ECOLOGICAL STUDY OF LIANAS AND SOME VINES IN MO SINGTO BIODIVERSITY RESEARCH PLOT, KHAO YAI NATIONAL PARK, THAILAND

KANOK LERTPANICH

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY (BIOLOGY)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY
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Kanok Lertpanich

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ECOLOGICAL STUDY OF LIANAS AND SOME VINES IN MO SINGTO BIODIVERSITY RESEARCH PLOT, KHAO YAI NATIONAL PARK, THAILAND

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ABSTRACT

The ecological study of lianas in Mo Singto Biodiversity Research Plot started with the survey of all stems of ≥ 3 cm dbh lianas. The 28.56 ha area contained 9510 stems (genets), which included 35 families, 116 species, plus six unknown species. The families Leguminosae and Apocynaceae had the most species. On the other hand the highest density families were Rubiaceae, followed by Apocyanaceae.

The lianas of ≥ 1cm dbh were censused in 40 sampling plots 20 x 20 m for the analysis of liana density and diversity. This dataset was also used with the constraint factors data for investigating the liana community in relation to environmental factors. The liana density of the four habitat types were not significantly different. The regression of ecological diversity (S or ln S) and ecological density (ln N) showed no differences among the four habitats, and the species richness was simply related to differences in the overall abundance among the habitats. The study found that the lianas of ≥ 1 cm dbh had a density of 26.9 ± 11.28 stems per 0.04 ha and diversity of 14.80 ± 4.68 species per 0.04 ha. The SHE analysis (species richness, diversity and equitability) was performed for the ≥ 1 cm dbh lianas in Mo Singto site dataset and found that the species conform to the logarithmic series distribution. The liana community had a log series alpha of 24.07 ± 1.96 and log series x = 0.98 ± 0.01 within the total 1.6 ha area.

The study of the relations between lianas and environmental factor was carried out by multiple regression analysis. This analysis was used for finding the key environmental factors that determined the liana density and diversity. The results showed that there was no significant relation between environmental factors and either liana density or liana diversity.

KEY WORDS: LIANAS/ ECOLOGICAL DIVERSITY/ ECOLOGICAL DENSITY/ KHAO YAI NATIONAL PARK/ ENVIRONMENTAL FACTORS/ ECOLOGY

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นิเวศวิทยาของเถาวัลย์ในแปลงศึกษาความหลากหลายทางชีวภาพมอสิงโต เขตอุทยานแห่งชาติเขาใหญ่ (ECOLOGICAL STUDY OF LIANAS AND SOME VINES IN MO SINGTO BIODIVERSITY RESEARCH PLOT, KHAO YAI NATIONAL PARK, THAILAND)

กนก เลิศพานิช 4137537 SCBI/D

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บทคัดย่อ

การศึกษาเถาวัลย์ในแปลงศึกษาความหลากหลายทางชีวภาพมอสิงโต พบว่าเถาวัลย์ขนาดเส้นผ่าศูนย์กลางระดับอกตั้งแต่ 3 ซม.มีจำนวน 9510 ต้น แบ่งเป็น 35 วงศ์ 116 ชนิด ไม่รวมเถาวัลย์ที่ไม่ทราบชนิด เถาวัลย์ในวงศ์ Leguminosae และ Apocynaceae เป็นวงศ์ที่มีจำนวนชนิดมากที่สุด ส่วนวงศ์ Rubiaceae และ Apocynaceae เป็นวงศ์ที่มีจำนวนต้นมากที่สุด

ข้อมูลของเถาวัลย์ขนาดเส้นผ่านศูนย์กลางระดับอกตั้งแต่ 1 ซม.ในพื้นที่ที่แตกต่างกันจำนวน 40 แปลงทดลอง ใช้ในการศึกษาความหลากชนิดและความหนาแน่นของเถาวัลย์ นอกจากนี้ข้อมูลนี้ใช้ร่วมกับข้อมูลของปัจจัยจำกัดเพื่อใช้ในการตรวจหาปัจจัยจำกัดที่กำหนดลักษณะของโครงสร้างสังคมชีวิตของเถาวัลย์ การศึกษาพบว่าไม่มีความแตกต่างอย่างมีนัยสำคัญระหว่างเถาวัลย์ในพื้นที่ที่แตกต่างกัน นอกจากนี้การวิเคราะห์ความถดถอยระหว่างจำนวนชนิดและจำนวนต้นของเถาวัลย์ในแต่ละพื้นที่ พบว่าไม่มีความแตกต่างกันอย่างมีนัยสำคัญระหว่างสี่พื้นที่ จำนวนต้นของเถาวัลย์มีอิทธิพลต่อความหลากหลายชนิด ดังนั้นสรุปได้ว่าเถาวัลย์ขนาดเส้นผ่านศูนย์กลางระดับอกตั้งแต่ 1 ซม.มีจำนวน 26.9 ± 11.28 ต้น และ 14.80 ± 4.68 ชนิดต่อพื้นที่ขนาด 0.04 เฮกแตร์ นอกจากนี้การวิเคราะห์ SHE (ดัชนีความหลากหลาย) พบว่าการกระจายตัวของเถาวัลย์เป็นแบบ logarithmic series โดยมีค่า log series alpha เท่ากับ 24.07 และ log series x เท่ากับ 0:98 ภายในพื้นที่ 1.6 เฮกแตร์

การศึกษาความสัมพันธ์ระหว่างเถาวัลย์ขนาดเส้นผ่านศูนย์กลางระดับอกตั้งแต่ 1 ซม. และปัจจัยสิ่งแวดล้อมโดยใช้การวิเคราะห์ความถดถอยเชิงซ้อน พบว่าจำนวนต้นและจำนวนชนิดของเถาวัลย์ไม่มีความสัมพันธ์กับปัจจัยสิ่งแวดล้อม

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CHAPTER I
INTRODUCTION

Ecological knowledge can be used for conservation or improvement of the ecosystems for human sustainable living on the earth. The changing of base sequences in the DNA can produce new characters in the phenotype. Consequently the changing of population occurs by the process of different base pairs passing their effects through the cell, organ, and individual levels during the process of natural selection. Moreover, the higher levels, such as community, ecosystem and finally biome, are affected by such alternations. Ecological research can provide the appropriate information to aid decisions on human economic development which may be harmful to other organisms. The lianas or woody climbers may be impacted by human wood harvesting. The lianas are frequently considered as agricultural and silvicultural weeds (1, 2). Research on lianas can lead to the proper treatment to lianas, which do not danger other levels of organization.

Lianas are an important life form in the forest ecosystem, especially in the tropical forest. The proportion of liana species is high in the forest ecosystems when compared with other life forms. The percentage of lianas on Barro Colorado Island is approximately 18 % of all vascular plants (3), similar to Gentry's studies (4, 5) which reported 24% and 18% of stems in the dry forest, and lowland moist, and wet forest, respectively. Moreover, liana diversity varies among regions, and estimated percentages are 10 % to 44 % of all plants (6, 7, 8), in the forest. Despite the high density and abundance of lianas in tropical forests; the study of lianas has been neglected compared with other life forms. The modern study was initiated on in 1984 by F. E. Putz (9), and since then the study of lianas has become a hot and interesting topic. However, in Thailand lianas studies are few. Ogawa, et al. (10) studied some functional parts of lianas in Thailand, long ago (1965). More study of lianas in Thailand is urgently required for conservation.

Khao Yai National park was the first established park in Thailand. It contains five vegetation types excluding the part damaged by slash and burn farming. The park provides habitats for many species animals and birds. The park can be accessed by two main routes, one is in Nakhon Ratchasima province and the other is via Prachinburi province. Good roads induce high numbers of tourists to visit. Not only the native tourists, but also the numerous foreigners make the trip and camp in the park. The high numbers of visitors can alter the forest ecosystem in the park, and may be harmful to forest structure. Moreover the park has many of *Aquilaria crassna* trees, which are exploited for aromatic medicinal and cosmetic substances. Poachers chop the stems and harvest the outer wood. This activity to obtain the aromatic oil causes stems of this species to fall. These activities may have important effects on in liana diversity and abundance. However, liana research can deal with the effects on liana populations whether by the tourists or by poachers. The alternation of liana density and abundance in the forest can change the forest structure and dynamics. Lianas can complete with trees, thus exert selection on the susceptible trees (11). The forest structure will be modified if liana density changes, which can be caused by the tourists, such as liana cutting to make a trail. The poachers create gaps in the forest, then the gaps provide the favorite conditions for lianas, which allows the lianas to increase in density and alter the forest structure. Such activities in the park can impact the forest community through the lianas. If the management does not have any knowledge of lianas, then the poor management practices may result and in the end finally unexpected environmental change may occur.

