COMPOSITION OF RATTAN COMMUNITIES (ARECACEAE, SUBFAMILY CALAMOIDEAE) IN FOREST RESERVES OF PENANG

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UNIVERSITI SAINS MALAYSIA

2014

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by

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Thesis submitted in fulfilment of the requirements for the degree of Master of Science

September 2014

ACKNOWLEDGEMENT

Alhamdullilah, thanks to Allah I finally completed my study. I would like to express my sincere gratitude to my supervisor, Dr Asyraf Bin Mansor for his excellent supervision, guidance, help, support and great patience throughout this endeavour. I would also like to thank Universiti Sains Malaysia for providing the financial support (Postgraduate Research Grant, IPS) and research university grant without which I will not able to complete my research. Not forgotten, my gratitude is also extended to the School of Biological Science for Graduate Assistant Scheme (GA) for supporting my financial throughout my research.

I am also grateful to Dr Rahmad Bin Zakaria, Cikgu Abu Husin bin Harun, Dr Patrick Addo-Fordjour and Dr Amiruddin bin Ahmad for their valuable guidance, constructive ideas and willingness to spend times to help me during my study. Special thanks to lab assistants and all drivers from the School of Biological Sciences; Mr Syed Mohd Edzham bin Syed Hamzah, Mrs Afida binti Tahir, Mr Nizam , Mr Shunmugam a/l Vellosamy, Mr Mohd Sukor Harun, Mr Nordin bin Ahmad, Mr Kalimuthu Supramaniam who always provided excellent services during my sampling. Special thanks to all rangers from Penang National Park, Penang Hill, Bukit Panchor Forest Reserve and Cherok Tokun Forest Resrve and others who are not mention here.

Not forgotten, my deepest appreciation and thanks to all botany laboratory lab mates and friends; Shaodah binti Juperi, Mashitah binti Zainuddin, Nur Atiqah binti Zulkifli, Mariani binti Mohd Zain, Safinah binti Baki, Nur Zhafarina binti Ali, Norahizah binti Abd Rahim, Mohd Saiful bin Mansor, Adam bin Omar, Mohamad Syafiq Bin Mohd Johari, Allahyarham Ainol Fauzei and many others who directly or indirectly lend some helps for me.

My heartiest gratitude to my family whom endlessly supported me; my father, Mr Wan Rozali bin Wan Hussin, mother, Mrs Wan Lijah binti Wan Daud, Abang and my siblings for their love, encouragement and prayers.

TABLE OF CONTENTS

CHAPTER FIVE: DISCUSSIONS

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

Abbreviation		Caption
BP	=	Bukit Panchor
CCA	=	Canonical Correspondence Analysis
CT	=	Cherok Tokun
GIS	=	Geographic Information System
GPS	=	Global Positioning System
NTFP	=	Non Timber Forest Product
OM	=	Organic Matter
PH	=	Penang Hill
PNPK	=	Penang National Park
RH	=	Relative Humidity
SMC	=	Soil Moisture Content
SOIL TEMP	=	Soil Temperature
TEMP	=	Temperature
UPGMA	=	Unweighted pair-group mean arithmetic

KOMPOSISI KOMUNITI ROTAN (ARECACEAE, SUBFAMILI CALAMOIDEAE) DI HUTAN-HUTAN SIMPAN DI PULAU PINANG

ABSTRAK

Terdapat koleksi data yang terhad terhadap corak taburan, kelimpahan species dan komposisi spesies rotan di kawasan yang berlainan di negara ini. Satu tinjauan yang efisien akan menyumbangkan bahan biologi untuk meningkatkan pengetahuan botani dan ekologi. Kajian rotan telah dijalankan di empat hutan simpan iaitu Taman Negara Pulau Pinang (2,563 ha), Bukit Bendera (32 ha), Bukit Panchor (445 ha), dan Cherok Tokun (37 ha) dari September 2011 hingga September 2012. Matlamat utama penyelidikan ini adalah untuk mengkaji diversiti dan komposisi rotan (Arecaceae, subfamili Calamoideae) di hutan-hutan rizab terpilih dalam Pulau Pinang. Objektif kajian ini adalah untuk menyiasat kelimpahan dan diversiti spesies rotan, serta untuk menganalisis diversiti dan taburan rotan termasuk hubungannya dengan ketinggian (kajian kes di Bukit Bendera). Di samping itu, kajian ini juga bertujuan untuk menganalisis korelasi iklim mikro dan faktor tanah ke atas taburan rotan. Tambahan lagi, status regenerasi untuk setiap lokasi kajian juga telah dilaksanakan. Sejumlah 30 plot rawak (30 m X 30 m) telah dilakukan di lokasi yang berbeza bagi mengenalpasti rotan sehingga ke peringkat spesies. Sebanyak 5,482 individu rotan telah dicatatkan, mewakili 21 spesies rotan daripada lima genera. Bukit bendera merekodkan kelimpahan individu rotan tertinggi iaitu sebanyak 1,721 individu, diikuti Cherok Tokun (1,301 individu), Bukit Panchor (1,277 individu) dan Taman Negara Pulau Pinang (1,183 individu). Diversiti rotan di Bukit Panchor adalah paling tinggi dengan mencatatkan nilai tertinggi Shannon, H’=1.907 (11

