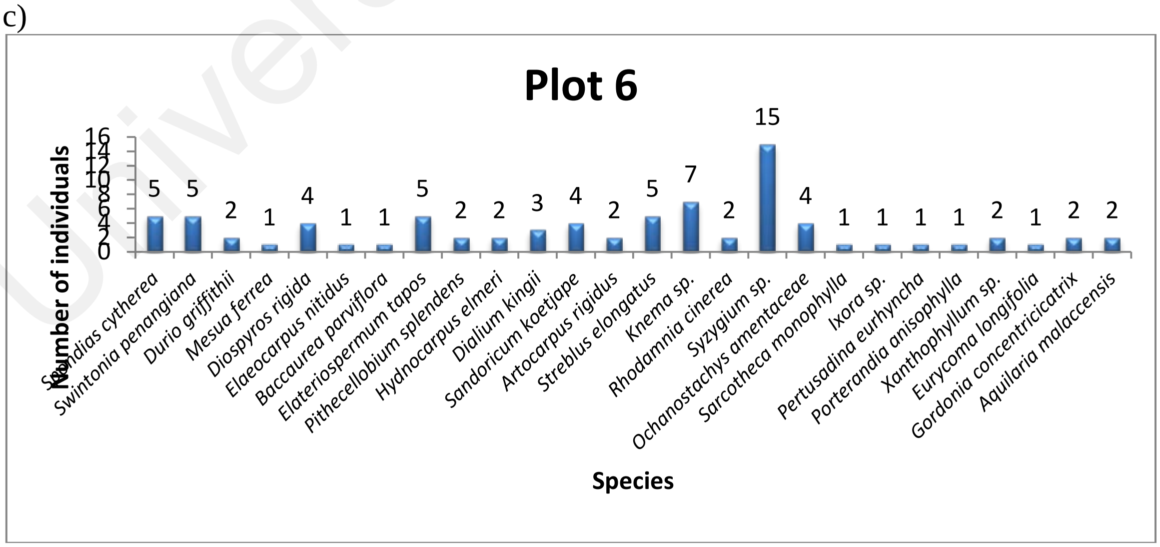


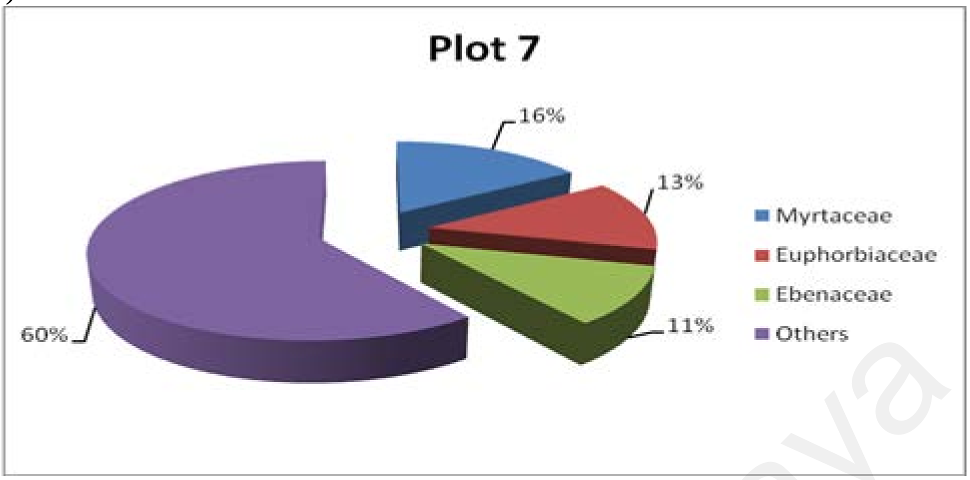
Figure 4.4: Number of individuals according to species collected from a) plot 4, b) plot 5, and c) plot 6 at the study area

At plot 7, 96 individuals were collected and represented 32 species from 22 families. The dominant family, Myrtaceae, accounted for 16% (15 individuals) of the total number of trees sampled in plot 7. The second dominant family was Euphorbiaceae with 13% (12 individuals) followed by Ebenaceae with 11% (10 individuals) (Figure 4.5a). Plot 7 was dominated by *Syzygium* sp. (15 individuals), followed by *Diospyros rigida* (10 individuals), and both *Aquilaria malaccensis* and *Elateriospermum tapos* with 8 individuals each (Figure 4.6a).

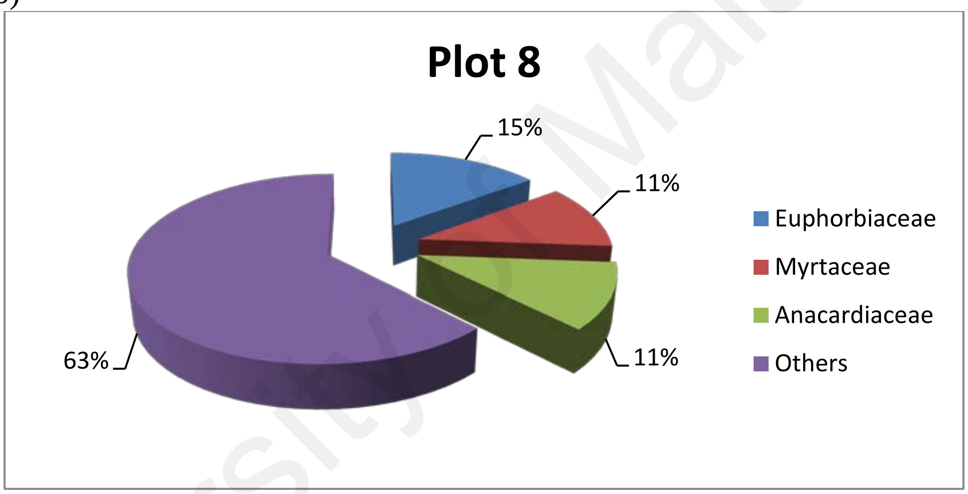
At plot 8, a total of 70 trees were sampled and were classified into 32 species from 22 families. The dominant family was Euphorbiaceae with 15% (10 individuals), followed by both Myrtaceae and Anacardiaceae with 11% (8 individuals) each (Figure 4.5b). *Syzygium* sp. was the most abundant tree species in plot 8 (8 individuals), while the second dominant species were *Spondias cytherea* (7 individuals), followed by *Elateriospermum tapos* (6 individuals) (Figure 4.6b).

At plot 9, 78 individuals were collected and represented 28 species from 19 families. The dominant family, Fagaceae, accounted for 23% (19 individuals) of the total number of trees sampled in plot 9. The second dominant family was Euphorbiaceae with 22% (17 individuals) followed by Myrtaceae with 9% (7 individuals) (Figure 4.5c). Plot 9 was dominated by *Lithocarpus* sp. (18 individuals), followed by *Syzygium* sp.(7 individuals), and *Durio griffithi*i (6 individuals) (Figure 4.6c).

a)



b)



c)

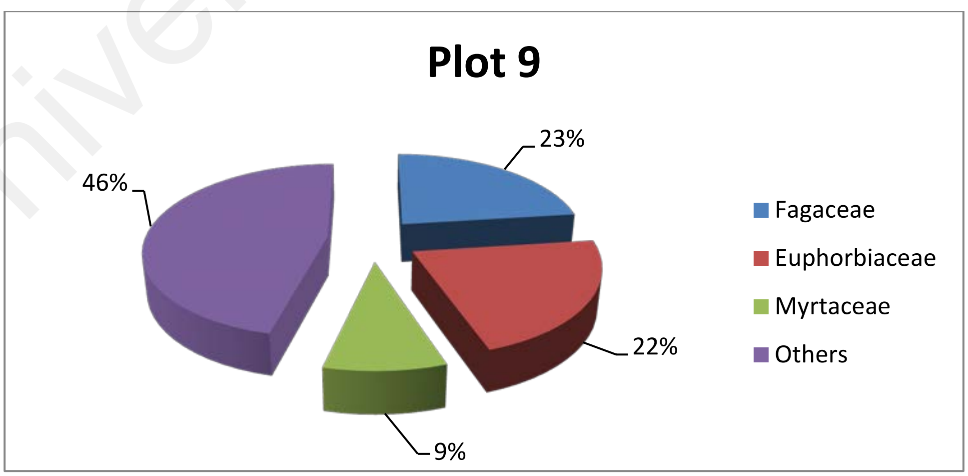


Figure 4.5: Species composition according to families (percent) of a) plot 7, b) plot 8, and c) plot 9 at the study area

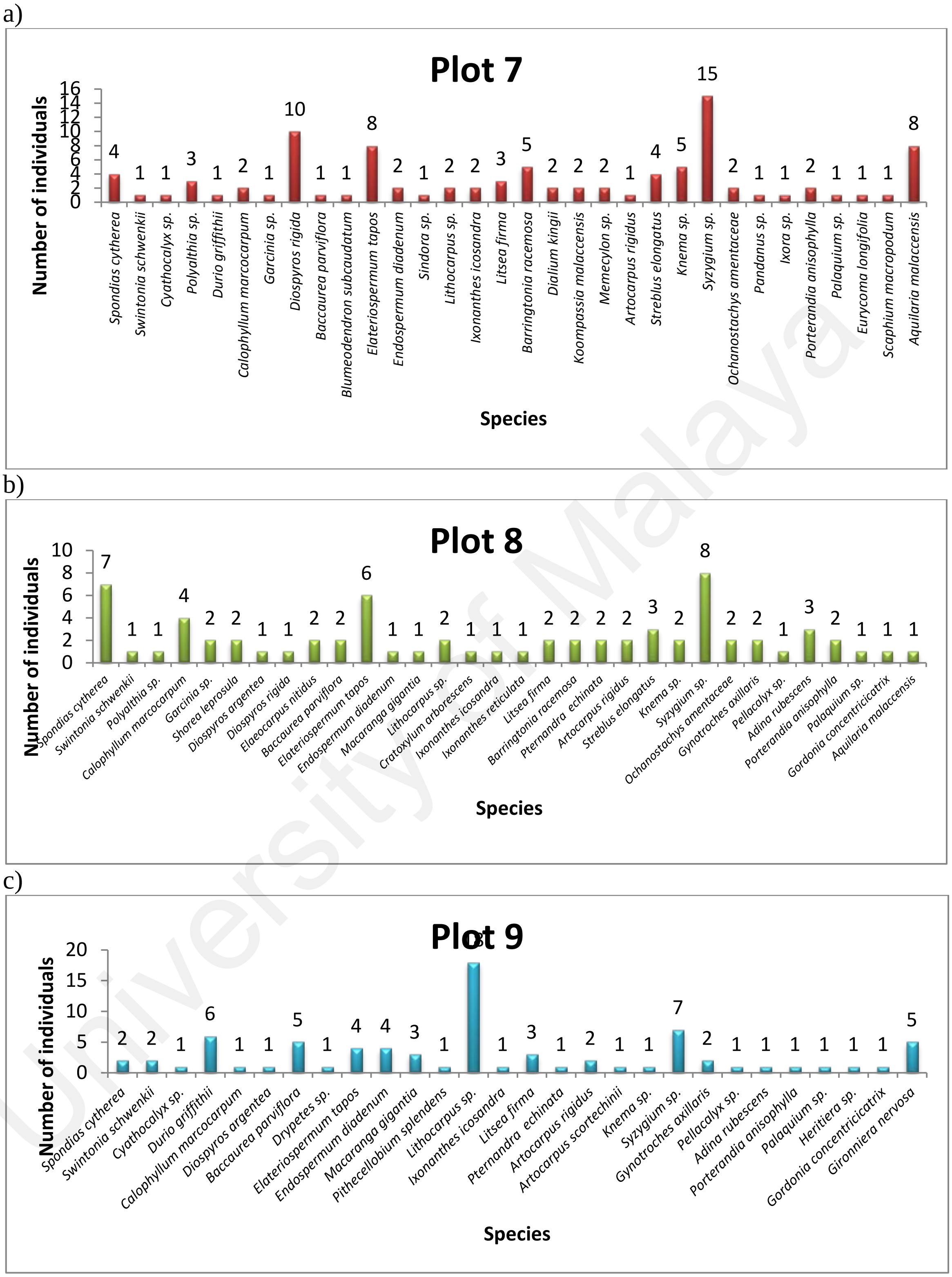


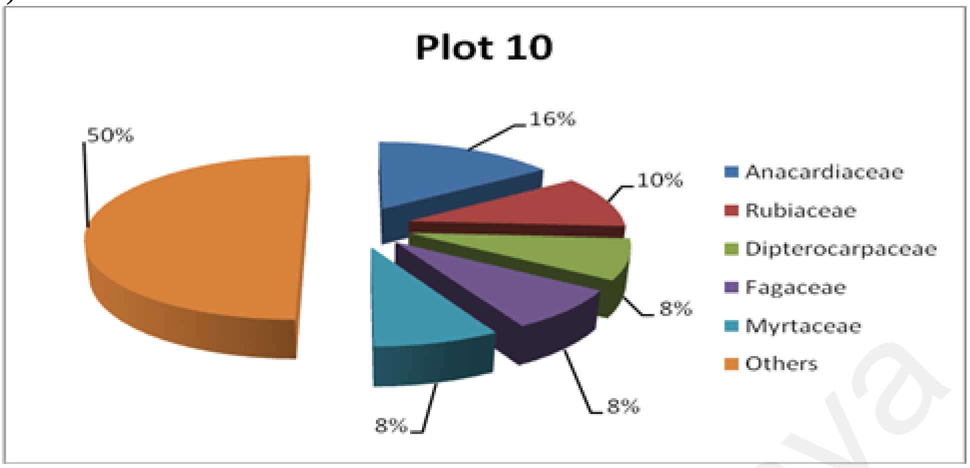
Figure 4.6: Number of individuals according to species collected from a) plot 7, b) plot 8, and c) plot 9 at the study area

At plot 10, a total of 77 trees were sampled and were classified into 33 species from 23 families. The dominant family was Anacardiaceae with 16% (12 individuals), followed by Rubiaceae with 10% (8 individuals). Dipterocarpaceae, Fagaceae and Myrtaceae each accounted for 8% (6 individuals) of the total number of trees sampled in plot 10 (Figure 4.7a). The dominant species, *Spondias cytherea*, accounted for 8 individuals of the trees sampled from plot 10, and the second dominant species were *Lithocarpus* sp., *Shorea leprosula* and *Syzygium* sp. with 6 individuals each (Figure 4.8a).

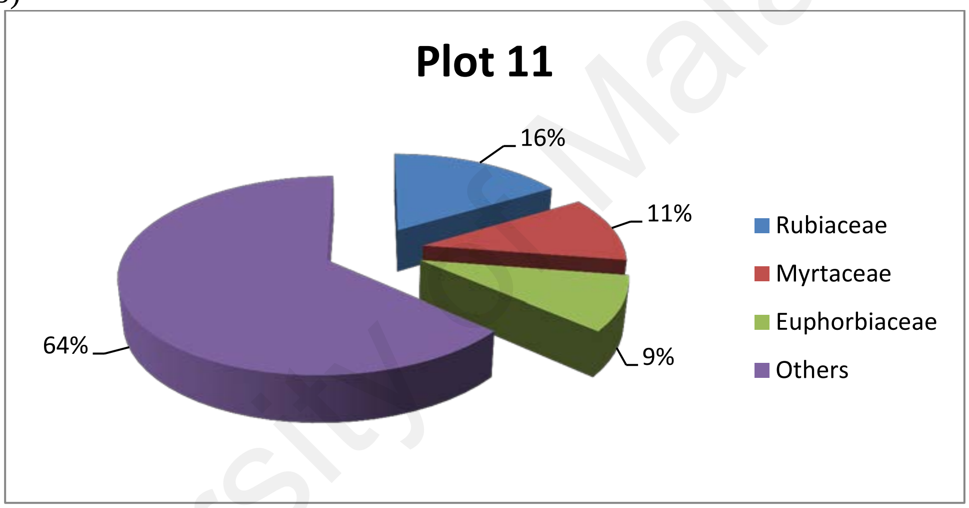
At plot 11, 67 individuals were collected and represented 39 species from 26 families. The dominant family, Rubiaceae, accounted for 16% (11 individuals) of the total number of trees sampled in plot 11. The second dominant family was Myrtaceae with 11% (7 individuals) followed by Euphorbiaceae with 9% (6 individuals) (Figure 4.7b). *Porterandia anisophylla* was the most abundant tree species in plot 11 (7 individuals), while the second abundant tree species was *Syzygium* sp.(6 individuals), followed by *Adina rubescens*, *Barringtonia racemosa*, *Pternandra echinata* and *Spondias cytherea*with 3 individuals, respectively (Figure 4.8b).

At plot 12, a total of 64 trees were sampled and were classified into 25 species from 20 families. The dominant family was Rubiaceae 17% (11 individuals), followed by Anacardiaceae 16% (10 individuals) and Myrtaceae 11% (7 individuals) (Figure 4.7c). Both *Porterandia anisophylla* and *Spondias cytherea* were the most abundant tree species in plot 12 with 9 individuals each, while the second dominant species was *Syzygium* sp. with 7 individuals (Figure 4.8c).

a)



b)



c)

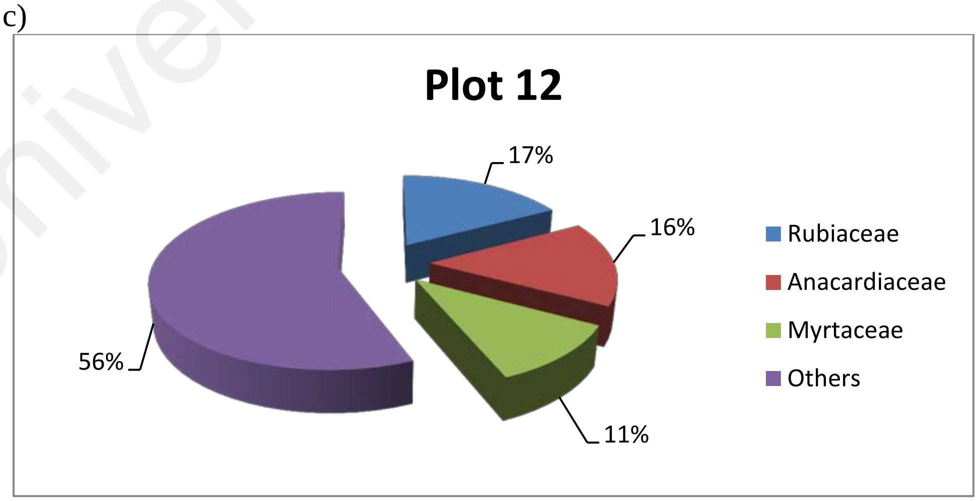
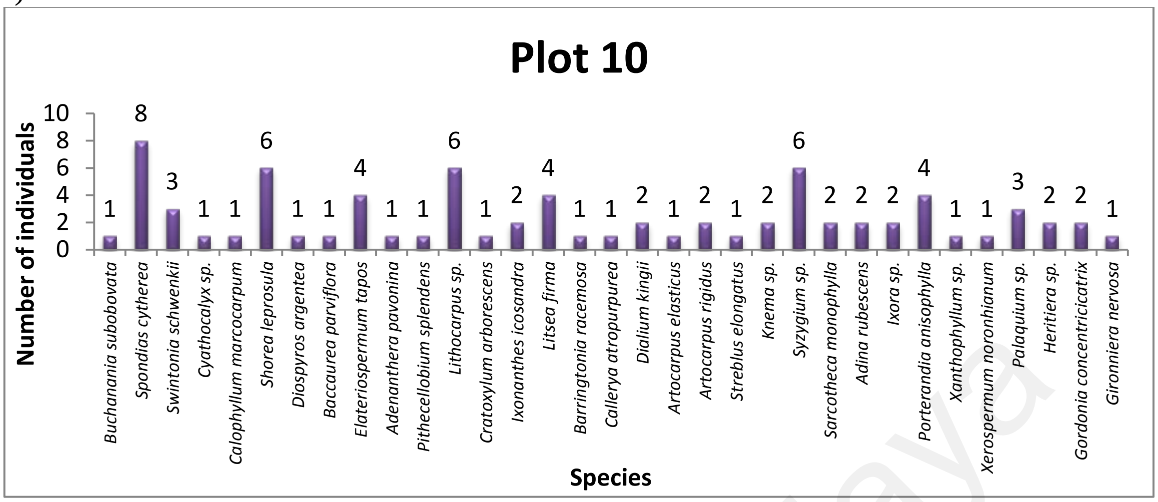
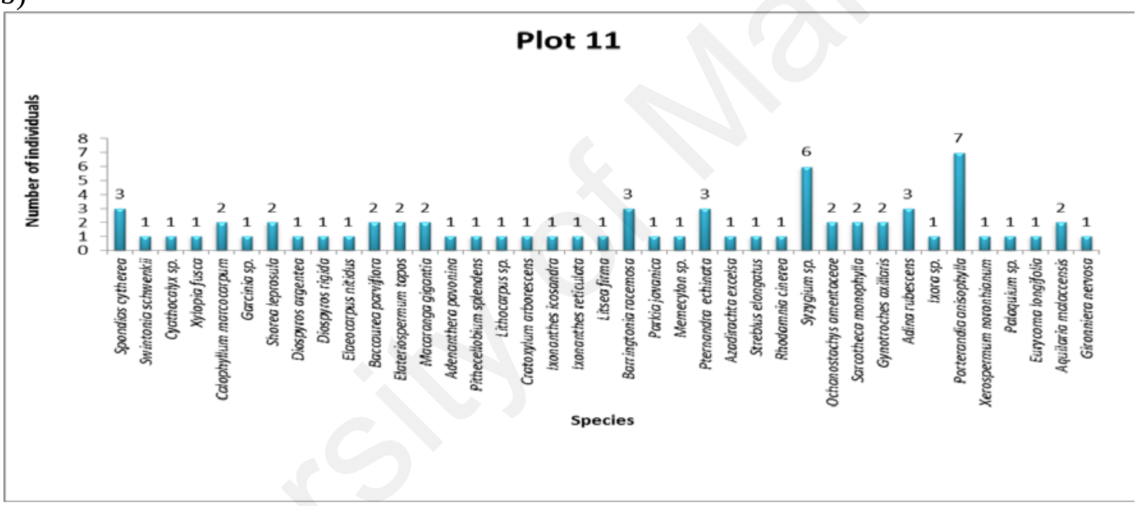


Figure 4.7: Species composition according to families (percent) of a) plot 10, b) plot 11, and c) plot 12 at the study area

a)



b)



c)

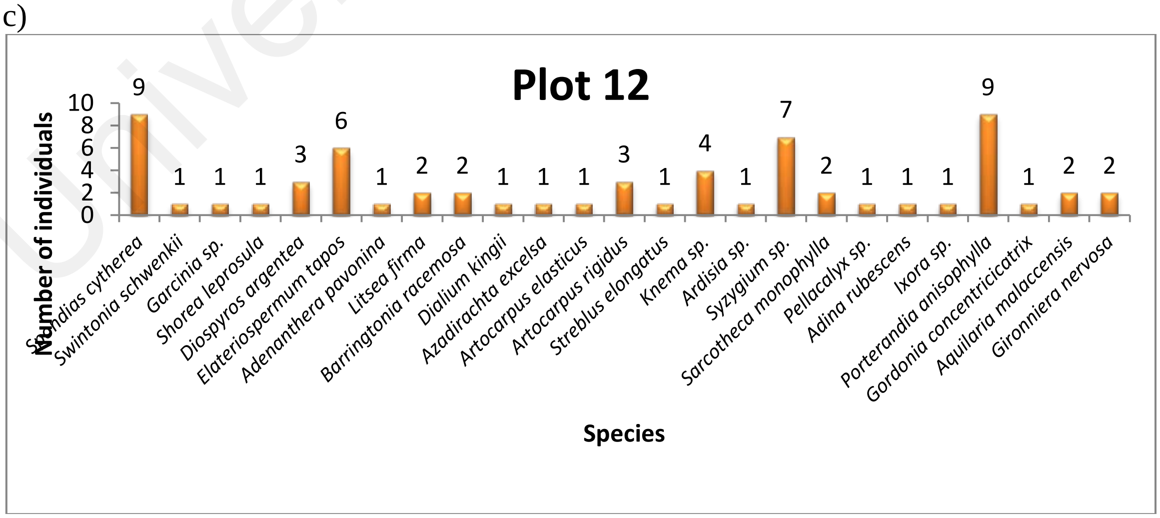


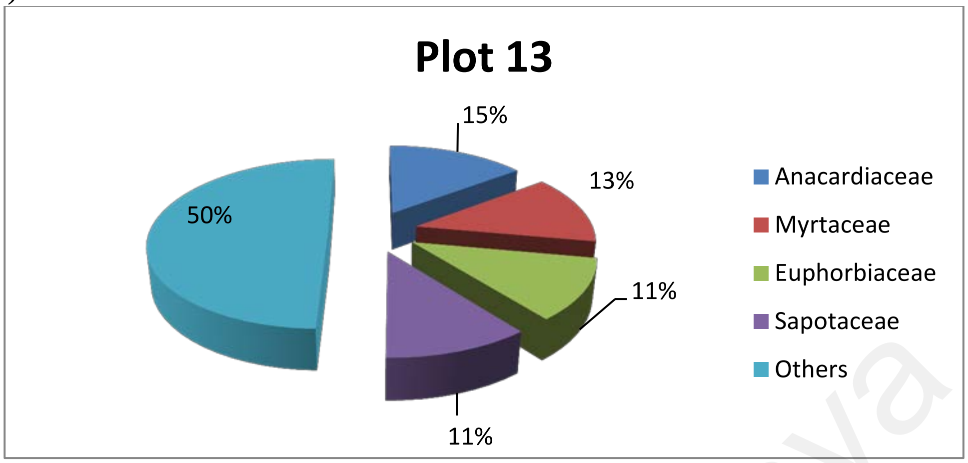
Figure 4.8: Number of individuals according to species collected from a) plot 10, b) plot 11, and c) plot 12 at the study area

At plot 13, 61 individuals were collected and represented 23 species from 20 families. The dominant family, Anacardiaceae, accounted for 15% (9 individuals) of the total number of trees sampled in plot 13. The second dominant family was Myrtaceae with 13% (8 individuals) followed by both Euphorbiaceae and Sapotaceae with 11% (7 individuals) each (Figure 4.9a). Plot 13 was dominated by both *Spondias cytherea* and *Syzygium* sp. with 8 individuals each, followed by both *Elateriospermum tapos* and *Palaquium* sp.with 7 individuals each (Figure 4.10a).

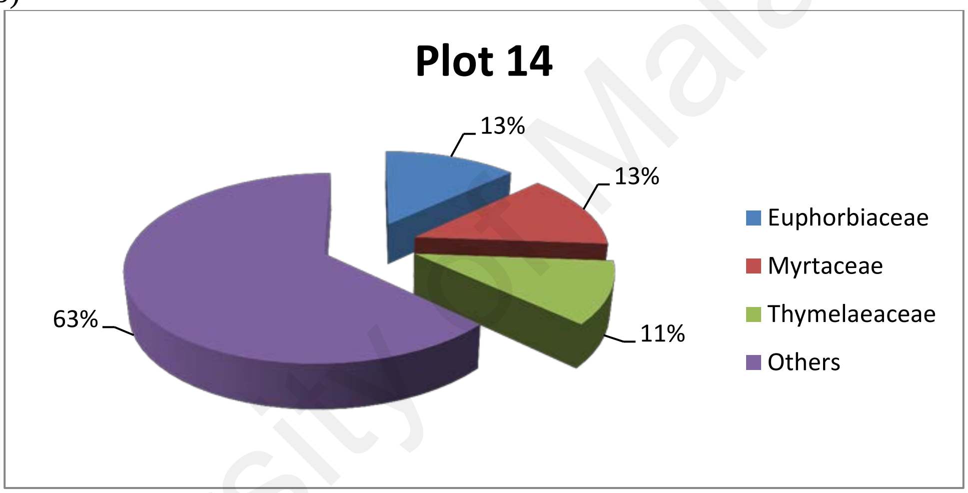
At plot 14, a total of 84 trees were sampled and were classified into 31 species from 23 families. The dominant family were both Euphorbiaceae and Myrtaceae with 13% (11 individuals), followed by Thymelaeaceae with 11% (9 individuals) (Figure 4.9b). The dominant species, *Syzygium* sp., accounted for 11 individuals of the trees sampled from plot 14, and the second dominant species were both *Aquilaria malaccensis* and *Elateriospermum tapos* with 9 individuals each (Figure 4.10b).

