LIANA DIVERSITY IN THE NORTHERN REGION OF PENINSULAR MALAYSIA

by

MOHAMAD SYAFIQ BIN MOHD JOHARI

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

March 2018

ACKNOWLEDGEMENT

In the name of ALLAH the Most Merciful and the Most Gracious Lord. I am very gratified for the ease He granted and blessing me mentally and physically until the final submission of the thesis.

In this contentment, I was very thankful to my diligent supervisor, Dr. Rahmad bin Zakaria for the time he had spared, all the knowledges he had taught, particularly his guidance in lianas ecology. Regardless his support, this study would be left in countless mistakes. I was also delighted for having Dr. Patrick Addo-Fordjour, a senior lecturer in Kwame Nkrumah University of Ghana for ushering me in several circumstances regarding data analysis and thesis writing. He helped a lot in coordinating and organizing the data.

To my parents, Mohd Johari bin Ali and Norliah binti Ibrahim, I thanked them for their persistent support, motivational guidance and prayers to escalating my spirit for the study completion. Millions of thanks to my fellow friends as well, Izzuddin, Syahir, Suhaimi, Safwan, Fakrul, Fawwaz, Nur Zhafarina, Nora, Kak Fasih, and others for their unanimous support.

I was also indebted to Mr. Abu Husin, Mr. Syed Edzham and Mr. Sukor Harun for providing me a great cooperation during field survey and they were very helpful to assist me logistically as well.

I owed a massive gratitude to USM Grant 1001/PBIOLOGI/811330 for sponsoring sufficient financial assistance to complete my research. Last but not forgotten, few other people that are not being mentioned here as their contribution and involvement are truthfully appreciated and invaluable to my research.

TABLE OF CONTENTS

CHAPTER FOUR: IMPACT OF HUMAN DISTURBANCE ON LIANA DIVERSITY AND ABUNDANCE. A CASE STUDY IN THE BELUM-TEMENGOR FOREST COMPLEX

CHAPTER FIVE: THE EFFECT OF TOPOGRAPHICAL VARIATIONS AND SOIL PROPERTIES TOWARDS THE DISTRIBUTION OF LIANAS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

a.s.l	above sea level
BTFC	Belum-Temengor Forest Complex
PHFR	Bukit Panchor Forest Reserve
PSP	Perlis State Park
GJ	Gunung Jerai
m	sample size for which diversity estimates of order q are computed; by default setting (in the left hand side of the screen), m represents the sample size for each of the 40 knots between 1 and the default endpoint (double the reference sample size). On the "General Setting", you can also either specify the endpoint and knots or specify the samples sizes for which you like to calculate diversity estimates.
method	interpolated, observed, or extrapolated, depending on whether the size m is less than, equal to, or greater than the reference sample size.
order	the diversity order of q you selected in the "General Setting" on the left hand side of the screen.
qD	the estimated diversity of order q for a sample of size m.
SC	the estimated sample coverage for a sample of size m.
qD.LCL	the bootstrap lower and upper confidence limits for the diversity of order q at the specified level in the setting (with a default value of 0.95).
SC.LCL	the bootstrap lower and upper confidence limits for the expected sample coverage at the specified level in the setting (with a default value of 0.95).

KEPELBAGAIAN LIANA DI BAHAGIAN UTARA SEMENANJUNG MALAYSIA

ABSTRAK

Tujuan utama kajian ini adalah untuk mengenal pasti dan menganggar kehadiran liana dari segi komposisi spesies dan famili dengan kelimpahan mereka di empat negeri pada bahagian utara Semenanjung Malaysia. Di Perak, kajian ini dijalankan di Kompleks Hutan Belum-Temengor diikuti Perlis (Taman Negeri Perlis), Pulau Pinang (Hutan Simpan Bukit Panchor) dan Kedah (Gunung Jerai). Kajian ini telah memakan masa selama satu tahun (Oktober 2015 - Oktober 2016) untuk menyiasat, memerhati dan menyelesaikan kerja lapangan untuk semua kawasan kajian. Dua kes kajian telah dijalankan untuk menyiasat kepelbagaian liana berikutan gangguan manusia yang berlaku terhadap mereka dan untuk menghubungkaitkan liana dengan ketinggian dan faktor edafik. Objektif kajian ini adalah, 1) untuk membandingkan komposisi dan kelimpahan liana di empat tapak hutan yang berbeza menggunakan analisis kelompok, 2) untuk menganggarkan kepadatan liana dalam jenis hutan yang berbeza iaitu hutan primer dan sekunder di Kompleks Hutan Belum-Temengor di Perak dan 3) untuk menghitung dan mengukur kepadatan liana di Gunung Jerai, Kedah berdasarkan ketinggian yang berbeza dan faktor edafik. Di setiap tapak kajian, liana telah di inventori di dalam 30 plot bersaiz 20 x 20m^2. Di Kompleks Hutan Belum-Temengor, sebanyak lima belas plot telah ditubuhkan di setiap jenis hutan sementara di Gunung Jerai, sepuluh plot digunakan di setiap ketinggian. Hanya liana dengan ukuran diameter paras dada (DBH) di atas 1.0 cm dan pada 1.3 m dari pangkal akar dikira. Sebanyak 168 spesies daripada 32 keluarga dan 1193 individu ditemui di semua kawasan kajian. Liana menunjukkan perbezaan yang signifikan dari segi komposisi spesies di kawasan kajian Kompleks Hutan Belum-Temengor dibandingkan dengan dua kawasan kajian yang lain iaitu di Taman Negeri Perlis dan Gunung Jerai (p=0.031, p=0.001), masing-masing, manakala tiada perbezaan yang signifikan dapat dikesan untuk Kompleks Hutan Belum-Temengor dan Hutan Simpan Bukit Panchor (p=0.346), Hutan Simpan Bukit Panchor dan Taman Negeri Perlis (p=0.708), Taman Negeri Perlis dan Gunung Jerai (p=0.999), Hutan Simpan Bukit Panchor dan Gunung Jerai (p=0.999). Analisis kluster menunjukkan perbezaan antara komposisi dan taburan spesies liana di semua kawasan kajian. Ketumpatan liana bertindak balas dengan perbezaan berikutan gangguan manusia di Kompleks Hutan Belum-Temengor. Terdapat kesignifikan di antara Taman Negeri Diraja Belum dan Hutan SimpanTemengor iaitu dari segi kekayaan spesies liana (p=0.007), Indeks Kepelbagaian Shannon-Weiner (p=0.009), Indeks Kepelbagaian Fisher Alpha (p=0.002), kelimpahan liana (p=0.001) dan keluasan pangkal (p=0.01). Walau bagaimanapun, perbandingan kaedah memanjat liana antara kedua-dua hutan terbukti tidak signifikan (p=0.885). Komposisi liana menunjukkan variasi dengan ketinggian (p <0.05) dan faktor edafik di Gunung Jerai dengan memaparkan perkaitan yang kuat dengan faktor tanah fisiko-kimia; kelembapan tanah, Ca, P, pH dan N. Melalui penemuan yang ditunjukkan, kepelbagaian dan kelimpahan liana adalah disebabkan oleh faktor persekitaran. Secara keseluruhannya, kajian ini merupakan batu loncatan untuk melengkapkan pemahaman yang lebih baik mengenai tingkah laku liana terhadap struktur hutan dan juga komuniti hutan.