Lianas produce more biomass in photosynthetic parts than in stems, and therefore lianas have less total biomass than trees. The nutrients are used by lianas instead of being accumulated in woody tissues as in trees (12). This evidence is important for sivilcultural management. The lianas are considered as weeds in this point of view (1). Moreover in disturbed areas, the control of liana density can improve the forest tree stand structure, but liana management should based on the study of each particular area.

The lianas not only play important roles for forest community structure but also provide structural components and food resources in the habitat (13). Morellato & Leitao-Filho (14) reported that lianas reproduce during the periods unfavorable to trees; hence they will supply foods for animals during the opposite season. Emmons & Gentry (15) reported that many tropical primates utilized lianas, which made up 21

% of all food plant species. They also postulated that the variation of liana density among the continents may help to determine the separation of vertebrate locomotor adaptations in the tropical forests of Asia, Africa and Neotropical region.

The lianas produce many secondary plant products, which are used for defense against herbivores. Those compounds can also be used in medical applications (16). The indigenous peoples not only use lianas for medicine, but also for all kinds of fiber, such as roof and wire for weaving containers. Moreover, lianas are used as edible materials. For example, in many species of genus *Piper*, leaves, fruit, and bark are used for cooking or eaten raw.

The importance of lianas can attract researchers to further knowledge in various fields, based on their background; for example pharmacists can find new medicines in lianas. The ecologist can investigate the lianas for gathering information, which can be used in park management. Moreover, the lianas ecological attributes can help evaluate the status of liana diversity and conservation. However, the lack of liana studies in Thailand will make it difficult to evaluate the status of lianas, and then more advanced studies will not be carried out. This research aims to provide ecological information on lianas which can be used for liana management and further study.

Research objectives

1. To determine the floristic composition of lianas in the study area.

2. To determine the diversity and the abundance of lianas in the forest area. The collected data can be used to evaluate the liana community structure, such as species diversity, species richness and evenness indices. Moreover, the abundance of lianas over the area is studied with respect to habitat variation, which can affect the number of lianas.

3. To determine the relation between liana community structure such as abundance and diversity, and physical constraints such as soil nutrients, slope, elevation, and host tree features by statistical methods.

Research hypotheses

The previous studies suggest the following ideas.

1. The floristic composition of lianas in the study area is similar to that of other adjacent areas, but the dominant families should differ from other regions.

2. The different habitat sites in the study area contain similar densities and diversities of lianas.

3. The liana diversity and abundance are not strongly determined by environmental factors such as soil nutrients, terrain, and canopy structure.

Scope of the study

The study was conducted in the Mo Singto Biodiversity Research Plot, at Khao Yai National Park, Thailand. The study area is located in tropical rain forest ecosystem. The monitoring plot was enlarged to cover the whole area (approximately 29 hectares, 724 (20 x 20 m) sampling quadrats). All of the lianas ≥ 3 cm dbh, are inventoried. The liana individuals will be considered if they were composed of roots, stem and shoot, and were considered in the study if they were totally in plot boundary. The constraint factors and the lianas ≥ 1 cm dbh are collected from 40 (20 x 20 m) randomly selected quadrats. The data collection started at November 2001 and ended in November 2002.

Research outcome

1. The basic information on lianas from this research can be used for national park management. The role of lianas in the forest community can be made clear for everyone in the conservation and ecological points of view.

2. The database of lianas in tropical rain forest in Khao Yai National Park Thailand can induce other ecologists to do more advanced research with lianas, such as the studies of animal diets and seed dispersal, and studies of liana productivity, and studies of natural products from lianas.

Terminology

Vines are generally referred to as climbing plants, which need mechanical support to reach appreciable height. There are both herbaceous and woody vines, the latter generally referred to as lianas or lianes (17). However, Gentry (18) classified climber plants into 4 fundamental climbing strategies. Lianas are the first group, which are woody, relatively thick-stemmed climbers. The second groups are vines, which are thin-stemmed climbers; they usually referred to as herbaceous vines. However, many of them are subwoody. Both groups begin their life as terrestrial seedings but lianas can grow in mature forests. On the other hand, vines generally grow in disturbed areas or at forest edges. The other group begin their life as epiphytic seedlings with roots later reaching the ground. This group is called hemiepiphytes, and also includes stranglers. There are also other woody hemiepiphytes, which begin their life as terrestrial climbers, later sending out a adventitious root systems and/or losing contact with the ground. The last group is herbaceous epiphytes and hemiepiphytes, which include all herbaceous species that climb appressed to tree trunks and limbs, usually via adventitious roots, whether or not they ever establish contact with the ground.

The terminology of vines and lianas is confusing. The word “liana” in this study is considered as a woody, relatively thick-stemmed, climber (liana), but also may includes 2 other major groups of climbing plants, which were subwoody vines and woody hemiepiphytes. The liana group was the most abundant group. The other two groups contain fewer species and numbers. However, the herbaceous species and stranglers are excluded from this analysis.

CHAPTER II
LITERATURE REVIEW

Liana life form

Lianas are important features of the tropical rain forest (19). They are also called liane, woody climbers, bush ropes and woody vines (20). They are the independent woody climbing plants, which need other plants for mechanical support. Grubb et al. (21) used the term photophytic climbers for lianas which are shade tolerant only in the immature period and reach to the canopy when mature. Richards (19) suggested that lianas are conspicuous dicotyledons, of which the major families with lianas are Annonaceae, Apocynaceae, Bignoniaceae, Celastraceae, Combretaceae, Connaraceae, Convolvulaceae, Dilleniaceae, Leguminosae, Malpighiaceae, Menispermaceae, Passifloraceae, and Sapindaceae. Some investigators include some monocotyledons, which are also climbing palms (rattans). Prósperi et al. (22) suggested that lianas are usually considered as woody climbing plant, which begin their life in the soil. In the young stages, supporting materials for climbing are not important, and the growth rate is relatively slow. Rapid growth occurs in the ascending stage, and the mature stage occurs in the canopy, where reproduction occurs when exposed to the sunlight.

Lianas can reproduce by either seeds or by some portion of stems (23). Vegetative propagation can occur in the shoot system, during many periods of life (24). The successful climbing shoots will lean on the ground and produce an additional adventitious root system, ramify, and finally branch out and became the new individuals or ramets. Moreover, longitudinal of the stem occurs after fissuring in many liana species (24), in which the plant has a cleavage in the shoot structure. Such shoot fragmentation is a form of asexual reproduction, but other methods occur, such as stolons, flagella, basal shoot sprouts, and lignotuber formation (22).

The liana life form needs other mechanical support to reach the sunlight. However, climbing strategies vary among the different species. The climbing features and the alteration of the direction of growth due to the host can separate the climbing strategies into active and passive mechanisms (25). The active mechanisms include hooks, tendrils, branch climbing, root attachment and twining methods. On the other hand, scrambling and use of thorns are considered to be passive mechanisms. Twining is an efficient mechanism for ascending small diameter host trees, as this method invests more energy for elongating the stem around the host trees. The branch twining method uses leader shoots which coil around the host trellis and then other shoots climb upward to higher trellises in the same manner. The hook mechanism occurs in several species of rattans, which construct recurved spines on the distil extension of the leaf. Tendrils can grasp only small diameter supports, similar to branch twiners; tendril is a modification of the leaf. The root attachment method uses adventitious roots for creeping up the host trunk, without the obstruction of the large host tree diameter, but the surface of the tree trunk is an important factor. Scramblers use stiff branches for climbing, which extend into the lower canopy. Different climbing strategies can be associated with different leaf characters (26). For example, scramblers have lower leaf area and leaf weight than twiners. Moreover, French (27) found that twiners have longer internodes and more delayed leaf area development than tendril species. However, the lianas frequently use a combination of strategies for reaching to canopy (20). Rattans use their thorns to attach the host and their hooks on the leaf extensions for firm climbing.