spesies) diikuti oleh Bukit Bendera (H’= 1.730, 10 spesies), Cherok Tokun (H’= 1.645, 9 spesies) dan nilai terendah dicatatkan di Taman Negara Pulau Pinang (H’= 1.372, 6 spesies). Kajian mendapati genera yang berbeza mendominasi tempat yang berbeza. Contohnya, *Calamus* mendominasi Bukit Panchor (852 individu). Cherok Tokun merekod jumlah tertinggi bagi rotan dari *Daemonorops* iaitu sebanyak 822 individu. *Plectocomia* hanya hadir di kawasan pulau sementara itu *Korthalsia* dan *Myrialepis* mempunyai jumlah yang tinggi di Cherok Tokun. Mengikut Taburan rotan dengan ketinggian, terdapat tiga julat ketinggian yang telah dikelaskan iaitu rendah (<300 m), sederhana tinggi (300 m - 600 m) and tinggi (>600 m). Diversiti spesies rotan tertinggi dicatatkan di kawasan sederhana tinggi (Shannon, H’=1.744) diikuti kawasan paling tinggi (H’=1.582) dan kawasan rendah (H’=0.959). Kajian ini juga menunjukkan pengaruh ketinggian adalah lemah terhadap komuniti rotan mengikut Jadual Spearman’s rho correlation test. Spesies/persekitaran CCA biplot menunjukkan *Daemonorops brachystachys* dan *Calamus dieppenhorstii* boleh bertoleransi dengan bahan organik dan kelembapan relatif yang tinggi. *Calamus javensis, Calamus calospathus, Plectocomia griffithii* dan *Calamus penicillatus* bergantung kepada pH tanah yang tinggi dan intensiti cahaya yang tinggi. Hasil dalam kajian ini juga menunjukkan bahawa kadar regenerasi rotan di kawasan pulau adalah lebih baik berbanding di kawasan Tanah Besar berdasarkan anak pokok di kawasan pulau adalah lebih tinggi. Bagi kajian berkaitan ketinggian, kawasan tinggi mempunyai status regenerasi yang baik (i.e., anak pokok, pokok muda, separuh matang dan pokok matang yang tinggi) berbanding kawasan sederhana tinggi dan rendah. Analisis kajian ini membuktikan bahawa setiap kawasan kajian mempunyai diversiti rotan, kelimpahan dan status regenerasi yang berbeza, di samping perbezaan persekitaran mempunyai pengaruh berbeza terhadap spesies rotan.

COMPOSITION OF RATTAN COMMUNITIES (ARECACEAE, SUBFAMILY CALAMOIDEAE) IN FOREST RESERVES OF PENANG

ABSTRACT

There is a limited data collection on distribution patterns, species abundance, and species composition of rattan elsewhere in the country. An efficient survey will provide biological material to improve knowledge of botany and ecology. Rattan assessment was conducted in four forest reserves namely Penang National Park (2,563 ha), Penang Hill (32 ha), Bukit Panchor (445 ha), and Cherok Tokun (37 ha) from September 2011 to September 2012. The aim of this research is to study the diversity and composition of rattan (Arecaceae: subfamily Calamoideae) in selected forest reserves of Penang. The objectives of this study were to investigate the abundance and diversity of rattan species, and to analyze rattan diversity and distribution in relation to elevations (study case in Penang Hill). Besides, this study analyzed the correlation of microclimates and soil properties on rattan distribution. Additionally, the regeneration status of rattan in all investigated forests also had been evaluated. A total of 30 randomly stratified enumeration plots (30 m × 30 m) were established at different selected locations to identify rattans to the species level. A total of 5,482 rattan individuals were recorded in this study, representing 21 rattan species belonging to five genera. Penang Hill recorded the highest abundance of rattan species with 1,721 individuals, followed by Cherok Tokun (1,301 individuals), Bukit Panchor (1,277 individuals), and Penang National Park (1,183 individuals). The rattan diversity of Bukit Panchor was the highest as indicated by the high value of Shannon, H'=1.907 (11 species), followed by Penang Hill (H'= 1.730, 10 species), Cherok Tokun (H'= 1.645, 9 species), and Penang National Park (H'= 1.372, 6 species). It was found that different genera dominated different study sites. For example, *Calamus* was dominant in Bukit Panchor (852 individuals). Cherok Tokun recorded the highest number of rattan individuals from *Daemonorops* genus with total number of 822 individuals. *Plectocomia* species were only present in Penang Island, while *Korthalsia* and *Myrialepis* were highest in dominance at Cherok Tokun. In terms of rattan distribution based on elevations, the field surveys were divided into three elevations namely low (<300 m), middle (300–600 m), and high (>600 m). High diversity of rattan species was observed in middle elevation (Shannon, H'=1.744), followed by high elevation (H'=1.582) and low elevation (H'=0.959). The study also discovered that the influence of altitudes was weak on rattan community according to the table of Spearman's rho correlation test. The CCA species/environment biplot showed that *Daemonorops brachystachys* and *Calamus dieppenhorstii* can tolerate high organic matter and high relative humidity. *Calamus javensis*, *Calamus calospathus*, *Plectocomia griffithii*, and *Calamus penicillatus* depended on high soil pH and high light intensities. The findings of this study also revealed that the regeneration rate of rattan species in Penang Island was better compared to those species in Penang Mainland as the seedlings in Penang National Park and Penang Hill were significantly high. In terms of elevation, this study found that high elevation had better regeneration status (i.e., higher abundance of seedlings, young plant, and partly mature and mature rattan) compared to middle and low elevations. Present analysis revealed that each of the studied locations was different in rattan diversity, abundance, and regeneration status as well as different environmental variables has different influence on rattan species.

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Tropical rainforest is a unique natural heritage with a complex ecosystem (Abdullah, 2003), and is the richest terrestrial ecosystems among other forests (Turner, 2004; Harrison, 2005). There are four main layers of a rainforest namely the ground layer, the understory layer, the canopy layer, and the emergent layer (Lowman & Bouricius, 2003). The ground layer receives less than 3 percent of the sunlight, and is quite humid (Lowman & Bouricius, 2003). The competition for understory light is intense so little sunlight reaches this area, and this competition becomes an important limiting factor for plant growth (Ashton *et al*., 2011). Therefore, the forest floor generally consists of shade-tolerant shrubs such as ferns, seedlings, and palms (Lowman & Bouricius, 2003), and rattan is a large and diverse group of climbing palms (Siebert, 2005).