At plot 15, 54 individuals were collected and represented 23 species from 18 families. The dominant family, Dipterocarpaceae, accounted for 18% (10 individuals) of the total number of trees sampled in plot 15. The second dominant families were Anacardiaceae and Myrtaceae each with 17% (9 individuals) (Figure 4.9c). Plot 15 was dominated by *Hopea* sp. (10 individuals), followed by *Syzygium* sp.(9 individuals) and *Spondias cytherea*(7 individuals) (Figure 4.10c).

a)



b)



c)

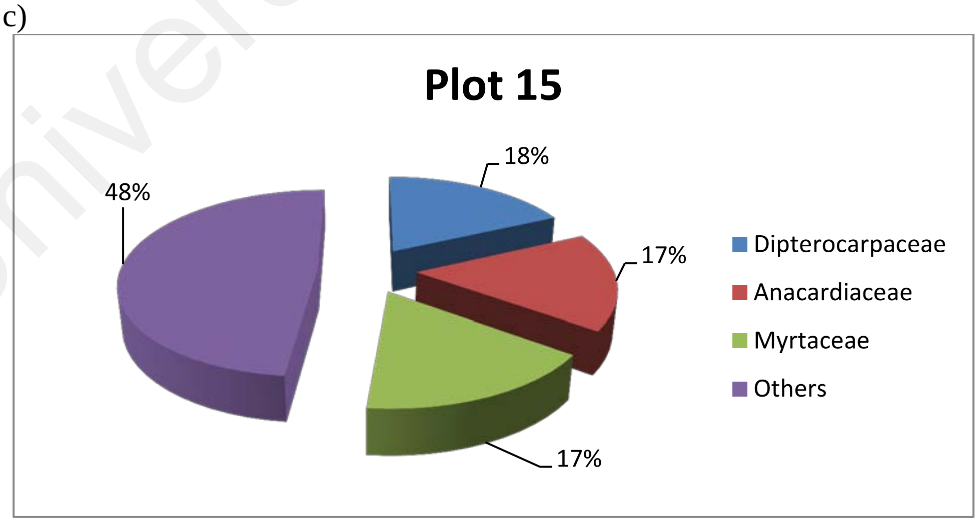


Figure 4.9: Species composition according to families (percent) of a) plot 13, b) plot 14, and c) plot 15 at the study area

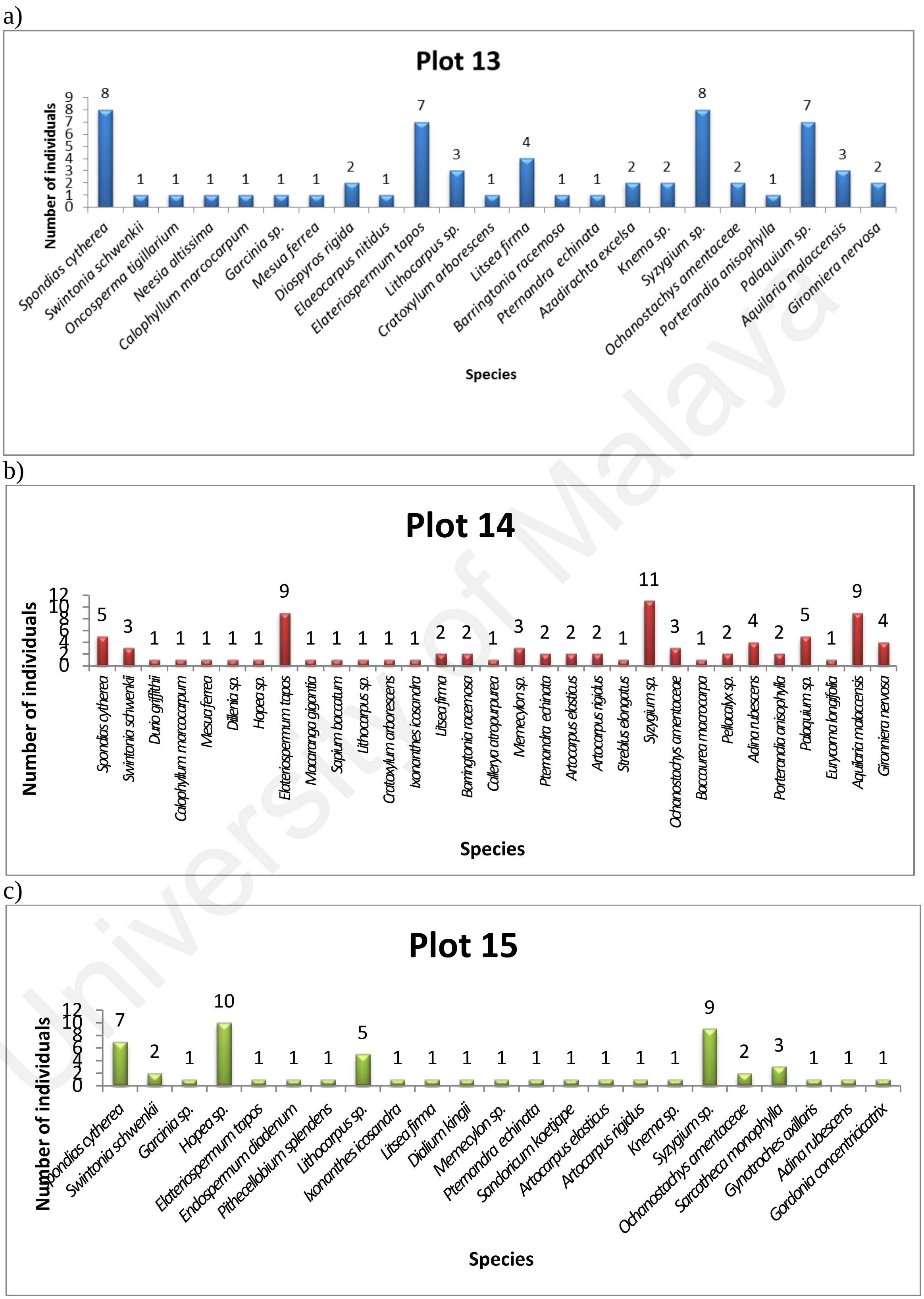


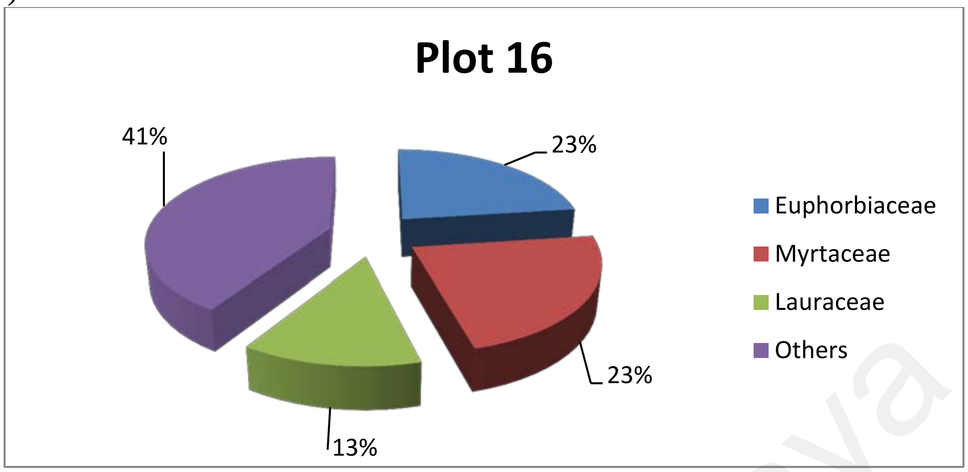
Figure 4.10: Number of individuals according to species collected from a) plot 13, b) plot 14, and c) plot 15 at the study area

At plot 16, a total of 61 trees were sampled and were classified into 22 species from 18 families. The dominant family were Euphorbiaceae and Myrtaceae with 23% (14 individuals), followed by Lauraceae with 13% (8 individuals) (Figure 4.11a). *Syzygium* sp. was the most abundant tree species in plot 16 (14 individuals), while the second dominant species was *Elateriospermum tapos* (12 individuals) followed by *Litsea firma* (8 individuals) (Figure 4.12a).

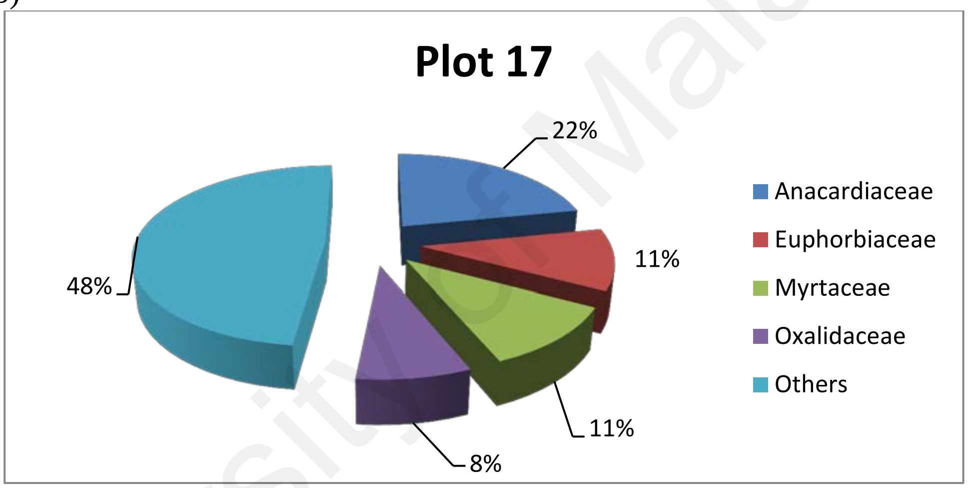
At plot 17, 46 individuals were collected and represented 28 species from 23 families. The dominant family, Anacardiaceae, accounted for 22% (10 individuals) of the total number of trees sampled in plot 17. The second dominant family were Euphorbiaceae and Myrtaceae each with 11% (5 individuals), followed by Oxalidaceae with 8% (4 individuals) (Figure 4.11b). Plot 17 is dominated by *Spondias cytherea* (6 individuals), followed by *Syzygium* sp.(5 individuals), with *Sarcotheca monophylla* and *Swintonia schwenkii* having 4 individuals each (Figure 4.12b).

At plot 18, a total of 55 trees were sampled and were classified into 24 species from 19 families. The dominant family was Myrtaceae 20% (11 individuals), followed by Anacardiaceae 15% (8 individuals) and Rubiaceae 11% (6 individuals) (Figure 4.11c). The dominant species, *Syzygium* sp., accounted for 11 individuals of the trees sampled from plot 18, and the second dominant species was *Spondias cytherea* (7 individuals), followed by both *Aquilaria malaccensis* and *Palaquium* sp. having 4 individuals each (Figure 4.12c).

a)



b)



c)

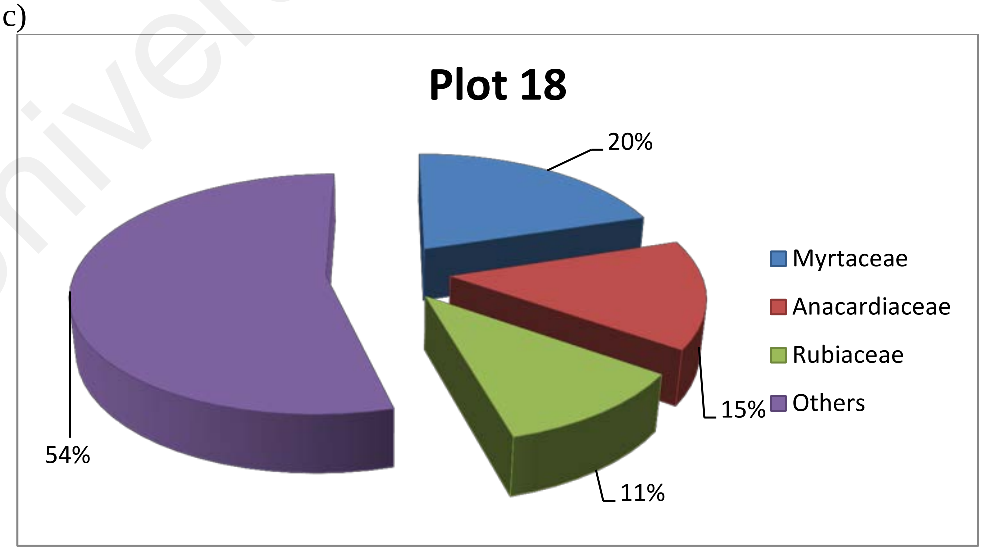
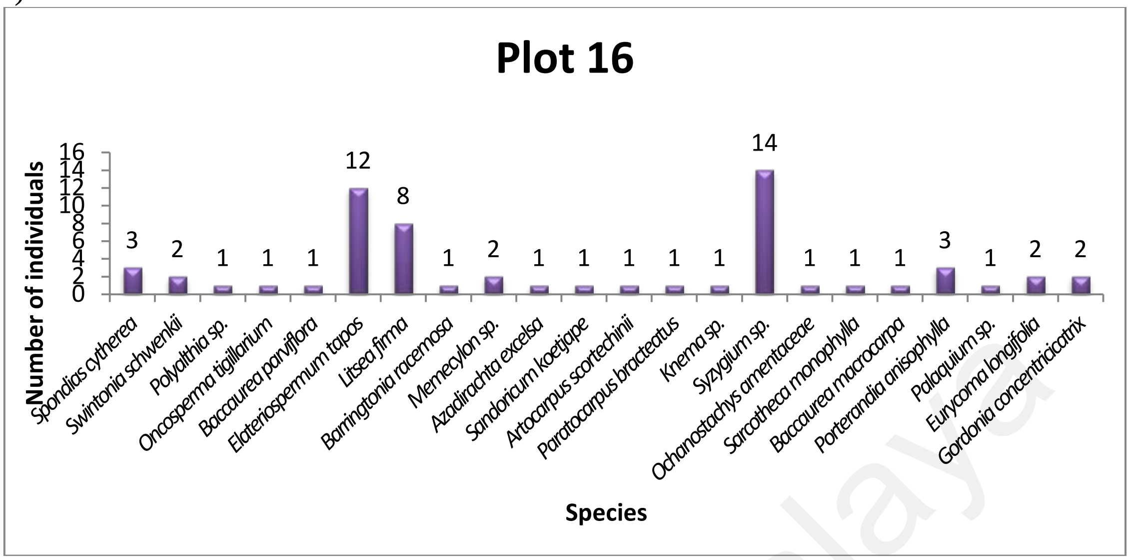
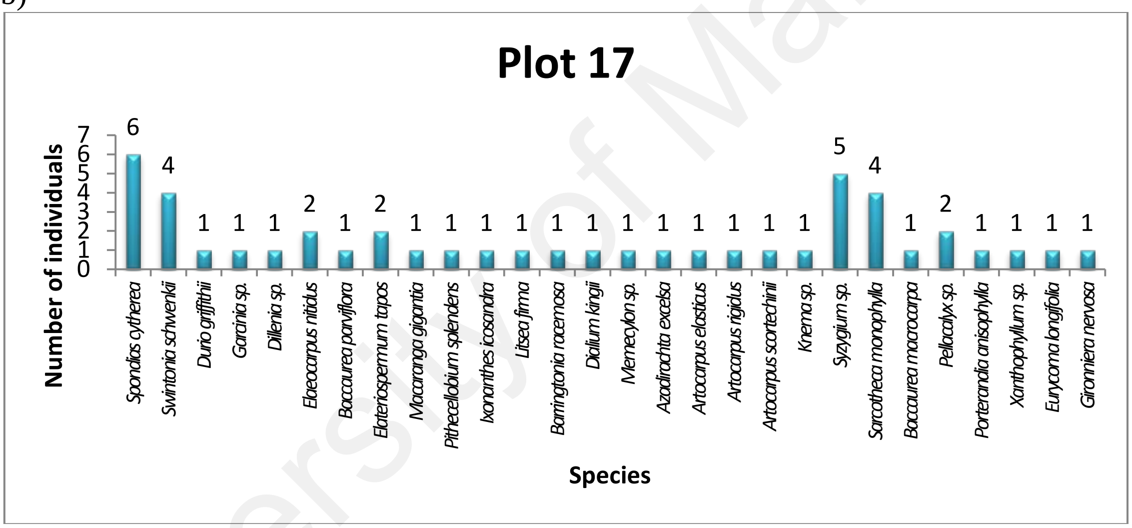


Figure 4.11: Species composition according to families (percent) of a) plot 16, b) plot 17, and c) plot 18 at the study area

a)



b)



c)

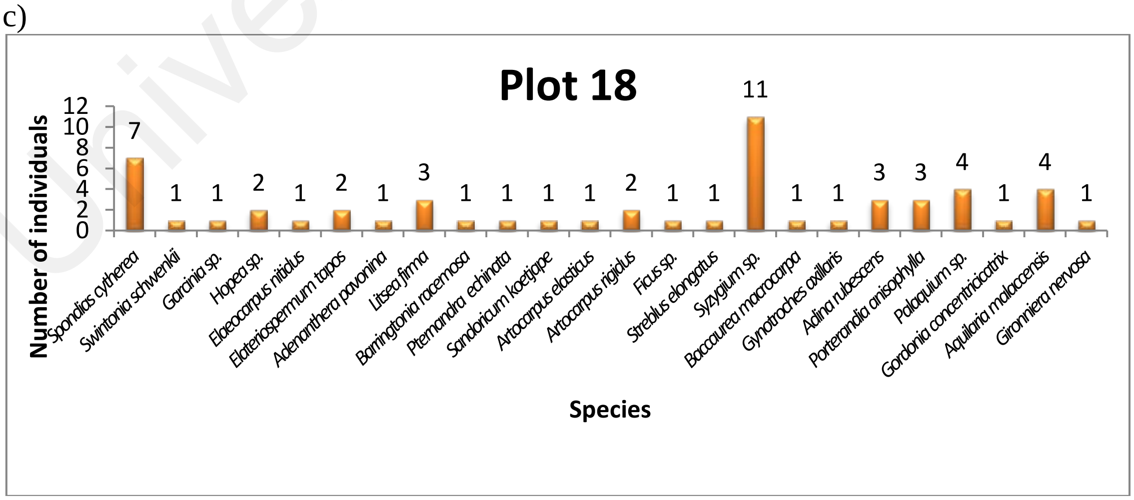


Figure 4.12: Number of individuals according to species collected from a) plot 16, b) plot 17, and c) plot 18 at the study area

At plot 19, 53 individuals were collected and represented 22 species from 18 families. The dominant family, Euphorbiaceae, accounted for 28% (15 individuals) of the total number of trees sampled in plot 19. The second dominant family was Anacardiaceae with 17% (9 individuals) followed by Lauraceae with 8% (4 individuals) (Figure 4.13a). Plot 19 was dominated by *Elateriospermum tapos* (13 individuals), followed by *Spondias cytherea*(8 individuals), and *Litsea firma* (3 individuals) (Figure 4.14a).

At plot 20, a total of 51 trees were sampled and were classified into 25 species from 16 families. The dominant families were both Euphorbiaceae and Ulmaceae with 22% (11 individuals), followed by both Anacardiaceae and Thymelaeaceae with 10% (5 individuals) each (Figure 4.13b). *Gironniera nervosa* was the most abundant tree species in plot 20 (11 individuals), while the second dominant species was *Aquilaria malaccensis* (5 individuals), followed by both *Elateriospermum tapos* and *Macaranga gigantia* with 4 individuals, respectively (Figure 4.14b).

At plot 21, 36 individuals were collected and represented 21 species from 19 families. The dominant families were Lauraceae, Moraceae and Myrtaceae with 14% (5 individuals) each, followed by Elaeocarpaceae with 11% (4 individuals) of the total number of trees sampled in plot 21 (Figure 4.13c). Plot 21 was dominated by both *Litsea firma* and *Syzygium* sp. with 5 individuals each, followed by *Elaeocarpus nitidus* (4 individuals) (Figure 4.14c).

a)
b)
c)

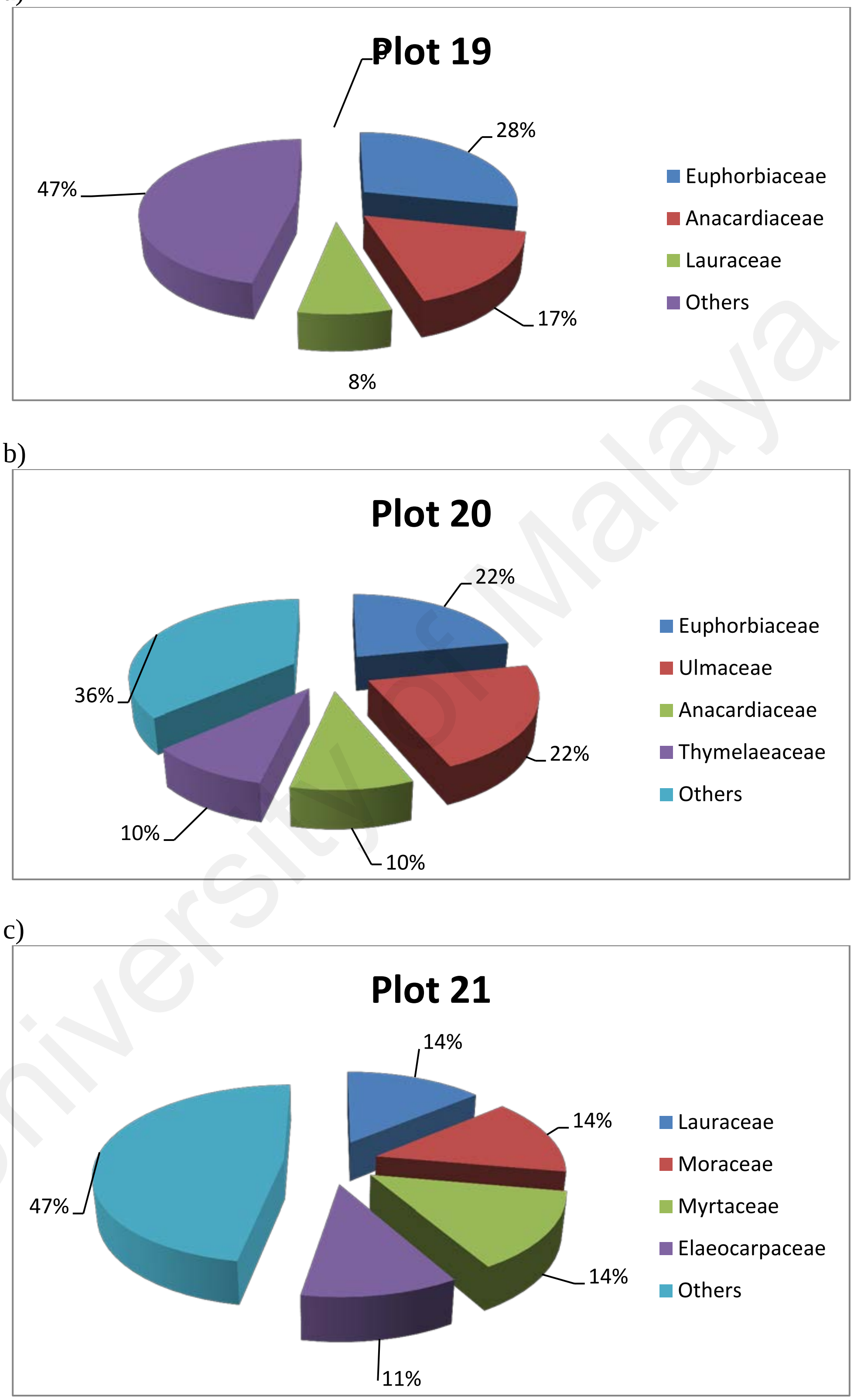
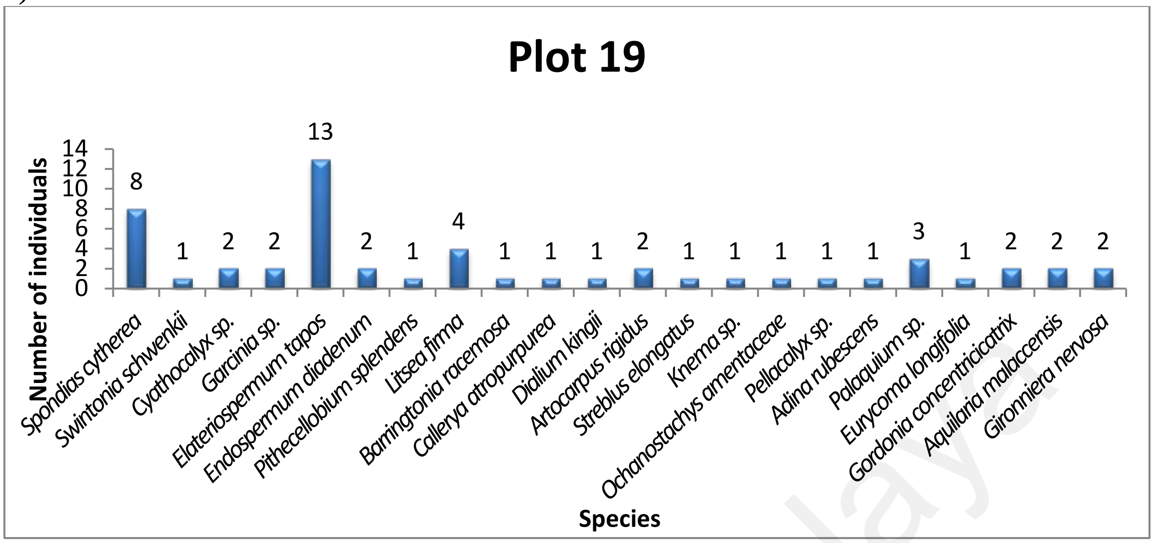
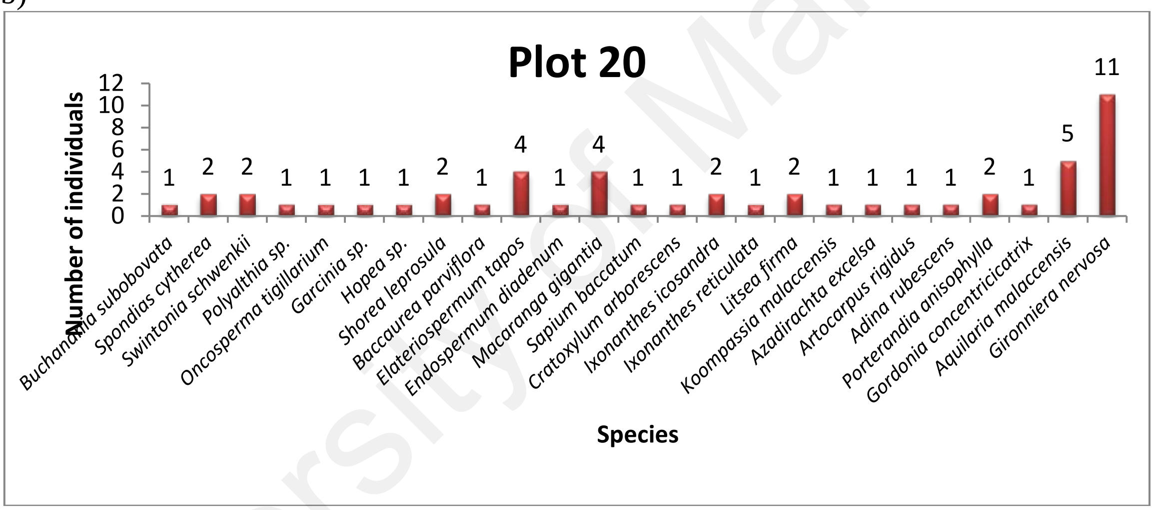


Figure 4.13: Species composition according to families (percent) of a) plot 19, b) plot 20, and c) plot 21 at the study are

a)



b)



c)

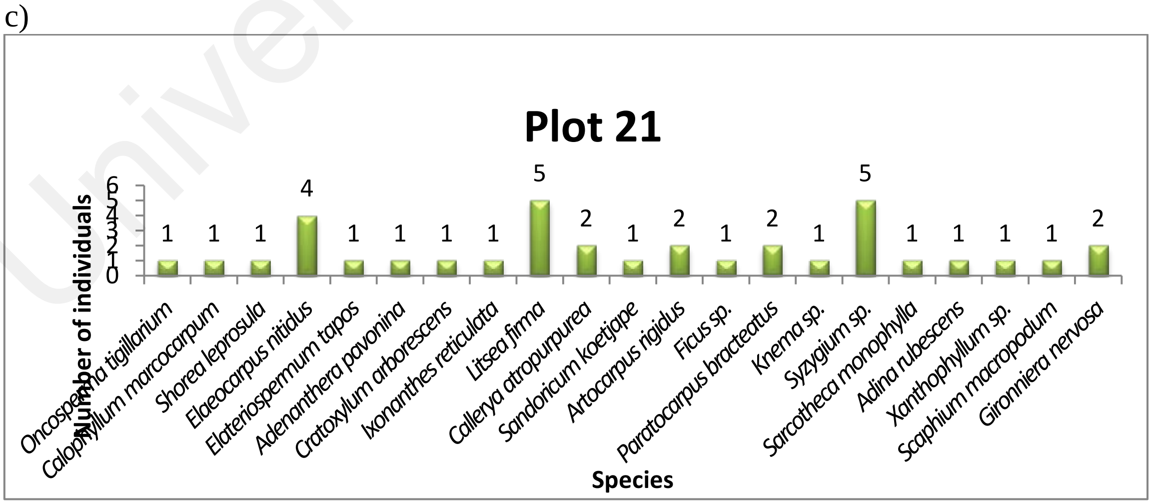


Figure 4.14: Number of individuals according to species collected from a) plot 19, b) plot 20, and c) plot 21 at the study area

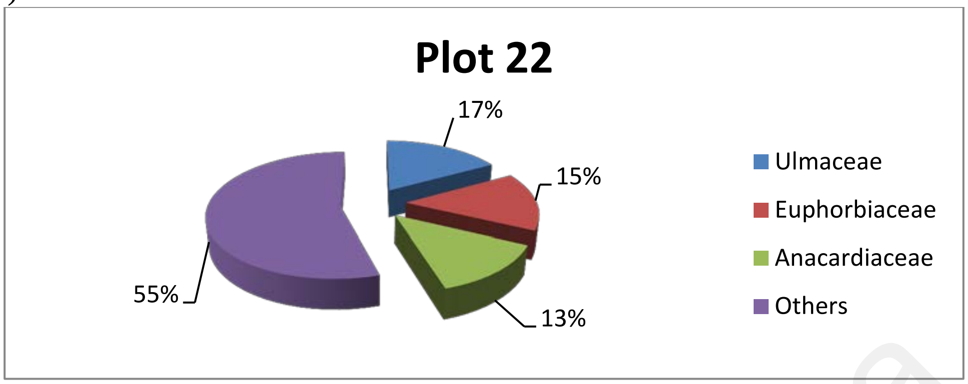
At plot 22, a total of 53 trees were sampled and were classified into 20 species from 16 families. The dominant family was Ulmaceae 17% (9 individuals), followed by Euphorbiaceae 15% (8 individuals) and Anacardiaceae 13% (7 individuals) (Figure 4.15a). The dominant species, *Gironniera nervosa*, accounted for 9 individuals of the trees sampled from plot 22, and the second dominant species was *Elateriospermum tapos* (8 individuals), followed by *Swintonia schwenkii* (7 individuals) (Figure 4.16a).