LIANA DIVERSITY IN THE NORTHERN REGION OF PENINSULAR MALAYSIA

ABSTRACT

The major aim of this study were to identify and enumerate lianas existence in terms of species, family compositions and their abundance in the four states of the Northern Peninsular Malaysia, namely Perak, Perlis, Penang and Kedah. In Perak, the study was conducted in Belum-Temengor Forest Complex followed by Perlis (Perlis State Park), Penang (Bukit Panchor Forest Reserve) and Kedah (Gunung Jerai). It took one year (October 2015 - October 2016) to investigate, observe and accomplish the sampling for all study sites. Two study cases were deployed to investigate the diversity of lianas following human disturbance occurred towards them and to contemplate the association of lianas with elevation and edaphic factors. The objectives in the study are, 1) to compare the composition and abundance of liana in four different forest sites using the cluster analysis, 2) to estimate the density of liana in different forest types basically in the primary and secondary forest of Belum-Temengor Forest Complex in Perak and 3) to enumerate and measure the density of lianas in Gunung Jerai, Kedah based on different elevation and edaphic factors. In each study site, lianas were inventoried in 30 plots each with the size of 20 x 20m^2. In the Belum-Temengor Forest Complex, a total of fifteen plots were established in each forest type while in Gunung Jerai, ten plots were demarcated in each elevation. Only rooted lianas with the diameter breast high (DBH) above 1.0 cm and at 1.3 m height at the rooting base were counted. A total of 168 species from 32 families and 1193 individuals were discovered in all study sites. Lianas showed a significant difference in terms of species composition in Belum-Temengor Forest Complex study site compared with the other two study sites namely Perlis State Park and Gunung Jerai ($p=0.031$, $p=0.001$), respectively, whereas no significant difference detected in Belum-Temengor Forest Complex and Bukit Panchor Forest Reserve ($p=0.346$), Bukit Panchor Forest Reserve and Perlis State Park ($p=0.708$), Perlis State Park and Gunung Jerai ($p=0.999$), Bukit Panchor Forest Reserve and Gunung Jerai ($p=0.999$). The cluster analysis displayed the dissimilarity of liana species composition and distribution in all study sites. Liana density responded differently following human disturbance in Belum-Temengor Forest Complex. There is a significant different between Royal Belum State Park and Temengor Forest Reserve in terms of liana species richness ($p=0.007$), Shannon-Weiner Diversity Index ($p=0.009$), Fisher Alpha diversity index ($p=0.002$), liana abundance ($p=0.009$) and basal area ($p=0.01$) as well. However, the comparison of climbing attributes between both forests proved to be insignificant ($p=0.885$). Lianas composition showed a variation with elevation ($p<0.05$) and edaphic factors in Gunung Jerai by displaying a strong association with soil physio-chemical factors; soil moisture, Ca, P, pH and N. Pertaining to the findings, liana diversity and abundance are affected by environmental factors. Conclusively, this study was a stepping stone to better understanding on the behaviour of lianas in forest structure and forest community as well.

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Tropical forest is a unique ecosystem in the world that encompasses by vast distributions of flora and fauna diversity (Kricher, 1997). About 30 % of the global carbon storage and 32 % of the global primary productivity are generated by this forest (Malhi, 2012). With promising climates, it is essential for all plant growth form to survive and thrive in tropical forest and in return, it performs the complexity of forest structure (Hartshon, 1983). In Malaysia for instance, the forests covered more than one million hectares of land area made up of huge portions of protected and unprotected forests. These types of forest exhibit high diversity of biological communities and remarkably, gains a recognition as the most diverse ecosystems composed by countless of living things (Allison *et al.*, 1993). Hence, Malaysia has been acknowledged as one of the mega biodiversity hubs among the other eleven countries in the world. In conjunction with the conservation effort, the beauty and the precious value of the forests, several measures have had been enforced to prolong their life-span and productivity.

The study of lianas was crucial during the second half of 19^{th} century embarking the observations on their diversity, morphology, climbing attributes, aerial architecture and species composition (Darwin, 1865). Liana is a growth form, often mistaken as a grouped plant family but actually consist of different plant families with massive number of species; Leguminosae, Cucurbitaceae, Sapindaceae, Vitaceae, Smilaceae and others (Gentry, 1993). Lianas are often recognized as one of the plant growth forms that possessing a structural support with a variety of climbing mechanism to get to the tree canopy (Schnitzer & Bongers, 2002). In addition, the dependency of lianas is very high due to the flexibility of the stem thus it relies highly on support availability to grow on (Houston, 1995).