Rattan, which is mostly straggling or climbing spiny-palm with characteristic of scaly fruits, is a versatile plant (Belcher, 1999). Rattan significantly contributes great social benefits in providing source of income for local people especially to the poorer societies living near the forest (Dransfield & Manokaran, 1994). Rattan is predominantly distributed throughout Southeast Asia, the Western Pacific, and in the humid areas of Africa (Lalnuntlunanga *et al*., 2010). Rattan comes from the family Arecaceae, and found in diverse ecosystems but mostly concentrated in tropical mountain rainforests, tropical evergreen monsoon forests or secondary forests. A few species of rattan can be found growing in tropical semideciduous monsoon forest and in subtropical evergreen broad-leaved forest (Huangcan *et al*., 1996). No rattans are found growing naturally in other tropical and subtropical areas, or in the temperate regions (Pantanella, 2005). According to Dransfield and Manokaran (1994), there are about 600 rattan species in 13 genera. Virtually, all the species of rattan are used locally, but only about 50 are used regularly and commercially. According to Dransfield (1992), Peninsular Malaysia recorded 106 species with eight genera, followed by Sarawak with 105 species and 79 species had been documented in Sabah.

Rattan studies cover various research areas. Material scientists are interested in clarification of the quality, strength, and physical properties of rattan. They are also interested in determining the efficient use of different species of rattan, and in facilitating better utilisation of these lesser-known resources (Mathew & Bhat, 1997). Mechanical and morphological studies of rattan have been done by Sudarmonowati *et al*. (2004), Isnard (2006), and Isnard & Rowe (2008). The genetic studies of rattan have been done by Sudarmonowati *et al*. (2004), Ramesha *et al*. (2007) and Sarmah *et al*. (2006) as the first step for formulating strategies for the conservation (Lyngdoh *et al*., 2005).

1.2 Justification of study

At present, the resource of rattan is seriously threatened by the loss of its habitat as forests are transformed to agricultural and other land uses, and by the overexploitation of the remaining stocks (Dransfield & Manokaran, 1994; Arinana *et al*., 2008; Hirshberger, 2011). In all countries, rattan resources are declining rapidly, particularly those commercially valuable species and species with large diameter

(Hirshberger, 2011). As the world's demand for rattan and rattan products increases, there is a remarkable pressure on the natural population of rattans. Inventories of rattan resources do not exist in most producer countries, and where they do exist, they are out-of-date or just irregular approximations (Hirshberger, 2011). As the actual volume and growth rate of rattan resources are unknown, the annual permissible cut has not been determined. This situation leads to overharvesting of commercially valuable rattan resources (Hirschberger, 2011).

Apart from extraction pressures, rattans are also sternly threatened by deviations in land use patterns (Meitram & Sharma, 2005). The industry is now undergoing raw material scarcity. In order to manage rattan industry, many manufacturers mainly the larger manufacturers have reinforced their links with suppliers particularly the regional traders. Some of them have initiated the establishment of plantations. Rattan availability in the forests has turned out to be unusual due to overexploitation over the years, and now there is a need to grow them in plantation to meet various demands (Haridasan *et al*., 2002).

Malaysia is known to have abundant resources of rattan (Hamid &Suratman, 2010). However, there is lack of data available in rattan species composition in the Malaysian forests. Furthermore, there is a limited data collection on distribution patterns, species abundance, and species composition of rattan elsewhere in the country. Besides, there is no complete inventory of rattan available for other specific area (Hamid & Suratman, 2010). Despite of many laboratory works and ecological studies on rattan, there is a gap of information and documentation specifically on rattan's ecology in Malaysia. Studying species distribution patterns with multiple parameters and identifying which parameters are ecologically important thus need to be conducted (Fischer *et al*., 2011). Therefore, in order to integrate biological and ecological data, this study assessed the effect of topographic gradient (altitude and slope), microclimates, and soil properties (physical and chemical properties) on the distribution pattern of rattan diversity in selected areas in Penang.

Rattan species existence in Penang has not been fully documented, so this project would add a further dimension for botanical and ecological information as little is known about rattan botanically (Dransfield, 1979). Only a few studies have examined the ecological aspects of wild populations of rattans (Watanabe & Suzuki, 2008). An efficient survey will provide biological material to improve knowledge of botany and ecology. In addition to that, investigating the relationship of the floral community with environment variables will contribute to the understanding of process that affects biodiversity. Figure 1.1 describes the research flow.