Growth in secondary areas or gaps tends to be by vegetative propagation rather than by seed systems (9, 23). Seed reproduction occurs mainly during in the dry season (28). Seeds are dispersed either by wind or by animals. Gentry (4, 29) found that wind dispersal tends to occur more in the dry forest than in wet forests. In the wet forest seed dispersal occurs mostly by mammals and birds. After seed germination, the young liana requires high atmospheric humidity (30). Lianas invest a large percentage of biomass in photosynthetic surface and this surface turns over rapidly (31, 32). This implies that lianas invest the more energy in photosynthetic structures than in stems. Liana stems increase in diameter extremely slowly. The average rate of increase in stem diameter was found to be 1.4 mm per year on Barro Colorado Island (33). A large stem diameter is not an advantage in non self-supporting life forms. The small liana stems diameter can transport plenty of nutrients and water for a large leaf area if it has more efficient vascular tissues. The narrow stems of lianas have a high xylem flux (34). Lianas have wide xylem vessels which can increase water flux but lianas also have additional narrow and short vessels during growth which also seen to provide more water flux.

The thin stem character needs some mechanism to protect itself. The lower number of branches on the stem reduce exposure to herbivores when compared to trees in the forest stand. Moreover, Hegarty et al. (35) found among liana species approximately 17 % can produce toxins, such as alkaloids, for herbivore protection. The lianas stems have a flexible, strong quality, which allows them to bends and resist pulling forces. The lianas can pull the group of host trees down when one host tree has fallen (36).

Liana abundance and diversity

Lianas are found in greater abundance in tropical forests than in temperate forests (37). However in the temperate zone, the north temperate forests have fewer lianas than south temperate areas at equivalent latitude (38). Gentry (13) compared the lianas density among regions, and found that density in the same continent was similar and was not strongly affected by environmental factors. However, the density of lianas changes greatly from region to region, being higher in Africa and Madagascar than in Asia and the Neotropics. Liana species diversity varies between forest sites in a particular region or continent. In the Neotropics, liana diversity increases form dry forests to wet forests. The lowland pluvial forests have approximately 50 species per 0.1 ha, lowland moist and wet forests contain 30-40 species per 0.1 ha, and lowland dry forests have 15-20 species per 0.1 ha. In the same forest type, the mean abundance and diversity of lianas in the lowland tropical moist and wet forests are similar, although Africa has distinctively higher liana abundance (39).

However, the results of studies of liana density and species richness vary among individual sites. Putz & Chai (20) reported that liana diversity in primary dipterocarp forest in Lambir National Park, Sarawak, totaled 24 families and 79 species of >1 cm dbh were found in ten 20 x 50 m sample plots. Foster & Hubbell (3) studied the abundance of lianas which reach at least 10 m into the canopy on Barro Colorado Island, Panama. They found 8 families and 158 species in the 50-ha plot. Proctor et al. (40) reported that liana (including rattans) density in Gunung Mulu National Park, classified in 3 diameter classes (< 1 cm, 1 – 9.9 cm and ≥ 10 cm) and investigated in 4 habitats (twenty-five 20 x 20 m plots per habitat). The density varied from 32 individuals ha^{-1} to 14,400 (95 % confidence limits) individuals ha^{-1} at 95 mean values. Bulfour & Bond (41) presenting the data in a different way, and found that small diameter (< 1cm) lianas ranged from <5 climbers tree^{-1} to >30 climbers tree^{-1}, depending on habitat type. Makana et al. (42) studied diversity of lianas in the Ituri forest in Democratic Republic of the Congo. Lianas ≥2 cm dbh included 179 species (including stranglers) belonging to 20 families in a mosaic of mono-dominant stands of forest and 177 species in 25 families in mixed semi-evergreen forest. Kadaval and Parthasarathy (43) found that the species richness and density of lianas ≥ 5 cm girth in Kalrayan hill, south India, were 28 species and 134 stems ha^{-1} in Vellimalae and 19 species and 93 stems ha^{-1} in Devanoor. In a study of lianas in Yasuní National Park, Ecuador, 606 stems and 138 species were counted in two 20 x 100 m plots (44). Another study in Yasuní National Park, Ecuador, revealed 311 species and 4348 stems per 12 (1 ha) plots. In a comparison of habitats in Ecuador, Burnham found that Terra firme plots had an the average of 98 species whereas flood plain plots, had only 77 species. However, the density in the two habitats was not significantly different, ranging from 292 to 441 stems ha^{-1} (45).

Gentry (13) also found that in lowland Neotropical forests Bignoniaceae is the most important liana family, followed by Leguminosae. Other important families are Hippocrateaceae, Menispermaceae, Sapindaceae, Malpighiaceae, Connaraceae, and Dilleniaceae. In montane forests Asteraceae is the predominant family. On the other hand, Bignoniaceae is found sparsely in the Paleotropics, being replaced by Apocynaceae in Africa and Asia, and also by Annonaceae and palms in Asia as the predominant lianas. The recent work in Neotropics in Yasuní National Park, Ecuador found that Leguminosae, Dilleniaceae and Bignoniaceae were the most dominant (44). In central Panamanian lowland forests, Bignoniaceae and Sapindaceae are the predominant families (46). In eastern Amazonian forests, Leguminosae, (especially *Bauhiniaital guianensis* Aubl) are the most common lianas (47). Nevertheless a study in the Ituri forest of Democratic Republic of the Congo, presents a different result. Connaraceae and Euphorbiaceae are the dominant families (42). In Asia the predominant families are different among various study sites. The predominant families in Kalrayan hills in the Eastern Ghats, South India, are Rhamnaceae, Verbenaceae and Asclepiadaceae (43), contrasting with Lambir National Park, Malaysia, in which Icacinaceae and Leguminosae are the predominant families (20). Prósperi et al. (22) analyzed 15 years of data collected from the intertropical zone of America, Africa and Asia and found that the largest number of lianas species were in family Leguminosae. The following families were Asclepiadaceae, Apocynaceae, Malpighiaceae, Bignoniaceae, Passifloraceae and Hippocrateaceae.

However, liana diversity is independently associated with lianas density (46). Resource partitioning of lianas may occur. The type of climbing methods may be related to host tree species. The shade-intolerant lianas can grow in high light conditions; they need gap habitat to establish. Moreover, disturbance in the forest ecosystem can provide the particular light conditions and host trees for specific liana species (46). There is evidence that disturbance can maintain liana diversity (39).

Liana limiting factors

Many studies have presented correlations between lianas and their limiting factors. The limiting factors determine liana abundance in various ways. Gentry (13) reported that in the Neotropics, liana abundance increases with seasonality in rainfall. Putz (9) suggested that the liana growth form demands high light. Disturbed forests provide favorable conditions for lianas. Tree-fall gaps and forest margin closely relate with light intensity and liana abundance (48, 49). The altitudinal gradient is also correlated with liana abundance. Putz & Chai (20) reported that lianas in Lambir National Park, Malaysia, were twice as abundant in the valleys as on hilltops. The same result has been reported in a South African forest (41). The altitudinal gradient is closely associated with the level of base nutrients in the soil except for nitrogen concentration (41). Proctor et al. (40) found that lianas in Gunung National Park, Sarawak, Malaysia, more frequently occur in alluvial forests, where the nutrients came with the floods, than in the higher altitude forest. On the other hand, soil fertility was not positively correlated with liana abundance. Gentry (13) found that liana density in 32 neotropical forests varied in soil fertility; a similar result has been found in Mexican forest (50).