The existence of lianas has significantly changed the behaviors of competition between the other woody plants for various kind of sources such as light, water and soil nutrients (Schnitzer, 2005). Throughout the tropical forest ecosystem worldwide, liana emerges abundantly and diversely that consequently affect the tree growth and regeneration. Taxonomically, lianas come from a variety of families same as the other plant growth forms particularly trees, shrub and herbs. At present, the large scale of liana diversity comes greatly from the America and Africa (Hu & Li, 2015). A census recorded by Gentry (1991) described at least 9,216 climbing plants species were discovered which belongs to 97 families in America involving North and South America regions. An observation by Hu & Li (2015) stated a total of 12,382 climbers from 143 families and 1,415 genera are recorded in the Old World's region (Eurasia and North Africa) where 57 families with woody climbers only. Interestingly, in Peninsular Malaysia, liana diversity is composed by 1,420 species with the present of 81 families and 369 genera which further the recognition as the most diverse climbers discovered in Old World region (Hu & Li, 2015). Generally, several number of studies has reported that the most abundant families typically found in Peninsular Malaysia forest were composed of Fabaceae, Annonaceae, Arecaceae, Connaraceae, Sterculiaceae and Menispermaceae (Appanah *et al*., 1993; Gentry, 1991; Ghollasimood *et al*., 2011; Kammesheidt *et al*., 2009; Mohd-Ridzuwan *et al.*, 2014; Nurfazliza *et al*., 2012; Putz & Chai, 1987).

1.2 Justification of study

The scientific breakthrough on liana diversity for the last two decades has embarked the new future of ecology works based on forest dynamics (Parren *et al*., 2005). Lianas are included in the forest census because of their huge contributions towards forest ecosystem including forest regeneration and functioning (Parren *et al.*, 2005). Due to that, numerous researchers all over the world has pointed out their findings to assess and scrutinizing the specific roles of lianas toward forest ecological system.

Liana has often been neglected in ecological research as they only bring a nuisance to forest regeneration (Schnitzer & Bongers, 2002). Furthermore, human activities have led to the changes in forest dynamics by increasing the rate of lianas regeneration and further increasing trees mortality (Addo-Fordjour *et al.,* 2009). Structural changes of the forest for instance by forest fragmentation and logging activities has increased the rate of liana recruitment and infestation to impede tree regeneration (Schnitzer & Bongers, 2011). In fact, tropical forest sequesters around 1.1 Pg C per year^{-1} but depleted as liana proliferation takes over (Pan *et al*., 2011). As a unique plant growth form, lianas compensate partly the aboveground biomass storage but unnecessarily high as trees (Duran & Sanchez-Azofeifa, 2015).

The main objective of this study was to provide the estimation of liana species composition which is thriving and expanding in our vast tropical rainforest. Hence, this study was stressing on this unique plant form which has been relatively neglected by researchers as they are thought to play limited role in forest dynamics (Parren *et al.,* 2005). Although several poor issues were raised regarding lianas existence, but still they brings many good services to the forest ecosystem hence their contributions should not be abandoned. Lianas connect the entire forest structure and create interactions with other living things (Schnitzer, 2005). They are beneficial in several aspects including food supply services and has great potential for numerous medicinal values. Unfortunately, the paucity of liana information for all types of forest area in Malaysia has triggered researchers to profoundly understanding of their role and functions since there is insufficient statistics to interpret reasonable explanations.

Particularly, four study sites were selected in the northern part of Peninsular Malaysia and the enumeration of lianas took place at each site. The study goes deeper into several factors that ecologically associate the distribution of lianas as little is known about their influence in Peninsular Malaysia forest. Liana distribution are corresponded by several ecological factors including host availability, soil nutrients, topographic and disturbance but not necessarily occur in the same habitat depending on the locality they thrive. The study on environmental factors towards lianas is much needed to understand their distribution patterns and roles in the forest ecosystems (Nurfazliza *et al.*, 2012). To acquire more information about the importance of liana compositions toward the diverse forest ecosystem in Malaysia, extensive findings should be conducted rigorously.

Study questions

To provide a better understanding of this research, the following research questions were addressed accordingly:

I. Do liana abundance and composition vary among selected forest area in four states of northern Peninsular Malaysia?
II. Do liana composition and abundance differ based on different elevations?
III. Which environmental factors influencing liana distribution?
IV. How the density of liana affected different type of forests formation?

1.4 Aims and Objectives

The main goal of this study was to identify and measure the composition of liana communities in four selected state of northern Peninsular Malaysia state namely Penang, Kedah, Perlis and Perak. Thus, this study focused on these selected objectives:

1) To compare the composition and abundance of liana in four different forest sites using the cluster analysis
2) To estimate the density of liana in different forest types basically in primary and secondary forest of Belum-Temengor Complex in Perak
3) To conduct an enumeration and measure the density of lianas based on different elevations and edaphic factors in Gunung Jerai, Kedah

1.5 Hypothesis Statements

To elucidate the patterns of liana diversity and abundance, few hypothesis statements were established to determine if:

Hypothesis 1:

Alternative (H_a): There is a significant difference of liana species diversity in the four investigated forest study sites of Northern Peninsular Malaysia

Null (H_o): There is no significant difference of liana species diversity in the four investigated forest study sites of Northern Peninsular Malaysia

Hypothesis 2:

Alternative (H_a): There is a significant difference of liana evenness, richness and dominance in different forest types for primary and secondary forest area

Null (H_o): There is no significant difference of liana evenness, richness and dominance in different forest types for primary and secondary forest area

Hypothesis 3:

Alternative (H_a): There is a significant difference of liana community characteristics based on different elevations and edaphic factors

Null (H_o): There is no significant difference of liana community characteristics based on different elevations and edaphic factors