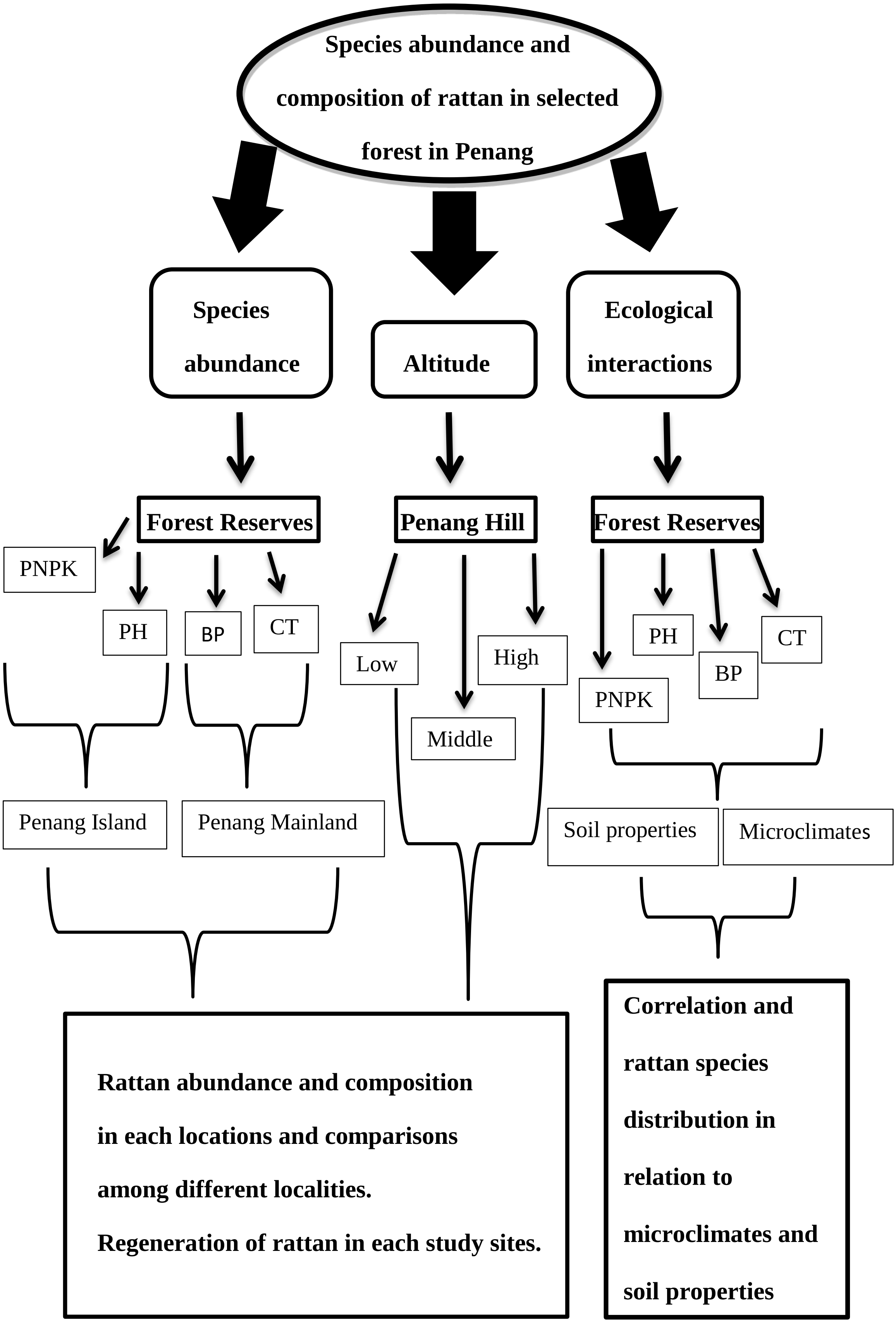

Figure 1.1: Research flow.

1.3 Study questions

Based on the literature search, the following research questions were addressed:

1) Do rattan composition and abundance vary among selected forest reserve in Penang Island and Penang Mainland?
2) Do rattan composition and abundance differ among different elevations?
3) Which is environmental factors influence rattan distribution?
4) What are the status of rattan regeneration within different locations and elevations?

1.4 Aims and objectives

The main aim of the study was to determine the composition of rattan communities (Arecaceae, subfamily Calamoideae) in four selected forest reserves of Penang. To narrow the knowledge gap of rattan diversity in Malaysia, this research was undertaken in the forests reserve of Penang to fulfill the following objectives:

i. To investigate the abundance and composition of rattan species in selected forest reserve in Penang Island and Penang Mainland.
ii. To analyze composition and distribution in relation to elevations (study case in Penang Hill).
iii. To analyze the influence of microclimates and soil properties factors on rattan distribution.
iv. To evaluate the regeneration status of rattan in all studied locations.

1.5 Hypothesis statements

In order to achieve the aims of this study, the following hypothesis were addressed:

Hypothesis 1:

There is difference in rattan composition and abundance in four investigated forests.

Hypothesis 2:

There is difference in rattan composition and abundance in all elevations.

Hypothesis 3:

There is correlation of microclimates, and soil properties on rattan distribution.

Hypothesis 4:

There is difference in rattan regeneration in all studied locations.

CHAPTER 2

LITERATURE REVIEW

2.1 Definition of rattan

Rattan has gained recognition as a valuable nontimber forest produce (NTFP) (Haridasan *et al*., 2002), which is a product of biological origin other than wood derived from forests or wooded land (Arinana *et al*., 2008). Rattan is prickly palm with edible scaly fruits and solid stem (Lalnuntluanga *et al.*, 2010). The stem is usually referred to as cane. Rattan is found in the tropical countries of Southeast Asia, Africa, and America.

The word *rattan* is derived from the Malay word "rotan", which is the local name for the climbing palm (Dransfield, 1979). Rattan is known as bet in Nepal, India, and Bangladesh, and is believed to be derived from the Sanskrit word "bethas", which means creeper (Paudel & Chowdhary, 2005). In Cambodia, "phdao" is a common name for rattan, and some villagers use the last name as a short form of "phdao soam", and sometimes they call it as "soam" (Hourt, 2008). Communities living in different areas use different local names for the same species, thus can lead to confusion (Hourt, 2008). The trade names for rattan are also very confusing and often do not conform with the botanical identity of the numerous rattan species (Weidelt, 1992). Occasionally, rattan is referred to base on its origin, such as Tongkin cane, Malacca cane, or Manila cane (Weidelt, 1992). Sometimes these names refer to the diameter ranges and regional names, and for some species, the names may also refer to certain processing stages (Weidelt, 1992).