At plot 23, 61 individuals were collected and represented 21 species from 17 families. The dominant family, Myrtaceae, accounted for 20% (12 individuals) of the total number of trees sampled in plot 23. The second dominant families were both Anacardiaceae and Euphorbiaceae with 13% (8 individuals) each, followed by Lauraceae with 11% (7 individuals) (Figure 4.15b). Plot 23 was dominated by *Syzygium* sp. (12 individuals), followed by *Litsea firma* (7 individuals), and *Aquilaria malaccensis*, *Elateriospermum tapos* and *Spondias cytherea*with 5 individuals each (Figure 4.16b).

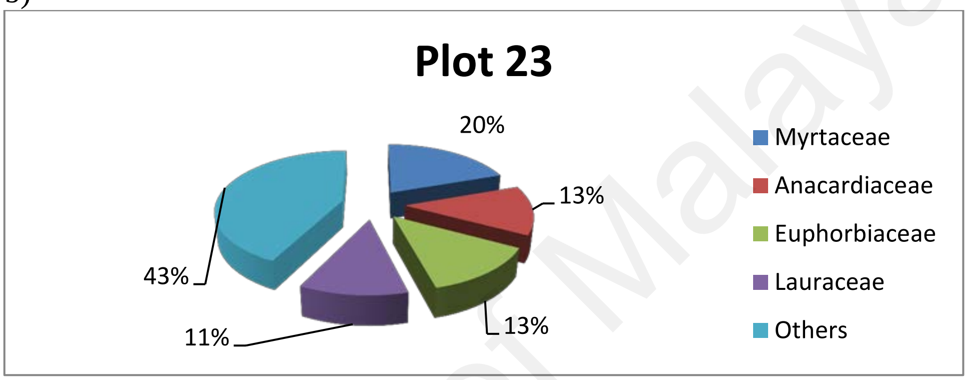
At plot 24, a total of 58 trees were sampled and were classified into 25 species from 17 families. The dominant family was Anacardiaceae with 26% (15 individuals). The second dominant family was Euphorbiaceae with 12% (7 individuals) followed by both Fabaceae and Myrtaceae with 9% (5 individuals) each (Figure 4.15c). *Spondias cytherea* was the most abundant tree species in plot 24 with 14 individuals, while the second dominant species was *Elateriospermum tapos* (6 individuals) followed by *Syzygium* sp. (5 individuals) (Figure 4.16c).

At plot 25, 58 individuals were collected and represented 24 species from 21 families. The dominant family, Lauraceae, accounted for 26% (15 individuals) of the total number of trees sampled in plot 25. The second dominant families were both Myrtaceae and Anacardiaceae with 12% (7 individuals) each (Figure 4.15d). Plot 25 was dominated by *Litsea firma* (15 individuals), followed by *Syzygium* sp.(7 individuals), and *Spondias cytherea*(5 individuals) (Figure 4.16d).

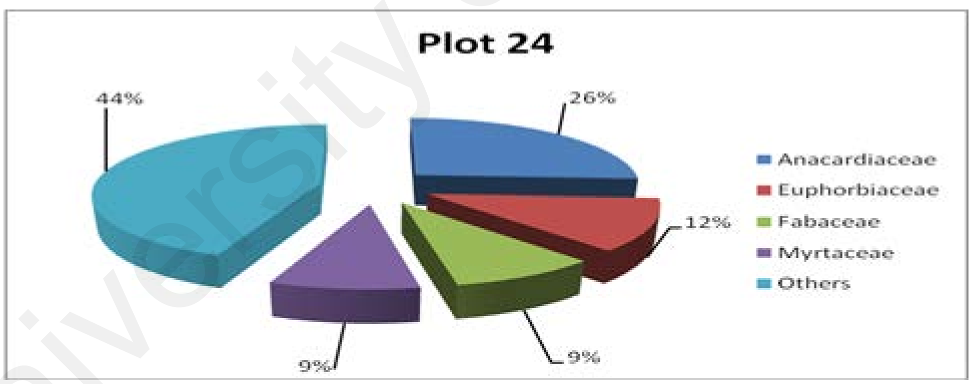
a)



b)



c)



d)

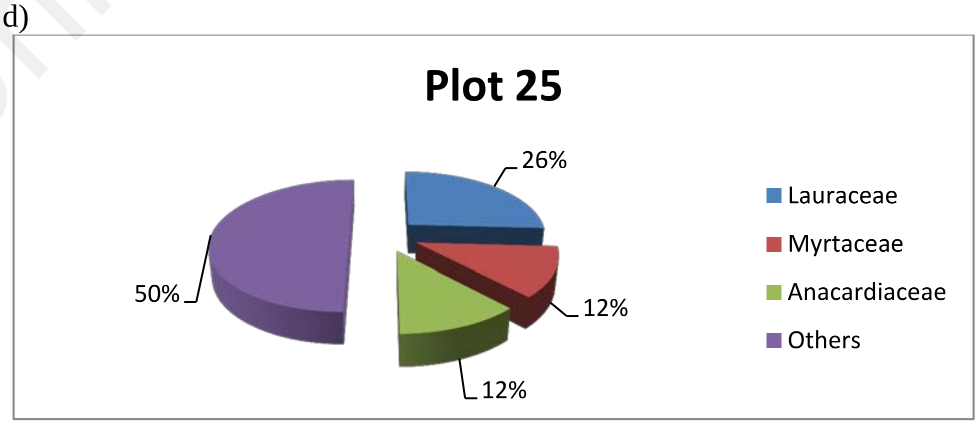
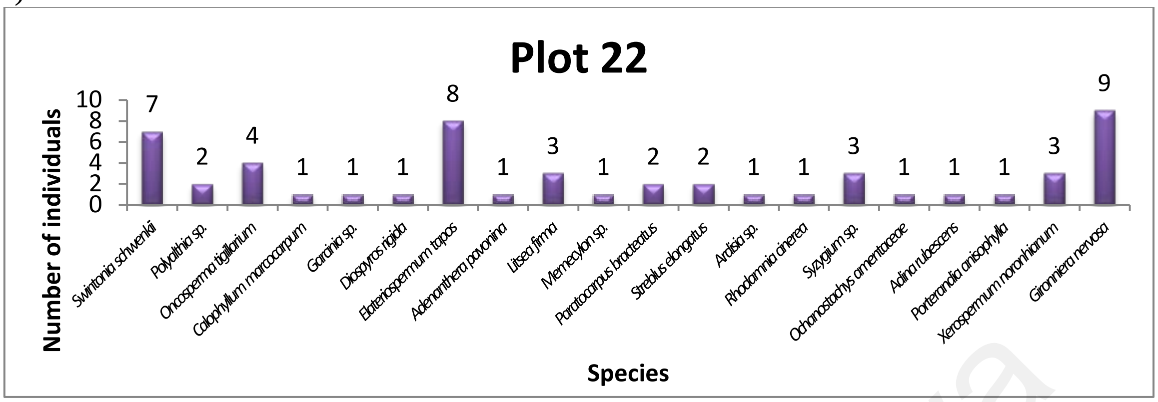
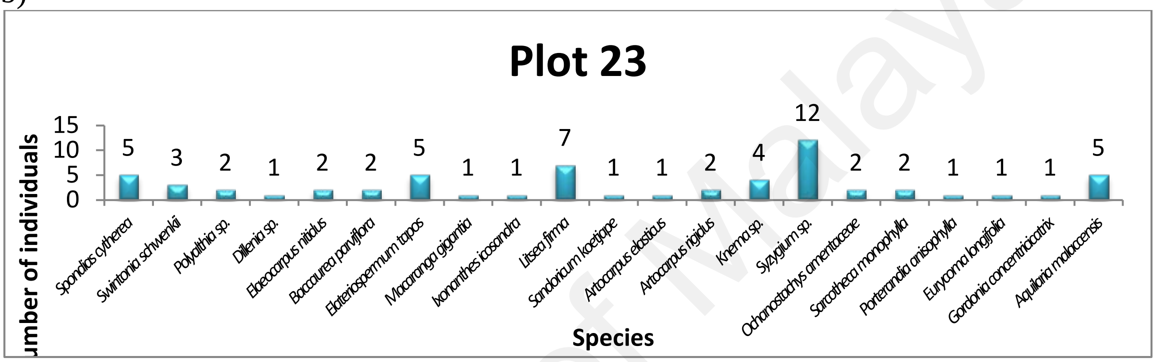


Figure 4.15: Species composition according to families (percent) of a) plot 22, b) plot 23, and c) plot 24 d) plot 25 at the study area

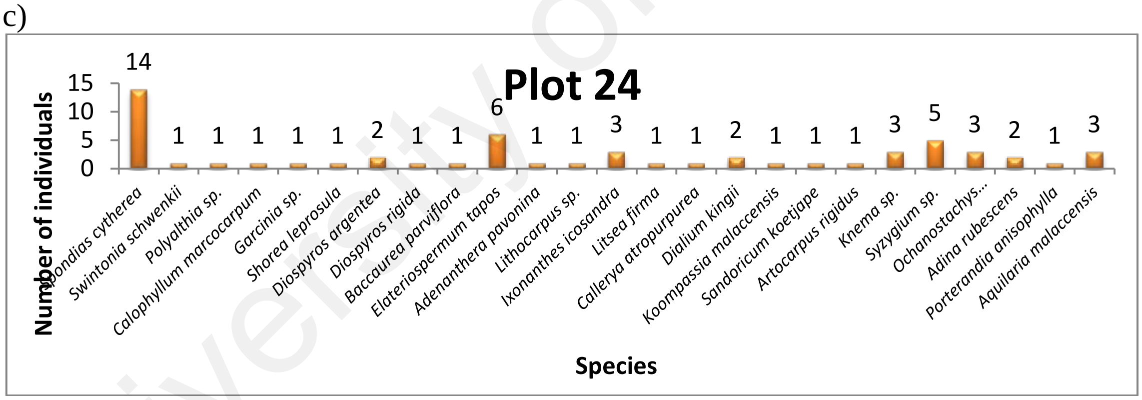
a)



b)



c)



d)

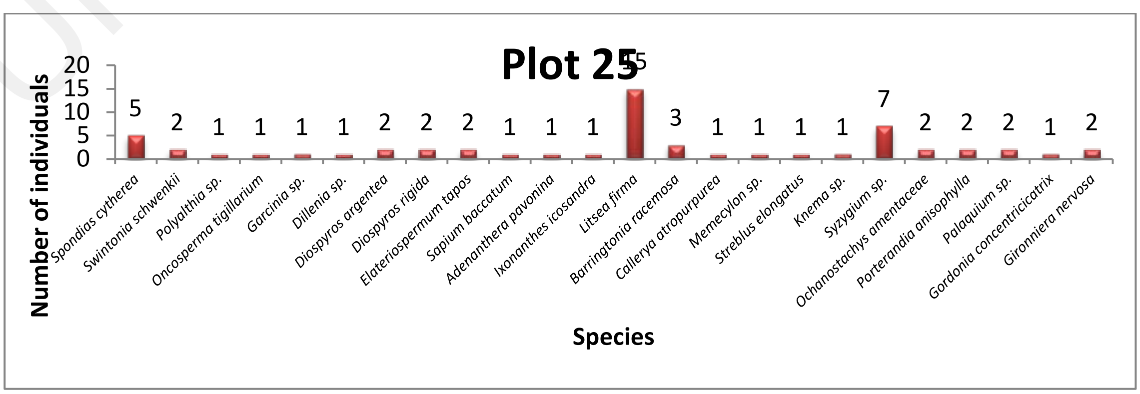


Figure 4.16: Number of individuals according to species collected from a) plot 22, b) plot 23, c) plot 24, and d) plot 25 at the study area

4.2 The Braun-Blanquet Table Analysis

4.2.1 Table of Raw Data

All the plot data in a well-organized form were compared easily and species groupings were identified efficiently in the table of raw data (Table 4.5). All the 85 species of the study area were listed at the left side of the table of raw data. Each species used one row in the table of raw data. Each column at the top of the table represents each plot of the study area which was from plot 1 until plot 25. The total number of species in each plot of the study area was also shown in the table of raw data. According to the table of raw data, plot 11 showed the highest total number of species (39 species) and plot 22 showed the lowest total number of species (18 species).

The cover and sociability data for all vegetation layers (herb, shrub, understory tree and canopy tree) of each species of each plot was recorded in each square (species × plot) of the table of raw data. Each square was devided into four parts in which the upper left quadrant was the cover and sociability value of the canopy tree layer (T_1), the upper right represented the understory tree layer (T_2), the lower left was for the shrub layer (S), and the lower right represented the herb layer (H). New plots were added in new columns to the right of the table of raw data and the new species were added in a downward manner.

Table 4.5 : Table of raw data

Plot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Number of species	19	27	34	26	36	27	32	32	31	32	39	26	23	31	23	23	26	24	23	26	21	18	21	24	19
Aquilaria malaccensis	2 . / . .	2 . / . .	3 . / . .	2 . / . .	1 . / . .	2 . / . +.2	4 1 / . 1	2 . / . .	. . / . .	. . / . .	3 . / . 1	2 . / . +.2	3 . / . 1	3 2 / . 1	. . / . .	. . / . .	. . / . .	3 . / . 1	3 . / . 1	3 + / . 1	. + / . .	. . / . .	2 . / . +.2	2 + / . 1	. . / + .
Artocarpus elasticus	1 . / . .	2 . / . .	+ . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	2 . / . .	. . / . .	1 . / . .	. . / . .	. + / + .	2 . / . .	. . / . .	2 . / . .	. + / . .	. . / . .	. . / . .	. . / . .	. . / . .	+ . / . .	. . / . .	. . / . .
Baccaurea macrocarpa	. + / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	+ . / . .	. . / . .	2 . / . .	. . / . .	. + / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .
Calophyllum marcocarpum	1 . / . .	+ . / . .	. . / . .	. . / . .	2 . / . +.2	. . / . .	1 . / . +.2	1 . / + +.2	. . / . +	. . / . +	. . / . +	. . / . .	. . / + .	. . / . +	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / + .	. . / . .	. . / . .	1 . / . .	. . / . .
Spondias cytherea	2 . / . .	+ . / . .	3 +.2 / . +	2 1 / . 1	4 3 / + 1	4 . / . .	3 1 / . 1	3 1 / + 1	. 1 / . +.2	2 + / . 1	3 . / . +.2	4 1 / + 1	3 +.2 / . 1	2 +.2 / . +.2	4 . / . .	2 + / . .	2 +.2 / . .	2 + / + +.2	3 +.2 / +.2 1	+ . / . +.2	. . / . .	. . / . .	+ +.2 / +.2 +.2	3 1 / + 1	2 + / +.2 +.2
Diospyros argentea	. + / . .	. . / . .	. . / . .	. + / . +.2	. . / . +	. . / . .	. . / . .	. . / . +	1 . / . .	1 . / . .	. . / . +	. . / + +.2	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / +.2 .	. + / . +.2
Elaeocarpus nitidus	1 . / . .	. . / . .	. . / +.2 .	. . / . .	2 . / . .	. . / . +	. . / . .	1 1 / . .	. . / . .	. . / . .	1 . / . .	. . / . .	+ . / . .	. . / . .	. . / . .	. . / . .	2 . / . .	. . / + .	. . / . .	. . / . .	2 . / + .	. . / . .	+ + / . .	. . / . .	. . / . .
Endospermum diadenum	2 . / . .	. . / . .	2 . / . .	1 . / . .	. . / . .	. . / . +	3 . / . .	. . / . +	3 . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. + / . .	. . / . .	. . / . .	. . / . .	2 . / . .	. . / . +	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .
Flacourtia rukam	. . / . .	. . / . .	. . / . +	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .
Gironniera nervosa	+ . / . .	. 1 / . .	2 2 / + +.2	. + / +.2 +.2	. . / . .	. . / . .	. . / . .	. . / . .	1 1 / +.2 +.2	. . / + .	. . / . +	. . / . +	. 1 / . .	. +.2 / + .	. . / . .	. . / . .	. + / . .	+ . / . .	. + / + .	2 2 / +.2 1	+ . / + .	2 +.2 / +.2 1	. . / . .	. . / . .	. . / . .
Ixonanthes icosandra	1 . / . .	. + / . .	1 + / . .	. 1 / + .	1 . / + +.2	. . / . .	2 . / . .	2 . / . .	. . / . +	. + / . +.2	. . / . +	. . / . .	. . / . .	. . / + .	+ . / . .	. . / . .	2 . / . .	. . / . .	. . / . .	. . / + +.2	. . / . .	. . / . .	. . / + .	+.2 2 / . .	. + / . .
Ixonanthes reticulata	2 . / . .	. . / . .	. . / . .	. . / . .	. . / . +	. . / . .	. . / . .	. . / . +	. . / . .	. . / . .	3 . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. + / . .	2 . / . .	. . / . .	. . / . .	. . / . .	. . / . .
Litsea firma	2 . / . .	. . / + .	. . / . .	. . / . +	. . / . +	. . / . .	2 . / + .	1 . / + .	1 1,1 / . +.2	2 . / + .	. . / . +	. + / . +.2	1 + / + +.2	2 . / . +.2	. + / . .	2 + / +.2 +.2	+ . / . .	+.2 + / . .	3 . / . .	. . / + +.2	2 + / +.2 +.2	2 . / + .	4 + / + +.2	+ . / . .	4 3 / +.2 +.2
Ochanostachys amentaceae	+ 1 / . .	. + / 1 .	. . / + .	. . / . .	2 + / . .	+ . / + 1	1 1 / . .	. . / + +.2	. . / . .	. . / . .	. . / +.2 .	. . / . .	. 1 / + .	. + / + +.2	+ + / . .	. + / . .	. . / . .	. . / . .	. + / . .	. . / . .	. . / . .	+ . / . .	. +.2 / . .	. + / +.2 .	. + / . +.2
Palaquium gutta	1 . / . .	. . / + .	2 . / . +	. . / . .	. . / . .	. . / . .	. 1 / . .	1 . / . .	. . / . +	1 +.2 / . .	. + / . .	. . / . .	4 + / . +.2	4 . / . +.2	. . / . .	+ . / . .	. . / . .	2 . / . .	2 + / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	+ + / . .
Polyalthia sp.	2 . / . .	+.2 2 / . .	. . / + .	. . / . .	2 . / . +	. . / . .	1 1 / + +.2	. . / + .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	2 . / . .	. . / . .	. . / . .	. . / . .	. . / . +	. . / . .	. + / + .	. + / + .	. . / . .	. . / . .
Porterandia anisophylla	+ . / . .	2 + / . .	1 + / . .	2 1 / . +.2	2 . / . +.2	2 . / . .	1 . / . +.2	1 1 / . .	. . / + .	2 . / + +.2	2 2 / +.2 +.2	2 2 / 1 1	1 . / . .	. . / . +	. . / . .	2 + / . .	+ . / . .	2 . / . .	. . / . .	+ . / . +.2	. . / . .	2 . / . .	+ . / . .	+ . / . .	1 . / . .
Sindora sp.	+ . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . +	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .
Syzygium sp.	2 1 / . .	2 1 / . .	1 1 / 2 1	+ + / . 1	2 + / . +.2	4 . / +.2 1	2 1 / +.2 1	2 1 / 1 1	2 1 / + 1	2 +.2 / . .	. + / . +.2	1 . / +.2 1	2 2 / + 1	. +.2 / +.2 1	3 +.2 / + 1	4 +.2 / + 1	2 . / +.2 .	+.2 +.2 / 1 +.2	. +.2 / . .	. +.2 / +.2 1	2 + / +.2 +.2	. . / + .	3 2 / +.2 1	2 + / + +.2	+ 2 / +.2 +.2
Xanthophyllum sp.	. + / . .	. . / . .	. . / +.2 +	. . / . .	. + / . .	. . / + +.2	. . / . .	. . / . .	. . / . .	1 . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. + / . .	. . / . .	. . / . .	. . / . .	. + / . .	. . / . .	. . / . .	. . / . .	. . / . .
Adina rubescens	. . / . .	. . / + .	2 . / . .	. . / . .	. . / . .	. . / . .	. . / . .	1 . / + +.2	. 1 / . .	. 1 / + .	. + / . +.2	. . / . +	. . / . .	+ + / + +.2	+ . / . .	. . / . .	. . / . .	2 . / . .	+ . / . .	. . / . +	+ . / . .	+ . / . .	. . / . .	+ + / . .	. . / . .
Aglaia sp.	. . / . .	. + / . .	. . / +.2 +	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .
Baccaurea parviflora	. . / . .	. 1 / 1 .	. . / +.2 1	+ 1 / + 1	. + / 1 .	. . / . +	. . / . +.2	. 1 / + .	. . / . +.2	. . / . +	. . / . +.2	. . / . .	. . / . .	. . / . .	. . / . .	. . / + +	. . / + .	. . / . .	. . / . .	. . / . +	. . / . .	. . / . .	. . / +.2 .	. . / + .	. . / . .
Barringtonia racemosa	. . / . .	. . / + .	. . / . +	. . / . .	. . / + .	. . / . .	. . / . 1	. . / + +.2	. . / . .	. . / . +	. . / + +.2	. . / +.2 .	. . / + .	. +.2 / . .	. . / . .	. . / + +	. . / + .	. . / + .	. + / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .
Blumeodendron subcaudatum	. . / . .	+ . / . .	. . / . .	1 . / . .	. . / . .	. . / . .	1 . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .
Bouea macrophylla	. . / . .	. + / . .	. + / + +	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .
Dacryodes rugosa	. . / . .	3 . / . .	. . / . .	2 . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .	. . / . .

Plot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Elateriospermum tapos		1 + / . .	1 . / + +	2 2 / + .	1 + / . +.2	2 + / + 1	3 . / +.2 1	2 1 / 1 +.2	. 1 / + +	1 . / + 1	+ . / + +.2	3 . / + 1	3 + / + +.2	2 +.2 / + 1	. + / . .	4 + / +.2 1	2 . / + .	+ . / + .	2 2 / + 1	3 . / . .	+ . / . +.2	2 + / +.2 +.2	1 + / +.2 +.2	2 2 / . .	2 . / . .
Garcinia sp.		2 . / . .	. . / . +.2	. . / . +			. . / . +	2 1 / . .			2 . / . .	1 . / . .	1 . / . .		+ . / . .		. + / . .	1 . / . .	+ . / . .	2 . / . .		2 . / . .		+ . / . .	+ . / . .
Hydnocarpus elmeri		. + / + .				1 . / + .																			
Knema sp.		. + / . .	1 + / +.2 1	1 . / 1 1	. + / . .	. + / 1 1	+ . / + +.2	. 2 / . .	. . / . +	. +.2 / . .		. 1 / . +.2	+ . / + .		. + / . .	. . / + .	. + / . .		. . / + .		. + / . .		. + / +.2 .	+ . / +.2 .	
Lithocarpus sp.		+ . / . .		+ . / . .			2 . / . +.2	1 . / . +.2	5 . / . .	2 + / . 1	+ . / . .		+ . / + +.2	2 . / . .	2 . / +.2 +.2									2 . / . .	
Mesua ferrea		+ . / . .		. + / . .		1 . / . .							+ . / . .	. . / . +											
Saraca sp.		. + / . .	. . / . +																						
Terminalia sp.		. + / . .																							
Adinandra sp.			+ . / + .																						
Antidesma sp.			. + / +.2 .																						
Ardisia sp.			. . / . +		. . / 1 .							. . / . +										. + / . .			
Azadirachta excelsa			+ + / . .		3 . / . 1						. . / + .	+ . / . .	1 . / . .			+ . / . .	+ . / . .			2 . / . .					
Durio griffithii			. . / + 1	. . / . +		. . / + +.2	. . / . +		. 1 / . +.2					2 . / . .		+ . / . .									
Ficus sp.			2 . / . +															+ . / . .			. . / + .				
Ixora sp.			. . / . +			. . / . +	. . / . +			. . / . +	. . / . +	. . / . +													
Pternandra echinata			+ . / . +	+ + / . .	. + / . .			1 1 / . .	. 1 / . .		+ + / . +.2		+ . / . .	+ . / . .	. + / . .			2 . / . .							
Sarcotheca monophylla			. . / + +.2	+ . / . +.2		. + / . .				. +.2 / . .	1 . / . .	1 . / . +.2			1 . / + .	. . / + +	3 + / . .				. . / + .		2 + / . .		
Urophyllum glabrum			. . / . +.2																						
Artocarpus scortechinii				1 . / . .					2 . / . .							+ . / . .	2 . / . .								
Bouea oppositifolia				. . / + .																					
Koompassia malaccensis				2 . / . .	2 . / . .		3 . / . .													. . / . +				2 . / . .	
Lansium sp.				1 . / . .	. . / + .																				
Rhodamnia cinerea				2 . / . .	1 . / . .	1 . / . .					. . / . +											. +.2 / . .			
Swintonia penangiana				+ . / . .		2 + / . 1			. . / . +		. . / . +														
Xerospermum noronhianum					1 . / . .					1 . / . .	+ . / . .											2 + / . .			
Dysoxylum sp.					1 . / . .																				
Adenanthera pavonina					1 . / . .				. . / . +		+ . / . .	1 . / . +.2						+ . / . .			. + / . .	2 . / . .		. + / . .	+ . / . .
Dialium kingii					3 . / + .	3 . / . .	1 . / . .			. . / + +.2		+ . / . .			. + / . .		. + / . .		1 . / . .					2 + / . .	

Plot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Drypetes sp.					1				+																
Pandanus sp.					+		+																		
Pellacalyx sp.					2			+	1			+		+ +			+ 2		+						
Pithecellobium splendens					1	1 +.2			+	+	1				+		+		+						
Sandoricum koetjape					+.2 +.2	1 +.2									+	+		+			+		+	+	
Streblus elongatus					+.2	1 1	1 1 +	1 +.2		+	+	+		+				+	+			+ 2			+
Swintonia schwenkii					2		1	1	1 +.2	1 +.2		+	+	+ +.2	1	2 +	3	+	+	+.2		2 + + +.2	1 +.2	+	+ +
Artocarpus rigidus					+	2 +.2	1	2 +.2	2 +.2	+ +		1 + +.2		2	2		3	2	3	+	2		2	2	
Diospyros rigida						2 +	3 +.2 1	+			+ +.2	+	1									+		+	+ +
Eurychoma longifolia						+	+				+			+		+.2	+		+				+		
Gordonia concentricicatrix						2		+	1	1		+ +.2			2	2 +		+	+ +	+			2		+
Pertusadina eurhyncha						1																			
Cyathocalyx sp.							1		+	1	+								+.2						
Memecylon sp.							1 +.2				+			+.2 +	+	+.2	+					+			+
Shorea leprosula								2 +.2	+	3 + +.2	2	+								2 +.2	2			+	
Gynotroches axillaris								1 +	1 +		3 +				+			+							
Cratoxylum arborescens								2		2	+		+	+						+	2				
Macaranga gigantia								+	2 1		+			+			+			2 + +.2			+		
Callerya atropurpurea										2				+					2		2 +			+	
Buchanania subobovata										1										+					
Heritiera sp.									+	2 +.2															
Parkia javanica											3														
Xylopia fusca											+														
Oncosperma tigillarium													1			+				2 +.2	+				+
Neesia altissima													+												
Hopea sp.														+	4 +.2 +.2			+ +		+					
Dillenia sp.														3			+						+		
Scaphium macropodum							+														+				
Sapium baccatum														+						+					2
Paratocarpus bracteatus																+						3			

4.2.2 Frequency Table

All the species in the frequency table were arranged in order of constancy and were produced from the table of raw data. Constancy refered to how many plots a species occurred and it was equivalent to frequency. In the frequency table, the species were re-ordered in descending order of frequency. *Syzygium* sp. was determined as the species with the highest total frequency (total number of plots in which the species was present) which was 25 and was re-ordered first in the frequency table. It was followed by other species in descending order (from top to bottom). *Flacourtia rukam* was found as the species with the lowest total frequency and thus, was re-ordered last in the frequency table.