CHAPTER 2

LITERATURE REVIEW

2.1 Definition of Liana

Morphologically, lianas are distinguished from trees feature by the elongation of woody stem and it is permanently rooted to the soil (Schnitzer & Bongers, 2002). It uses trees for vertical support to reach sunlight purposes (Parthasarathy & Vivek, 2015). Most lianas do not require external support until they reach a decimeter up to a meter or a little bit taller (Putz & Mooney, 1991). Woody lianas can reach a length of over 900 meters long depending on several factors that influence their development, but it is very subjective to justify (Harris & Hutchinson, 2007). Lianas are being a daunting issue to the researchers because of the difficulty in censusing and identifying specifically due to their complexity of morphological characteristics (Nurfazliza *et al*., 2012). The leaves which are important to recognize a species often located on top of the tree canopies and it is less visible (Parren *et al*., 2005). The estimated number of liana species were less accurate because lianas are difficult to classify as a climber (Hu & Li, 2015). DeWalt *et al*., (2000) proposed that lianas could be enlisted as one of the pioneer habit of the tropical forest because of their ability to colonize rapidly.

The terms "lianas", "lianes" and "vines" are used to describe the physical characteristic of climbing plants (Parsons, 2005) or can be defined as woody climbers (Schnitzer & Bongers, 2002) and vines as herbaceous stem, literally (Hu *et al*., 2010). Rattans are also belonged to climber group but often excluded from many inventories as they are extremely abundant, luxuriant, diverse and taxonomically difficult (Parren *et al*., 2005). As monocots plant, rattans and grasses are excluded from numerous liana ecological studies because the absent of true wood but members from Smilacaceae family are still included as most of them are categorized as woody vines (DeWalt *et al*., 2000).

2.1.1 Morphological attributes

Lianas have an assortment of adjustment for connecting themselves to their host tree and climb upward the forest canopy (Schnitzer & Bongers, 2002). The advantage of using trees as the host provides more production of leaf for photosynthesis without investing too much on stem production (Leicht, 2014). Lianas have various kind of climbing mechanisms which are categorized as follows: (a) Twiners: stem and branch were possessing the twining method, with the capability of the tip for a young shoot and leaf branches to twine around the support trees. (b) Hook-climbers and stragglers: lianas that possess hooks mechanism passively assist them in climbing or lean on the hosts without attachment. (c) Root-climbers: attachment on the host by clasping method using the fibrous structure of aerial roots securing their positions (d) Tendril climbers: highly sensitive to contact with a host, possess organs of varied morphology, usually by curling around on a small diameter tree (Padaki & Parthasarathy, 2000).

Lianas are found to be abundant in the disturbed forest because of their superiority to capitalize in excessive amount of light despite experiencing water deprivation which is intolerable for juvenile trees (Schnitzer, 2005). In dry condition, liana successfully survived due to the presence of efficient root and vascular systems that assist the efficacy of water absorption compared of what a tree has (Graham *et al*., 2003). Anatomically, liana uses less energy in constructing the stem in contrast with trees (Holbrook & Putz, 1996). Furthermore, liana sap flow traverses at high pace alongside its transpiration rates compared with trees. A few researchers carried out the experiment to reveal this exercise in Panamanian forest (Andrade *et al*., 2004). They found that lianas were able to transpire throughout the dry season and nearly all of them remained evergreen whereas many of the trees shed their leaves. The possible reason behind this incident was supported by the ability of lianas to tap the water deep into the ground to securing water source (Wyka *et al.*, 2013).

Liana stems have unusual wide xylem vessels which offer low friction and delivers larger water volumes than trees had (Masrahi, 2014). In Saudi Arabia, two species were tested; *Cocculus pendulus* and *Leptadenia arborea* growing in the dry sandy plain by twining their stems over *Acacia* spp. trees. The wide distribution of these two species was peculiar since almost lianas were only found in the humid forest or along river banks (Gentry, 1991). This incident depicted the importance of liana attribute to survive in unconditional habitat. Variation among lianas species dominance is due to dispersal and vegetative sprouting abilities and non-specific habitat requirements as well as seed-predator abundance (Ewango, 2010). The possession of discrete morphological traits or physiological properties by any liana species affect the patterns of abundance respectively (Addo-Fordjour & Rahmad, 2015b).

Long-distance clonal colonization is very common vegetative production by the larger rooted lianas (Schnitzer *et al*., 2012) and has greater ability to produce multiple clonal ramets compared with trees (Putz, 1984). It contributes to the increase of liana abundance and basal area in the Neotropical forest (Yorke *et al*., 2013). Falling lianas from the canopy of trees lead to the production of a numerous number of ramets hence increasing the capability for new reproduction from their mother genet (Putz, 1984; Gerwing, 2004). These ramets can survive successfully if the host tree falls on the ground and it will re-root and climb back to the forest canopy. As the rate of disturbance increase, the number of lianas recruitment as clonal stems would be elevated. All of these functional traits possess by lianas helps them to dominate a habitat with a high number of individuals in accordance with the species level (Addo-Fordjour *et al.*, 2013a).

2.2 Importance and Functions of Liana

The current understanding of the ecology of lianas and their role in forest dynamics, however, has lagged well behind than the other most vascular plant groups (Putz & Mooney, 1991). The realm of liana existence is poorly understood and often perceived by researchers as a nuisance which brings more harm than good to the forest structure. Because relatively few understanding on appraising lianas and their ecology, researchers might have assumed that lianas play a limited role in forest dynamics and hence most contemporary community-level forest studies have excluded their appearance (Schnitzer & Bongers, 2002). Globally, numerous researchers have discovered the potential of lianas to provide valuable importance for ecological and economical benefits to other living things such as humans, animals and primarily to the forest community.