The requirement for mechanical support is characteristic of the liana life form; hence the host tree is also a limiting factor. Hegarty (51) suggested that lianas are not randomly distributed on their potential host trees. Trees with long branch-free boles on deep-crowned trees are not suitable for lianas to reach the canopy because the exposed surface area is small (52). Lianas on Barro Colorado Island, Panama, more frequently climb rough-barked trees compared with smooth-barked trees (53). Regarding host diameter, lianas are favored to climb the trees ≤ 70 cm dbh, thus trees larger than 70 cm dbh are usually found without lianas (54). Putz (52) suggested that spiny-trunk trees carry lianas less frequently than spine-free trees because the spines damage liana stems during wind blowing. More flexible tree stems are less susceptible to lianas, because they have the swing mechanism for shedding lianas. Very long leaves or large compound leaves or a leaf-like branch structure can prevent liana infestion, as such leaves cannot hold the lianas stem weight.

Lianas and forest community

Lianas contribute to forest community structure in diverse ways. Appanah & Putz (37) reported that lianas pulled groups of host trees down when one member host tree was felled. Consequently, lianas in open areas such as tree-fall gaps and logging areas inhibit forest regeneration and decrease the growth rate of trees. Lianas often cause mechanical damage to host tress. Finally, lianas increase the mortality rate of trees (11). Hegarty & Caballe (25) emphasized the important role of lianas in the forest community; they contribute floristic, structural, and functional parts of the tropical rain forest. Moreover, lianas cause mechanical damage to their hosts by strangulation and mechanical abrasion (55). In the Temperate Zone, lianas make hosts more susceptible to ice and wind damage (56). These effects may control the growth rate of the host tree. Richards (19) suggested that twiner species may have a marked mechanical effect, which is the spiral grooved marks in the tree trunk, and the liana's weight often breaks the branches. However, Steven (57) found that the number of liana loads did not demonstrate a positive correlation with the growth and reproduction of the host tree at Santa Rosa National Park, Costa Rica.

Below-ground competition also occurs between lianas and trees. Dillenburg et al. (58) studied the above-ground and below-ground competition between 2 lianas species, *Lonicera japonica* and *Pathenocissus quinquefolia* and the tree *Liquidambar styraciflua*. The result showed that below-ground competition, especially in soil nitrogen, was stronger rather than light competition. However this study found that the competition for soil moisture did not occur on the study site which was provided with plenty of water. Competition for water between lianas and trees cannot explain the trend, the similar studies found the opposite results (59, 60).

Pioneer trees have opportunities to survive in gaps, which are created by lianas. The lianas can create gaps by increasing tree mortality and also by pulling other trees down if one of the host trees falls. Moreover, the gap can maintain a high light zone for up to 20 years by the lianas' suppression of tree growth; this condition can promote the pioneer trees (9). The occurrence of lianas in a particular site can be a selective force for some species of trees in the forest and help construct a specific forest community structure.

The lianas are more frequently found in young stands than in old growth forest. Dewalt et al. (46) found that the younger forest (20 and 40 years) had greater abundance and diversity of lianas than the older forest (70, 100 year and >500 years old growth). The older forests contain conditions unfavorable to lianas, such as lower overall light levels and poorer habitat for liana seedling establishment (61). The older forests contain higher liana density in the understory but the young plants cannot reach the canopy (9). Regarding liana diversity in the forest community, Dewalt et al. (46) suggested that all liana species can survive in the younger forests. Only a few lianas species can occur in many different ages of forest stands. However, the old growth forest frequently had long lived lianas, resulting from increasing liana size with stand age. Moreover, some climbing methods restricted the survival of lianas in some successional stages. In the succession process, the relative abundance of tendril climbers decreased, while that of twiners increased (46).

Khao Yai National Park

Khao Yai National Park was the first national park created in Thailand. It covers 2172 km^2 in the northeast and lies between $14^{\circ} 10'$ N and $14^{\circ} 35'$ and between $101^{\circ} 05'$ and $101^{\circ} 50'$ E. The park boundary is located in 4 provinces: Saraburi, Nakhon Ratchasima, Prachinburi, and Nakhon Nayok. The average altitude on the mountain is 600-1000 m and the mountain top covers 834 $km.^2$ The lowest area is located at Klong Wang Ta Krai (60-160 m) and the highest area is Khao Rom ridge (1351 m). The southwest monsoon from Indian Ocean influences the annual precipitation of 2000-3000 mm, which falls mostly during May to October. The dry season begins in November and ends in April. The average annual temperature is 23° C and ranges between 5° C to 30°C. The highest temperature is in April and May and the lowest in December and January. These conditions constitute average humidity at 86%. The park provides habitat for 25 large mammal species. There are also 40 small mammals species and 318 species of birds (62).

At least eighty percent of Khao Yai National Park is forest. There are 5 vegetation types and the dominant regeneration type is moist evergreen forest, occurring from 500-1000 m above sea level, which covering 60% of the park. The east and south slopes are covered by dry evergreen forest at elevations between 200-400 m. Dry mixed deciduous forest occurs from 300-600 m along the northern edge of the park. Hill evergreen forest occurs at elevations above 1000 m on Khao Khieo ridge. The grassland and secondary growth were created by slash and burn farming before park establishment (63).

CHAPTER III
METHODOLOGY

Floristic composition inventory

Lianas were studied in the 20 x 20 m (400 m^2) quadrats, laid out in the Mo Singto Biodiversity Research plot. The study plot is located in a tropical seasonal evergreen forest ecosystem. The monitoring plots were enlarged to cover the whole area (approximately 724 plots), and the sample quadrats were located in various habitats. Some of the sample quadrats were placed in valley habitat, hillside, and also in hill top habitat. All lianas ≥ 3 cm dbh rooted in the quadrats were studied. The liana individuals were considered if they were composed of roots, stem and growing shoot. The multiple stems were noted down as one individual. However each ramet received a single tag, thus some individuals received more than one tag. This tagging system was important in the chronosequence study, which could be studied by the other researchers. Moreover, ramets can propagate into other individuals over time, thus the researcher can recognize their origin. The smaller stems were tagged with anti-rust wire and the bigger ones (> ~ 5 cm) with anti-rust nails instead. The diameter at breast height of each ramet was measured at 1.3 m above the ground and marked with red oil-base paint. The liana positions were mapped and voucher specimens were collected for identification.

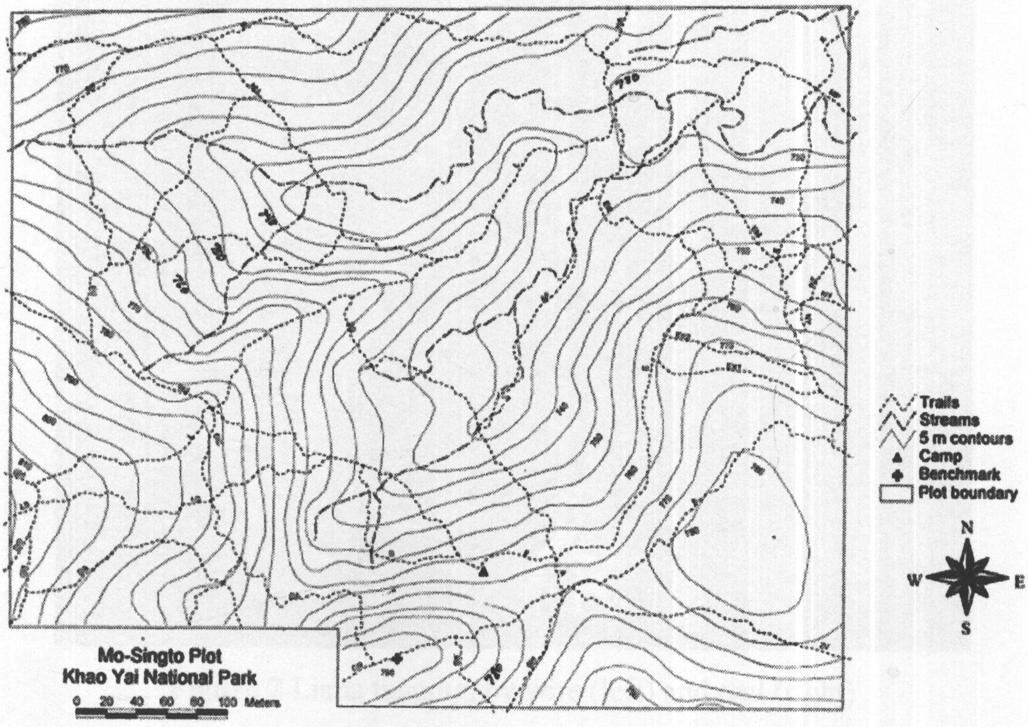

Figure 1 The Mo Singto Biodiversity Research Plot map

Figure 2 Liana tagging, by wire (left) and nail (right)