Meanwhile, the plots were re-ordered in ascending order of total number of species in every plot (Table 4.6). Thus, Plot 22 with the lowest total number of species (18 species) was re-ordered first and followed by other plots of the study area in ascending order (from left to right). Plot 11 which showed the highest number of species with 39 species was the last plot re-ordered in the frequency table.

The data in each square (which is defined as species × plot) of the frequency table was written by a single number which was the largest total estimate value in any four layers (herbs, shrubs, canopy tree and understory tree). Thus, other total estimate scores (other than the largest) and the sociability score were omitted in this frequency table. This was totally different from the previous table of raw data which recorded both the total estimate and sociability data (for each species in each particular plot and for all vegetation layers) in every square.

Table 4.6: The frequency table

Plot number	**22**	**1**	**25**	**21**	**23**	**15**	**16**	**24**	**13**	**19**	**18**	**4**	**17**	**20**	**6**	**2**	**12**	**9**	**10**	**14**	**7**	**8**	**3**	**5**	**11**	
Number of Species	**18**	**19**	**19**	**21**	**21**	**23**	**23**	**24**	**23**	**23**	**24**	**26**	**26**	**26**	**27**	**27**	**26**	**31**	**32**	**31**	**32**	**32**	**34**	**36**	**39**	**Frequency**
Syzygium sp.	+	2	2	2	3	3	4	2	2	+	1	1	2	1	4	2	1	2	2	1	2	2	2	2	+	**25**
Elateriospermum tapos	2	.	2	+	1	+	4	2	3	2	+	2	2	3	2	1	3	1	1	2	3	2	1	1	+	**24**
Spondias cytherea	.	2	2	.	+	4	2	3	3	3	2	2	2	+	4	+	4	1	2	2	3	3	3	4	3	**23**
Litsea firma	2	2	4	2	4	+	2	+	1	3	+	+	+	+	.	+	+	1	2	2	2	1	.	+	+	**23**
Porterandia anisophylla	2	+	1	.	+	.	2	+	1	.	2	2	+	+	2	2	2	+	2	+	1	1	1	2	2	**22**
Aquilaria malaccensis	.	2	+	+	2	.	.	2	3	3	3	2	.	3	2	2	2	.	.	3	4	2	3	1	3	**19**
Knema sp.	.	.	.	+	+	+	+	+	+	+	.	1	+	.	1	+	1	+	+	.	+	2	1	+	.	**18**
Swintonia schwenkii	2	.	+	.	1	1	2	+	+	+	+	.	3	+	.	.	+	1	1	+	1	1	.	2	.	**18**
Ochanostachys amentaceae	+	1	+	.	+	+	+	+	1	+	.	.	.	.	1	1	.	.	.	+	1	+	+	2	+	**17**
Ixonanthes icosandra	.	1	+	.	+	+	.	2	.	.	.	1	2	+	.	+	.	+	+	+	2	2	1	1	+	**17**
Adina sp.	+	.	.	+	.	+	.	+	.	+	2	.	.	+	.	+	+	1	1	+	.	1	2	+	+	**16**
Gironniera nervosa	2	+	.	+	.	.	.	.	1	+	+	+	+	2	.	1	+	1	+	+	.	.	2	.	+	**16**
Artocarpus rigidus	.	.	.	2	2	2	.	2	.	3	2	.	3	+	2	.	1	2	+	2	1	2	.	+	.	**16**
Garcinia sp.	2	.	+	.	.	+	.	+	1	+	1	+	+	2	.	2	1	.	.	.	+	2	+	.	2	**16**
Baccaurea parviflora	.	.	.	.	+	.	+	+	.	.	.	1	+	+	+	1	.	+	+	.	+	1	1	1	+	**15**
Palaquium sp.	.	1	+	.	.	.	+	.	4	2	2	.	.	.	.	+	.	+	1	4	1	1	2	.	+	**14**
Barringtonia racemosa	.	.	.	.	.	.	+	.	+	+	+	.	+	.	.	+	+	.	+	+	1	+	+	+	+	**14**
Calophyllum marcocarpum	.	1	.	+	.	.	.	1	+	.	.	.	.	.	.	+	.	+	+	+	1	1	.	2	+	**12**
Gordonia concentricicatrix	.	.	+	.	2	2	2	.	.	+	+	.	.	+	2	.	+	1	1	.	.	+	.	.	.	**12**
Streblus elongatus	2	.	+	.	.	.	.	.	.	+	+	.	.	.	1	.	+	.	+	+	1	1	.	+	+	**12**
Elaeocarpus nitidus	.	1	.	2	+	.	.	.	+	.	+	.	2	.	+	.	.	.	.	.	.	1	+	2	1	**11**
Sarcotheca monophylla	.	.	.	+	2	1	+	.	.	.	.	+	3	.	+	.	1	.	+	.	.	.	+	.	1	**11**
Lithocarpus sp.	.	.	.	.	.	2	.	2	+	.	.	+	.	.	.	+	.	5	2	2	2	1	.	.	+	**11**
Artocarpus elasticus	.	1	.	.	+	2	.	.	.	.	+	.	2	.	.	2	1	.	2	+	.	.	+	.	.	**10**

Diospyros argentea	.	+	+	.	.	.	.	+	.	.	.	+	.	.	.	.	+	1	1	.	.	+	.	+	+	**10**
Polyalthia sp.	+	2	.	.	+	.	2	.	.	.	.	.	.	+	.	2	.	.	.	.	1	+	+	2	.	**10**
Endospermum diadenum	.	2	.	.	.	+	.	.	.	2	.	1	.	+	+	.	.	3	.	.	3	+	2	.	.	**10**
Pternandra echinata	.	.	.	.	.	+	.	.	+	.	2	+	.	.	.	.	.	1	.	+	.	1	+	+	+	**10**
Adenanthera pavonina	2	.	+	+	.	.	.	+	.	.	+	.	.	.	.	.	1	+	.	.	.	.	.	1	+	**9**
Dialium kingii	.	.	.	.	.	+	.	2	.	1	.	.	+	.	3	.	+	.	+	.	1	.	.	3	.	**9**
Diospyros rigida	+	.	+	.	.	.	.	+	1	.	.	.	.	.	2	.	+	.	.	.	3	+	.	.	+	**9**
Pithecellobium splendens	.	.	.	.	.	+	.	.	.	+	.	.	+	.	1	.	.	+	+	.	.	.	.	1	1	**8**
Azadirachta excelsa	.	.	.	.	.	.	+	.	1	.	.	.	+	2	.	.	+	.	.	.	.	.	+	3	+	**8**
Sandoricum koetjape	.	.	.	+	+	+	+	+	.	.	+	.	.	.	1	.	.	.	.	.	.	.	.	+	.	**8**
Eurychoma longifolia	.	.	.	.	+	.	+	.	.	+	.	.	+	.	+	.	.	.	.	+	+	.	.	.	+	**8**
Memecylon sp.	+	.	+	.	.	+	+	.	.	.	.	.	+	.	.	.	.	.	.	+	1	.	.	.	+	**8**
Shorea leprosula	.	.	.	2	.	.	.	+	.	.	.	.	.	2	.	.	+	+	3	.	.	2	.	.	2	**8**
Xanthophyllum sp.	.	+	.	+	.	.	.	.	.	.	.	.	+	.	+	.	.	.	1	.	.	.	+	+	.	**7**
Durio griffithii	.	.	.	.	.	.	+	.	.	.	.	+	.	.	+	.	.	1	.	2	+	.	1	.	.	**7**
Cratoxylum arborescens	.	.	.	2	.	.	.	.	+	.	.	.	.	+	.	.	.	.	2	+	.	2	.	.	+	**7**
Pellacalyx sp.	.	.	.	.	.	.	.	.	.	+	.	.	2	.	.	.	+	1	.	+	.	+	.	2	.	**7**
Macaranga gigantia	.	.	.	.	+	.	.	.	.	.	.	.	+	2	.	.	.	2	.	+	.	+	.	.	+	**7**
Ixonanthes reticulata	.	2	.	2	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	+	3	**6**
Ixora sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	+	.	+	.	+	.	+	**6**
Mesua ferrea	.	.	.	.	.	.	.	.	+	.	.	+	.	.	1	+	.	.	.	+	.	.	.	.	.	**5**
Rhodamnia cinerea	+	.	.	.	.	.	.	.	.	.	.	2	.	.	1	.	.	.	.	.	.	.	.	1	+	**5**
Koompassia malaccensis	.	.	.	.	.	.	.	2	.	.	.	2	.	+	.	.	.	.	.	.	3	.	.	2	.	**5**
Cyathocalyx sp.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	+	1	.	1	.	.	.	+	**5**
Gynotroches axillaris	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	1	.	.	.	1	.	.	3	**5**
Callerya atropurpurea	.	.	.	2	.	.	.	+	.	2	.	.	.	.	.	.	.	.	2	+	.	.	.	.	.	**5**
Oncosperma tigillarium	.	.	+	+	.	.	+	.	1	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	**5**
Baccaurea macrocarpa	.	+	.	.	.	.	2	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.		**4**
Ardisia sp.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	1	.	**4**
Swintonia penangiana	.	.	.	.	.	.	.	.	.	.	.	+	.	.	2	.	.	+	.	.	.	.	.	.	+	**4**
Artocarpus scortechinii	.	.	.	.	.	.	+	.	.	.	.	1	2	.	.	.	.	2	.	.	.	.	.	.	.	**4**

Xerospermum noronhianum	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	+	**4**
Hopea sp.	.	.		.	.	4	.	.	.	.	+	.	.	+	.	.	.	.	.	+	.	.	.	.	.	**4**
Blumeodendron subcaudatum	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	+	.	.	.	.	1	.	.	.	.	**3**
Ficus sp.	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	2	.	.	**3**
Sapium baccatum	.	.	2	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.	.	**3**
Dillenia sp.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	3	.	.	.	.	.	**3**
Sindora sp.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	**2**
Pandanus sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	**2**
Aglaia sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	**2**
Bouea macrophylla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	**2**
Paratocarpus bracteatus	3	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**2**
Dacryodes rugosa	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	3	.	.	.	.	.	.	.	.	.	**2**
Hydnocarpus elmeri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.	.	.	.	.	.	**2**
Lansium sp.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	+	.	**2**
Buchanania sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	1	.	.	.	.	.	.	**2**
Drypetes sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	1	.	**2**
Scaphium macropodum	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	**2**
Heritiera sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	2	.	.	.	.	.	.	**2**
Saraca sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	**2**
Terminalia sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	**1**
Adinandra sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	**1**
Antidesma sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	**1**
Urophyllum glabrum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	**1**
Bouea oppositifolia	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	**1**
Dysoxylum sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	**1**
Pertusadina eurhyncha	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	**1**
Parkia javanica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	**1**
Xylopia fusca	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	**1**
Neesia altissima	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**1**
Flacourtia rukam	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	**1**

+ = few individuals, cover <5%; 1 = few larger individuals, cover <5%; 2 = 5%-25% cover; 3 = 25% - 50% cover; 4 = 50% - 75% cover

4.2.3 Partial Table

In the partial table, species combinations were identified by choosing species which have intermediate constancy (Table 4.7). Intermediate constancy is identified as frequency values from class II (21 - 40% of plots) to class IV (61 – 80% of plots). Thus, the most common species and the rarest species were omitted. These were due to the fact that species with high constancy were characteristics of the entire group of plots and were not useful for differentiating plant community types. Meanwhile, species with very low constancy did not represent the characteristics of the group of plots.

The intermediate constancy (or also known as frequency) of this study were identified as 6 to 20 (frequency values from class II to class IV). Thus, the most common species in this study with the total frequency of 21 and above which were *Syzygium* sp., *Elateriospermum tapos, Spondias cytherea, Litsea firma* and *Porterandia anisophylla* were omitted in the partial table.

Meanwhile, the rare species in this study with the total frequency of 5 and below were also omitted in the partial table. Those rare species were identified as *Mesua ferrea, Rhodamnia cinerea, Koompassia malaccensis, Cyathocalyx* sp., *Gynotroches axillaris, Callerya atropurpurea, Oncosperma tigillarium, Baccaurea macrocarpa, Ardisia* sp., *Swintonia penangiana, Artocarpus scortechinii, Xerospermum noronhianum, Hopea* sp., *Blumeodendron subcaudatum., Ficus* sp., *Sapium baccatum, Dillenia* sp., *Sindora* sp., *Pandanus* sp., *Aglaia* sp., *Bouea macrophylla, Paratocarpus bracteatus, Dacryodes rugosa, Hydnocarpus* sp., *Lansium* sp., *Buchanania* sp., *Drypetes* sp., *Scaphium* *macropodum*, *Heritiera* sp., *Saraca* sp., *Terminalia* sp., *Adinandra* sp., *Antidesma* sp., *Gordia* sp., *Urophyllum glabrum*, *Bouea oppositifolia*, *Dysoxylum* sp., *Pertusadina eurhyncha*, *Parkia javanica*, *Xylopia fusca*, *Neesia altissima* and *Flacourtia rukam.*

The remaining species which were known as the intermediate species having a total frequency of 6 to 19 were listed in descending order of frequency in the partial table. The intermediate species with the highest frequency was listed first in the partial table which was *Aquilaria malaccensis* with a frequency of 19, followed by *Knema* sp., *Swintonia schwenkii, Ochanostachys amentaceae, Ixonanthes icosandra, Adina rubescens, Gironniera nervosa, Artocarpus rigidus*, *Garcinia* sp., *Baccaurea parviflora, Palaquium gutta*, *Barringtonia racemosa, Calophyllum marcocarpum*, *Gordonia concentricicatrix, Streblus elongatus, Elaeocarpus nitidus, Sarcotheca monophylla, Lithocarpus* sp., *Artocarpus elasticus*, *Diospyros argentea*, *Polyalthia* sp., *Endospermum diadenum, Pternandra echinata, Adenanthera pavonina*, *Dialium kingii*, *Diospyros rigida*, *Pithecellobium splendens*, *Azadirachta excelsa*, *Sandoricum koetjape*, *Eurychoma longifolia*, *Memecylon* sp., *Shorea leprosula*, *Xanthophyllum* sp., *Durio griffithii*, *Cratoxylum arborescens*, *Pellacalyx* sp., *Macaranga gigantia*, *Ixonanthes reticulata* and *Ixora* sp. in descending order of frequency.

Table 4.7: The partial table

Plot number	**22**	**1**	**25**	**21**	**23**	**15**	**16**	**24**	**13**	**19**	**18**	**4**	**17**	**20**	**6**	**2**	**12**	**9**	**10**	**14**	**7**	**8**	**3**	**5**	**11**
Number of Species	**10**	**13**	**12**	**14**	**15**	**17**	**14**	**17**	**15**	**17**	**15**	**12**	**19**	**16**	**18**	**14**	**20**	**20**	**22**	**20**	**21**	**26**	**20**	**23**	**27**
Aquilaria malaccensis	.	2	+	+	2	.	.	2	3	3	3	2	.	3	2	2	2	.	.	3	4	2	3	1	3
Knema sp.	.	.	.	+	+	+	+	+	+	+	.	1	+	.	1	+	1	+	+	.	+	2	1	+	.
Swintonia schwenkii	2	.	+	.	1	1	2	+	+	+	+	.	3	+	.	.	+	1	1	+	1	1	.	2	.
Ochanostachys amentaceae	+	1	+	.	+	+	+	+	1	+	.	.	.	.	1	1	.	.	.	+	1	+	+	2	+
Ixonanthes icosandra		1	+	.	+	+	.	2	.	.	.	1	2	+	.	+	.	+	+	+	2	2	1	1	+
Adina sp.	+	.	.	+	.	+	.	+	.	+	2	.	.	+	.	+	+	1	1	+	.	1	2	+	+
Gironniera nervosa	2	+	.	+	.	.	.	.	1	+	+	+	+	2	.	1	+	1	+	+	.	.	2	.	+
Artocarpus rigidus	.	.	.	2	2	2	.	2	.	3	2	.	3	+	2	.	1	2	+	2	1	2	.	+	.
Garcinia sp.	2	.	+	.	.	+	.	+	1	+	1	+	+	2	.	2	1	.	.	.	+	2	+	.	2
Baccaurea parviflora	.	.		.	+	.	+	+	.	.	.	1	+	+	+	1	.	+	+	.	+	1	1	1	+
Palaquium sp.	.	1	+	.	.	.	+	.	4	2	2	.	.	.	.	+	.	+	1	4	1	1	2	.	+
Barringtonia racemosa	.	.	.	.	.	.	+	.	+	+	+	.	+	.	.	+	+	.	+	+	1	+	+	+	+
Calophyllum marcocarpum	.	1	.	+	.	.	.	1	+	.	.	.	.	.	.	+	.	+	+	+	1	1	.	2	+
Gordonia concentricicatrix	.	.	+	.	2	2	2	.	.	+	+	.	.	+	2	.	+	1	1	.	.	+	.	.	.
Streblus elongatus	2	.	+	.	.	.	.	.	.	+	+	.	.	.	1	.	+	.	+	+	1	1	.	+	+
Elaeocarpus nitidus	.	1	.	2	+	.	.	.	+	.	+	.	2	.	+	.	.	.	.	.	.	1	+	2	1
Sarcotheca monophylla		.	.	+	2	1	+	.	.	.	.	+	3	.	+	.	1	.	+	.	.	.	+	.	1
Lithocarpus sp.	.	.	.	.	.	2	.	2	+	.	.	+	.	.	.	+	.	5	2	2	2	1	.	.	+
Artocarpus elasticus	.	1	.	.	+	2	.	.	.	.	+	.	2	.	.	2	1	.	2	+	.	.	+	.	.
Diospyros argentea	.	+	+	.	.	.	.	+	.	.	.	+	.	.	.	.	+	1	1	.	.	+	.	+	+
Polyalthia sp.	+	2	.	.	+	.	2	.	.	.	.	.	.	+	.	2	.	.	.	.	1	+	+	2	.
Endospermum diadenum	.	2	.	.	.	+	.	.	.	2	.	1	.	+	+	.	.	3	.	.	3	+	2	.	.
Pternandra echinata	.	.	.	.	.	+	.	.	+	.	2	+	.	.	.	.	.	1	.	+	.	1	+	+	+
Adenanthera pavonina	2	.	+	+	.	.	.	+	.	.	+	.	.	.	.	.	1	+	.	.	.	.	.	1	+
Dialium kingii	.	.	.	.	.	+	.	2	.	1	.	.	+	.	3	.	+	.	+	.	1	.	.	3	.
Diospyros rigida	+	.	+	.	.	.	.	+	1	.	.	.	.	.	2	.	+	.	.	.	3	+	.	.	+
Pithecellobium splendens	.	.	.	.	.	+	.	.	.	+	.	.	+	.	1	.	.	+	+	.	.	.	.	1	1

Azadirachta excelsa	.	.	.	.	.	.	+	.	1	.	.	.	+	2	.	.	+	.	.	.	.	.	+	3	+
Sandoricum koetjape	.	.	.	+	+	+	+	+	.	.	+	.	.	.	1	.	.	.	.	.	.	.	.	+	.
Eurychoma longifolia	.	.	.	.	+	.	+	.	.	+	.	.	+	.	+	.	.	.	.	+	+	.	.	.	+
Memecylon sp.	+	.	+	.	.	+	+	.	.	.	.	.	+	.	.	.	.	.	.	+	1	.	.	.	+
Shorea leprosula	.	.	.	2	.	.	.	+	.	.	.	.	.	2	.	.	+	+	3	.	.	2	.	.	2
Xanthophyllum sp.	.	+	.	+	.	.	.	.	.	.	.	.	+	.	+	.	.	.	1	.	.	.	+	+	.
Durio sp.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	+	.	.	1	.	2	+	.	1	.	.
Cratoxylum arborescens	.	.	.	2	.	.	.	.	+	.	.	.	.	+	.	.	.	.	2	+	.	2	.	.	+
Pellacalyx sp.	.	.	.	.	.	.	.	.	.	+	.	.	2	.	.	.	+	1	.	+	.	+	.	2	.
Macaranga gigantia	.	.	.	.	+	.	.	.	.	.	.	.	+	2	.	.	.	2	.	+	.	+	.	.	+
Ixonanthes reticulate	.	2	.	2	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	+	3
Ixora sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	+	.	+	.	+	.	+

+ = few individuals, cover <5%; 1 = few larger individuals, cover <5%; 2 = 5%-25% cover; 3 = 25% - 50% cover; 4 = 50% - 75% cover

4.2.4 Differentiated Table

The groups of differential species that characterize the various plant communities were identified in this stage. The rows and columns of the intermediate species (also known as the species combination) were re-ordered from trial and error in the differentiated table with the aim to group the species occurances into reasonable clusters. Species that occur together in the study area were grouped and grouping ceased when species that occurred together could not be found. Site description for each plot in the study area such as the vegetation height and the site elevation were selected as a reference in the grouping procedure. Environmental and other relevant information such as plot size, altitude and inclination were added at the top of the differentiated table.

The community in this study derived its name from the intermediate species (with a total frequency ranged from 6 to 19) extracted from the previous partial table. *Aquilaria malaccensis* was the first intermediate species (with highest frequency of 19) to be listed in the differentiated table. Furthermore, *Aquilaria malaccensis* has many large value of total estimate in each square (species × plot), followed by *Artocarpus rigidus* also with many large value of total estimate in its each square. Thus, the community is named as *Aquilaria malaccensis-Artocarpus rigidus* community (Table 4.8).

Meanwhile, as for the other two sub-communities, both *Palaquium gutta* and *Barringtonia racemosa* have the highest frequency in their species groupings and were listed first in each group. Thus, two sub-communities known as *Palaquium gutta* sub-community and *Barringtonia racemosa* sub-community were determined as the name of each species grouping in this study and were presented in the differentiated table along with other species.

These communities or also known as the species group were put at the top of the differentiated table, followed by other species in descending order of frequency. In the differentiated table, the groups of associated species which were *Aquilaria malaccensis-Artocarpus rigidus* community and two sub-communities known as *Palaquium gutta* subcommunity and *Barringtonia racemosa* subcommunity were defined with vertical lines and outlined blocks.

The final conclusion of the procedures of table analysis in this study which resulted with the construction of differentiated table ended up in a different condition. The vegetation units of this study have no relationship to the recognized pre-established units of the Braun-Blanquet's system. This situation was due to the fact that to create a formal association name and to find the community type in a Braun-Blanquet hierarchical system involves the preparation of a summary table, that contain the summary of related information from various plots of other phytosociological studies in a single column. Since this study is one of the few first phytosociological studies in Malaysia, the preparation of a summary table is quite impossible due to the lack of information on the literature of the phytosociological studies in Malaysia. Thus, the vegetation units were not known as associations but were called 'community type' instead.

Table 4.8: The differentiated table showing the plant communities of the study area

Plot number	**3**	**4**	**6**	**24**	**23**	**17**	**7**	**14**	**15**	**18**	**19**	**9**	**13**	**16**	**8**	**10**	**11**	**12**	**5**	**1**	**2**	**20**	**21**	**22**	**25**
Area (m2) x 10	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Altitude (m)	57	54	60	87	75	80	61	67	73	77	70	59	56	64	60	55	59	60	56	50	53	55	62	64	58
Inclination (°)	10	10	20	20	20	20	15	15	15	20	20	10	10	15	15	15	15	15	15	15	15	15	15	15	15
Average height of tree layer (m)	27	26	33	31	29	32	30	28	30	31	30	29	28	32	29	27	30	31	29	29	24	28	30	31	26
Average height of shrub layer (m)	11	11	13	12	12	11	12	12	13	13	13	12	12	10	13	13	13	13	12	10	10	12	13	13	12
Average height of herb layer (m)	5	5	5	5	-	-	5	5	-	-	-	5	5	-	-	5	5	5	5	-	5	-	5	-	5
Differential species of *Aquilaria malaccensis*-*Artocarpus rigidus* community																									
Aquilaria malaccensis	3	2	2	2	2	.	4	3	.	3	3	.	3	.	2	.	3	2	1	2	2	3	+	+	+
Swintonia schwenkii	.	.	.	+	1	3	1	+	1	+	+	1	+	2	1	1	.	+	2	.	.	+	.	2	+
Knema sp.	1	1	1	+	+	+	+	.	+	.	+	+	+	+	2	+	.	1	+	.	.	.	+		
Ixonanthes icosandra	1	1	.	2	+	2	2	+	+	.	.	+	.	.	2	+	+	.	1	1	.	+	.	.	+
Ochanostachys amentaceae	+	.	1	+	+		1	+	+	.	+	.	1	+	+	.	+	.	2	1	.		.	+	+
Artocarpus rigidus	.	.	2	2	2	3	1	2	2	2	3	2	.	.	2	+	.	1	+	.	.	+	2	.	.
Garcinia sp.	+	+	.	+	.	+	+	.	+	1	+	.	1	.	2	.	2	1	.	.	.	2	.	2	+
Gironniera nervosa	2	+	.	.	.	+	.	+		+	+	1	1	.	.	+	+	+	.	+	.	2	+	2	.
Adina rubescens	2	.	.	+	.	.	.	+	+	2	+	1	.	.	1	1	+	+	+	.	.	+	+	+	.
Baccaurea parviflora	1	1	+	+	+	+	+	.	.	.	.	+	.	+	1	+	+	.	1	.	.	+	.	.	.
Differential species of *Palaquium gutta* sub-community																									
Palaquium gutta.	2	.	.	.	.	.	1	4	.	2	2	+	4	.	.	.	.	.	.	.	.	.	.	.	.
Gordonia concentricicatrix	.	.	2	.	2	.	.	.	2	+	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Lithocarpus sp.	.	+	.	2	.	.	2	2	2	.	.	4	+	.	.	.	.	.	.	.	.	.	.	.	.
Sarcotheca monophylla	+	+	+	.	2	3	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Endospermum diadenum	2	1	+	.	.	.	3	.	+	.	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.
Pternandra echinata	+	+	.	.	.	.	.	+	+	2	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.
Diospyros rigida	.	.	2	+	.	.	3	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Dialium kingii	.	.	3	2	.	+	1	.	+	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sandoricum koetjape	.	.	1	+	+	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pithecellobium splendens	.	.	1	.	.	+	.	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Memecylon sp.	.	.	.	.	.	+	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eurycoma longifolia	.	.	+	.	+	+	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Durio griffithii	1	+	+	.	.	.	+	2	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Pellacalyx sp.	.	.	.	.	.	2	.	+	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.
Xanthophyllum sp.	+	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ixora sp.	+	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Differential species of *Barringtonia racemosa* sub-community																									
Barringtonia racemosa	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	.	.	.	.	.	.
Calophyllum macrocarpum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	.	2	1	+	.	+	.	.
Streblus elongatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	+	+	+	.	.	.	.	2	+
Elaeocarpus nitidus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	2	1	.	.	2	.	.
Polyalthia sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	+	.	.	.	2	2	2	+	.	+	.
Artocarpus elasticus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	1	.	1	2	.	.	.	.
Diospyros argentea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+	+	+	+	.	.	.	.	+
Adenanthera pavonina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	1	.	.	.	+	2	+
Shorea leprosula	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	3	2	+	.	.	.	2	2	.	.
Azadirachta excelsa	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	+	3	.	.	2	.	.	.