2.2 Biology and ecology of rattan

Palms (Family: Arecaceae) belong to the monocotyledonous plants whose characteristic feature is the absence of secondary growth in diameter (Stiegel *et al*., 2011). Solitary and cluster-forming species are found among rattans however solitary growth in rattan is rare (Weidelt, 1992). Rattans are characterised by spiny stems and scaly fruits (Stiegel *et al*., 2011). The fruits are covered by a scaly pericarp. Inside is a fleshy sarcotesta with usually one seed embedded.

There are different types of rattan palms such as high or low climbers, which can be clustering or solitary rattan species (Dransfield, 1979). Some types have very short and underground stems, whilst several rattan species are known to reach lengths of 100 m (Dransfield, 1979). Clustering species sometimes possess up to 50 stems of varying ages in each clump, and produce suckers that continually replace the stem loss through natural senescence (Polthanee & Banterng, 2002). Stem diameter varies enormously in the different species, from 2 mm to 10 cm (Polthanee & Banterng, 2002). The diameter of rattan is usually smallest directly above the root collar, and increases in size up to the first meter (Weidelt, 1992). Rattans have no secondary diameter growth as there is no cambium layer. After germination, rattan grows at first like a rosette on the forest floor until it reaches its final diameter. Only then does the stem begins to lengthen (Weidelt, 1992).

All rattan species have pinnate leaves and can extend 0.5–2.0 m in length (Nagabhatla *et al*., 2007). In many species, the midrib extends into a whip-like organ with short, barbed spines called “cirrus”. For some species, the leaf sheaths also have a whip with barbed spines. This leaf sheath extension is called “flagellum” (Weidelt, 1992). Cirri and flagella are mutually exclusive as they are found either one in a species (Weidelt, 1992). Cirri and flagella are the climbing organs of rattans as they serve as a firm hold when the rattans make their way to the canopy (Weidelt, 1992). The outer part of the leaf sheaths covering the stem is covered with spines typical for each species, and used in identification (Weidelt, 1992).

Rattan canes are composed of different types of cells, each with a particular function. The arrangement and distribution of these cells play a significant role on its physical and mechanical properties (Yoshida *et al*., 2005). One unique feature of rattan canes is its ability to be moulded or to be reconfigured indefinitely (Yoshida *et al*., 2005). Appropriate amount of thermal softening process will not significantly alter the mechanical properties of the cane (Yoshida *et al*., 2005).

2.3 Importance and functions of rattan

Due to the strength, lightness, versatility, pliability of its stems, durability, elasticity, and natural resistance to impacts, this forest product has been widely utilised by furniture industry, or made into crafts and other household uses (Karki *et al*., 1996; Lapis *et al.*, 2004). Rattan is widely used for making furniture, and in handicraft industries (Aquino & Adriano, 2006). The quality of the cane depends on its age and maturity (Kwaku, 2006).

The role of rattan in the rural economy is very important as local people very much depend on rattan for their living (Blažková & Jeníček, 2006). Rattan supports the livelihood of many forest-dwelling communities (Meitram & Sharma, 2005). Rattan was the raw material readily available in the rural areas in the old day that local people used it to produce various utensils for their own use (Arinana *et al*., 2008). Extraction of forest products is commonly conducted by the poorer members of society who are not able to apply intensive farming, and who have few alternative livelihood sources (Widayati *et al*., 2010). In fact, cash income can be obtained from handicraft made from rattan (Arinana *et al*., 2008). Collectors estimate that rattan collecting can provide for their subsistence for about two months in a year (Belcher, 1999).

Rattan collection, trade, processing, and manufacturing operate with a complex and dynamic socioeconomic, political, and ecological contexts (Blažková & Jeníček, 2006), and widely recognised as an important domestic and internationally traded commodity (Blažková & Jeníček, 2006). Therefore, rattan becomes one of the most important nonwood forest products ecologically, economically, and socially important in Asian rainforests (Gentry, 1991; Noor *et al*., 1999; Stiegel *et al*., 2011). Indeed, rattan can be considered the "flagship" NWFP due to its unsurpassed importance in household, village, provincial, and national economies (Blažková & Jeníček, 2006).

2.4 Environmental factor influencing diversity and abundance of rattan

Species biodiversity is used greatly in vegetation studies, and environmental evaluation is one of the main criteria to determine the condition of ecosystem (Abedi & Pourbabaei, 2010). Species diversity has been found to have a correlation with many environmental factors because these factors are interacting with each other. Since 1980s, great progress has been made in quantitative research on the relationship among plants and their environments at a regional landscape level (Chahouki *et al*., 2012). Study on the plant community pattern has become one of the focuses of plant ecology research (Chahouki *et al*., 2012). In a broader sense, the plant community distribution pattern is influenced by many environmental factors such as climate, soil, and topographic features (Chahouki *et al*., 2012).

The relationship between rattan and environmental factors has been well-documented by Svenning (2001), Siebert (2005), and Watanabe & Suzuki (2008). Moreover, in natural populations, microenvironmental factors influence the growth rates of certain individuals (Bagh, 1996). Establishment of plant species depends on climatic, edaphic, and biological conditions (Azarnivand *et al*., 2010). Comprehensive analysis of the topography, soil, and vegetation relationship has been conducted in a number of studies. Such analysis is important subject of ecological and geographic studies (Auestad *et al*., 2008; Xua *et al*., 2008). Examples of factors affecting community composition include rainfall, temperature, moisture, availability of minerals, exposure, humidity, and soil properties (Gentry, 1988; Leach & Givnish, 1999). According to Chahouki *et al.* (2012), topography is a factor that explains the variation in soil properties and the distribution of plants.