The ≥1 cm dbh lianas and environmental factors

≥1 cm dbh liana data collection

The 30 (20 x 20 m) sampling quadrats were randomly selected from whole area of the Mo Singto Biodiversity Research Plot in a stratified manner. All of the sampling plots were categorized into 3 groups, which were valley habitat, slope habitat and hilltop habitat. The hilltop habitat was the convex or flat area on the ridge of the hill, and the slope of the ridge represented the slope habitat. The lower area next to the slope side was the valley habitat, which was usually the concave area or the creek-side area. Ten sampling plots were selected from each habitat. The study area also contained secondary forest habitat, and hence this study included 10 more sampling plots from this habitat. The secondary forest habitat was recovering forest area after slash and burn farming, which contained many smaller stem trees. Moreover this habitat has only one or two low canopy layers. Lianas ≥ 1 cm dbh (genets) were censused in the study, which were rooted and climbing on host trees within the sampling plot boundary. The multiple stems were noted down only as single individuals. The smaller stem liana specimens were collected for identification. In addition monocotyledons (rattans) and some hemiepiphytes of genus Ficus, and also succulent creepers on trunks were excluded. The specimens were compared with the reference collection at the Center for Conservation Biology, ISTRD, which is now located in the National Center for Genetic Engineering and Biotechnology (BIOTEC), Science Park, Pathum Thani.

Soil sampling

The soil samples were taken in each 40 sampling plots at 0-20 cm deep where the lianas were rooted. The composite soil samples were collected in 6 holes covering the plot area. Soil samples were dried and sieved for the important nutrient analysis, which were organic matter, phosphorus and potassium. The essential importance of these nutrients is as follows. Organic matter can modify the soil physical properties, which affect the nutrient uptake of plants. Soil organic matter was used for estimation of the amount of nitrogen in soil. Nitrogen is the most limiting nutrient, which the plant uses for growth processes and chlorophyll proteins and nucleic acids.

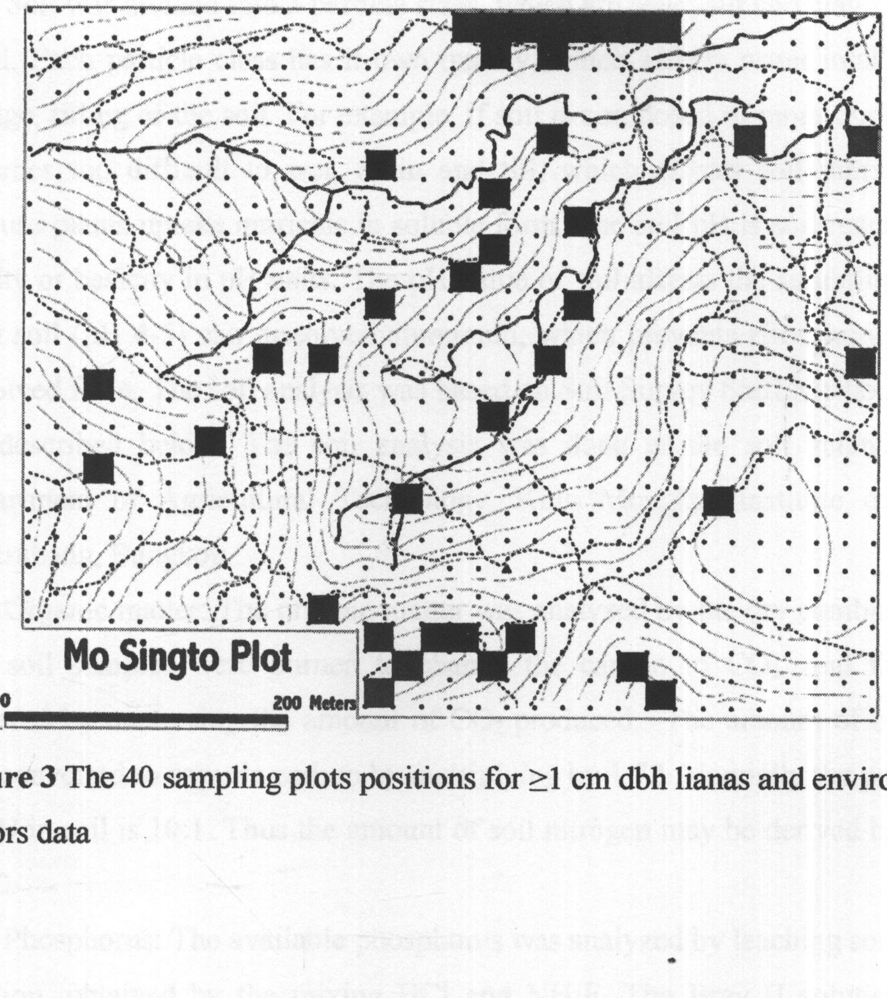

Figure 3 The 40 sampling plots positions for ≥1 cm dbh lianas and environmental factors data

Phosphorus is the second most limiting nutrient; it is a constituent of plant cell nuclei and part of energy storage molecules. The depletion of both nutrients causes plant stunting and finally death. Potassium occurs in plants in mobile soluble ion form, and affects cell division, the formation of carbohydrates, translocation of sugar, and many other functions. However, the availability of nutrients in soil depends on other factors such as draining quality and pH. The water draining quality is correlated with soil texture.

Soil was divided into 3 particle sizes, which are sand, silt and clay, from coarse to small. Each particle class has it own quality, which affects water intake rates, water storage, tilling of the soil. For example, if soil is composed of more than 30 % clay, it becomes too difficult to wet, drain and till, which effects soil nutrients available because plants uptake nutrients in soluble form. The soil pH is soil reaction, indicates acidity or basicity in pH units. The pH value of soil affects the solubility of minerals. Acid soil (pH 4-5) can dissolved aluminum, which prevents phosphorus changing to dissolved form. The soil analysis was based on Soil Survey Staff Methods (64), which are described below. The soil analysis was done at the soil science laboratory, Department of Agricultural Technology, King Mongkut Institute of Technology Ladkrabang, Bangkok.

Organic matter: The organic matter was analyzed by the dry combustion method. The soil samples were burned to change the carbon to CO_2, and the result was gathered by measuring the amount of CO_2 produced. The amount of organic matter was converted to organic carbon by multiplying by 1.72. Normally the proportion of C and N in soil is 10:1. Thus the amount of soil nitrogen may be derived by multiplying by 10.

Phosphorus: The available phosphorus was analyzed by leaching soil with Bray II solution, obtained by the mixing HCl and NH_4F. The Bray II solution digests the calcium phosphate and ferrous phosphate to complex ion and releases phosphorus. The spectrophotometer was used at wavelength 882 nm for investigation of the amount of phosphorus. The available phosphorus concentration was obtained from the percentage of light absorbance value, converted to phosphorus with a standard phosphorus curve.

Potassium: Soil potassium analysis deals with exchangeable K concentration in soil sample, which is obtained from digesting soil with NH_4Oac pH 7.0 and filtrated with Whatman No. 5 paper. Then the filtrates are measured by flame emission spectrophotometer at wavelength 768 nm. The concentration of exchangeable K is obtained by comparing the intensity value with the standard curve of potassium.