Cratoxylum arborescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	+	.	.	.	.	+	2	.	.
Macaranga gigantia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	2	.	.	.
Ixonanthes reticulate	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	3	.	+	2	.	+	2	.	.
Characteristics species of higher units																									
Mesua ferrea	.	+	1	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Rhodamnia cinerea	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1	.	.	.	.	+	.
Koompassia malaccensis	.	2	.	2	.	.	3	.	.	.	.	.	.	.	.	.	.	.	2	.	.	+	.	.	.
Cyathocalyx sp.	.	.	.	.	.	.	1	.	.	.	+	+	.	.	.	1	+	.	.	.	.	.	.	.	.
Gynotroches axillaris	.	.	.	.	.	.	.	.	+	+	.	1	.	.	1	.	3	.	.	.	.	.	.	.	.
Callerya atropurpurea	.	.	.	+	.	.	.	+	.	.	2	.	.	.	.	2	.	.	.	.	.	.	2	.	.
Oncosperma tigillarium	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.	.	.	.	2	+	.	+
Baccaurea macrocarpa	.	.	.	.	.	.	.	+	.	+	.	.	.	2	.	.	.	.	.	+	.	.	.	.	.
Ardisia sp.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	+	.
Swintonia penangiana	.	+	2	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.
Artocarpus scortechinii	.	1	.	.	.	2	.	.	.	.	.	2	.	+	.	.	.	.	.	.	.	.	.	.	.
Xerospermum noronhianum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	1	.	.	.	.	2	.
Hopea sp.	.	.	.	.	.	.	.	+	4	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
Companion species																									
Blumeodendron subcaudatum	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ficus sp.	2	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Sapium baccatum	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	2
Dillenia sp.	.	.	.	.	+	+	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sindora sp.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Pandanus sp.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Aglaia sp.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bouea macrophylla	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Paratocarpus bracteatus	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	3	.
Dacryodes rugosa	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hydnocarpus elmeri	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lansium sp.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Buchanania subobovata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	+	.	.	.
Drypetes sp.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	1	.	.	.	.	.	.
Scaphium macropodum	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Heritiera sp.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	2	.	.	.	.	.	.	.	.	.
Saraca sp.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Terminalia sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Adinandra sp.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Antidesma sp.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Urophyllum glabrum	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bouea oppositifolia	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dysoxylum sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Pertusadina eurhyncha	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Parkia javanica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.
Xylopia fusca	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Neesia altissima	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Flacourtia rukam	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

+ = few individuals, cover <5%; 1 = few larger individuals, cover <5%; 2 = 5%-25% cover; 3 = 25% - 50% cover; 4 = 50% - 75% cover

4.3 Vegetation Communities

4.3.1 *Aquilaria malaccensis-Artocarpus rigidus* community

A total of 10 species belonging to 10 genera and 10 families were found in the *Aquilaria malaccensis-Artocarpus rigidus* community. The forest vegetation of this community was commonly distributed at altitudes of 30 m to 87 m. This community exhibited three vegetation layers which were tree, shrub and herb layers. The tree layer was 6 m - 40 m in height, with a 65% - 55% general cover. The shrub layer was 2 m - 5 m in height, with a 20% - 35% general cover. Total coverage of the herb layer was between 15% and 25%, and reached below 2 m in height.

The population of *Aquilaria malaccensis* within the study area consisted of 56 individual trees. *Aquilaria malaccensis* were found scattered randomly in 16 plots out of the 25 plots of the study area. Plot 7 and plot 14 both have a high abundance of *Aquilaria malaccensis* trees with 8 individual trees and 9 individual trees, respectively. The trees were found both in wet ground and hill slopes of the study area. The largest *Aquilaria malaccensis* tree of the community was found in plot 7 which has a 62 cm in diameter at breast height (DBH). The second largest *Aquilaria malaccensis* tree of the community was found in plot 1 which has a 57 cm in diameter at breast height (DBH) and followed by *Aquilaria malaccensis* tree from plot 14 which has a 50 cm in diameter at breast height (DBH).

The characteristic and differential species of the community were *Aquilaria malaccensis, Knema* sp*., Swintonia schwenkii,Ochanostachys amentaceae, Ixonanthes* *icosandra, Adina* sp., *Gironniera nervosa, Artocarpus rigidus, Garcinia* sp. and *Baccaurea parviflora*.

4.3.2 *Palaquium gutta* sub-community

A total of 14 species belonging to 14 genera and 13 families were found in the *Palaquium gutta* sub-community. This sub-community occurred at altitudes of 30 m to 82 m. This sub-community was found on flat areas or slightly undulating terrain which occurred on ridge area (0 - 10 degree). The coverage rates of tree, shrub, and herb layers were 70% - 80%, 10% - 20%, and 10% - 25%; and the average heights were 30 m, 10 m, and 2 m, respectively.

The biggest tree of this sub-community was *Endospermum diadenum,* which has 87 cm in diameter at breast height (DBH) and 50 m in height. Most species of the emergent tree layer of this sub-community, such as *Callerya atropurpurea* (85 cm, 50 m) and *Aglaia* sp. (82 cm, 45 m) showed a large diameter at breast height (DBH).

No erosion or trampling was seen evident in this sub-community even though wildlife paths transect the sub-community. Wild boar runways, burrows, nests and dung were also seen scattered within the vegetation of the sub-community. However, some of the plots in the *Palaquium gutta* sub-community were situated at the forest area with canopy gaps due to disturbance caused by tree fall. Furthermore, visitor paths such as tiles coverage for pathway and rubbishes existed in some of the plots of this sub-community and created the anthropogenic disturbances.

The characteristic and differential species of this sub-community were *Palaquium gutta*, *Gordonia concentricicatrix*, *Lithocarpus* sp., *Sarcotheca monophylla*, *Endospermum diadenum*, *Pternandra echinata*, *Diospyros rigida*, *Dialium kingii*, *Sandoricum koetjape*, *Eurychoma longifolia*, *Pithecellobium splendens*, *Memecylon* sp., *Durio griffithii*, *Pellacalyx* sp., *Xanthophyllum* sp. and *Ixora* sp.

4.3.3 ***Barringtonia racemosa*** **sub-community**

A total of 12 species belonging to 12 genera and 11 families were found in the *Barringtonia racemosa*sub-community. This sub-community occurred at altitudes of 34 m to 61 m on slope areas (11 - 20 degree). This sub-community was composed of tree, shrub and herb vegetation layers.

The general coverage of the tree layer ranged from 70% to 90%, and heights ranged from 6 m to 40 m. Total coverage of the shrub layer was from 10% to 30%, and ranged from 2 m to 5 m in height. Coverage of the herb layer ranged from 10% to 20%, and heights ranged from < 2 to 2 m.

The biggest trees of this sub-community were *Artocarpus rigidus* and *Ixonanthes reticulata*, both has a 110 cm in diameter at breast height (DBH) and 55 m in height, respectively. Most species of the emergent tree layer of this sub-community, such as *Paratocarpus bracteatus* (94 cm, 53 m), *Parkia javanica* (85 cm, 50 m), *Shorea leprosula* (84 cm, 50 m) and *Dacryodes rugosa* (82 cm, 45 m) had a big diameter at breast height (DBH).

Some of the plots in the sub-community were inundated by a small stream, generally in shallow furrows entering or draining the depressions. Some erosion was evident and moderate trampling from wild boars were present. Wild boar runways, burrows, nests and dung were also seen scattered within the plots of the sub-community.

The characteristic and differential species of this sub-community were *Barringtonia racemosa, Calophyllum marcocarpum, Streblus elongatus, Elaeocarpus nitidus, Polyalthia* sp., *Artocarpus elasticus, Diospyros argentea, Adenanthera pavonina, Shorea leprosula, Azadirachta excelsa, Cratoxylum arborescens, Macaranga gigantia* and *Ixonanthes reticulata*.

4.4 Species richness coverage

The species richness coverage of all the vegetation layers which were herb (H), shrub (S), understory tree (T_2), canopy tree (T_1) and super tree (ST) of *Palaquium gutta* sub-community and the *Barringtonia racemosa* sub-community were determined in this study.

4.4.1 *Palaquium gutta* sub-community

According to Figure 4.17, plot 3 had the highest coverage of herb layer which was 16% of total coverage and followed by plot 4 with 7% of total coverage. Plots 6, 7, 9, 13 and 14 each had 4% total coverage of herb layer and were followed closely by plot 24 with 2% total coverage of herb layer.

For shrub layer, plot 3 had the highest percentage of total coverage which was 12% and was followed closely by plot 4 with 8% of total coverage of shrub layer. Plots 6, 9, 13 and 23 each had a 6% of total coverage of shrub layer. Meanwhile, plots 17, 19, and 24 each with 5% of total coverage of shrub layer leaving plots 7, 14, 15 and 18 with 4% of total coverage of shrub layer.

For the T_2 layer, plot 4 had the highest percentage of total coverage which was 20% and followed by plots 3, 7 and 15 each with 12% of total coverage. Plots 9 and 14 each had 10% of T_2 layer coverage and plots 6, 13, 23 and 24 each had 8% of total coverage of T_2 layer. Plots 17, 18 and 19 had the lowest percentage with 6% of total coverage of T_2 layer.

For T_1 layer, plot 4 had the highest percentage of total coverage which was 40% and was followed closely by plots 23 and 24 each with 38% of total coverage. Plot 7 had 32% of T_1 layer coverage and plots 19 had 24% of T_1 layer coverage. Each plots 9, 13, 14, and 15 had 20% of total coverage and plots 3, 17 and 18 each had 14% total coverage of T_1 layer. Plot 6 had the lowest percentage of total coverage of T_1 layer which was 12%.

For ST layer, plot 18 had the highest percentage of total coverage which was 76% and was followed closely by plot 17 with 75% of total coverage. Plot 6 had 70% of ST layer coverage and plots 19 had 65% of ST layer coverage. Plot 15 had 64% of ST layer coverage and was followed closely by plots 13 and 14 with 62% of total coverage. Plot 9 had 60% of ST layer coverage and was followed by plot 7 and 23 each with 48% of total coverage. Plot 24 had 47% of ST layer coverage and was followed closely by plot 3 with 46% of total coverage. Plot 4 had the lowest percentage of total coverage of ST layer which was 25%.

All plots showed that ST layer had the highest percentage of coverage, followed closely by T_1 layer. Meanwhile, T_2, shrub and herb layers had a lower percentage of total coverage as compared to ST and T_1 layers.

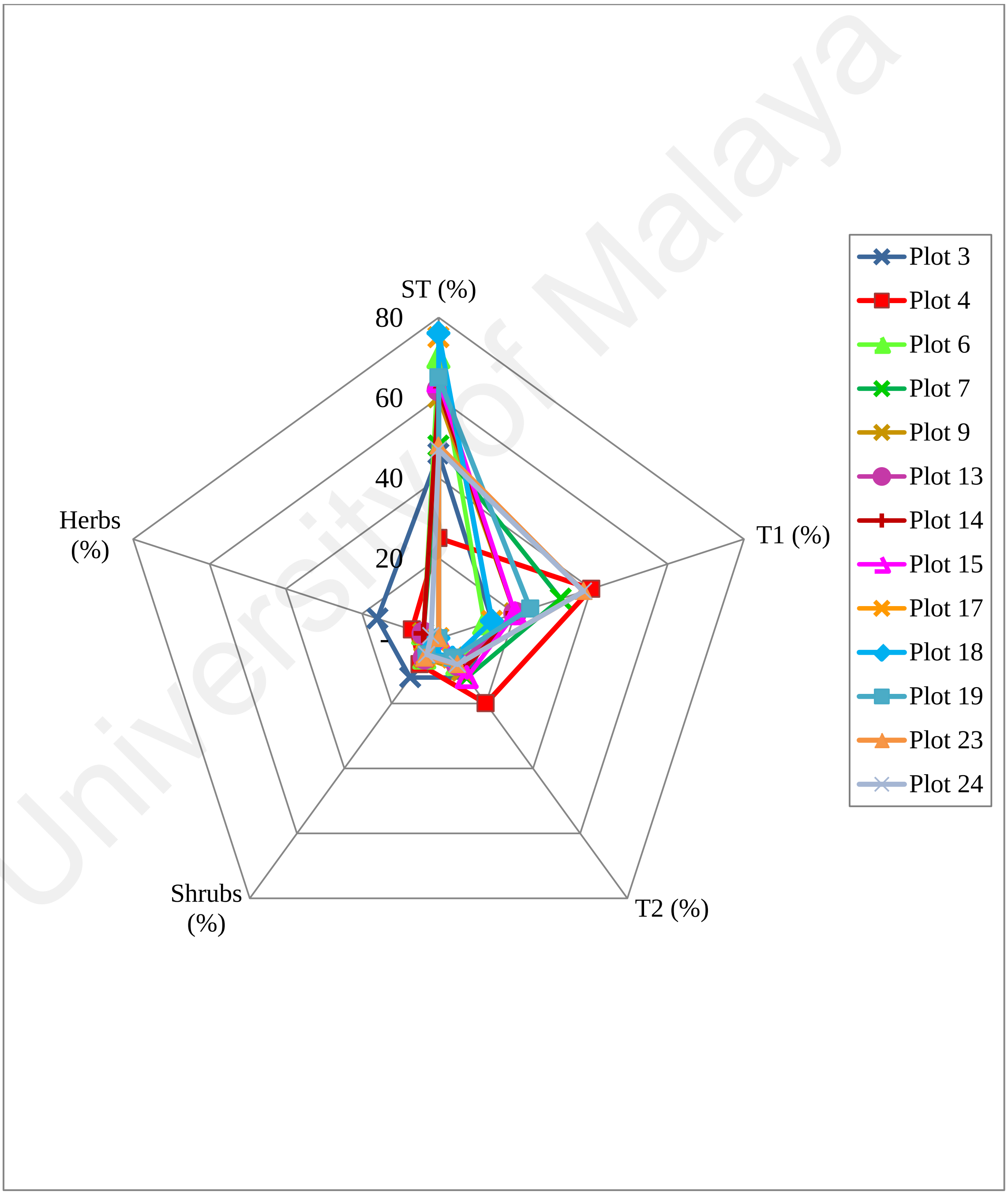


Figure 4.17: Species-richness polygon of *Palaquium gutta* sub-community in the study area

4.4.2 *Barringtonia racemosa* sub-community

According to Figure 4.18, plot 12 had the highest coverage of herb layer which was 8% of total coverage and followed by plot 21 with 5% of total coverage. Plots 5, 10, 11, and 25 each had 4% of total coverage of herb layer. Plot 2 had the lowest percentage of total coverage of herb layer which was 1%.

For shrub layer, plot 2 had the highest percentage of total coverage which was 16% and followed closely by plot 12 and plot 25 each with 10% of total coverage of shrub layer. Plots 5, 8, and 11 each had an 8% of total coverage of shrub layer. Meanwhile, plots 10 and 16 each with 6% of total coverage of shrub layer leaving plot 20, 21 and 22 with 5% of total coverage of shrub layer.

For the T_2 layer, plot 1 had the highest percentage of total coverage which was 24% and followed closely by plots 25 with 21% of total coverage. Plot 2 had 18% of total coverage and plot 8 and 12 each had 12% of T_2 layer coverage. Plots 20 and 21 each had 10% of total coverage of T_2 layer. Meanwhile, plots 5, 10 and 11 had 8% of total coverage and plots 22 and 16 had a low percentage of total coverage of T_2 layer which were 5% and 4% respectively.

For T_1 layer, plot 20 had the highest percentage of total coverage which was 45%, followed closely by plots 8, 21 and 25 each with 40% of total coverage of T_1 layer. Plot 1 had 34% of total coverage and plot 5 and 12 had 30% of total coverage. Plot 2 had 25% of total coverage and plots 11 and 22 each had 20% of total coverage. Plot 10 and 16 had a low percentage of total coverage of T_1 layer which were 12% and 10% respectively.

For ST layer, plot 16 had the highest percentage of total coverage which was 80% followed closely by plot 10 and 22 each with 70% total coverage. Plot 11 had 60% of ST layer coverage and plot 5 had 50% of ST layer coverage. Plot 1 had 42% of ST layer coverage followed closely by plots 2, 8, 12, 20 and 21 with 40% of total coverage. Plot 25 had the lowest total coverage of ST layer which was 25%.

All plots showed that ST layer had the highest percentage of coverage followed closely by T_1 layer. Meanwhile, T_2, shrub and herb layers had a lower percentage of total coverage as compared to ST and T_1 layers.

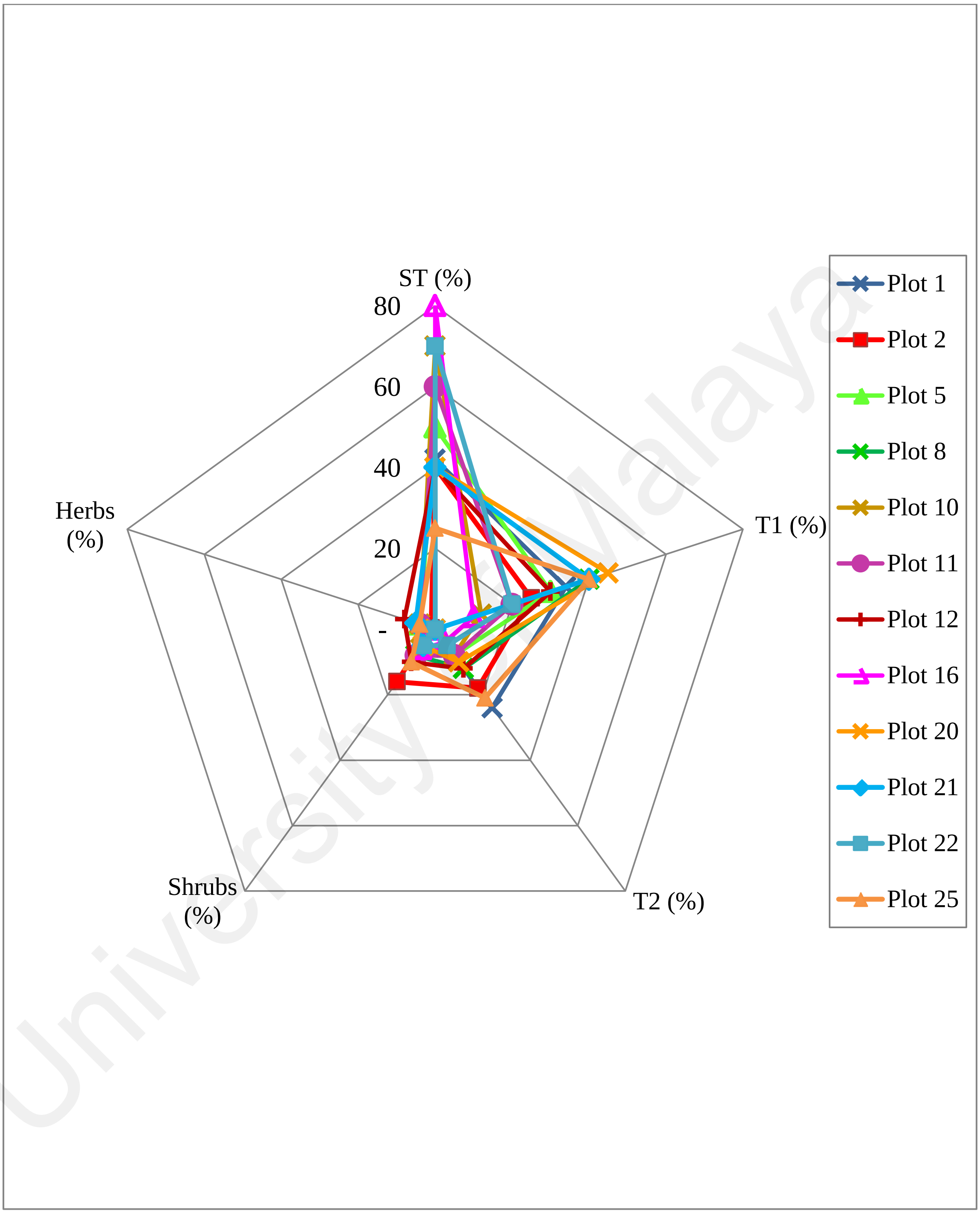


Figure 4.18: Species-richness polygon of *Barringtonia racemosa* sub-community in the study area

4.5 Species Importance

4.5.1 Relative Density

The value of relative density for this study ranged from 0.1% to 12.6% (showed that the density of each species has a wide gap). *Syzygium* sp. (Myrtacea) with 210 trees was the species with the highest density in this study and represented 12.6% of total trees in this study. The species with the second highest density was *Spondias cytherea* (Anacardiaceae) with 144 trees and represented 8.6% of total trees in this study, followed by *Elateriospermum tapos* (Euphorbiaceae) and *Litsea firma* (Lauraceae) with 129 trees (7.7%) and 78 trees (4.7%), respectively. The ten leading species with the highest relative density of this study were listed in Table 4.9 in descending order.

Table 4.9: The ten leading species with the highest relative density in the study area at Sungai Udang Forest Reserve, Malacca

Species	Relative Density (%)
Syzygium sp.	12.6
Spondias cytherea	8.6
Elateriospermum tapos	7.7
Litsea firma	4.7
Porterandia anisophylla	4.3
Gironniera nervosa	4.1
Aquilaria malaccensis	3.4
Knema sp.	3.2
Baccaurea parviflora	2.8
Lithocarpus sp.	2.5

4.5.2 Relative Frequency

Elateriospermum tapos (Euphorbiaceae) appeared most frequently in this study with a frequency of 96%. Both *Spondias cytherea* (Anacardiaceae) and *Syzygium* sp. (Myrtacea) had the second highest frequency which was 92%, followed by both *Litsea firma* (Lauraceae) and *Porterandia anisophylla* (Rubiaceae) with a frequency of 88%. The ten leading species with the highest frequency of this study were listed in Table 4.10 in a descending order.

Table 4.10: The ten leading species with the highest frequency in the study area at Sungai Udang Forest Reserve, Malacca

Species	Frequency (%)
Elateriospermum tapos	96
Spondias cytherea	92
Syzygium sp.	92
Litsea firma	88
Porterandia anisophylla	88
Swintonia schwenkii	76
Knema sp.	76
Ixonanthes icosandra	68
Ochanostachys amentaceae	68
Gironniera nervosa	68

4.5.3 Basal Area

The ten species with the highest basal area are listed in Table 4.11 in descending order. Total basal area of this study was 63.12 m^2 ha^{-1}. *Spondias cytherea* (Anacardiaceae) had the highest total basal area in the study area with a value of 7.87 m^2 ha^{-1}. The species with the second highest total basal area was *Artocarpus rigidus* (Moraceae) with a value of 5.11 m^2 ha^{-1} followed by *Aquilaria malaccensis* (Thymelaeaceae) and *Syzygium* sp. (Myrtaceae) with a value of 4.81 m^2 ha^{-1} and 4.47 m^2 ha^{-1}, respectively.

Table 4.11: Ten species with the highest basal area of the study area

Species	Basal Area (m^2 ha^{-1})
Spondias cytherea	7.87
Artocarpus rigidus	5.11
Aquilaria malaccensis	4.81
Syzygium sp.	4.47
Aglaia sp.	4.39
Elateriospermum tapos	3.87
Endospermum diadenum	2.75
Shorea leprosula	2.43
Lithocarpus sp.	1.89
Porterandia anisophylla	1.71

4.5.4 Importance Value Index

The Importance Value Index (IV_i) of ten leading species at the study area in Sungai Udang Forest Reserve, Malacca is shown in Table 4.12. Based on the calculated Importance Value Index (IV_i), *Spondias cytherea* (Anacardiaceae) was the most important species in the study area with an importance value index (IV_i) of 23.9%. The second most important species in the study area was *Syzygium* sp. (Myrtaceae) with an importance value index (IV_i) of 22.8%, followed by *Elateriospermum tapos* (Euphorbiaceae) and *Aquilaria malaccensis* (Thymelaeaceae) with an importance value index (IV_i) of 17.2% and 13.0%, respectively.

Table 4.12: The ten leading important species at Sungai Udang Forest Reserve study area in descending order of its Importance Value Index (IV_i)

Species	IV_i (%)
Spondias cytherea	23.9
Syzygium sp.	22.8
Elateriospermum tapos	17.2
Aquilaria malaccensis	13.0
Artocarpus rigidus	11.7
Porterandia anisophylla	10.2
Litsea firma	9.4
Gironniera nervosa	7.9
Swintonia schwenkii	7.7
Aglaia sp.	7.2

4.6 Species Diversity

Table 4.13 shows the diversity indices for three different communities. The Shannon-Weiner Diversity Index (*H'*) for the *Aquilaria malaccensis-Artocarpus* community showed an index value of 3.67. Meanwhile, the *Palaquium gutta* sub-community indicated a value of 3.57 and the *Barringtonia racemosa* sub-community showed an index value of 3.66.

The Simpson's index of diversity (1-D) for the *Aquilaria malaccensis-Artocarpus* community showed an index value of 0.96. Meanwhile, the *Palaquium gutta* sub-community indicated a value of 0.95 and the *Barringtonia racemosa* sub-communityshowed an index value of 0.96.

Table 4.13: Diversity indices for the three different communities of the study area

Community	Shannon diversity index (H')	Simpson diversity index (1-D)
Aquilaria malaccensis-Artocarpus rigidus	3.67	0.96
Palaquium gutta sub-community	3.57	0.95
Barringtonia racemosa sub-community	3.66	0.96

4.7 Physico-chemical analysis of soil

The results of the analysis of surface soil (0 - 30 cm) samples from 25 different plots were presented in Table 4.14, Table 4.15 and Table 4.16. The distribution of the vegetation communities showed a clear geographical and environmental preference for specific soil types as seen in those tables. Soil factors that were analyzed in this study included all the physical, chemical and biological properties of the soil.

4.7.1 Physical characteristics

Table 4.14 presents the studied physical characteristics of soil showing soil particle (%) and soil texture of the 25 sampling plots in Sungai Udang Forest Reserve, Malacca. Mean values of clay, silt and sand of the 25 plots from the Sungai Udang Forest Reserve were 50.72%, 24.32% and 24.96%, respectively. Thus, the analyses of particle size indicated that the soils of the study area were dominated by clay loam texture whereby 4 out of the 25 plots showed this soil texture.

The soil of the *Aquilaria malaccensis-Artocarpus rigidus* community had high organic matter. It was rich in available macro elements such as Ca, K and P and was sandy-loamy in texture. Meanwhile, the soil of *Palaquium gutta* sub-community had high organic matter and was loamy in texture. As for the *Barringtonia-racemosa* sub-community, it consisted of limeless brown soil and loamy in texture.

Table 4.14: Physical characteristics of soil showing soil particle (%) and soil texture of the 25 sampling plots

Plots	Clay %	Silt %	Sand %	Texture
1	44	16	40	Clay
2	20	44	36	Clay
3	60	36	4	Clay
4	40	44	16	Silty Clay
5	20	32	48	Sandy Loam
6	52	24	24	Clay Loam
7	20	20	60	Sandy Loam
8	64	28	8	Clay
9	68	28	4	Clay
10	64	20	16	Clay
11	24	8	68	Sandy Loam
12	32	20	48	Sandy Loam
13	56	12	32	Clay
14	44	16	40	Clay
15	52	44	4	Silty Clay
16	72	20	8	Clay
17	68	28	4	Clay
18	72	12	16	Clay
19	36	24	40	Clay Loam
20	60	28	12	Clay
21	64	32	4	Clay
22	64	24	12	Clay
23	60	8	32	Clay
24	56	20	24	Clay Loam
25	56	20	24	Clay Loam
Mean	50.72	24.32	24.96	Clay Loam
Min	20	8	4	Clay
Max	72	44	68	Clay Loam

4.7.2 Chemical properties

Table 4.15 shows the studied chemical properties of soil at all 25 plots in the study area. The soil pH varied from 4.11 to 4.95 (mean 4.65), showed that all the soil samples of the study area were acidic. As for the floristic composition, the pH values of soil of the *Aquilaria malaccensis-Artocarpus rigidus* community ranged from 4.11 to 4.95 for all the 25 plots clearly indicated that the soil had an acidic character. The mean range of the total cation exchange capacity (CEC) in this study was between 4.4 and 17.2 (mean 8.99), which was considered low.

The result of soil nutrient indicated that the available P in all the 25 plots of the study area was low. The available P in this study ranged from 0.010 (c mol/kg) to 0.204 (c mol/kg) (mean 0.087). The available K in the study site was also low. The available K in this study ranged from 0.009 (c mol/kg) to 0.036 (c mol/kg) (mean 0.019). The available Mg in this study ranged from 0.144 (c mol/kg) to 0.601 (c mol/kg) (mean 0.304).

Table 4.16 shows the content of total carbon and nitrogen of the 25 sampling plots in Sungai Udang Forest Reserve, Malacca. The total C contents ranged from 1.46% to 2.99% (mean 2.07%). The total N contents varied from 0.09% to 0.69% (mean 0.28%).