2.2.1 Ecological values

Generally, lianas add considerably towards forest plant diversity with various types of fruits and flowers providing a source of food for animals (DeWalt *et al.*, 2000; Putz & Mooney, 1991). Indeed, during dry season, lianas can produce leaves and flowers which provide critical resources for animals to feed on a stable food supply (Schnitzer, 2015). One of the morphological attributes of lianas with the long woody stem is to connect the entire forest with the strangling and various climbing method thus forming sturdy bridges on forest canopy for movement support (Putz, 2012). Consequently, it provides many arboreal animals with pathways to transverse the tree tops (Emmons & Gentry, 1983). According to Clark and Poulsen (2001), these arboreal animals plays a crucial role in dispersing the seed of lianas fruit they eat. Besides that, lianas offer securable accommodation and food from their foliar resources to several herbivorous insects largely from Lepidoptera, Coleoptera and Orthoptera groups (Pathasarathy *et al.*, 2015).

Lianas have a tremendous influence on forest composition and functioning (Schnitzer & Bongers, 2011) and play deleterious roles in many aspects including suppressing tree regeneration and increasing tree mortality (Putz & Mooney, 1991). Recently, a few studies have demonstrated the increasing roles of lianas (woody vines) in forest regeneration, species diversity and ecosystem-level processes, particularly in the tropical forest (Schnitzer & Bongers, 2002). The contribution of lianas to forest regeneration and competition, not only by competing directly with trees but also by differentially affecting tree species composition and thus changing trees competitive abilities among themselves (Schnitzer & Bongers, 2002). In addition, they contribute considerably to ecosystem-level processes, such as whole-forest transpiration and carbon sequestration (Schnitzer & Bongers, 2002). Thus, increasing carbon content in atmospheric could possibly elucidating the pattern of increasing liana abundance and biomass in the Neotropical forest (Yorke *et al*., 2013).

Lianas do have a higher proportion of leaf biomass during early successional stages (Putz, 1983) and may have contributed approximately 20% to canopy leaf biomass in tropical forest (Putz, 1983). However, lianas have shorter leaf lifespan than trees hence the amount of leaf litter much higher compared with trees during leaf senescence (Hegarty, 1990). Therefore, lianas might contribute a large component of nutrients on forest floor thus very crucial to re-establish nitrogen cycling process during early forest succession (Reiners *et al*., 1994).

The parasitic plant also invades the stem of lianas like in genus *Tetrastigma*. The pride of parasite, *Rafflesia* is an endophytic holo-parasites, which lack leaves and stems. They parasitize a small number of species of *Tetrastigma* (i.e., members of the grapevine family, Vitaceae) hosts, on which they rely exclusively for their nutrition (Xi *et al*., 2012). Species of *Balanophora*, are also fungi that occasionally parasitize the stem of *Tetrastigma*. *Rhizanthes* is another genus which is much rarer in appearance than *Rafflesia* has only been collected from three localities in Peninsular Malaysia. It is recognized by the earthstar with 14-16 pointed lobes (Cranbrook, 1988).

2.2.2 Economical values

Most economic appraisals of tropical forests concentrate on timber as the major product. However, large numbers of forest community actually provide a large variety of non-timber products consumed by millions of people around the world and these include all wild animal and plant products that are harvested from natural and planted forests (Ros-Tonen, 2000). Lianas are substantially important in remote areas where regular "modern" western medicines and various other products are not easily available and accessible (Abbiw, 1990; Van Andel, 2000; Arnold & Perez, 2001). Unfortunately, in several regions, the knowledge of useful plants is disappearing more rapidly than the plants themselves (Bongers *et al*., 2002).

Lianas constitute a very important group of non-timber forest products, as their presence becomes a useful natural product over the last decade (Bongers *et al*., 2002). Lianas are used in many different ways such as for the medicinal purpose, edible fruits, and domestic purpose (Muthumperumal & Parthasarathy, 2013). Liana has gained favorability for their fibrous stem for examples from the genus of *Gnetum*, *Smilax* and *Dioscorea* (Schnitzer *et al.*, 2008) because of the flexibility to making ropes, weaving baskets, hammocks and fishing nets (Philips, 1991). In the tropical region, people largely consumed on various species of *Dioscorea* and *Ipomoea* as their diet for daily servings (Philips, 1991). Some liana species have a significant important, for example, the discovery of one Cameroonian liana named *Ancistrocladus korupensis* which contains alkaloids to restrain HIV harmful activity (Foster & Sork, 1997). Numerous liana species are traditionally prescribed to treat various medical ailments such as eye inflammation, malaria and urinary infection (Tra Bi *et al.*, 2005). The extraction of liana leaves is widely used in the industry to obtain the natural component for ointment rather than the other part of the whole structure (Parthasarathy *et al.*, 2015). Milow *et al.*, 2014 described numerous liana species commonly found in Malaysia for their edible fruits and the potential to be commercialized for the future of economic industry.

2.3 Environmental factors affecting liana diversity and abundance

Liana diversity is greatly affected by several factors (abiotic and biotic) and the main focuses on several leading works are to describe only on the total species richness and abundance of liana species rather than the factors affecting their distribution. The factors are induced by a few abiotic factors like the total rainfall, seasonality of rainfall, soil fertility and disturbances (Schnitzer & Bongers, 2011) whereas biotic factors are constituted by elevation gradients, host interactions, soil properties. Light availability is the greatest limiting factor for plant recruitment and this factor corresponded to the limitation of nutrient accumulation in belowground as well (Coomes and Grubb, 2000; Cai *et al.*, 2008).

The limited capacity of aboveground and belowground resources are important for lianas to compete intensely in a vast tropical forest. As a part of vegetative community in the forest, lianas are capable of utilizing above and belowground resources efficiently and compete with other plant life forms for survival purpose.

Lianas are widely distributed as they acclimatize to the high amount of light and nutrients are because of greater competitive ability compared with trees due to their distinctive morphological traits (Schnitzer, 2005). Lianas are also strongly corresponded to any occurrence of environmental changes and this phenomenon can be curbed because lianas possess high phenotypic plasticity in their structure (Cai *et al*., 2008).