Soil texture: Soil texture can be analyzed by the Bouyoucos method. The analysis considers only particles less than 2 mm diameter (Sand is particles within 2-0.05 mm diameter, silt is 0.05-0.02 mm diameter particle and clay particles are not bigger than 0.02 mm). The soil samples were cleared of rocks and pebbles. The hydrogen peroxide was used for destroying humus in the soil samples. After that the soil sample was sieved in water for collection of only > 2 mm particles, the soil samples were weighed, and mixed with distilled water and dispersing agent (5% calgon solution). The mixed sample was homogenized within 2-5 minutes with a mixer. The mixed sample was then poured into a sedimentation cylinder. A hydrometer was put in the cylinder, and the distilled water was added to make 1 liter. The hydrometer was removed and the sample was mixed in a cylinder. The buoyancy particles value was read at 40 sec and 2 hr with a hydrometer, during the measurement temperature was also read by thermometer. At 40 seconds, the value represents the amount of clay, silt and calgon, as sand particles have already sunk to the bottom by gravity. The clay particles and calgon still float in colloid form after 2 hr. The readings yield the percentages of sand, silt and clay, excluding the calgon.

Soil pH: The soil pH is the simplest to analyze. A soil sample of 20 g is mixed with distilled water and set aside for 30 minute for the reaction. The pH value is read from a pH meter.

Elevation and slope

Elevation is correlated with soil nutrient accumulation, which effects liana growth. The high variation in elevation also affects light beam angles during the day, which constrains the photosynthesis rate per day. Thus elevation is a passive constraint factor. The elevation was measured based on references in Pak Chong, and survey data for the plot, by Global Positioning System and by plot survey results gathered from the means of the measured corner stakes. The slope height was measured with a measuring tape and clinometer. Simple trigonometry calculation was used for calculating slope. The slope height is important to liana settlement. The highest slopes are found on landslide which prevents the lianas from establishing in that area.

Host trees

All trees were considered for availability as host trees in the sampling plots. The tree data were noted down into two categories. The first group included all trees ≤ 70 cm dbh, which represented the favored host trees. The larger than 70 cm dbh trees indicated unsuitable host trees (54). Although the larger trees were not favored by lianas, these trees also carried lianas, depending on their mode of climbing. Where large trees make up the forest canopy, they inhibited the light from penetrating to the understory. Then the highly light demanding life forms such as lianas need to climb to reach to crown canopy. Finally the unfavored host trees became the necessary host trees by the inter-crown climbing. They are also mostly infested while young.

Canopy structure

The canopy character determines the light conditions below. Moreover, the canopy structure can obstruct lianas from reaching sunlit areas. The forest height and canopy distinctiveness (forest height coefficient of variation) were considered as constraint factors. The forest height represents the mean height of each sampling plot, which was gathered from the mean of 9 position height measurement within each sampling plot boundary. Higher forest height obstructs lianas from reaching to other canopy layers. The canopy distinctiveness (forest height coefficient of variation) indicates the continuity of the canopy. The inter-crown connections increase the growth of lianas in the canopy. Hegarty (51) found that trees with long branch-free boles on deep-crowned trees are not suitable for lianas to reach to canopy because the exposed trunk surface area is small. A flat canopy can prevent light penetration, which creates unfavorable conditions for lianas. The point-intercept method (65) was used for collecting mean forest height and canopy distinctiveness data. The measurement was done in 10 m intervals, which contained 9 positions per sampling plot. The forest height was obtained from the mean height within each sampling plot. Canopy distinctiveness was measured from the standard deviation of height readings.

Data analysis

Floristic composition

The floristic composition was investigated by taxonomic work. The proportion of each family in the study area can represent either numbers of species or the numbers of stems. The dataset was gathered from the ≥ 3cm dbh lianas survey. This study included a few hemiepiphytes, such as *Schefflera elliptica* (Bl.) Harms, *Fagraea ceilanica* Thunb., *Poikilospermum suaveolens* (Lour.) Merr., and *Trachelospermum asiaticum* (Sieb. & Zucc.) Nakai.

Distribution map construction

The liana genet positions in the Mo Singto Biodiversity Research Plot were referred from distance and angle from the sampling plot stakes. The genet positions were input in the treexy program. This program provided the distribution map of each liana species on the white pane. Distribution maps were adjusted size to same pixel size with the elevation map of Mo Singto Biodiversity Research Plot. Both map types were piled up together. Then the liana distributions can interpret distribution over the elevation.

Liana diversity and density

The liana density was obtained from the randomly selected sampling plots which represented the whole study area. Thus the ≥ 1 cm dbh liana abundance was gathered from the 40 randomly selected sampling plots and was representative for the lianas of the whole area.

The liana mean density was derived from the statistical point of view, which is $\bar{x}$ obtained from:

$$\bar{x} = \sum_{i} (Xi/N)$$

Where Xi is the number of liana stems in the sampling plot i and N equals the total number of plots. The liana population variance was used to describe the scatter of individual observations from the liana density mean. The variance is estimated by this equation:

$$s = \sum (Xi-\mu)^2/(N-1)$$

The standard deviation (s) is obtained from the square root of variance. The standard deviation is used for explain the fluctuation about the mean value. The mean liana density represents the average number of lianas stems per area.

Regression of liana density and diversity

The lianas diversity can be estimated by the regression method (66). The species and density curve plot by the lianas density (N) and liana diversity (S) from the observation. The N within sampling plots was transformed into the ln value and regressed with either S (semi-logarithmic) or ln S (ln-ln plot). After that, the regression of the ln N and S produces the equation:

$$S = a + b \ln N$$

S is the estimated number of liana species per N stems, here a and b are constants. The regression process yields the coefficient of determination (r^2) for the amount explained variation, if r^2 is value close to 1 the equation is more precise. The r^2 derived from this equation:

$$r^2 = (s^2_y - s^2_{y \cdot x}) / s^2_y$$

Where $s^2_{y \cdot x}$ (the variance of the estimation) is the error variance gathered from the linear regression equation. The s^2_y represents the total amount of variance of y values, which are the mean densities.

The ln-ln plot produces the equation,

$$S = cN^d$$

Where S is the estimated number of lianas species per N stems per plot. The c and d are constants derived from regression. However, in this study decides to use power curve estimation (ln-ln equation), because this equation gave more precise results than the semi-logarithmic equation.

The estimate S is the number of liana species in relation to the number of stems, and therefore it is the relation between S and N which measures diversity best. The ln-ln relationship provides an index of species richness which is independent of sample size or N, and provides a method for comparing species richness between habitats. ANCOVA was used for this purpose.

Fisher's alpha

Fisher's alpha is the most generally accepted diversity index for large collections of species in the tropics. The index α is a constant in the log series distribution; it value is interpreted as the approximate number of species expected by one individual. Fisher (66) explained the log series distribution as the series expansion:

$$-\alpha\ln(1-x) = ax + (ax^2)/2 + (ax^3)/3 + \ldots + (ax^n)/n$$

Here x is a constant, less than or equal to 1 but and greater than 0. The right part of equation expresses the expected number of species containing 1, 2, ..., n individuals. Moreover, the α and x can converge the equation to:

$$x = N/(N+\alpha)$$

and

$$\alpha = [N(1+x)]/x$$

Finally the equation can eliminate x out and derived the equation:

$$N/S = [e^{S/\alpha} - 1]/[S/\alpha]$$

Here N is total number of individuals. The total number of species is S. The α represents the Fisher's alpha.

SHE analysis

The SHE analysis is used to evaluate the characteristics of the liana community structure, which are heterogeneity, species richness and evenness in a single analytic method (66). The dataset will derived from the accumulation of sampling plots. The SHE analysis can also describe the spatial distribution. The SHE analysis starts with the investigation of H, which derives from Shanon's information function (68):

$$H = -\Sigma_i \; pi\log_2(pi)$$

Here pi is the proportion of total individual belonging to i species. Moreover the $\log_2$ can substitute by ln or $\log_{10}$, which found in many studies. After that the calculation of E (measures of equitability or dominance) is required. The E in this relationship is proposed by Buzas and Gibson (69), the equation is:

$$E = (e^H)/S$$

Where H is the heterogeneity index (Shanon's H). The total number of species is represented by S. In addition SHE analysis requires an other dataset, which is ln (S). ln (E) and ln(E)/ln(S) derives from taking the log of the cumulative number of species and E value. Moreover the ln (E) value also can be calculated from Shanon's H minus with ln (S). After that all of derived data is plotted into the same graph, the ln (E) and ln(E)/ln(S) need to multiply by 10 for keeping all lines scaled close together. Then the trend patterns indicate whether the broken stick, log normal or log series pattern best fits the data.