Table 4.15: Chemical properties of soil of the 25 sampling plots of the study area

Plots	pH	(c mol/kg)				CEC
		Ca	Na	K	Mg	
1	4.56	0.008	0.021	0.024	0.362	9.8
2	4.76	0.138	0.018	0.015	0.183	8.9
3	4.44	0.039	0.009	0.018	0.350	5.8
4	4.82	0.013	0.009	0.015	0.330	8.6
5	4.68	0.048	0.008	0.013	0.293	8
6	4.5	0.071	0.012	0.021	0.229	8.3
7	4.52	0.302	0.017	0.020	0.601	10.2
8	4.59	0.099	0.012	0.014	0.410	10.6
9	4.73	0.118	0.013	0.020	0.251	7.7
10	4.11	0.039	0.014	0.018	0.315	7.5
11	4.7	0.011	0.009	0.017	0.208	6.9
12	4.74	0.067	0.013	0.031	0.230	5.4
13	4.7	0.116	0.012	0.036	0.431	7.4
14	4.82	0.071	0.010	0.023	0.265	8.3
15	4.53	0.061	0.009	0.011	0.385	8.7
16	4.67	0.104	0.012	0.013	0.298	8.6
17	4.82	0.037	0.008	0.019	0.313	8.5
18	4.88	0.082	0.010	0.016	0.372	10.5
19	4.48	0.012	0.009	0.016	0.244	14
20	4.94	0.134	0.012	0.012	0.297	4.4
21	4.95	0.037	0.012	0.021	0.500	17.2
22	4.87	0.042	0.009	0.009	0.144	15.4
23	4.58	0.004	0.007	0.023	0.185	6.3
24	4.4	0.010	0.013	0.029	0.230	10.8
25	4.52	0.045	0.009	0.022	0.171	7
Mean	4.65	0.07	0.01	0.02	0.30	9.0
Min	4.11	0.01	0.01	0.01	0.14	4.4
Max	4.95	0.30	0.02	0.04	0.60	17.2

Table 4.16: Content of total carbon and nitrogen of every 25 plots

Plots	C (%)	N (%)	C/N
1	2.99	0.45	7.75
2	1.46	0.34	5.01
3	1.62	0.32	5.90
4	1.76	0.22	9.33
5	2.35	0.27	10.15
6	1.54	0.23	7.81
7	2.51	0.27	10.84
8	4.21	0.29	16.93
9	1.64	0.21	9.11
10	2.19	0.20	12.77
11	1.76	0.17	12.07
12	1.81	0.17	12.41
13	1.69	0.16	12.32
14	2.04	0.16	14.87
15	1.61	0.15	12.52
16	1.81	0.48	4.40
17	1.84	0.41	5.23
18	2.26	0.43	6.13
19	2.86	0.17	19.62
20	1.50	0.13	13.45
21	2.38	0.11	25.23
22	1.55	0.09	20.08
23	1.53	0.36	4.96
24	2.63	0.69	4.44
25	2.24	0.47	5.56
Mean	2.07	0.28	10.75
Min	1.46	0.09	4.397
Max	2.99	0.69	25.228

4.7.3 Pearson correlaton analysis

4.7.3.1 Relationships between soil physico-chemical properties

The correlation between the physico-chemical characteristics of soil at all the 25 plots in the Sungai Udang Forest Reserve was examined and shown in Table 4.17. The clay was negatively correlated with silt where r = -0.124. Furthermore, clay also showed a highly negative correlation with sand where r = -0.837. The result indicated that soil with a high percentage of clay will have a lower percentage of silt and sand. In addition, silt was also negatively correlated with the percentage of sand where r = -0.440. There were also significant correlations between sand and available K (r = 0.312, p<0.01), but negative correlation between clay and P (r = -0.375), silt and K (r = -0.471).

Available P was significantly correlated to available C (r = 0.482 p<0.001). Available P also showed a positive correlations with CEC (r = 0.108, p<0.05). However, available P was negatively correlated to available K and available N with r = -0.019 and r = -0.085, respectively. CEC was significantly correlated with available C (r = 0.391, p<0.01). CEC also showed a positive correlations with Mg (r = 0.219, p<0.05) and P (r = 0.108, p<0.05). However, CEC showed a negative correlation with available K and available N with r = -0.192 and r = -0.098, respectively. Available C also showed a significant correlation with Mg (r = 0.367, p<0.001) and N (r = 0.256 p<0.05). Available N also had a positive correlation with K (r = 0.206, p<0.05).

The pH in this study was positively correlated with both available CEC (r = 0.172, *p*<0.05) and Mg (*r* = 0.007, *p*<0.05). Meanwhile, the pH in this study was negatively correlated with available K (*r* = -0.150), available P (*r* = -0.102), available C (*r* =-0.259) and available N (*r* = -0.290).

Table 4.17: The correlation matrix of soil physico-chemical properties at Sungai Udang Forest Reserve

	pH	**Mg**	**K**	**P**	**CEC**	**C**	**N**	**%Clay**	**%Silt**
Mg	0.007*								
K	- 0.150	0.079							
P	- 0.102	0.188	- 0.019						
CEC	0.172 *	0.219*	- 0.192	0.108*					
C	- 0.259	0.367***	0.014	0.482***	0.391**				
N	- 0.290	- 0.119	0.206*	- 0.085	- 0.098	0.256*			
%Clay	0.043	0.019	- 0.057	- 0.375	0.107	- 0.016	0.177		
%Silt	0.110	0.107	- 0.471	0.190	0.108	- 0.122	- 0.181	- 0.124	
%Sand	- 0.100	- 0.076	0.312**	0.234	- 0.156	0.082	- 0.060	- 0.837	- 0.440

*p<0.05; **p<0.01, ***p<0.001

4.7.3.2 Relationships between vegetation and soil parameters

Table 4.18 shows the Pearson's correlation values obtained between soil parameters and diversity index for the plant species of this study according to communities. Highly significant correlations were found between soil pH and diversity index for all the three communities. For example, soil pH showed a highly significant correlation with the diversity index of *Aquilaria malaccensis – Artocarpus rigidus* community (r = 0.365, p<0.01). Soil pH also showed a significant correlation with the diversity index of *Barringtonia racemosa* sub-community where (r = 0.548, p<0.05). Meanwhile, soil pH showed a highly significant correlation with the diversity index of *Palaquium gutta* sub-community where (r = 0.221, p<0.01).

Furthermore, highly significant correlations were also found between CEC and diversity index of the plant species for all the three communities. For example, CEC showed a highly significant correlation with the plant species of *Aquilaria malaccensis – Artocarpus rigidus* community (r = 0.423, p<0.01). Similarly, CEC showed a highly significant correlation with the species diversity of *Barringtonia racemosa* sub-community (r = 0.438, p<0.01). Meanwhile, CEC showed a strong positive correlation with the species diversity of *Palaquium gutta* sub-community (r = 0.532, p<0.01).

Available K appeared significantly correlated with the species diversity of *Barringtonia racemosa* sub-community (r = 0.217, p<0.05). Meanwhile, available P showed a significant correlation with the species diversity of *Palaquium gutta* sub-community (r = 0.252 p<0.05). Available C also showed a positive correlation with the species diversity of *Palaquium gutta* sub-community (r = 0.225, p<0.05). Available N showed a significant correlation with the species diversity of *Palaquium gutta* sub-community (r = 0.213, p<0.05).

Available Mg was sifnificantly correlated with the species diversity of *Palaquium gutta* sub-community (r = -0.247 p<0.05), followed by the species diversity of *Barringtonia racemosa* sub-community which was also significantly correlated with available Mg (r = 0.344, p<0.05).

Table 4.18: Pearson's correlation between soil parameters and diversity index of the plant communities at Sungai Udang Forest Reserve

	***Aquilaria malaccensis-Artocarpus rigidus* community**	***Palaquium gutta* sub-community**	***Barringtonia racemosa* sub-community**
	H'	***H'***	***H'***
pH	0.365**	0.221*	0.548**
Mg	- 0.091	- 0.247*	0.344*
K	0.023	0.037	0.217*
P	0.068	0.252*	- 0.135
CEC	0.423**	0.438**	0.532**
C	0.114	0.225*	- 0.070
N	0.062	0.213*	- 0.103

H': Shannon's diversity; *p<0.05; **p<0.01

CHAPTER 5: DISCUSSION

5.1 Floristic Composition

The most speciose family within the 25 plots was the Euphorbiaceae with 224 individual trees, which was represented by 9 species in 9 genera. The floristic composition in the family level obtained in this study with Euphorbiaceae as the dominant family is quite similar from those found in other tropical forest in Peninsular Malaysia. Several studies have also reported similar observation of which Euphorbiaceae was the most speciose family in their study areas. Different forest structures can have similar floristic composition (Millet *et al.*, 2010).

For instance, a study on the species composition and floristic variation of tree communities at Kenong Forest Park, Kuala Lipis, Pahang, Malaysia has reported Euphorbiaceae as the most speciose family which was represented by 40 species in 15 genera (Nizam *et al.*, 2012). Meanwhile, a study of biomass and floristic composition at Bangi Permanent Forest Reserve recorded Euphorbiaceae as the largest family with 10 genera and 119 species (Lajuni & Latiff, 2013). A study of tree species composition and diversity in Ulu Muda Forest Reserve, Kedah, Malaysia has also reported Euphorbiaceae as the largest family with 11 genera and 20 species (Mardan *et al.*, 2013).

The second most speciose family in this study was the Myrtaceae with 212 individual trees, which was represented by two genera in two species. A study by Khairil *et al.* (2014) reported a similar result of which Euphorbiaceae had the highest density in inland and riverine forests with 266 and 197 individuals ha^{-1} respectively, while Myrtaceae had the highest density in seasonal flood forest with 168 individual ha^{-1}. Disturbed areas can amplify the density of Myrtaceae and the severity of the disturbance can have an impact accordingly on the abundance of Myrtacea (Prado Júnior *et al.*, 2014). Among the common shrubs found in the coastal region of Peninsular Malaysia are known as Myrtaceae or myrtles (Mat-Salleh *et al.*, 2003).

The third most speciose family in this study was the Anacardiaceae with 197 individual trees, which was represented by 6 species in 4 genera. A study by Abdul Hayat *et al.*, (2010) on the plant species diversity of a logged-over coastal forest within the Pasir Tengkorak Forest Reserve, Langkawi, Malaysia reported quite a similar result of which Anacardiaceae and Myrtaceae families were the most common species and widespread all over the country. However, Abdul Hayat *et al.*, (2010) stated that Myrtaceae family was commonly found in the coastal beach, while Anacardiaceae was commonly found at the lowland forest.

The majority of the trees studied fall into DBH class one with 875 individuals showed that the forest of the study area consisted of mostly young trees and saplings, thus, is an actively regenerating forest. The DBH distribution obtained in this study is similar to those obtained by Lajuni and Latiff (2013) in their study on the floristic composition of Bangi Permanent Forest Reserve, which most of the trees also fall into DBH class one with 669 numbers of trees.

The existence of several large trees in the study area such as *Artocarpus rigidus* (Moraceae), *Ixonanthes reticulata* (Ixonanthaceae), *Paratocarpus bracteatus* (Moraceae), *Endospermum diadenum* (Euphorbiaceae), *Callerya atropurpurea*

(Fabaceae), *Parkia javanica* (Fabaceae), *Shorea leprosula* (Dipterocarpaceae) and *Dacryodes rugosa* (Burseraceae) ranged from 55 m to 45 m in height, which are tall enough to form the emergent canopy indicated that Sungai Udang Forest Reserve is a matured or climax forest. One of these trees which is *Shorea leprosula* (Dipterocarpaceae) is a commercial timber tree. Many large trees were found in the three plots of the study area demonstrating that the forests were at a mature stage (Lü *et al.*, 2010). Anacardiaceae, Dipterocarpaeae, Guttiferae, Myristicaceae, Myrtaceae, Melastomataceae, Palmae, and Sapotaceae generally demonstrated a higher species richness and importance in rain forests of Southeast Asia (Zhu, 1997).

5.2 Vegetation Communities

5.2.1 *Aquilaria malaccensis-Artocarpus rigidus* community

The local people have collected agarwood using traditional way by deliberately wounded the trees with large knives or hammered nails into trunks, and this action has wounded the *Aquilaria malaccensis* trees in Sungai Udang Forest Reserve (Mohamed *et al.*, 2010). Nevertheless, despite being wounded the *Aquilaria malaccensis-Artocarpus rigidus* community was continuously protected against unconscious cutting and over-grazing due to the area's status as a natural forest reserve. It is illegal to collect agarwood from natural forests and *Aquilaria* trees are nowadays protected in nearly all countries (Akter *et al.*, 2013).

According to La Frankie (1994) in his studies on population biology of *Aquilaria malaccensis* in Pasoh Forest Reserve in Malaysia, there was no evidence to prove of the organized gaharu collecting activities. Since 1917, the gaharu collecting activities from Pasoh Forest Reserve has been illegal without a permit.

The large *Aquilaria malaccensis* trees in this study area shared quite a similar traits from those found in other tropical forest in Peninsular Malaysia, in terms of its diameter at breast height (DBH). For instance, a study by La Frankie (1994) on the population biology of *Aquilaria malaccensis* in a 50 ha permanent plot of Pasoh Forest Reserve in Peninsular Malaysia acknowledged that the population of *Aquilaria malaccensis* within the large-scale plot of Pasoh Forest Reserve consisted of 125 trees and the largest tree was 41.3 cm in diameter at breast height. Those trees were also found in wet ground and hill slopes.

This study showed that *Palaquium gutta, Endospermum diadenum, Agrostistachys longifolia* and several other species can be found in all the four vegetation layers and in several plots. Most of these species showed that they had grown in colonies or in certain populations. Thus, the study by Kwan and Whitmore (1970) which stated that the trees of some species could grow as a group and extend across numerous plots is feasible.

The lesser known wood species such as *Macaranga* sp. (Mahang), *Endospermum diadenum* (Sesenduk)and *Artocarpus* sp.(Terap) is abundant in secondary forest and they could act as a potential substitute supply of raw materials for wood based industries (Ang *et al.,* 2014). Despite the existence of some species that were commonly distributed, this community also showed several species that have occurred only once or twice in all plots. This factor suggested that the tropical forest consisted of many aggregated species and small numbers of randomly distributed species (Hubbel, 1979; Masaki *et al.*, 1992; Tanouchi & Yamamoto 1995; Yamamoto *et al.*, 1995). The four soil types which were sandy loam, loam, fine loam and clay are favourable by tree species in a Bornean mixed dipterocarp forest which is proven by the 73% distribution of tree species in a 52 hectare forest dynamics plot (Russo *et al.*, 2005).

5.2.2 *Palaquium gutta* sub-community

Some of the plots in the *Palaquium gutta* sub-community were situated at the forest area with canopy gaps due to disturbance caused by branch and tree fall. These small and large gaps by all sizes of trees from small branches to large trees were created by strong windstorms. A study on the forest structure, canopy gap dynamics and light environment in the understory of an unlogged lowland rain forest in Pasoh Forest Reserve, Negeri Sembilan, Peninsular Malaysia stated the formation of frequent and huge canopy gaps in primary forest might be largely due to large trees (Numata *et al.*, 2006). The impacts of a single fallen tree to the extent of the destruction of several hundred km^2 are some of the well-known natural disturbances in tropical forest (Ting & Poulsen, 2009). A lightning strike or death of an emergent individual from a pathogen might cause the existence of canopy gaps, in which can resulted to the tree die standing, the branches slowly rotting off, with little damage to individuals beneath and minimal increase in light at the forest floor (Ashton, 2008).

Species from the family Euphorbiaceae such as *Macaranga* sp. were also found in the canopy gaps area. The quite frequent occurrence of species from the family Euphorbiaceae may indicate that the forest in the study area is a disturbed forest.

Species such as *Macaranga* sp., *Melastoma malabathricum* and Zingiberaceous plants are usually the characteristic species of the secondary forest (Miyagi *et al.,* 1988).

Some invasive plant species entered the floristic structure of this sub-community due to the effect of canopy gaps. The invasion by light-demanding species is assisted by the removal of canopy trees which increases light availability in the understory (Padmanaba & Corlett 2014). Able to persist in a suppressed condition and able to cope with large differences in light availability on the forest floor is one of the requirements of many tree species (Numata *et al.*, 2006).

Furthermore, the plots of this sub-community were situated near the anthropogenic disturbances such as trampling due to visitors coming from adjacent lands and coverage such as rubbishes, which created the habitat for exotic species. The composition and plant diversity of the forest might be affected by anthropogenic disturbances, such as coverage, trampling and deforestation and indirect anthropogenic disturbances such as terrain (Wang *et al.,* 2012).

A study of plant association and composition from Mount Tahan, Malaysia using GIS and phytosociological approaches by Mohd Hasmadi *et al.,* (2010) stated that direct disturbance by vegetation trampling on the mountain recreation trail and camp-sites destroyed fragile above-ground plants. Severe human trampling in mountain trails and camping site has affected vegetation which encourage the need of information concerning environments that is exposed to human impact.

5.2.3 *Barringtonia racemosa* sub-community

The available macroelements (Ca, K, Mg, and Na), organic matter and salt were low in this sub-community due to unsuitable environmental conditions such as high inclination and erosion from a steep slope. Steep slope also promoted and triggered the formation of a few landslip or landslide in the sub-community area. These factors have contributed to a poor floristic composition of this sub-community. The variation of soil across the landscape will influence the distribution and association of the vegetation due to the fact that plants only grow in areas where the soil is favourable (Munishi *et al.*, 2007).

According to Ashton (2008), steep slopes often include large areas of successional stands because steep slopes experience higher landslip frequency. Thus, these forest habitats experiences differing proportions of individual in opposition to multiple tree deaths. Differing levels of shelter from wind throws are contributed by differing geomorphologies and are prone to landslips.

Some of the plots in the sub-community were inundated by a small stream, generally in shallow furrows entering or draining the depressions. Floodplains, formed mainly of river sediments and subject to flooding, occurred during the rainy season at certain areas of low lying ground adjacent to the small stream of the *Barringtonia racemosa*sub-community, had contributed to the decrease of species richness in the area. Floods might contribute to the lower density of tree species in riverine and seasonal flood forests which would affect the growth of seedlings or saplings or even can lead to the destroy of the small trees (Khairil *et al.*, 2014). The tree roots in floodplain is shallow which lead to frequent windthrow, and is all over the floodplains and shallow peat swamps (Ashton, 2008). Floristic composition of a particular association may be altered due to long flooding periods (Yalcin *et al.,* 2014). Rains influenced the fluctuation of species composition and population level from year to year (Perveen *et al.,* 2008).

Moderate trampling from wild boars was present in this sub-community. Thus, wild boar runways, burrows, nests and dung were seen scattered within the plots of the sub-community. These wild boars severely disturb the topsoil at their nest sites and when foraging within the sub-community. However, the activities by the wild boars did not significantly affect the floristic composition of the sub-community. The wild pig activities do not disrupt subsoil to the same extent as tree fall, but the upper few decimeters were mainly affected by the wild pig activities (Adzmi *et al.*, 2010). Species richness was lower in the communities nearby water sources, suggesting intensive grazing and tramping by the wild boars, than in the typical community of the drier zone. Grazing had decreased the species richness and changed the floristic composition (Cheng *et al.,* 2013).

5.3 Species Importance

A species with important value index of more than 10% is considered as the dominant species in a particular community (Curtis and Macintosh, 1951). Thus, *Spondias cytherea* (Anacardiaceae) was identified as the most dominant species of the tree community in this study with an importance value index (IV_i) of 23.9%, followed by *Syzygium* sp. (Myrtaceae) (22.8%), *Elateriospermum tapos* (Euphorbiaceae) (17.2%), and *Aquilaria malaccensis* (Thymelaeaceae) (13.0%) in descending order. A study by Nizam *et al.* (2013) also included *Elateriospermum tapos* as on of their most important species with importance value index of 1.98% at one of their study site. A study by Khairil *et al.* (2014) also reported quite a similar result where both Myrtacea and Euphorbiaceae were found to be one of the most important families in their study area.

A study at Jambu Bongkok Forest Reserve, Terengganu, Peninsular Malaysia has also included Euphorbiaceae and Myrtaceae as the most dominant families in their study (Jamilah *et al.,* 2014). The dominance of Euphorbiaceae is expected and not startling as Euphorbiaceae is well-known to dominate or co-dominate many lowland forests of Malaysia and other short stature vegetation formations, bushes and secondary vegetation (Whitmore, 1983).

Saiful and Latiff (2014) have done a study on the effects of selective logging on tree species composition, richness and diversity and stated that Euphorbiaceae was not only dominant before logging with 24 species and 116 individual trees, but also maintain the dominant position after the devastating logging activity in a primary hill dipterocarp rainforest in Peninsular Malaysia, with 20 species and 73 individual trees.

According to Lajuni and Latiff (2013), the importance value index is used as a significant parameter in giving information on the timber value of a forest. A particular forest will be classified as an economically valuable forest if the species with the highest importance value index of that particular forest belongs to a valuable timber species. However, the importance value index of the timber species in this study was not high enough to be classified as such. For example, in this study *Shorea leprosula* and *Hopea* sp. which are well-known as one of the most economically valuable timber species only showed an importance value index of 5.6% and 1.8%, respectively.

5.4 Species Diversity

Species richness (the number of different species in a particular area) that is weighted by some measure of abundance such as number of individuals or biomass is identified as species diversity (Abdul Hayat *et al*., 2010). The Shannon-Weiner Diversity Index (*H'*) for the whole 25 plots of the study area (*Aquilaria malaccensis-Artocarpus* community) showed an index value of 3.67. Meanwhile, the *Palaquium gutta* sub-community indicated a value of 3.57 and the *Barringtonia racemosa* sub-community showed an index value of 3.66.

Those *H'* values showed that the study plots are considered as obtaining a fairly high species diversity in comparison with many studies conducted at the tropical rainforests in Peninsular Malaysia. A low value of Shannon H' indicates domination by a few species, while a high value of Shannon H' indicates a large number of species with similar abundances (Saiful & Latiff, 2014).

For instance, a study at Kenong Forest Park, Kuala Lipis, Pahang, Malaysia on species composition and floristic variation of tree communities in two distinct habitats recorded a fairly high species diversity with *H'* value of 4.42 (limestone cave) and *H'* value of 4.79 (lowland area) (Nizam *et al.*, 2012). Meanwhile, a study of biomass and floristic composition at Bangi Permanent Forest Reserve recorded a value of 6.99 which indicated the existence of a large number of species with similar abundances (Lajuni & Latiff, 2013).

These fairly high species diversity values also indicated that the study plots are considered able to conserve tree species diversity. For instance, a study on the tree species diversity at three sites in tropical rainforest ecosystem of South-West Nigeria reported quite a similar result with the H' value of 3.66 (Shasha Forest Reserve), H' value of 3.62 (Ala Forest Reserve) and H' value of 3.34 (Omo Forest Reserve), and suggested that the sites were able to conserve tree species diversity (Adekunle, 2006).

The Simpson's index of diversity (1-D) for the whole 25 plots (*Aquilaria malaccensis-Artocarpus* community) showed an index value of 0.96. Meanwhile, the *Palaquium gutta*sub-community indicated a value of 0.95 and the *Barringtonia racemosa*sub-community showed an index value of 0.96.

These values also indicated that the study plots are considered as obtaining a fairly high species diversity as compared to other various studies. For instance, a study on the plant species diversity of the Pasir Tengkorak Forest Reserve, Langkawi, Malaysia reported quite a similar result of which the Simpson's index of diversity was 0.96, which suggested that diversity is high in the 1-ha plot of the study area (Abdul Hayat *et al.,* 2010).

5.5 Physico-chemical characteristics of soil

5.5.1 Relationships between soil properties

The correlation analysis between the physico-chemical characteristics of soil at all the 25 plots in the Sungai Udang Forest Reserve concluded that the correlation between the chemical content of soil in this study was moderate. For instance, the clay was negatively correlated with silt and also showed a highly negative correlation with sand, which indicated that soil with a high percentage of clay will have a lower percentage of silt and sand.

The studied physical characteristics of soil showing soil particle and soil texture of the 25 sampling plots in Sungai Udang Forest Reserve, Malacca showed the soils of the study area were dominated by clay loam texture. Clay loam is classified as a loam in which clay is dominant (Khairil *et al.*, 2014). The structure of loam which is not too compact, allowing roots to penetrate while water and air in the soil are balanced, thus, make the texture of loam more suitable for plantation activities (Othman & Shamshuddin, 1982).

According to Martins *et al.*, (2015), the growth of tropical trees is strongly affected by soil texture, nutrient concentration and moisture levels in different ways. Soils with medium clay content (30-60%) have a tendency to favor tree height and diameter growth. Hence, it is estimated that the dynamics of tropical forests are influenced by variations in soil characteristics.

The pH in this study was positively correlated with both available CEC and available Mg but the correlations were low. This indicated that highly acidic soil will have a higher content of CEC and available Mg. Meanwhile, the pH in this study was negatively correlated with available K, available P, available C and available N. It showed that highly acidic soil will have a lower content of available K, available P, carbon and nitrogen.

The pH values in the study area varied between 4.11 (plot 10) and 4.95 (plot 21) obviously showed that the soil was acidic in nature and there was no major difference in the pH values of the soil samples in all stands at different plots. High organic matter content and the undisturbed nature of the soils in the study area contributed to the low pH of the soil (Gairola *et al.*, 2012). A study by Khairil *et al.* (2014) reported a similar result, of which all soil found in the three forest types of the study area in Peninsular Malaysia which were inland forest, seasonal flood forest and riverine forest showed a low pH and acidic in nature.

According to Othman and Shamshuddin (1982), most soil in Peninsular Malaysia tropical rainforests was acidic with pH values between 3.5 and 5.5. It is common for soil to become so weathered and leached in wet tropical regions which caused high acidity in the soil.

Khairil *et al.,* (2014) stated that the total sum of exchangeable cation that can be adsorbed by the soil is known as cation exchange capacity (CEC). The role of CEC was to measure the fertility, the capacity of nutrient retention and the capacity to protect groundwater from cation contamination. The content of clay and organic matter influence the cation exchange capacity. In this study, the content of clay was positively correlated with cation exchange capacity which showed that soil with a high content of clay will have a higher cation exchange capacity. The cation exchange capacity will become higher if the percentage of clay and organic matter is higher (Othman & Shamshuddin, 1982).

Furthermore, according to the Pearson correlation analysis, the CEC in this study was significantly correlated with available C. This indicated that soil with a high CEC will have a higher available carbon. CEC also showed positive correlations with available Mg and available P but both correlations were low. However, CEC showed a negative correlation with both available K and available N.

The mean range of the total cation exchange capacity (CEC) in this study was between 4.4 and 17.2 meq/100g. A study on the soil physico-chemical characteristics from three forest types in tropical watershed forest of Chini Lake, Peninsular Malaysia stated quite a similar result of CEC with the range of mean values of the cation exchange capacity in the inland forest was between 4.59 and 12.99 meq 100g, the seasonal flood forest was between 4.63 and 16.70 meq 100g, while the riverine forest indicated between 5.66 and 13.888 meq 100g (Khairil *et al.*, 2014).

This study also found a positive correlation between nitrogen and K. This indicated that the soil in this study with a high content of nitrogen will also have a high content of available K. The values of total nitrogen in the study area ranged between 0.09% (Plot 22) and 0.69% (Plot 24). The value of total nitrogen in Plot 24 was the highest due to higher water holding capacity and the presence of heavy litter and humus content of the studied forest types. The amount and properties of organic matter largely influenced the availability of nitrogen (Haan, 1977). Therefore, the low amount of organic matter in the forest types of Plot 22 was also one of the reasons for the lowest value of nitrogen as compared to other plots.

Available C was significantly correlated to available P with r = 0.482. This indicated that the soil in this study with a high content of carbon will also have a high content of available P. Available C also showed a significant correlation with available Mg (r = 0.367) and N (r = 0.256). However, available P was negatively correlated to available K and available N in this study. This indicated that soil with a high content of available P will have a lower content of available K and available N.

5.5.2 Relationships between vegetation and soil properties

Soil had an important role on the plant diversity and is one of the major environmental factors in the plant communities of this study area. This has been proven from a study by Munishi *et al.*, (2007) on compositional gradients of plant communities in two submontane rainforests which concluded that within a single range, the plant distribution is influenced by elevation and soil factors (particularly texture, CEC, CAT, soil pH, percent clay, percent carbon and percent nitrogen).

Meanwhile, in this study, for the relationships between plant communities and soil, significant correlations were also found between plant diversity and soil physico-chemical parameters. For example, highly significant correlations were found between soil pH and diversity index for all the three communities (*Aquilaria malaccensis* – *Artocarpus rigidus* community, r = 0.365; *Barringtonia racemosa* sub-community, r = 0.548; *Palaquium gutta* sub-community, r = 0.221). This indicated that soil pH has a huge influence on the vegetation community.

A study from Nizam *et al.,* (2012) indirectly supported the result of this study by saying that some of the many soil factors that may influence the floristic variation in the study area at Kenong Forest Park are the calcium element and soil pH, based on the facts that the limestone area has high calcium concentration, which also signifies high pH content (Nizam *et al.,* 2012).

Furthermore, strong and highly significant correlations were also found between CEC and diversity index of the plant species for all the three communities. This indicated that CEC has a huge influence on the vegetation community. A study by Peng *et al.* (2015) reported a similar result, of which correlation between vegetation diversity and soil factors of their study area has found that the vegetation community was largely influenced by CEC with r = 0.899.

According to the Pearson correlation analysis, the vegetation diversity or plant community in this study showed a significant, though not strong, positive correlation with available C. This indicated that the available C has an important influence on the vegetation diversity of this study area. Higher levels of carbon inputs to the soil and more favourable microclimatic conditions linked to more diverse plant communities result in more active, more abundant and more diverse soil microbial communities (Lange *et al*., 2015). High species diversity and richness of an area is promoted by high organic carbon content which reflects high fertility of the soil (Bauri *et al.,* 2013).