2.3.1 Elevation gradients

The distribution of liana diversity along altitudinal gradients was highly significant. The topographic variable also showing an affiliation with the accumulation of soil nutrients necessarily to provide a good condition for plants recruitment and development (Zhang *et al.*, 2014). Specifically, the main attributes of the topographic factor are basically comprised by elevation and slope. These two features are responsible for discerning the patterns of liana vegetative distribution (Zhang *et al.*, 2014). Liana preferred to survive on low and mid-elevation level compared to the top level in Gunung Ledang, Johor and the Western Ghats, India (Padaki & Parthasarathy, 2000; Rahmad *et al*., 2013). Only a few species were recorded at high elevation level which elucidated that liana diversity decreases as altitude increases (Balfour & Bond, 1993).

In Lambir National Park located in Sarawak, a discovery from liana inventory showed that the valley contains more diverse in lianas compared to the hilltop area. The reason behind this event was promoted by the availability of water potential which eventually enriched the soil to provide more nutrients in valley sites and further regarded to be a co-founder of counted lianas (Putz & Chai, 1987). This incident was explicated as the lower ground receives a high accumulation of soil, water and organic matter drained by erosion and runoff events from the higher ground (Troeh &

Thompson, 2005). Liana abundance and basal area differed among all topographic habitat amid some variations in soil properties. Liana community, diversity, and composition are lower in higher altitude because of extreme weathering reduces the decomposition rates of soil which are rich in iron sesquioxides, aluminum and clay aggregated by organic matter (Addo-Fordjour & Rahmad, 2015b).

2.3.2 Host interactions

The estimated percentage of all dicotyledonous plant to accommodate at least one representative climber are about 60% (Heywood, 1993). The behavioral of lianas was studied by looking at the host tree interactions from the circumnutation and phenotypic responses (Gianoli, 2015). Climbing mechanism determines the maximum diameter support a liana can use (DeWalt *et al.,* 2000). Nevertheless, to reach a maximum diameter size, large trees is required to support their weight although lianas are incapable of choosing their own host (Homeier *et al.,* 2010; Philips *et al.,* 2005). Specifically, liana attached to the trees is determined by a different climbing mechanism (twiners, hooks, clasping with adventitious roots and tendrils) and it depends on a certain species (Padaki & Parthasarathy, 2000; Putz, 1984).

Generally, stem twining was the most preferred climbing mechanism used by liana species and the most predominant climbing mechanisms among liana communities in the tropics (Addo-Fordjour *et al.,* 2008; Addo-Fordjour & Rahmad, 2015b; DeWalt *et al*., 2000; Laurance *et al*., 2001; Parthasarathy *et al*., 2004). Lianas apparently deployed twining method more than other climbing mechanisms in Sarawak (Putz & Chai, 1987) and the Western Ghats, India (Padaki & Parthasarathy, 2000). DeWalt *et al*., (2000) suggested that stem twiners predominated among all lianas sampled through various forest ages. The size of support influenced the suitability for twining lianas (Gianoli, 2015). They are capable of ascends larger diameter trees while lianas with tendrils appeared to attach on small diameter trees for structural support.

Climbers with tendril mechanism would be better suited to gaps and forest edges, where the smaller diameter of the host are more common, than forest interiors (Putz & Holbrook, 1991; Pathasarathy *et al.*, 2015). Tendril climbers seemed to be decreased in its proportion across the forest ages as the support availability increases their size (DeWalt *et al*., 2000). When the diameter of the host increases, liana will likely lose their attachment (Putz, 1984). Lianas with the aid of clasping method can attach dependently without regard to the diameter of the host (Putz, 1984).

Larger trees tend to support more individuals of liana rather than small trees. This exercise showed a great influence on liana species richness and abundance (Addo-Fordjour *et al*., 2009). The density of the host trees also demonstrates a substantial impact on the availability of liana present. Muoghalu & Okeesan (2005) found that liana species infested on trees more than in the family level. The positive correlation between 31-50 cm d.b.h of infested trees indicates that lianas favored to climb at particular trees and the selection of host were randomly chosen (Padaki & Parthasarathy, 2000). The variation of host trees are restricted to the Dipterocarps family since their structure are less susceptible to liana infestation as they often shedding their branches, has long clear bole which permits no liana attachment and has dense canopy to allow less light penetration (Campbell & Newberry, 1993; Kammesheidt *et al.*, 2009; Wright *et al.*, 2015).

2.3.3 Light availability

In a particular event when the forest suffered from a disturbance, it permits the large amount of light penetration (Kricher, 1997). The requirement of light varies between liana species due to phenotypic plasticity or genetic differentiation (Gianoli *et al.*, 2012). Lianas favor on high light availability because of their rapid growth in tolerance of light intensity and their presence in disturbed areas such as along waterways and treefall gaps are commonplace (Putz, 1984). Light availability shot up rightfully aftermath a disturbance and decreases rapidly as pioneer trees and other early-successional species closes the canopy (Brown & Lugo, 1990). Under its luxuriant proliferation, liana alters forest dynamics because they grow rapidly under canopy opening and manage to eradicate tree sapling growth in treefall gaps (Putz, 1984). The height of canopy influences the amount of light availability by increasing the abundance of lianas (Brown & Parker, 1994) and lowering the rate of seed establishment (Denslow and Guzman In press). Under the shade of dense canopy where the projection of light is partially restricted, the growth and survival of lianas are distorted by the means of low light intensity (Pathasarathy *et al.,* 2015).