Liana species-area curve

The ≥ 1cm dbh liana dataset was used for investigating the relation between liana species and area. The regression between accumulative area and number of species can be transformed to the ln formation. The regression of ln A and ln S will give S estimated as the function of area. The equation is:

$$S = cA^{z}$$

Here A is the size of study area; c and z are the constants. After that the S estimated will be plotted against area. The curve can explain the character of the relation. For example a fine-grained area and high equitability will give increase of S at the beginning and the curve will approach an asymptote; the course-grained and equal patch sizes area will produce the stepped species-area curve (70).

Liana diversity and density among different habitats

The ≥ 1 cm dbh lianas were considered in this study. The 4 habitats sites were compared with respect to liana diversity and density. The 4 habitats were with Valley, Slope, Hill top and Secondary forest. Each habitat contained 10 sampling plots; randomly selected in Valley, Slope and Hilltop habitat. The Secondary forest habitat included from all secondary growth areas (10 sampling plots) in the northern part of the Mo Singto Research plot. The numbers of stems per sampling plot among habitats were compared by ANOVA. Before testing analysis, the dataset required standardization. The variance-mean ratio among habitat sites was examined. If the ratio is approximately 1.0, the square root was taken of each value; and logs were taken if the ratio was > 2.0.

The liana species diversity among habitats was studied by regression of ln N on ln S. The S estimated from the regression equations were compared by ANCOVA to test for differences in lianas species richness among habitats. If the species richness is not different between habitats Fisher's alpha will be calculated for each area, and compared together.

Lianas and their environmental factors

In lianas ≥ 1 cm dbh the effect of environmental factors was examined. Firstly the 40 sampling plots were used by the numbers of stems and numbers of species in the sampling plot. A multiple regression was used to describe the relation between liana density and diversity in 40 sampling plots and their environmental factors. Liana density and diversity were use as dependent variables. The environmental factors, such as elevation, soil pH, percentage of sand particles and canopy distinctiveness were considered as independent variables. This relation provides the regression equation. The multiple regression analysis yielded r^2 (coefficient of determination), r (total relation of independent variables), standard error of the estimate, and the Durbin-Watson value. The Durbin-Watson value indicates independent of standard error, which close to 2 presents more independent value. This analysis also used ANOVA for test the significant effects on the independent variables. A significance value < 0.05 indicates that at least one independent variable is related with the dependent variables. The coefficients table gathers from other step of analysis. This step tests the relation between dependent variable and independent variables, tested one by one. This step also provides beta (standardized coefficient) values, in which a higher value indicates that an independent variable is more related with dependent variables than others.

CHAPTER IV
RESULTS

Floristic composition

The liana survey found 9,510 rooted stems (genets) ≥ 3 cm dbh. Some liana individuals had more than one stem (ramet), and a total 11,526 ramets were found in 29 ha of the Mo Singto Biodiversity Research Plot. Regarding the number of families, the liana inventory result found 35 families and 116 species, excluding 6 unknown species. The proportion of the unknown species was 5 % of all species but only 0.1 % of the total number of stems (genets). The results of the inventory are presented in the Table 1. The top four families in terms of number of stems were Rubiaceae which had 1,963 stems, followed by Apocynaceae, Leguminosae,Vitaceae and Verbenaceae, which contained 1,299, 725, 647 and 613 stems, respectively. The proportion of stems per family is presented in figure 4. However, the ranking of families by number of species per family gives a different order. The top five families were Leguminosae, Apocynaceae, Rubiaceae, Annonaceae and Moraceae, which had 13, 12, 9, 8, and 7 species, respectively. The proportion of lianas species per family is presented in figure 5. However, there results do not include the unknown stems and species in the ranking. For the three most abundant families we can construct the graph showing the distribution of number of stems per species. The Rubiaceae contained 9 species; the most abundant species in this family was *Uncaria scandens* (594 stems). The runner-up species was *Uncaria macrophylla* which had 480 stems (figure 6). The Apocynaceae were composed of 12 species. *Trachelospermum asiaticum* represented the highest number of stems, on 305 stems. Similarly with Rubiaceae, the second species had 74 less stems than the top species. The other species in this family tended to decrease rapidly in abundance (figure 7). The Leguminosae showed the same result, but the first two species were close together in number. *Spatholobus harmandii* stems had 5 more stems than *Mucuna macrocarpa* stems, which were 197 and 192 stems respectively. The remaining species declined in the same fashion (figure 8).

Table 1 The numbers of stems (genets) and species per family

Family	Stems	Species
Annonaceae	574	8
Apocynaceae	1244	12
Araliaceae	20	1
Asclepiadaceae	24	6
Celastraceae	499	4
Combretaceae	80	2
Compositae	14	2
Connaraceae	166	2
Convolvulaceae	566	6
Cucurbitaceae	8	2
Dilleniaceae	430	2
Elaeagnaceae	77	1
Euphorbiaceae	57	1
Gnetaceae	119	2
Hernandiaceae	156	1
Leguminosae	725	14
Loganiaceae	20	2
Melastomataceae	124	1
Menispermatceae	166	2
Moraceae	191	7
Myrsinaceae	9	1
Oleaceae	13	2
Piperaceae	159	2
Polygalaceae	1	1
Ranunculaceae	1	1
Rhamnaceae	183	6
Rubiaceae	1963	8
Rutaceae	68	2
Sabiaceae	404	1
Thymelaeaceae	55	1

Table 1 (Continued)

Family	Stems	Species
Tiliaceae	57	2
Urticaceae	66	1
Verbenaceac	613	4
Vitaceae	647	5
Unknown 6	1	1
Unknown 8	1	1
Unknown 9	2	1
Unknown 19	2	1
Unknown 38	1	1
Unknown 39	3	1