Soil gives support in terms of moisture, nutrient, and anchorage for vegetation to grow effectively (Eni *et al*., 2011). Differences in chemical soil properties reflect species abundance pattern. However, changes in soil structure are also accompanied with slight degradation (Virágh *et al*., 2011). The higher susceptibility of vegetation to changes in short periods of time as compared to soils presents a problem for an establishment of vegetation-soil relationships (EI-Din *et* *al*., 1994). On the other hand, many species occur over a wide range of soil properties and other environmental factors, thus resulting in apparently similar plant communities on contrasting soils capable of producing different plant communities (EI-Din *et al*., 1994).

2.4.1 Microclimate

Microclimate can be defined as the climate at small scale, say from 0.01 to 1000 m (Oke, 1978). There are at least five variables that together characterise the microclimate, namely sunlight exposure, wind exposure (magnitude and direction), precipitation, temperature (of air and soil), and moisture content (of air and soil) (Davies-Colley *et al*., 2000). The natural world exhibits substantial variation in climate that influences the distribution, reproductive success, and survival of plants and animals. Microclimate, for example, can influence plants to successfully germinate (Tomimatsu & Ohara, 2004). Thus, microclimate can have a profound effect on local community structure and biodiversity. This is particularly true for plants because they are unable to move and thus are often limited by local environmental conditions (Fontaine *et al.*, 1978).

Besides soil properties (physical and chemical properties), other environmental variables, which include temperature, light, wind speed, and moisture provide meaningful indicators for habitat selection (Chen *et al*., 1996) for a particular species. Gradients in air temperature and humidity have a significant influence on the presence of some species (Godefroid *et al*., 2007). Microclimatic variables differ in the degree to and distance over which they show an edge effect (Gehlhausen *et al*., 2000). Distributions of individual species as well as changes in plant community composition indicate that competition may influence the response of the vegetation from the edge to interior gradient (Gehlhausen *et al*., 2000). According to Oliet and Jacobs (2007), microclimatic conditions influence morphophysiological development of plants. This development is a complex phenomenon that depends on environmental conditions. It is important to understand the potential impacts of small changes in local microclimate, and to understand the structure and function of local environments on plant distribution (Fontaine *et al*., 1978). Microclimates such as air temperature and humidity have a significant influence on the presence of some species, and the contribution of these environmental variables to the species composition and diversity has been documented by Godefroid *et al*. (2007).

2.4.2 Altitude/elevation

Elevation, geographical aspect, and slope are the three main topographic factors that control the distribution and patterns of vegetation in mountainous areas (Titshall *et al*., 2000). Among these three factors, elevation is the most important factor (Day & Monk 1974; Busing *et al*., 1992). Elevation is well-known to determine vegetation characteristics (Sundqvist *et al*., 2011). Moreover, elevation is also the most important variable in terms of variations in species diversity (Zhang and Zhang, 2007) as richness of organismic taxa declines with elevation (Rawat, 2011). The most common pattern is decreasing richness with increasing elevation, or called as hump-shaped pattern, in which diversity peaks at mid-elevations (Rahbek 2005; Mccain 2009).

Mathew and Bhat (1997), Siebert (2005), and Watanabe and Suzuki (2008) have found that other than microclimate influence, altitude factor also plays a major role in controlling the environmental variables. This factor also influences the composition and distribution of rattan species. Only certain rattan species can grow and establish well under optimum conditions. The vegetation types have a direct relationship with the regional altitude, and it has been an area of special interest for vegetation researchers since the early 19^{th} century (Mani, 1978). Vegetation of this geographically diverse zone is mainly controlled by rainfall and redistribution of water that decreases with the increase in altitude (Shaheen & Ahmad, 2011). In addition, altitude may also influence the characteristics of rattan species. For example, the diameter growth of young stem of palm family depends on the species, geographic location, and altitude (Pantanella, 2005).

Both community composition and abundance change along with altitudinal gradients (Sirin *et al*., 2010). Such changes are likely to occur as a result of several environmental factors that may or may not vary with altitude. Siebert (2005) and Stiegel *et al*. (2011) have documented rattan distribution in relation to elevation. Some species are restricted to certain altitude to obtain sufficient needs. Different altitude provides different essentials for each species, such as nutrient, soil organic matter, and soil pH (Siebert, 2005).

Rangeland plant community distribution and species composition are known to be related to specific soil properties such as soil climate (moisture and temperature), texture, depth, structure, fertility, pH, salinity, and toxic influences (EI-Din *et al*., 1994). Chahouki *et al*. (2012) revealed that edaphic factors such as texture, potassium, and organic matter play a main role in the distribution of plant species. Recent work by Harrison and Bardgett (2010) has shown that the effects of intraspecific plant-soil feedback also play an important role in mixed plant communities. According to Iwara and Ogundele (2011), vegetation and soil are interrelated and exert reciprocal effects on each other.

2.4.3 Relative humidity

Ashcroft *et al*. (2009) document the relationship between soil and air temperatures. The relationship is closely related to air humidity. Ashcroft *et al*. (2009) also state that a change in humidity may affect soil temperatures and thus the distribution of species, even if there is no change in mean air temperatures. High plant diversity is also due to fertility and humidity of sites (Abedi & Pourbabaei, 2010). A study stated that relative humidity is also one of the most important environmental variables that determine seedling microclimate (Spittlehouse & Stathers, 1990). This variable affects seedling survival and growth. In addition, Godefroid *et al*. (2006) document the effect of humidity on plant species. They revealed a significant correlation between plant species composition and humidity.