2.3.4 Soil properties

In a spatial scale of geography, several layers of rocks underneath formed multiple sorts of soil parent material and this process leads to the variation of soil properties (John *et al*., 2007). Physical properties of soils constitute by their texture, depth, structure, porosity and consistency (Troeh & Thompson, 2005). Each component incidently made up other chemicals and biological aspects to form a complex structure of soil properties (Troeh & Thompson, 2005). Several trends has demonstrated the importance of soil properties to influence species composition in various habitats of tropical rainforest generally by the inception of several soil chemical (macronutrients and micronutrients) composed of phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) as well as soil moisture content (Sollins, 1998). The availability of soil nutrients is extremely influenced by the acidity of soil and relative concentration of nutrient limiting factor which inadvertently facilitates the growth and development of lianas (Troeh & Thompson, 2005).

2.3.5 Soil texture

The contribution of various soil textures is rather important for water holding capacity and the ability of the soil to store and releasing plant nutrients (Troeh & Thompson, 2005). Texture influenced the promotion of water availability, air and roots passage through the soil (Troeh & Thompson, 2005).

2.3.6 Soil pH

Significantly, soil pH might have impacted liana diversity and abundance by constraining the nutrient availability in the soil (Bagamba *et al.*, 2007; Troeh & Thompson, 2005). An average reading for soil pH in the tropical forest of Malaysia is between 3.4 -5.5 which demonstrate the high acidity content (Othman & Shamsuddin, 1982). It results from bases cation ($H^+$and Al^{3+}) which drained away from the soil causing high acidity (Lal & Greenland, 1979). Nutrients uptake by plants were hugely affected by the soil pH hence influencing the solubility of nutrients, microbial activity and physical properties of the soil (McCauley *et al.*, 2009). Furthermore, the acidity of soil also have an effect on the availability of several nutrients composed of Ca, Mg, K and P, for instance, the low acidic soil would lower the concentration of those mentioned nutrients, particularly occurs at pH<5 (John *et al.,* 2007).

2.3.7 Soil nutrients

One of the factors that influence the distribution of plants is by having a greater belowground resource of soil nutrients (John *et al.,* 2007). No matter how much the concentration utilized, the capability of each plant species as a nutrient consumer is very crucial to sustaining their life. Soil macronutrient were important determinants of liana diversity in tropical rainforest. On top of that, the availability of soil Magnesium (Mg) and Calcium (Ca) were identified as a major factor to correlate the diversity of liana and their respected abundance. Soil phosphorus (P) concentration and soil moisture are impactful to the abundance and basal area (Addo-Fordjour & Rahmad, 2015b). High concentration of P is related to the high content of organic matter and was also regulated by the presence of soil acidity.

There were several lianas species distributed along the pH gradients, ammonium-N gradients, nitrate-N gradients, Mg, K and P gradients (Nurfazliza *et al*., 2012). Soil cation concentration comprised by K, Ca and Mg were determined to be influenced in different plant-life form as cited by Sollins (1998). The accumulation of soil nutrients is controlled by other limiting nutrient based on the numerous studies that have been conducted (John *et al.,* 2007; Russo *et al.,* 2005). Basically, the nutrient limiting factor consist of two macronutrients namely phosphorus (P) and potassium (K) and these limiting elements can affect the growth of particular plant species, respectively (John *et al.,* 2007). Physiologically, the presence of nitrogen (N) is essential for liana seedlings to rapidly stimulate the establishment of leaves. Moreover, N availability is not a limiting factor for lianas to carry out photosynthesis as postulated by Cai et al. (2008) and has some influence to flourish the abundance of lianas (Homeier *et al.,* 2010).

2.3.8 Soil moisture

Liana proliferation influenced the amount of soil moisture as lianas have effective root systems to absorb high water content compared with trees (Reid *et al*., 2015). Soil moisture was strongly responded through the increasing of light intensity, warmer soil temperature and lower relative humidity for the current condition of forest interior (Reid *et al*., 2015). The soil moisture content is also highly regulated by the increasing seasonality as well as the total downpours occurs periodically and eventually influence the assemblages of lianas (Schnitzer, 2005). Tropical forest experiences lower amount of soil moisture during dry season which prompted a greater competition for water availability among liana and trees (Cai *et al*., 2009).

2.3.9 The relationship between topographic and edaphic factor in affecting liana distribution

Variation in topography is a major aspect to influence the heterogeneity of soil properties in the tropical forest. The availability of soil moisture, the concentration of soil nutrients and the acidity of soil along the elevation gradient were investigated to be strongly affected by the topographic factor. Hubbell (1998) emphasized on the distribution of tree species in Barro Colorado Island which recorded the highest species composition in slope region as compared with the upper land. Apart from that, Daws *et al.* (2002) further investigated that the density of lianas on the flatland habitat was higher than the slope habitat which indicates that the lower elevation maintains soil water potential effectively. These studies were concluded as the presence of adequate water catchment are presumed to cater their growth and regeneration. Reciprocally, the concentration of soil nutrients among the elevation heights were significantly differed as the result of leaching process that occurs from the upper mountain to the lower ground of a habitat. Soil leaching is attributed by water potential that drains to the lowest ground and this event inadvertently affect the solubility of soil nutrients concentration.

2.3.10 Human Disturbance

Generally, a disturbed forest caused by anthropogenic factors subsequently affect liana abundance and composition in particular forest for instance by illegal logging activity. Ground surfaces are vulnerable to the high intensity of light hence encouraging the proliferation of lianas as they respond rapidly with the increasing light penetration (Dalling *et al.*, 2012). Human disturbance could have influenced liana species dominance by causing the changes in liana species abundance, distribution and basal area in the disturbed forest (Addo Fordjour & Rahmad 2015b). Earlier studies have confirmed that disturbed area harbored higher liana diversity and abundance compared with undisturbed area (Schnitzer & Bongers, 2011).

Excessive lianas proliferation may affect the natural regeneration for tree sapling and seedling in disturbed forest thus can impede forest recovery process (Addo-Fordjour & Rahmad, 2015b). Liana proliferation unfavourably reducing the tree seedlings recruitment rather than in the less affected area. Apparently, liana favors thickening the disturbed forest because of high CO_2 present, high gap opening and high elevated sunlight (Gerwing & Farias, 2000). Over-abundant lianas in the disturbed forest has to be controlled to ensure the forest structure recover successfully (Addo Fordjour & Rahmad, 2015).