Similarly, the vegetation diversity or plant community in this study also showed a significant, though not strong, positive correlation with available N. This indicated that the available N has an important influence on the vegetation diversity of this study area. Lack of nitrogen will result in the plant remaining stunted and comparatively undeveloped, thus, nitrogen is a vital element for all growth processes in plants (Gairola, 2012). Many research around the world are interested in the potential of nitrogen (N) fixation in increasing production in forest ecosystems, thus, it has been widely studied and has been examined throughout the years (Son *et al.*, 2007). Meanwhile, a study by Zak *et al.*, (2003) added that plant diversity altered microbial community composition and function, which will increase the supply of soil N to plants and contributed to greater productivity in the most species-rich experimental plant communities.

Furthermore, the vegetation diversity or plant community in this study also showed a significant, though not strong, positive correlation with available P and available K. This indicated that the available P and available K have an important influence on the vegetation diversity of this study area. Two main limitations for trees growing on highly-weathered soils in the tropics are soil P deficiency and acidity (Yost & Ares, 2007). In other words, the increase in nutrients could enhance the plant diversity in this study area.

CHAPTER 6: CONCLUSION

This study shows that the plants in *Aquilaria malaccensis-Artocarpus rigidus* community, *Palaquium gutta* sub-community and *Barringtonia racemosa* sub-community can successfully interact socially with each other and can live healthily together in an ecosystem. This was proven from the fairly high species diversity obtained from the study area. High species diversity of the study area means it has a great number of successful species and a stable ecosystem. High species diversity also suggests that the study area has a complex food webs and an environmental change is harmless and unlikely will damage the ecosystem as a whole.

The good soil characteristics of this study area also contribute to the successful relationship of *Aquilaria malaccensis* and its communities. The physico-chemical characteristic of the soil in this study was acidic and dominated by clay loam which shows that the soil of this study is suitable for the provision of nutrients to the plants. This study also concluded that high soil fertility promotes the high species diversity and richness of an area. The vegetation diversity or plant communities were significantly and positively correlated with soil parameters, particularly soil pH, CEC, available K, available P, available C and available N. Therefore, the soil characteristics of an environment should be an important criterion for species distribution.

The new information on *Aquilaria malaccensis* and its communities obtained from this study can contribute to the future plantation work, by using all the exact species existed in the discovered new communities as a reference in planting trees for rehabilitation projects. For instance, the actual natural vegetation identified from this phytosociological study can be suggested as the potential natural vegetation in future rehabilitation project to rehabilitate degraded forest areas. The restoration of *Aquilaria malaccensis* and its communities will become more feasible with all the basic information about the vegetation communities obtained from this phytosociological study.

Future works can be done by doing more phytosociological studies of *Aquilaria malaccensis* and its communities at other lowland tropical rainforestin Malaysia, to come up with a variety of information on new communities, for the benefit of future conservation and management. Apparently, an excellent way to manage and conserve this valuable tropical tree known locally as ‘karas’ would be to know its composition and the ecological relationship between the species within its community, and this could be achieved with phytosociological studies.

The composition and distribution of species in this study might be also influenced by other environmental gradients such as abiotic conditions, altitude and topography. This study is only a preliminary research, thus, further research should be made to determine whether those mentioned environmental gradients could be the source of floristic variation of tree species. Identifying these environmental gradients is essential in developing strategy to conserve and protect forest habitats.

This study is one of the first few phytosociological studies at a national scale in Malaysia and involves the floristic and vegetation study of plant communities in Sungai Udang Forest Reserve, Malacca. The limitation of scientific information on the phytosociology study of vegetation in Malaysia made it very difficult to compare the floristic similarity of the community described in this study with other possible similar studies. Thus, this study is useful as a main stimulus for further botanical documentation in Malaysia.

This study is beneficial in providing more information on the growth response of the mixed dipterocarp forest for the development of proper forest management. It also provides a better insight into the composition, the distribution and the main threats to their conservation.

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LIST OF PUBLICATIONS AND PAPERS PRESENTED

ISI-Cited Publication

a) Sarah, A. R., Nuradnilaila, H., Haron, N. W., & Azani, M. (2015). A Phytosociological Study on the Community of *Palaquium gutta* (Hook.f) Baill. (Sapotaceae) at Ayer Hitam Forest Reserve, Selangor, Malaysia. *Sains Malaysiana*, *44*(4),491-496.

b) Sarah Abdul Razak & Noorma Wati Haron (2015). Phytosociology of *Aquilaria malaccensis* Lamk. and its communities from a tropical forest reserve in Peninsular Malaysia, *Pakistan Journal of Botany, 47*(6), 2143-2150.

Papers Presented

a) Poster Presentation at The 18th Biological Sciences Graduate Congress, 6th to 8th January 2014, Faculty of Science, University of Malaya, Kuala Lumpur, Malaysia.

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APPENDIX A PUBLISHED MANUSCRIPT IN SAINS MALAYSIANA

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A Phytosociological Study on the Community of *Palaquium gutta* (Hook.f.) Baill. (Sapotaceae) at Ayer Hitam Forest Reserve, Selangor, Malaysia

(Suatu Kajian Fitososiologi ke atas Komuniti *Palaquium gutta* (Hook.f.) Baill di Hutan Simpan Ayer Hitam)

A.R. SARAH*, H. NURADNILAILA, N.W. HARON & M. AZANI

ABSTRACT

A phytosociological study on the flora and vegetation community of Palaquium gutta *(Hook.f.)Baill.was carried out in Compartment 13 of Ayer Hitam Forest Reserve, Selangor. The main objectives of this study were to identify, characterize and classify the* P. gutta *community which is naturally distributed in Ayer Hitam Forest Reserve. A total of 10 plots (30×30 m in size) were constructed according to the line transect method. The vegetation sampling and data analysis were done according to the Braun-Blanquet approach. The results showed that there were 59 species belonging to 54 genera and 34 families in the form of herbs, shrubs, understorey trees and also canopy tree layers. The most common species in the study area were* P. gutta *and* Endospermum diadenum *(Miq.) Airy Shaw. The phytosociological study identified a community of* Palaquium gutta-Endospermum. diadenum *along with two sub-communities known as* Dracaena *sp. sub-community and* Streblus elongatus *sub-community. The results also showed that most of the species belong to the Euphorbiaceae. This indicates that the forest is a secondary forest.*

Keywords: Braun-Blanquet; Endospermum diadenum; Palaquium gutta; *phytosociology; vegetation community*

ABSTRAK

Suatu kajian fitososiologi ke atas flora dan komuniti vegetasi Palaquium gutta *(Hook.f.)Baill, telah dijalankan di petak 13 Hutan Simpan Ayer Hitam, Selangor.Objektif utama kajian ini ialah untuk mengenal pasti, menciri dan mengelaskan komuniti* P. gutta *yang tersebar secara semula jadi di Hutan Simpan Ayer Hitam.Sejumlah 10 plot (30×30 m) telah dibina mengikut kaedah transek garisan.Pensampelan vegetasi dan analisis data telah dilakukan mengikut pendekatan Braun-Blanquet. Keputusan menunjukkan terdapat 59 spesies dan 54 genus serta 34 famili herba, pokok renek, pokok lapisan bawah dan juga lapisan pokok kanopi. Spesies paling kerap dijumpai di kawasan kajian ialah* P. gutta *dan* Endospermumdiadenum *(Miq.)Airy Shaw.Kajian fitososiologi telah mengenal pasti satu komuniti iaitu* Palaquium gutta-Endospermum diadenum *ass.nova diikuti dengan dua subkomuniti dikenali sebagai subkomuniti* Dracaena *sp. dan subkomuniti* Streblus elongatus*. Keputusan juga menunjukkan bahawa kebanyakan spesies adalah daripada Euphorbiaceae.Ini menunjukkanbahawa hutan tersebut adalah hutan sekunder.*

Kata kunci: Braun-Blanquet; Endospermum diadenum; *fitososiologi; komuniti vegetasi;* Palaquium gutta

INTRODUCTION

Phytosociology involves plant communities within the same environment, their floristic composition and development and the social relationships between them. A phytosociological study gives information on the distribution of species as well as affinities between species or groups of species, resulting in a valuable evaluation of the vegetation within the study area (Frenedozo-Soave 2003). A phytosociological system is a system for classifying these communities. Phytosociology provides useful basic data for ecology, geography, landscape science, conservation and environmental science because the data represent integrated units in vegetation systems (Fujiwara 1987).

According to Enright and Nuñez (2013), Braun-Blanquet pioneered the classification of vegetation into units (associations) based on floristic composition and the identification of characteristics species. The advantages and problems, associated with the phytosociological approach to vegetation analysis pioneered by Braun-Blanquet have been reviewed many times, and inevitably will continue to do so as the vegetation science community increasingly becomes a globalised one.

Palaquium gutta is known locally as ‘Nyatoh TabanMerah’ and is from the Sapotaceae family. *Palaquium* species can be found in primary lowland forest about 300 m below and also on hill forest in Peninsular Malaysia. *Palaquium* species have been recorded in all states ofMalaysia except Perlis, Kedah and north of Terengganu (Roche & Dourojeanni 1984). According to Prakash et al. (2005), *Palaquium* species are natural inhabitants of Southeast Asia, particularly in Malaysian and Indonesian archipelago. Gutta-percha is a dried coagulated extract from several *Palaquium* species including *P. gutta*. The gutta -percha yielding tree is a medium to tall trees, in which a series of cuts (concentric or v -shaped cuts) is made to obtain the latex. The inertness of gutta-percha to biodegradation makes them useful as an impermeable coating for undersea cables and gutta-percha is still used in dentistry as a filling material (van Beilen & Poirier 2012).Ayer Hitam Forest Reserve is a lowland dipterocarp forest which contains valuable wood, medicinal and economic plants and is also suitable for recreation. It had been selectively logged from 1936 to 1965 (Faridah- Hanum 1999). The main silvicultural operations in the 1950's were associated with timber extraction. Anthropogenic disturbances such as logging operations, construction of new roads, land development, shifting cultivation and uncontrolled deforestation are believed to be the major causes in the decline of biodiversity. Logging operations in the tropical forest impairs the ecological balance and devaluates the original forest. Lack of care during partial felling operations resulted in the damage to residual stand and young trees. Logging could also affect the watershed areas. Some 3.15 million ha of the total natural forest in hilly areas are protected as water catchment areas (Zakri 1995).

The main objectives of this study were to identify, characterize and classify the *P. gutta* community which is naturally distributed in Ayer Hitam Forest Reserve. An excellent way to conserve this valuable tropical tree species would be to know its composition and the ecological relationship between the species within its community and this could be achieved with a phytosociological study. Furthermore, the knowledge gained from this phytosociological study will contribute to the mass planting of *P. gutta* and this indirectly could help in the past or future logging issues in Ayer Hitam Forest Reserve. Knowledge on the floristic composition (phytosociology) of *P. gutta* at natural forest in Malaysia is literally unknown and an empirical botanical documentation provides a main stimulus for the present study.

MATERIALS AND METHODS

STUDY SITE

This study was conducted at Compartment 13 of Ayer Hitam Forest Reserve. Its latitudes is between 2°57'N and 3°04'N and longitudes between 101°38'E and 101°41'E. The forest is a lowland dipterocarp forest and is known as a secondary disturbed forest due to the previous logging activities since 1930. Currently, the total forest area is 1248 ha.

The mean annual temperature is 25.2°C with a maximum temperature at 27.6°C and minimum at 22.9°C. The rainy season occurs in January-March and June-September and the average annual rainfall is 2178 mm. The topography of the forest is rather undulating with 15 and 233 m above sea level. The soil type in Ayer Hitam Forest Reserve is alluvium-colluvium soil which reshaped from metamorphic rock with sandy clay loam soil texture. There are three major rivers in the study area which are Sungai Rasau, Sungai Bohol and Sungai Biring.

FIELD SURVEYS AND DATA COLLECTION

Field surveys and data collection were done based on the techniques described in detail by Braun-Blanquet (1964) and Fujiwara (1987). A total of 10 plots with 30×30 m in size were constructed according to the line transect method. The size of the plot was estimated by means of a 'minimal area' which was 900 m^2 for each plot. The plots were located at various altitudes, expositions, inclinations and reliefs. An effort was made to achieve high ecological and physiognomic homogeneity within each the plot. Every plot was georeferenced with a Garmin GPS.

Scientific names of each vascular plant species in each plot were identified. Cover or abundance data of all vascular plant species for each plot were verified. All vascular plant species in each plot with a trunk diameter at breast height (DBH) ≥5 cm were marked and numbered and their diameter and height were recorded. Trunk perimeter measurement was taken using a metric tape and tree height was estimated with the aid of a clinometer. Lastly, these samples were classified in a phytosociological table according to their floristic composition. The vegetation layers in the forest were divided into five layers as shown in Table 1.

DATA ANALYSIS

As for the numerical analysis, the cover or abundance values on the scale of Braun-Blanquet were transformed into the 1-9 ordinal scales of van der Maarel (1979).
With the goal of identifying the floristic composition of these groups, this synthetic phytosociological table was elaborated by scoring species in percentage or constancy classes according to Braun-Blanquet's scale. Lastly, the associations of the species were described based on all the 10 plots.

RESULTS

COMMUNITY STRUCTURE AND FLORISTIC COMPOSITION

A total of 59 species belonging to 54 genera and 34 families were identified in all the 10 plots. The most dominant life forms were trees, followed by herbs and shrubs. A new community *Palaquium gutta- Endospermum diadenum* and two sub-communities known as *Dracaena* sp. sub-community and *Streblus elongatus* sub-community were determined in this study and these associations were shown in the association table (Table 2).

TABLE 1. Types of vegetation layers

Vegetation layers	Height	Symbol
Super tree	≥30m	ST
Canopy tree layer	10-25m	T1
Understory tree layer	6-9m	T2
Shrub layer	2-5m	S
Herb layer	0.1-2m	H

TABLE 2. Association table

Plot reference number	1	2	3	4	5	6	7	8	9	10
Original plot number in field	1	5	4	6	2	3	9	10	8	7
Number of species	35	31	31	34	22	24	27	18	21	24
Palaquium gutta-Endospermum diadenum community										
Palaquium gutta	4	r	3	3	2	2	3	+	2	+
Endospermum diadenum	2	r	+	r	2	2	2	+	+	+
Agrostistachys longifolia	4	3	4	4	.	2	4	2	4	+
Gonystylus sp.	3	2	1	+	2	2	+	r	+	+
Blumeodendron Calophyllum	1	+	+	.	1	r	+	+	+	r
Calamus sp.	4	1	4	•	3	.	2	r	3	4
Diospyros argentea	3	r	+	r	3	+	r	.	r	r
Knema sp.	2	1	2	r	2	1	r	.	+	.
Phyllanthus pulcher	3	3	.	+	3	3	2	1	3	2
Rothmannia macrophylla	4	+	3	2	.	2	+	+	r	+
Canarium sp.	3	r	+	r	.	.	+	+	+	+
Calophyllum sp.	2	r	r	+	2	r	.	r	r	.
Dipterocarpus crinitus	r	+	r	r	+	1	r	.	.	.
Elateriospermum tapos	2	2	2	r	1	.	r	.	+	+
Eugeissona tristis	4	.	1	3	4	.	+	4	4	+
Knema hookeriana	2	r	.	r	2	+	+	r	r	r
Pavetta sp.	4	+	+	+	2	1	r	.	.	+
Pellacalyx saccardianus	3	r	1	+	.	.	2	1	3	+
Scaphium macropodum	2	1	+	+	.	.	+	r	r	r
Shorea macroptera	+	.	.	r	+	+	+	r	r	r
Syzygium sp.	2	r	2	+	2	1	r	.	.	+
Differential species of *Dracaena* sp. sub-community										
Dracaena sp.	3	.	2	1	.	.	.	.	.	.
Polyalthia sp.	3	r	r	.	.	.	.	.	.	.
Artocarpus sp.	2	.	+	.	.	.	.	.	.	.
Anisophyllea griffithii	3	+	.	r	.	.	.	.	.	.
Lijndenia laurina	2	.	+	r	.	.	.	.	.	.
Ochanostachys amentacea	3	2	.	.	.	.	.	.	.	.
Barringtonia racemosa	2	.	2	.	.	.	.	.	.	.
Oncosperma horridum	.	+	.	+	.	.	.	.	.	.
Selaginella intermedia	4	4	.	3	.	.	.	.	.	.
Cyathea latebrosa	.	3	.	.	.	.	.	.	.	.
Pternandra echinata	.	.	3	+	.	.	.	.	.	.
Semecarpus curtisii	r	r	.	r	.	.	.	.	.	.
Melastoma malabathricum	.	.	+	1	.	.	.	.	.	.
Chassalia chartacea	1	.	.	+						
Differential species of *Streblus elongatus* sub-community										
Streblus elongates	.	.	.	.	1	+	.	.	.	.
Durio zibethinus	.	.	.	.	.	.	r	.		r
Lasianthus oblongus	.	.	.	.	2	2	.	+	.	+
Macaranga triloba	.	.	.	.	+	.	r	.	r	.
Pandanus sp.	.	.	.	.	.	.	+	.	.	+
Vitex vestita	.	.	.	.	+	r	.	.	.	.
Macaranga gigantea	.	.	.	.	+	.	.	.	+	+
Companion species	.	.	.	.	.	.	.	.	.	.
Shorea parvifolia	r	.	r	.	.	r	.	.	r	.
Acrotrema costatum	.	.	.	.	.	r	.	.	.	.
Artocarpus elasticus	.	r	.	.	.	.	r	.	.	r
Dillenia indica	.	.	r	r	.	r	.	r	.	.
Shorea laevis	.	r	.	.	.	.	.	.	.	.
Bouea oppositifolia	.	.	.	.	.	.	+	.	.	.
Bauhinia integrifolia	+	.	.	.	.	.	.	.	.	.
Aglaia sp .	.	.	+	.	.	.	.	.	.	.
Garcinia nervosa	.	.	r	.	.	.	.	.	.	.
Hopea beccariana	.	.	.	r	.	.	.	.	.	.
Trema cannabina	2	.	.	.	.	r	.	.	.	.
Gironniera nervosa	.	+	.	.	.	.	.	.	.	r
Lithocarpus wallichianus	.	.	r	.	.	r	r	.	.	.
Mischocarpus pentapetalus	r	.	.	r	.	r	+	.	.	.
Palaquium maingayi	.	.	r	.	+	.	.	.	.	.

A total of 21 species belonging to 21 genera and 13 families were found in the *Palaquium gutta-Endospermum diadenum* community. This communitywas characterized by *P. gutta* and *E. diadenum* as the dominant tree species. Other characteristics and differential species of the community were *Agrostistachys longifolia*,*Gonystylus* sp ., *Blumeodendron calophyllum*, *Calamus* sp., *Diospyros argentea*, *Knema* sp., *Phyllanthus pulcher*,*Rothmannia macrophylla*, *Canarium* sp., *Calophyllum* sp., *Dipterocarpus crinitus*, *Elateriospermum tapos*,*Eugeissona tristis*, *Knema hookeriana*, *Pavetta* sp., *Pellacalyx saccardianus*, *Scaphium macropodum*, *Shorea macroptera* and *Syzygium* sp. This community consistedof all four forms of layers which were herbs, shrubs, understory trees and canopy tree layers. The highest layer was 25 m while the lowest layer was below 2 m with the thickness of litter layer at 5.2 cm in average.

A total of 14 species belonging to 13 genera and 10 families were found in *Dracaena* sp. sub-community. The characteristic and differential species of this sub- community were *Dracaena* sp., *Polyalthia* sp., *Artocarpus* sp., *Anisophyllea griffithii*, *Lijndenia laurina*, *Ochanostachys amentacea*, *Barringtonia racemosa*, *Oncosperma horridum*, *Selaginella intermedia*, *Cyathea latebrosa*, *Pternandra echinata*, *Semecarpus curtisii*, *Melastoma malabathricum* and *Chassalia chartacea*.Meanwhile, the *Streblus elongatus* sub-community consisted of seven species belonging to seven genera and seven families. The characteristics and differential species of this sub-community were *Streblus elongatus*, *Duriozibethinus*, *Lasianthus oblongus*, *Macaranga triloba*, *Pandanus* sp., *Vitex vestita* and *Macaranga gigantea.*

SPECIES RICHNESS COVERAGE

Plot 2 had the highest coverage of herbs layer which was 65% of total coverage and followed by plot 5 with 50% of total coverage (Figure 1). Plots 1, 3, 9 and 10 had 45% total coverage of herb layer and this was followed closely by plots 4, 6, 7 and 8 with 40% total coverage of herb layer. For shrub layer, plot 6 had the highest percent of total coverage 35% and followed closely by plot 8 with 30% total coverage of shrub layer. Plots 5, 9 and 10 had a 25% total coverage of shrub layer. Meanwhile, plots 1, 4 and 7 had 20% total coverage of shrub layer, leaving plot 2 with 15% total coverage and plot 3 with 10% total coverage of shrub layer.

For the T2 layer, both plots 3 and 7 had the highest percentage of total coverage 30% and followed by plots 1 and 4 with 25% total coverage. Plots 8, 9 and 10 had 20% of T2 layer coverage and plots 2, 5 and 6 had 15% total coverage of T2 layer.

For T1 layer, plot 10 had the highest percentage of total coverage 20%, followed by plots 3 and 4 with 15% total coverage of T1 layer. Plots 1, 5, 6, 8 and 9 had 10% of total coverage and plots 2 and 7 had the lowest total coverage of T1 layer (5%).

All the plots showed that herb layer had the highest percentage of coverage followed closely by shrub layer. Meanwhile, both T1 and T2 layers had the lowest percentage of total coverage compared to shrub and herb layers.

The trees in the study area could not regain its original height due to the slow regeneration caused by previous logging and other anthropogenic disturbances. Thus, this has resulted to the absent of ST (trees with height above 30

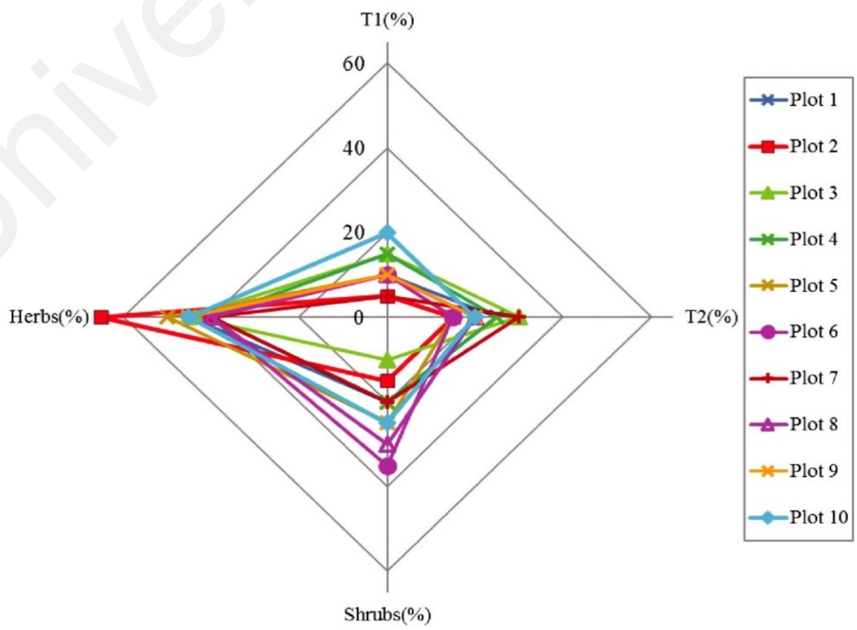

FIGURE 1. Species-richness polygon of all the 10 plots in Compartment 13, Ayer Hitam Forest Reserve

m) and the low coverage of T1 and T2 layers in the study area.

DISCUSSION

The present study has recorded a total of 59 species belonging to 54 genera and 34 families from all the 10 plots at Ayer Hitam Forest Reserve. Meanwhile, previous study by Faridah-Hanum and Khamis (2004) recorded a total of 430 species of seed plants belonging to 203 genera and 72 families from all parts of Ayer Hitam Forest Reserve. Understanding the species composition and diversity can enlighten our knowledge of newer species as well as their behaviour in a particular forest type (Mardan et al. 2013). The environmental gradient in particular the soil gradient plays an important role in influencing the distribution of vegetation communities of a particular forest ecosystem (Nurfazliza et al. 2012).

This study has shown that *P. gutta, E. diadenum, A.longifolia* and several other species can be found in all thefour vegetation layers and in a several plots. Most of these species grew in colonies or were in certain population. Thus, it is feasible that trees of some species could grow as a group and spread across several plots (Kwan & Whitmore 1970). The lesser known wood species (LKS) such as Mahang (*Macaranga* sp.), Sesenduk (*E. diadenum)* and Terap (*Artocarpus* sp.) emerged in large quantity in secondary forest and could become as potential alternative supply of raw material for wood based industries (Ang et al. 2014).

Previous logging affected the nutrient in soil and contributed to the slow regeneration of the trees. Thus, the trees could not regain its original height which has resulted to the absence of emergent strata (trees with height above 30 m) and the low coverage of T1 and T2 layers in the study area. The slow regeneration of the trees in Ayer Hitam Forest Reserve suggests that the area was actually recovering from the past disturbance (Roland 2000). Disturbance would reduce the potential height of trees from 25 to 50% (Ng 1983).

Furthermore, anthropogenic disturbances such as visitor frequentation and adjacent land use create the habitat for exotic species. Anthropogenic disturbances, including coverage (rubbishes and tiles), trampling (paths, visitors coming from different adjacent lands and the distance to edge) and deforestation (anthropogenic caves and stumps) and indirect anthropogenic disturbances (terrain such as slope and aspect) might have integrated effect on composition and plant diversity of forest (Wang et al. 2012). High anthropogenic disturbances might increase similar non- native herb species in urban area and low disturbances might promote co-existence of wood species in suburban area (Li et al. 2012).

Trees from the family Euphorbiaceae were also common in the study area. The frequent occurrence of members of family Euphorbiaceae may indicate that the forest in the study area is disturbed (Ekarelawan 1995).

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Secondary forest is usually characterized by species such as *Macaranga* sp., *Melastoma malabathricum* and zingiberaceous plants (Miyagi et al. 1988).

Despite the existence of some species commonly distributed, this study has also shown several species that have occurred only once or twice in all the plots. This factor suggests that the tropical forest consists of many aggregated species and small numbers of randomly distributed species (Hubbell 1979; Masaki et al. 1992; Tanouchi & Yamamoto 1995; Yamamoto et al. 1995). The distribution of 73% of tree species in a 52 ha forest dynamics plot in Bornean mixed dipterocarp forest were significantly aggregated on one of the four soil types which were sandy loam, loam, fine loam and clay (Russo et al. 2005).

With the present rapid rate of clearing and logging, it is predicted that there will be fewer primary or virgin forests exist in the future, and most of what available then will be disturbed, logged-over or secondary forests (Lajuni & Latiff 2013). Biologists are concerned that disturbed, logged-over and secondary forests are not as good as primary forests in term of species diversity, composition, biomass and structure.

CONCLUSION

Based on the high percentage of herbs, the *P. gutta* community in Ayer Hitam Forest Reserve is actually a secondary forest and is evolving into a primary forest. Restoration of *P. gutta* will become more feasible with all the basic information on the *P. gutta* community obtained in this study. The composition and distribution of species in this study were influenced by environmental factors such as natural forest gap, soil mineral viability, altitude and the topography. This study is only a preliminary research, thus, further research should be conducted on those mentioned factors especially the altitude. This study provides information on the growth response of the mixed dipterocarp forest for development of proper forest management.

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APPENDIX B PUBLISHED MANUSCRIPT IN PAKISTAN JOURNAL OF BOTANY

PHYTOSOCIOLOGY OF *AQUILARIA MALACCENSIS* LAMK. AND ITS COMMUNITIES FROM A TROPICAL FOREST RESERVE IN PENINSULAR MALAYSIA

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Abstract

A phytosociological study on the floristic and vegetation communities of *Aquilaria malaccensis* was carried out in Sungai Udang Forest Reserve, Malacca, Malaysia. The main objectives of this study were to identify, characterize and classify the *Aquilaria malaccensis* communities which were naturally distributed in the Sungai Udang Forest Reserve. A total of 25 plots (40 m x 20 m) in size were constructed according to the line transect method. The vegetation sampling and data analysis were done. A total of 80 species belonging to 79 genera and 40 families were found from all the 25 plots in Sungai Udang Forest Reserve. The most abundant family was the Euphorbiaceae with 220 individual trees, followed by Myrtaceae and Anacardiaceae representing 212 and 197 individual trees, respectively. A community which was *Aquilaria malaccensis* – *Artocarpus rigidus* community with two new sub-community known as *Palaquium gutta*sub-communityand*Barringtonia racemosa*sub-community were identified on the basis of statistical and phytosociological analyses. These community and sub-community also showed preference on different geographical and environmental factors such as soils and local relief. This study is useful in providing more information on the growth response of the mixed dipterocarp forest in the development of proper forest management.