2.4.4 Air temperature

Air temperature and humidity are important factors for plants (Kitano & Eguchi, 1985). Change in humidity may affect the distribution of species (Ashcroft *et al*., 2009). Prasad *et al*. (2000) document the consequences and effect of air temperature on plant establishment. The high specific heat of water may affect the transfer of heat between soil and air. Therefore, the transfer of heat to the soil is more efficient when the air is humid and the soil is dry than when the air is dry and the soil is moist (Ashcroft *et al*., 2009). Apart from that, Flanagan and Johnson (2005) studied on the interacting effects of temperature, soil moisture, and plant biomass production on ecosystem. Amount and activity of plants can be reflected from the changes in environmental conditions (including temperature) that control plant growth, development, and photosynthesis (Flanagan & Johnson, 2005).

2.4.5 Light intensities effect

Light is also an important environmental factor affecting plant survival, growth, reproduction, and distribution (Liao *et al*., 2006; Devkota & Jha, 2010). Light intensity affects photosynthesis. Light intensity is also related to the accumulation of organic matter and biomass (Devkota & Jha, 2010). Different species however respond differently to light intensity (Devkota & Jha, 2010). Neri *et al*. (2003) state that there is a strong interaction among assimilation, light, and temperature. At high light intensities, the assimilation rate is significantly affected by temperature, but no positive effects have been observed at lower light levels (Neri *et al*., 2003). According to Hajiboland *et al*. (2011), increasing light intensities leads to increased stomatal conductance, transpiration, and CO_2 assimilation rate.

2.4.6 Wind velocity

The physiognomy, structure, and floristic composition of tropical vegetation exhibit marked changes with increasing altitude (Siebert, 2005). The harsh environment of the area imposes great constraints on plants, which must cope with aridity, extreme diurnal temperature fluctuations, and strong winds at the higher altitudes. Under such conditions, the productivity is generally very low, and the vegetation is most often sparse (Dvorský *et al*., 2011). In case of rattan species, if there is no support, or if the support is weak, the rattan will fall down abruptly or gradually due to its own weight or being blown by wind (Technical Report, 2007).

2.4.7 Slope/aspects

Vegetation patterns along topographical gradients may vary among different successional stages (Ozaki & Ohsawa, 1995). This is because competition is expected to be more important for determining species distribution in mature communities where total biomass approaches the carrying capacity of the habitat (Ozaki & Ohsawa, 1995). Topography has direct and indirect effects on plant distribution, and knowing the relationship between vegetation and topographic factors can be effective on the estimation of species kind for ecological management in different rangeland ecosystems (Tamartash *et al*., 2010).

According to Tamartash *et al*. (2010), different plant communities exhibit different correlations physiographic factors. On slopes, differences in species composition are explained by resource availability, especially water (Badano *et al*., 2005; Gong *et al*., 2008). Slope and geographical aspect have a major influence on the amount of solar radiation received above a vegetation canopy, and these factors have a much greater effect on site warming than on photosynthesis (Spittlehouse & Stathers, 1990). Physical factors (e.g., elevation, slope, and aspect) that limit tree regeneration may increase light availability to other plants such as herbs or shrubs, and contribute to diversification of plants species and communities (Coop *et al*., 2010).

2.4.8 Soil pH

Precipitation changes may lead to various species composition and soil pH (Montes *et al*., 2003). Among many soil properties, soil pH is one of the most important soil properties that provide a good indication of the chemical status of the soil, and can be used in part to determine potential plant growth (Londo *et al*., 2006). pH is one of the soil properties that largely determine the tree species that will grow on a site (Londo *et al*., 2006). The many reactions in the soil are largely controlled by soil pH (Londo *et al*., 2006). Trees may or may not be able to use nutrients because of these reactions (Londo *et al*., 2006). Soil pH influences nutrient uptake and tree growth (Londo *et al*., 2006), and determines the nutrient availability to plants (Hoffmann, 2010). Some nutrients become tied up in the soil at certain pH levels (Hoffmann, 2010). While most plants prefer neutral soil, some are suited to other pH levels (Hoffmann, 2010). All plants are affected by the extremes of pH, but there is a wide variation in their tolerance of acidity and alkalinity (Lake, 2000). Some plants grow well over a wide pH range, whilst others are very sensitive to small variations in acidity or alkalinity (Lake, 2000).

2.4.9 Soil moisture content

Soil moisture is an essential driver of most ecosystem processes (Liancourt *et al.*, 2011). Soil water balance is determined by multiple factors including precipitation, temperature, slope, and vegetation (Liancourt *et al*., 2011). The effect of soil moisture content on soil temperature is complex (Haskell *et al*., 2012) because soil moisture affects both chemical and physical properties of soils (Misra, 2003). Soil moisture regimes and different soils have a marked effect of the behaviour of important nutrient ions (Ibrahim *et al*., 2011). Soil moisture controls the evolution of vegetation cover and patterns, above- and belowground biomass production, soil erodibility, as well as the C and N soil turnover processes (Schneider *et al*., 2011). Germination of seeds and seedling emergence are also greatly influenced by soil physical conditions especially bulk density and soil moisture status (Nivedita, 1992). Seed germination varies with the species of the plant as well as with the soil moisture status (Nivedita, 1992). The effect of soil moisture is likely caused by direct effects on the activity of plant and microbe metabolic rates (Flanagan & Johnson, 2005). Soil moisture may be highly variable over time and space (Schneider *et al*., 2011).

2.4.10 Soil temperature

In general, soil temperature is related to air temperature (Kranenburg, 2007). Soil temperature could affect the growth of the plant (Reddell *et al*., 1985). Nutrients become available to the root as a result of root extension, and the rate of root growth depends on the soil temperature (Ungs, 1982). The effects of soil temperature and moisture are important for both herbaceous and woody plants (Haskell *et al*., 2012).