2.3.11 Natural disturbance

Recent studies have illustrated that disturbance could impede liana species diversity depending on the level of disturbances (Schnitzer & Bongers, 2002). For a small-scale of disturbances, treefall gaps were believed to maintain liana species diversity (Denslow, 1987) as lianas have anomalous stem anatomy and produce many rooting stems to colonize the gaps (Fischer & Ewers, 1991). Liana has higher probability to survive on gap-phase regeneration site rather than in non-gap sites (Schnitzer & Carson, 2001). For a larger scale of disturbances for instance hurricanes or any catastrophic events, it could increase liana diversity as what have been pictured in Panama and Florida (DeWalt *et al*., 2000; Laurence *et al*., 2001). The reason behind this situation was strongly influenced by the capability of lianas to colonize rapidly by producing many clonal stems in an excess light availability (Schnitzer, 2015). Somehow, liana distributions are obliged by the intensity of canopy disturbance that control the amount of light to reach the ground but this pattern are restricted to be driven only by the topographical factor (Dalling *et al.,* 2012).

2.4 Issues related to the existence of lianas on forest structure

Lianas are visibly found both in naturally and anthropogenically disturbed areas (Hegarty & Caballe, 1991) hence contribute substantially to the diversity and structure of a mature tropical forest (Gentry, 1991). Thus when trees fell, climbers accomplished temporarily in abundance and luxuriance. Likewise, gaps established by the removal of large trees soon becomes filled with an impenetrable tangle of climbers in which young trees grows with difficulty as the abnormal abundance of climbers is considered a character of young secondary forest (Richards, 1957). This close association between climbers and disturbed forest, treefall gaps, and forest margins has led to the suggestion that liana is a life-form that endorses intense light availability (Phillips, 1991; Putz, 1984; Uhl *et al.,* 1988).

High infestation of lianas also leads to the increasing volume of biomass therefore altered the tropical forest composition and dynamics subsequently (Schnitzer *et al*., 2011). The reason is because lianas have lower carbon content compared to trees and it does not compensate for tree biomass they displaced as they may increase tree mortality and reducing tree growth (Chave *et al*., 2001). This is one of the reason why silvicultural treatment that was popularly practiced during early 1970’s in selected forest area of Malaysia has successfully improved the growth, composition, and quality of timber products (Addo-Fordjour, 2013b). Management of liana is crucial in tropical forests as it has the capability to obstruct tree regeneration (Addo Fordjour & Rahmad 2015b).

2.5 Patterns of liana diversity and abundance in Malaysia tropical forest

Malaysia's tropical forest harbors high taxonomic diversity of lianas which is obviously distinguish our tropical forest from the temperate forest (Addo-Fordjour & Rahmad, 2015a). The patterns of liana distribution are influenced by rainfall, soil nutrients, seasonality and natural disturbances (Parthasarathy *et al.,* 2015). Lianas were diversified by the current disturbance occurred in forest edge and interiors of tropical forest (Schnitzer & Bongers, 2011). Liana established abundantly on low elevation, suggesting that available nutrients, light availability and water storage holds by the soil were contributing this phenomenon (Addo-Fordjour & Rahmad, 2015a).

However, comparative study between liana diversity and composition among woody plant species in Peninsular Malaysia, Sarawak and Sabah are relatively scarce. Researches have been focusing innumerably on tree ecology but plenty on lianas which is why their appearance are elusive in forest ecological studies. Only few studies have been conducted in several localities around Malaysia and the survey to estimate the proportion of lianas were accomplished by Ghollasimood *et al*., (2011) and Appanah *et al*., (1993). Ghollasimood *et al*., (2011) recorded a total of 9 % liana species among other woody plants from an inventory in Perak which constitute a lower proportion of lianas compared with tree species. Appanah *et al*., (1993) censuses about 30% of liana species composition over the counted trees species, in other way to illustrating that different forest habitat stores different floristic composition of lianas (Nurfazliza *et al*., 2012).

Apart from that, liana species diversity, composition, and structure were adversely affected by human disturbance compared with undisturbed area. The tendency of lianas to proliferate and propagate are strongly influenced by the suitability of host trees in which their availability are severely crippled by disturbance (Schnitzer & Bongers, 2002). Addo-Fordjour (2014) has observed this event in Penang National Park and further concluded that the current status of liana proliferation has illustrated the decreasing of basal area and species composition in response to human disturbance. However, liana species could maintain high dominance in disturbed forest indicates that human disturbances could also maintain liana diversity (Addo-Fordjour, 2014).

To measure the level of disturbance, variation of climbing mechanisms for liana individuals were often counted to correlate the diversity of lianas between disturbed and undisturbed forest. The most predominant stem twining method was successfully applied by liana assemblages in undisturbed area of Penang National Park (Addo-Fordjour, 2014) and Lambir National Park (Putz & Chai, 1987). This is consistent with previous studies conducted among liana communities in tropical regions throughout the world (DeWalt *et al*., 2000).

The topographic factor examined in different types of forest area in Malaysia demonstrate the significant variations in liana diversity and abundance. Topographical factor on liana distribution is co-vary with environmental factors (Addo-Fordjour *et al.*, 2013b) and does not depend solely on this factor. In Penang Hill Forest Reserve, liana species richness and their respective abundance recorded the highest number in flatland habitat and least in slope and valley habitat (Addo-Fordjour, 2014). The pattern is consistent with other localities as well (Mohd-Ridzuwan *et al.,* 2014; Nurfazliza *et al.,* 2012; Putz and Chai 1987) which reported that the abundance is remarkably highest in the lower habitat. Liana stem diameter and basal area were positively significant in flatland area than the other habitats (Addo-Fordjour, 2014).