Key Words: *Aquilaria malaccensis*, Braun-Blanquet, Peninsular Malaysia, phytosociology, vegetation community

Introduction

Phytosociology provides useful basic data for ecology, geography, landscape science, conservation and environmental science because the data represent integrated units in vegetation systems (Fujiwara, 1987). A phytosociological study gives information on the distribution of species as well as affinities between species or group of species, resulting in a valuable evaluation of the vegetation (Frenedozo-Soave, 2003).

Phytosociology involves plant communities within the same environment, their floristic composition and development, and the social relationships between them (Sarah *et al.*, 2015). A favourable growing conditions means the existence of a rich floristic diversity and any ecological and plant resource management requires the involvement of a list of species (Hussain *et al.*, 2015). The planning, management and exploitation of natural resources are assisted by phytosociological surveys (Haq *et al.*, 2015). Classification of natural ecosystems into potential plant communities and habitat types is important for the long term management of natural resources (Khan *et al.*, 2011).

Enright and Nuñez (2013) stated that Braun-Blanquet pioneered the classification of vegetation into units (associations) based on floristic composition and the identification of characteristics species. The advantages, and problems, associated with the phytosociological approach to vegetation analysis pioneered by Braun-Blanquet have been reviewed many times, and inevitably will continue to do so as the vegetation science community increasingly becomes a globalized one.

The principal plant used in this study is *Aquilaria malaccensis* Lamk. (or known locally as 'Karas'). *Aquilaria malaccensis* ranks among the most highly valuable non-timber products harvested from tropical forests and used in the manufacture of perfume, incense, traditional medicine, and other commercial products by Muslims and Asian Buddhists (Turjaman *et al.*, 2006). The aromatic resin known locally as 'gaharu' yield an essential oil that is a key perfume ingredient through distillation, meanwhile, incense are commonly processed from distillation residues and lesser quality material.

Aquilaria malaccensis is a major producer of agarwood in Malaysia for international trade (Wong *et al.*, 2013). Some of the well-known natural populations of *Aquilaria malaccensis* in Malaysia are Sungai Udang in Melaka, Bukit Bauk in Terengganu, Gua Musang in Kelantan, Jelebu in Negeri Sembilan, and Jeli in Kelantan (Lee *et al.*, 2011).

Aquilaria malaccensis is absent from Sarawak while other species of this genus are reported rare (Tawan, 2004). Logging activities and ongoing forest conversion in Sumatra and Kalimantan might account for low densities of *Aquilaria* spp. in these two regions, although anecdotal evidence suggests that concessionaires do not fell *Aquilaria* species as the wood is not valuable for plywood (Soehartono & Newton, 2000).

Many studies have reported a reductionin the natural populations of *Aquilaria malaccensis* due to the high demand of agarwood. As a result, this species is classified as 'vulnerable' by the International Union for the Conservation of Nature (Anon., 2002). To make matter worse, *Aquilaria malaccensis* have been listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (Anon., 2011).

This endemic genus with restricted distributions has received concerns from foresters, biologists and naturalists who aim at conserving these species in the wild (Lee *et al.*, 2011). Overexploitation of the species in their natural environments is expected to be reduced by the development of massive *ex-situ* plantations combined with techniques able to induce agarwood production on young plants (Faridah-Hanum *et al.*, 2009).

The tropical rain forest plants contain diverse resources of biologically and chemically important components as they synthesize various chemicals as defense agents against pests, diseases and predators (Danial *et al.*, 2013). One way to conserve this valuable tropical tree would be to produce agarwood in a sustainable manner by mass planting the trees and collecting agarwood in non-destructive manner (Mohamed *et al.*, 2010). Thus, the knowledge gained from phytosociology study will contribute to the mass planting of *Aquilaria malaccensis* and indirectly could contribute to the conservation efforts.

Currently, research on the phytosociology of *Aquilaria malaccensis* such as detailed studies on its floristic aspects and its plant community level is literally unknown. In view of these, the main objectives of this study were to identify, characterize and classify the *Aquilaria malaccensis* and its communities which were naturally distributed in Sungai Udang Forest Reserve.

Materials and Methods

Study area: Phytosociological data of *Aquilaria malaccensis* trees were obtained from a forest reserve at Sungai Udang, Malacca, Malaysia (2°19′N, 102°8'E) (Fig. 1). The Sungai Udang Forest Reserve is a lowland Dipterocarp forest and is home to various flora and fauna. The trees were all within walking distance within a 100 m in radius. The data were collected within the boundary of 20 hectares of forest reserve known as Compartment 4 which were considered representative of *Aquilaria malaccensis* communities. The study areas in Compartment 4 are protected from any logging activities. Sungai Udang Forest Reserve was announced in 1987 as Permanent Forest Reserve area of the remaining approximately 335 acre of land area. The area has a rough topography and ranges in altitude from 10 to 90 m. The area has a tropical rainforest climate which is punctuated by much rainfall. The rainy seasons or heavy monsoon season occurs on October through March every year. The dry season occurs from May through July every year. The weather is warm and humid all year round with temperatures ranging from 21°C to 32°C. Mean annual rainfall of the study area was recorded as 2000 mm and it is considered as one of the driest area in Malaysia. Mean annual maximum and minimum precipitation was recorded as 74% and 35%, respectively. The relative humidity typically ranged from 54% to 96% throughout the year.

Vegetation sampling: Field surveys and data collection were done based on the techniques described by Braun-Blanquet (1964) and Fujiwara (1987). Fieldwork was carried out from September 2012 to November 2012 and from January 2013 until April 2013. A total of 25 plots (20 x 40 m) in size were constructed according to the line transect method. The size of the plot was estimated by means of a "minimal area" which was 800 m^2 in each plot. Plots were 20m separated from each other. The plots were located at various altitudes, expositions, inclinations, and relief. An effort was made to achieve high ecological and physiognomic homogeneity within each plot. Every plot was georeferenced with a Garmin GPS. Scientific names of each vascular species in each plot were determined. Cover or abundance data of all vascular plant species for each plot were verified using the Braun-Blanquet (1964) method. All vascular plant species in each plot with a trunk diameter at breast height (DBH) ≥5 cm were marked and numbered, and their diameters and heights were recorded. Trunk perimeter measurements were taken using a metric tape and tree height was estimated with the aid of a clinometer. These samples were classified in a phytosociological table according to their floristic composition. The vegetation layers in the forest were divided into five layers as shown in Table 1.

Data analysis: As for the numerical analysis, the cover or abundance valueson the scale of Braun-Blanquet were transformedinto the 1–9 ordinal scale of van der Maarel (1979). With the goal of identifying the floristic composition of these groups,this synthetic phytosociological table was elaborated by scoring species in percentage or constancy classes, according to Braun-Blanquet's scale. Lastly, the communities of the species were described based on all the 25 plots that were surveyed (Fig. 2).

Results and Discussion

Community Structure and Floristic Composition: A total of 80 species belonging to 79 genera and 40 families were found in all the 25 plots. The most abundant family was Euphorbiaceae with 220 individuals trees, followed by Myrtaceae and Anacardiaceae representing 212 and 197 individual trees, respectively. The most dominant species was *Syzygium* sp. (Myrtaceae) followed by *Elateriospermum tapos* (Euphorbiaceae) and *Spondias cytherea*(Anacardiaceae), respectively. A community known as *Aquilaria malaccensis – Artocarpus rigidus* communityand two sub-communities were determined in this study as shown in the community table (Table 2).

Aquilaria malaccensis – Artocarpus rigidus**community:**A total of 10 species belonging to 10 genera and 10 families were found in the *Aquilaria malaccensis – Artocarpus rigidus* community. The forest vegetation of this community was commonly distributed at altitudes of 30 m to 87 m. The pH of the soil of this community ranged from 4.11 to 4.95 for all the 25 plots clearly indicated that the soil had an acidic character. The soil of the community had high organic matter, rich in available macro elements such as Ca, K and P and is sandy-loamy, loamy in texture. This community exhibited 3 vegetation layers which were tree, shrub and herb layers. The tree layer was 15 m – 40 m high, with a 65%-55% general cover. The shrub layer was 2 m - 10 m high, with a 20%-35% general cover. Total coverage of the herb layer was between 15% and 25%, and reaches below 2m in height. The characteristic and differential species of the community were *Aquilaria malaccensis, Knema* sp., *Swintonia schwenkii,Ochanostachys amentaceae, Ixonanthes icosandra, Adina* sp., *Gironniera nervosa, Artocarpus rigidus, Garcinia* sp. and *Baccaurea parviflora*.

Aquilaria malaccensis trees in Sungai Udang Forest Reserve had been wounded or injured by the native people using traditional means in their attempt to gather agarwood (Mohamed *et al.*, 2010). Nevertheless, despite being wounded or the existences of a few clear areas and canopy openness due to tree felling, the *Aquilaria malaccensis – Artocarpus rigidus* communitywas protected against unconscious cutting and over-grazing due to its status as a natural park. This study shows that *Palaquium gutta, Endospermum diadenum, Agrostistachys longifolia* and several other species can be found in all the four vegetation layers and in several plots. Most of these species showed that they grow in colonies or in certain population. The trees of some species could grow as a group and spread across several plots (Kwan & Whitmore, 1970). Despite the existence of some species that were commonly distributed, this community also showed several species that have occurred only once or twice in all plots. This factor suggested that the tropical forest consisted of many aggregated species and small numbers of randomly distributed species (Hubbell 1979; Masaki *et al.*, 1992; Tanouchi & Yamamoto 1995; Yamamoto *et al*., 1995).

***Palaquium gutta* sub-community:** A total of 14 species belonging to 14 genera and 13 families were found in the *Palaquium gutta* sub-community. This sub-community occurred at altitudes of 30 m to 82 m. This sub-community was found on flat areas or slightly undulating terrain which occured on ridge area (0-10 degree). The soil of this sub-community had an acidic character, high organic matter and was loamy in texture. The coverage rates of tree, shrub, and herb layers were 70%-80%, 10%-20%, and 10%-25%; and the average heights were 30 m, 10 m, and 2 m, respectively. The characteristic and differential species of this subassociation were *Palaquium* sp., *Gordonia concentricicatrix, Lithocarpus* sp., *Sarcotheca monophylla, Endospermum diadenum, Pternandra echinata, Diospyros rigida, Dialium kingii, Sandoricum koetjape, Pithecellobium splendens, Memecylon* sp., *Durio* sp., *Pellacalyx* sp., and *Xanthophyllum* sp.

Some of the plots in *Palaquium gutta* sub-communitywere situated at the forest area with canopy gaps due to disturbance caused by branch and tree fall. These small and large gaps by all sizes of trees from small branches to large trees were created by strong windstorms. Large trees might be important for the formation of frequent and huge canopy gaps in primary forest (Numata *et al.*, 2006). Natural disturbances in tropical forest can be of different scale such as from the impact of a single fallen tree to the extent of the destruction of several hundred km^2 (Ting and Poulsen, 2009). Some invasive plant species penetrated into the floristic structure of this sub-community due to the effect of canopy openness. The removal of canopy trees inevitably increases light availability in the understory, thus facilitating invasion by light-demanding species (Padmanaba & Corlett, 2014).

***Barringtonia racemosa*sub-community:** A total of 12 species belonging to 12 genera and 11 families were found in the *Barringtonia racemosa*sub-community. This sub-community occurred at altitudes of 34 m to 61 m on slope areas (11-20 degree). The soil of this sub-community consisted of the limeless brown soil and this soil was acidic and loamy in texture. This sub-community was composed of tree, shrub and herb vegetation layers. The general coverage of the tree layer ranged from 75% to 90%, and heights ranged from 20 m to 35 m. Total coverage of the shrub layer was from 10% to 30%, and ranged from 10 m to 15 m in height. Coverage of the herb layer ranged from 10% to 20%, and heights ranged from 2 m and below. The characteristic and differential species of this subassociation were *Barringtonia racemosa*, *Calophyllum marcocarpum*, *Streblus elongatus*, *Elaeocarpus nitidus*, *Polyalthia* sp., *Artocarpus elasticus*, *Diospyros argentea*, *Adenanthera pavonina*, *Shorea leprosula*, *Azadirachta excelsa*, *Cratoxylum arborescens*, and *Ixonanthes reticulata*.

The soil of *Barringtonia racemosa*sub-community had a slightly basic character and low electrical conductivity, calcium carbonate, and K. Due to unfavourable environmental conditions such as high inclination and erosion, available macroelements (Ca, K, Mg, and Na), organic matter and salt were low. Steep slope also promoted and triggered the formation of a few landslip or landslide in the sub-community area. As a result, the floristic composition of this sub-community was poor. Phytosociological characters differ among aspects and position, even in the same vegetation type (Khan *et al.*, 2010). Species richness was lower in the communities nearby water sources suggesting intensive grazing and tramping than in the typical community of the drier zone. The distribution and abundance of plant species are influenced significantly by human and animal impacts (Ghazal, 2015). This factor suggested that grazing had changed the floristic composition and decreased the species richness in the area (Cheng *et al.*, 2013). Disturbance would reduce the potential height of trees from 25% to 50% (Ng, 1983). Floodplains, formed mainly of river sediments and subject to flooding, occurred during the rainy season at certain areas of low lying ground adjacent to the small stream of the *Barringtonia racemosa* sub-community, had contributed to the decrease of species richness in the area. Floods might contribute to the lower density of tree species in riverine and seasonal flood forests which would affect the growth of seedlings or saplings or even can lead to the destroy of the small trees (Khairil *et al.*, 2014). As a result of long flooding periods, floristic composition of a particular association may be changed (Yalcin *et al.*, 2014). Species composition and their population level fluctuate from year to year depending on the rains (Perveen *et al.*, 2008).

Conclusions

From the results of the present study it can be concluded that an excellent way to conserve this valuable tropical tree and its communities would be to know its composition and the ecological relationship between the species within its communities, and this could be achieved with a phytosociological studies.

The vegetation communities in Sungai Udang Forest Reserve needs prior conservation to sustain its diverse flora, and the restoration of *Aquilaria malaccensis* and its communities will become more feasible with all the basic information of the vegetationcommunities obtained from this phytosociological study.

High soil fertility promotes high species diversity and richness of an area. Therefore, soil characteristics of an environment should be the important criteria for its species distribution. The composition and distribution of species in this study could also be influenced by other environmental factors such as natural forest gap, altitude and the topography. This study is only a preliminary research, thus, further research should be made on those mentioned factors especially regarding the soil characteristics.

The lack of scientific information on the phytosociology study of vegetation in Malaysia made it very difficult to compare the floristic similarity of the association described in this study with other possible similar studies.

Thus, this study is useful as a main stimulus for further botanical documentation and to provide more information on the growth response of the mixed dipterocarp forest for the development of proper forest management. Besides that, this study also provides a better insight into the composition, distribution of the plant communities and of the main threats to their conservation.

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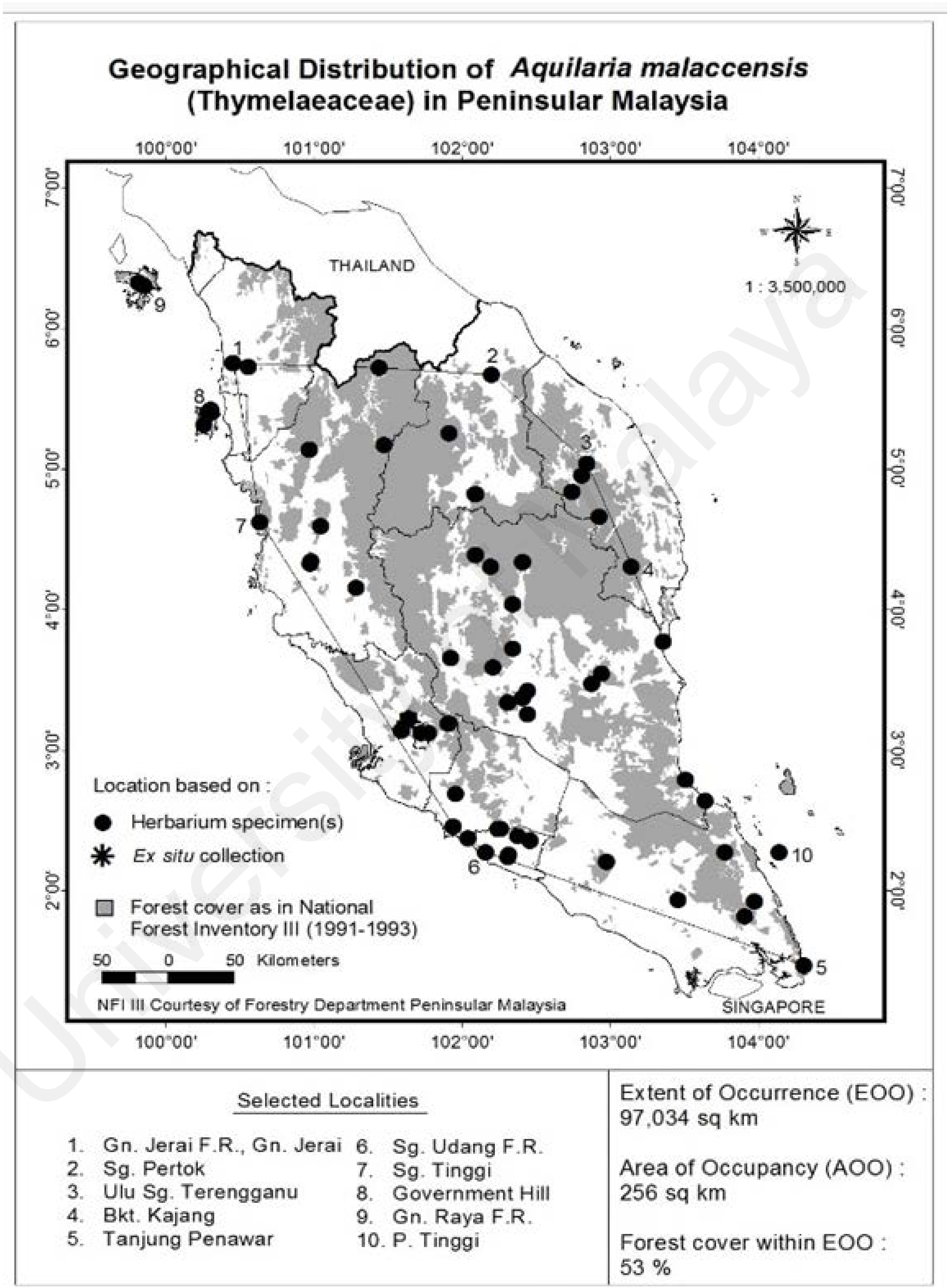
APPENDIX C DISTRIBUTION OF *AQUILARIA MALACCENSIS*



(Source: Forest Research Institute Malaysia)

APPENDIX D SUMMARIES OF RELATIVE DENSITY, IVi AND BASAL AREA

Species	Relative Density (%)
Syzygium sp.	12.6
Spondias cytherea	8.6
Elateriospermum tapos	7.7
Litsea firma	4.7
Porterandia anisophylla	4.3
Gironniera nervosa	4.1
Aquilaria malaccensis	3.4
Knema sp.	3.2
Baccaurea parviflora	2.8
Lithocarpus sp.	2.5
Swintonia schwenkii	2.3
Ochanostachys amentaceae	2.3
Palaquium sp.	2.0
Ixonanthes icosandra	1.8
Artocarpus rigidus	1.6
Adina rubescens	1.6
Barringtonia racemosa	1.6
Streblus elongatus	1.4
Diospyros rigida	1.3
Sarcotheca monophylla	1.3
Garcinia sp.	1.3
Polyalthia sp.	1.2
Durio griffithii	1.1
Calophyllum marcocarpum	1.1
Elaeocarpus nitidus	1.1
Dialium kingii	1.1
Gordonia concentricicatrix	1.0
Shorea leprosula	0.9
Diospyros argentea	0.9
Endospermum diadenum	0.9
Pternandra echinata	0.9
Hopea sp.	0.8
Azadirachta excelsa	0.8
Macaranga gigantia	0.8
Memecylon sp.	0.7
Sandoricum koetjape	0.7
Xanthophyllum sp.	0.7
Artocarpus elasticus	0.7
Pithecellobium splendens	0.6
Oncosperma tigillarium	0.5
Adenanthera pavonina	0.5

Koompassia malaccensis	0.5
Pellacalyx sp.	0.5
Eurycoma longifolia	0.5
Gynotroches axillaris	0.5
Cratoxylum arborescens	0.4
Ixonanthes reticulata	0.4
Callerya atropurpurea	0.4
Ixora sp.	0.4
Swintonia penangiana	0.4
Cyathocalyx sp.	0.4
Rhodamnia cinerea	0.4
Xerospermum noronhianum	0.4
Bouea macrophylla	0.3
Mesua ferrea	0.3
Aglaia sp.	0.3
Artocarpus scortechinii	0.3
Paratocarpus bracteatus	0.3
Ardisia sp.	0.3
Dillenia sp.	0.2
Drypetes sp.	0.2
Hydnocarpus elmeri	0.2
Ficus sp.	0.2
Baccaurea macrocarpa	0.2
Antidesma sp.	0.2
Blumeodendron subcaudatum	0.2
Sapium baccatum	0.2
Heritiera sp.	0.2
Buchanania subobovata	0.1
Dacryodes rugosa	0.1
Saraca sp.	0.1
Sindora sp.	0.1
Flacourtia rukam	0.1
Lansium sp.	0.1
Pandanus sp.	0.1
Urophyllum glabrum	0.1
Scaphium macropodum	0.1
Bouea oppositifolia	0.1
Xylopia fusca	0.1
Neesia altissima	0.1
Terminalia sp.	0.1
Parkia javanica	0.1
Dysoxylum sp.	0.1
Pertusadina eurhyncha	0.1
Adinandra sp.	0.1

Species	IVi (%)
Spondias cytherea	23.9
Syzygium sp.	22.8
Elateriospermum tapos	17.2
Aquilaria malaccensis	13.0
Artocarpus rigidus	11.7
Porterandia anisophylla	10.2
Litsea firma	9.4
Gironniera nervosa	7.9
Swintonia schwenkii	7.7
Aglaia sp.	7.2
Lithocarpus sp.	6.9
Knema sp.	6.6
Palaquium sp.	6.6
Endospermum diadenum	6.4
Ochanostachys amentaceae	6.0
Ixonanthes icosandra	6.0
Shorea leprosula	5.6
Baccaurea parviflora	5.4
Adina rubescens	5.2
Garcinia sp.	5.0
Dialium kingii	4.3
Barringtonia racemosa	4.2
Sarcotheca monophylla	4.1
Elaeocarpus nitidus	3.9
Calophyllum marcocarpum	3.9
Polyalthia sp.	3.7
Streblus elongatus	3.6
Gordonia concentricicatrix	3.4
Ixonanthes reticulata	3.3
Diospyros rigida	3.1
Pternandra echinata	3.0
Koompassia malaccensis	2.9
Azadirachta excelsa	2.8
Pithecellobium splendens	2.7
Artocarpus elasticus	2.7
Cratoxylum arborescens	2.6
Diospyros argentea	2.5
Callerya atropurpurea	2.5
Durio griffithii	2.4
Adenanthera pavonina	2.3
Sandoricum koetjape	2.3
Memecylon sp.	2.1
Macaranga gigantia	2.1

Species	IVi (%)
Artocarpus scortechinii	1.9
Xanthophyllum sp.	1.9
Paratocarpus bracteatus	1.9
Pellacalyx sp.	1.9
Oncosperma tigillarium	1.8
Hopea sp.	1.8
Eurycoma longifolia	1.8
Gynotroches axillaris	1.5
Rhodamnia cinerea	1.4
Dillenia sp.	1.4
Ixora sp.	1.3
Xerospermum noronhianum	1.3
Swintonia penangiana	1.3
Mesua ferrea	1.3
Cyathocalyx sp.	1.2
Dacryodes rugosa	1.2
Parkia javanica	1.1
Baccaurea macrocarpa	1.0
Sapium baccatum	1.0
Ardisia sp.	1.0
Blumeodendron subcaudatum	0.9
Ficus sp.	0.9
Bouea macrophylla	0.7
Heritiera sp.	0.6
Hydnocarpus elmeri	0.6
Drypetes sp.	0.6
Lansium sp.	0.5
Saraca sp.	0.5
Sindora sp.	0.5
Buchanania subobovata	0.5
Scaphium macropodum	0.4
Flacourtia rukam	0.4
Pandanus sp.	0.4
Antidesma sp.	0.3
Adinandra sp.	0.3
Urophyllum glabrum	0.3
Pertusadina eurhyncha	0.3
Xylopia fusca	0.3
Bouea oppositifolia	0.2
Neesia altissima	0.2
Terminalia sp.	0.2
Dysoxylum sp.	0.2

Species	**Basal Area (m2)**
Spondias cytherea	7.87
Artocarpus rigidus	5.11
Aquilaria malaccensis	4.81
Syzygium sp.	4.47
Aglaia sp.	4.39
Elateriospermum tapos	3.87
Endospermum diadenum	2.75
Shorea leprosula	2.43
Lithocarpus sp.	1.89
Porterandia anisophylla	1.71
Palaquium sp.	1.67
Swintonia schwenkii	1.65
Ixonanthes reticulata	1.31
Dialium kingii	1.24
Ixonanthes icosandra	1.07
Koompassia malaccensis	1.04
Litsea firma	0.94
Garcinia sp.	0.91
Gironniera nervosa	0.80
Elaeocarpus nitidus	0.80
Adina rubescens	0.80
Callerya atropurpurea	0.78
Sarcotheca monophylla	0.78
Paratocarpus bracteatus	0.77
Cratoxylum arborescens	0.76
Ochanostachys amentaceae	0.71
Artocarpus scortechinii	0.69
Pithecellobium splendens	0.60
Parkia javanica	0.57
Calophyllum marcocarpum	0.53
Dacryodes rugosa	0.53
Azadirachta excelsa	0.53
Polyalthia sp.	0.45
Gordonia concentricicatrix	0.45
Swintonia penangiana	0.43
Pternandra echinata	0.42
Knema sp.	0.39
Diospyros rigida	0.36
Artocarpus elasticus	0.36
Dillenia sp.	0.35
Streblus elongatus	0.30
Adenanthera pavonina	0.29
Oncosperma tigillarium	0.27

Species	Basal Area (m2)
Barringtonia racemosa	0.24
Xerospermum noronhianum	0.24
Hopea sp.	0.24
Sandoricum koetjape	0.24
Sapium baccatum	0.23
Rhodamnia cinerea	0.18
Pellacalyx sp.	0.18
Mesua ferrea	0.17
Blumeodendron subcaudatum	0.16
Gynotroches axillaris	0.16
Baccaurea parviflora	0.15
Macaranga gigantia	0.15
Xanthophyllum sp.	0.11
Ficus sp.	0.11
Baccaurea macrocarpa	0.11
Durio griffithii	0.11
Memecylon sp.	0.09
Bouea macrophylla	0.09
Heritiera sp.	0.09
Cyathocalyx sp.	0.08
Diospyros argentea	0.07
Lansium sp.	0.07
Adinandra sp.	0.05
Pertusadina eurhyncha	0.04
Ardisia sp.	0.04
Eurycoma longifolia	0.03
Saraca sp.	0.03
Xylopia fusca	0.03
Sindora sp.	0.03
Hydnocarpus elmeri	0.02
Buchanania subobovata	0.02
Bouea oppositifolia	0.02
Neesia altissima	0.02
Drypetes sp.	0.01
Scaphium macropodum	0.01
Ixora sp.	0.01
Flacourtia rukam	0.01
Terminalia sp.	0.01
Urophyllum glabrum	0.00
Antidesma sp.	0.00
Pandanus sp.	0.00
Dysoxylum sp.	-

APPENDIX E STATUS OF *AQUILARIA MALACCENSIS* IN CITES

	Appendices	
I	**II**	**III**
THYMELAEACEAE (Aquilariaceae) Agarwood, ramin		
	***Aquilaria* spp.** #14 ***Gonystylus* spp.** #4 ***Gyrinops* spp.** #14	
TROCHODENDRACEAE (Tetracentraceae) Tetracentron		
		Tetracentron sinense #1 (Nepal)
VALERIANACEAE Himalayan spikenard		
	Nardostachys grandiflora #2	
VITACEAE Grapes		
	Cyphostemma elephantopus ***Cyphostemma laza*** ***Cyphostemma montagnacii***	
WELWITSCHIACEAE Welwitschia		
	Welwitschia mirabilis #4	
ZAMIACEAE Cycads		
Ceratozamia* spp.** ***Chigua* spp.** ***Encephalartos* spp.** ***Microcycas calocoma	**ZAMIACEAE spp.** #4 (Except the species included in Appendix I)	
ZINGIBERACEAE Ginger lily		
	Hedychium philippinense #4	
ZYGOPHYLLACEAE Lignum-vitae		
	Bulnesia sarmientoi #11 ***Guaiacum* spp.** #2	