High temperature stress is one of the major uncontrollable factors affecting plant growth, development, and productivity (Marshall, 1982). Kranenburg (2007) states that plant growth is accelerated by increasing soil temperature. However, in the case of drought, extended periods of soil water deficit and associated high air and soil temperatures could affect a wide range of physiological plant functions (Wolchansky, 2005). Solar radiation, humidity, air temperature, wind speed, and soil temperature may all be altered along edges (Rowley *et al*., 1999). This soil temperature can have a dramatic impact on the vegetation and, ultimately, the wildlife (Rowley *et al*., 1999). Increased soil temperature and decreased soil moisture may prevent seeds of shade-tolerant species from germinating, and favour other plant species (e.g., species that thrive on increased light) (Rowley *et al*., 1999).

2.4.11 Particle size analysis

Particle size distribution of soil means the percentages of the different individual particle sizes in the soil. Particle size distribution may strongly influence many important physical and chemical soil properties such as soil water retention and nutrient storage capacity (Hernádi *et al*., 1998). One of the most common measures of substrate structure is particle size distribution (Dzal *et al*., 1999). Particle size analysis is a measurement of the size distribution of individual particles in the soil sample (Hernádi *et al*., 1998). This parameter measures the weight and volume fractions of the solid particles in the substrate (Dzal *et al*., 1999). Particle size also influences the volume of air and water held by the substrate (Ansorena, 1994; Samadi, 2011). Particle size distribution is important for describing the physical quality of the material and its suitability for plant growth (Samadi, 2011).

Soil texture and the properties influences such as porosity directly affect water and air movement in the soil with subsequent effects on plant water use and growth (McCauley *et al*., 2005). Soil particle has the ability to hold water as a thin film on individual soil particles and is said to be in adsorption (Rogers & Sothers, 1996), while water stored in the pores of the soil is said to be in capillary storage (Rogers & Sothers, 1996). This water storage in soil is an important function for plant growth and establishment.

2.4.12 Bulk density

Bulk density influences other soil physical factors especially soil temperature, moisture potential, total porosity, soil aeration, and hydraulic conductivity of the soil (Nivedita, 1992). The soil bulk density is important because it is a measurement of the porosity of the soil (Rogers & Sothers, 1996). Soil bulk density is used as a measure of soil compaction (Reichardt *et al*., 2006). The effect of increasing bulk density is considerable at low soil moisture contents (Nivedita, 1992). A compacted soil has low porosity, and thus a high bulk density (Rogers & Sothers, 1996), which can restrict the growth of the plants (Singh, 2010). Bulk density reduces the root length, and limits the root penetration growth in the soil (Singh, 2010). Restricted root penetration and elongation reduces the volume of soil that can be exploited by a plant for essential nutrients and water, which can eventually cause a reduction in total growth (Daddow & Warrington, 1983). This is because plant roots cannot penetrate compacted soil as freely as they would in noncompacted soil, thus limiting their access to water and nutrients present in subsoil and eventually inhibiting their growth (Hagan *et al*., 2013).

2.4.13 Soil organic matter

Soil organic matter (SOM) is understood today as the nonliving product of the decomposition of plant and animal substances (Manlay *et al*., 2007). Some consider SOM as a source of nutrients to be exploited, whereas others can afford to utilise it as a key component in the management of the chemical, biological, and physical fertility of soils (Craswell & Lefroy, 2001). Maintenance of adequate organic matter levels in the soils is also very important to maintain soil fertility (Lin *et al*., 2011). SOM tightly controls many soil properties and major biogeochemical cycles. Its status is often taken as a strong indicator of fertility and land degradation as organic matter contains mineral elements required by plants (Manlay *et al*., 2007).

The presence of organic matter, growing plants, and an active soil flora and fauna in most soils promotes stabilisation in soil (Gardner *et al*., 1999). Loss of organic matter can lead to a decline in soil structure (Gardner *et al*., 1999). This is because the formation of SOM promotes the capture of nutrients into its structure, especially the important nutrients namely N, P, and S (Horwath, 2005). Organic matter (OM) from the soil components is significantly correlated with species diversity. So, OM has a significant effect on species diversity (Fattahi & Ildoromi, 2011).

2.5 Spatial distribution effect

Natural variability in plant community species composition is shaped by complex interactions of biotic and abiotic factors acting at both local and regional spatial scales. Biodiversity varies geographically, and understanding why is one of the fundamental questions in biogeography, macroecology, and conservation ecology (Acharya *et al*., 2011). A different sampling area (or spatial scale) probably produces different values of species diversity. In other words, species diversity depends on spatial scale (Crawley and Harral, 2001; Wang *et al*., 2008). In addition, different diversity variables such as species richness and abundance respond differently to spatial scale (Wang *et al*., 2008). Species diversity and abundance are among the most important subjects of ecology and conservation (Watanabe & Suzuki, 2008).

Interactions between environmental controls on vegetation are manifested as changing relationships along an ecological gradient or through space (Danz *et al*., 2011). Plant distribution is controlled by environmental variables such as climate, soil, and topography (Jafari *et al*., 2004). Zuo *et al*. (2008) document the relationship between vegetation and environmental factors. They revealed that there are correlations among vegetation characteristics, soil properties, and geographic features. Pausas and Austin (2001) review patterns of plant species richness with respect to variables related to resource availability and variables that have direct physiological impact on plant growth or resource availability. The spatial dispersion of individuals in a species is an important pattern that is controlled by many mechanisms (Li *et al.*, 2009). Transition zones between biomes or biogeographical