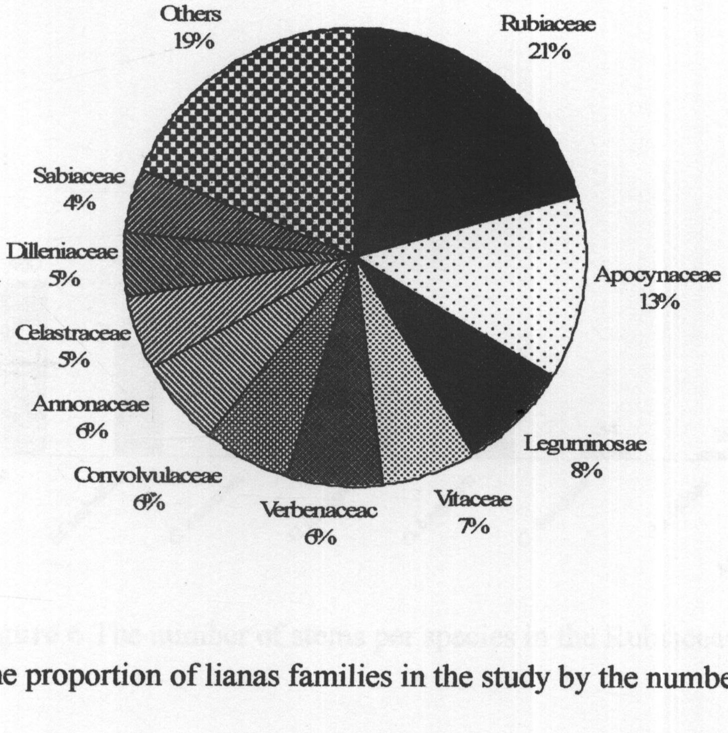

Figure 4 The proportion of lianas families in the study by the number of stems

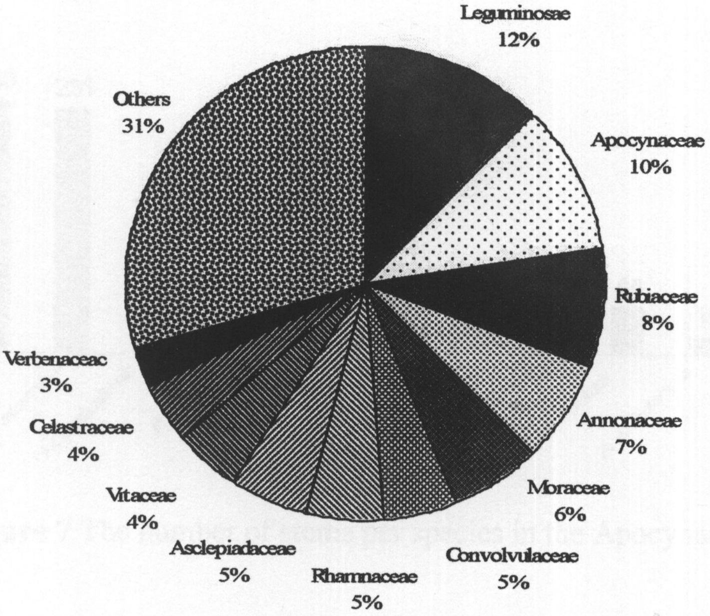

Figure 5 The proportion of lianas families in the study by the number of species

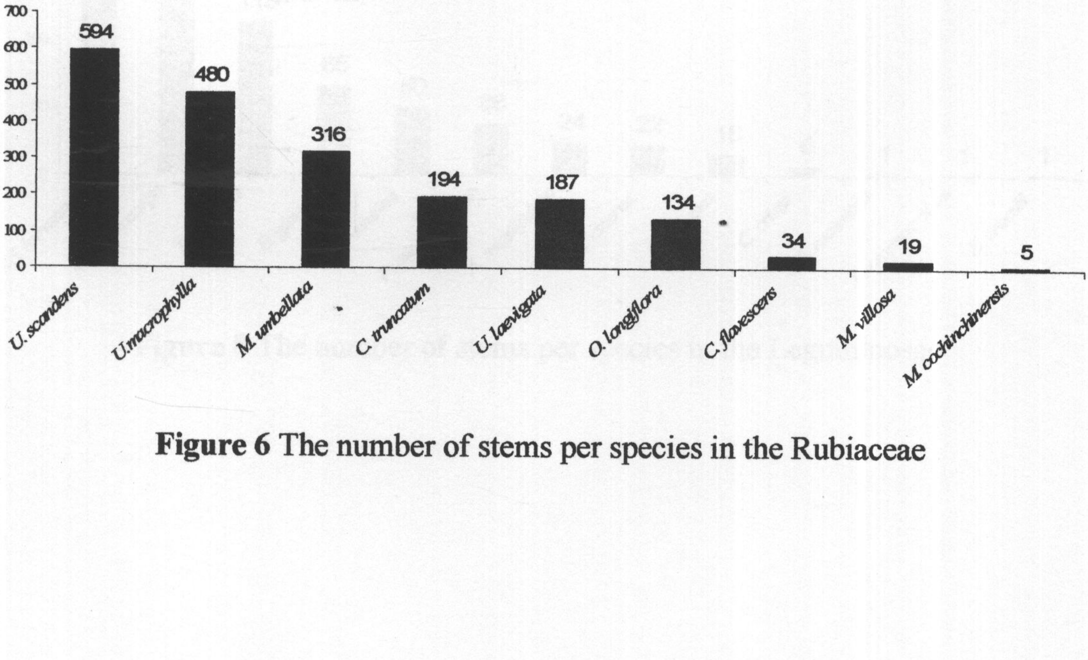

Figure 6 The number of stems per species in the Rubiaceae

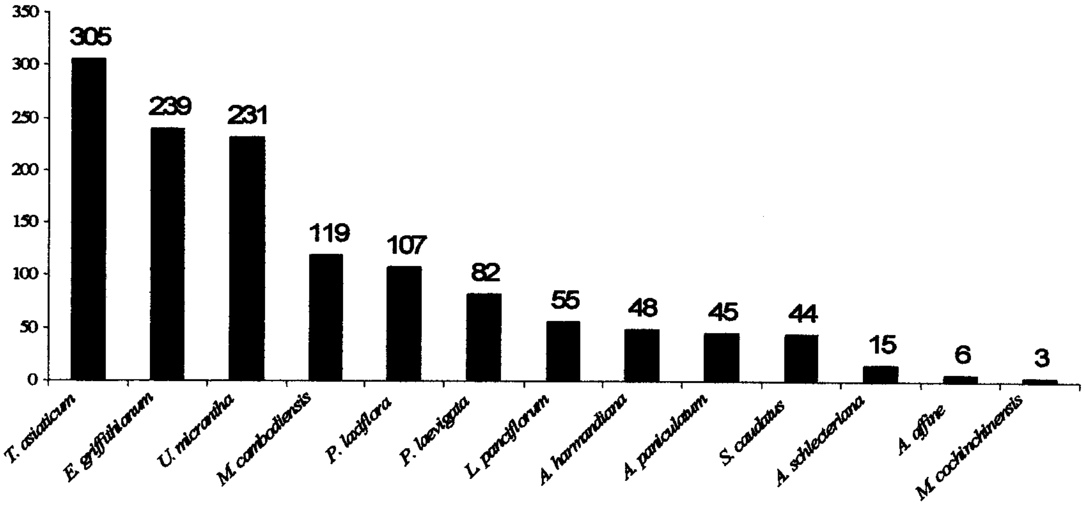

Figure 7 The number of stems per species in the Apocynaceae

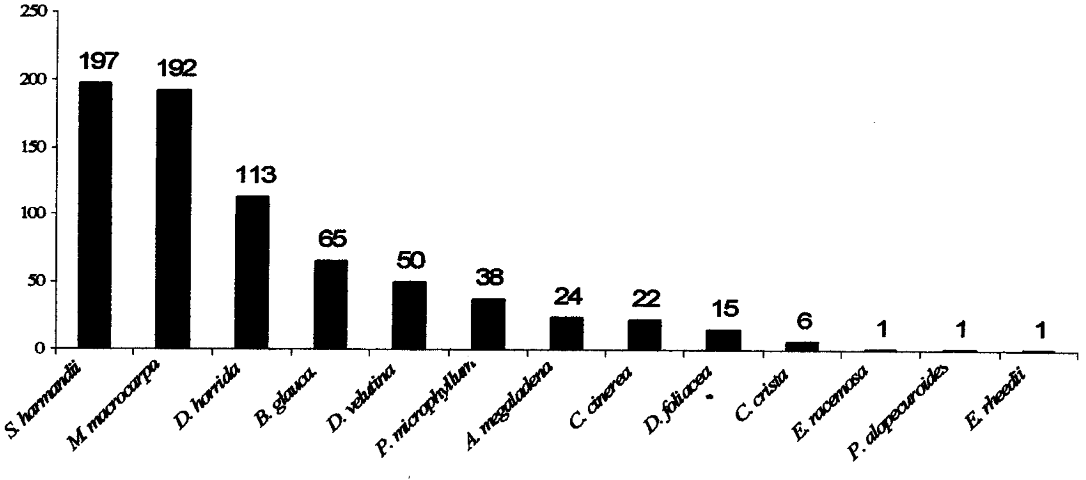

Figure 8 The number of stems per species in the Leguminosae

The top ten most abundant species on the plot were scattered in many families. Rubiaceae contained three species in the ranking, *Uncaria scandens*, *Uncaria macrophylla* and *Morinda umbellata.* The Verbenaceae had 2 species in the high density group, *Premna flavescens* and *Sphenodesme pentandra.* The remaining families had only one species per family, which were Sabiaceae (*Sabia limoniacea*), Vitaceae (*Tetrastigma laoticum*), Dilleniaceae (*Tetracera indica*), Celastraceae (*Celastrus approximata*) and Apocynaceae (*Trachelospermum asiaticum*). The shape of the graph of stems per species decreased rapidly from the highest number of stems to the last five species (figure 9). All of the 9,510 stems are plotted in the same graph and distributed by species. The result shows that the number of stems decreases rapidly in the beginning, but after ten species the rate of decline is low. The rarest species contained only one stem. This plot excluded the unknown species which had only a single stem (figure 10).

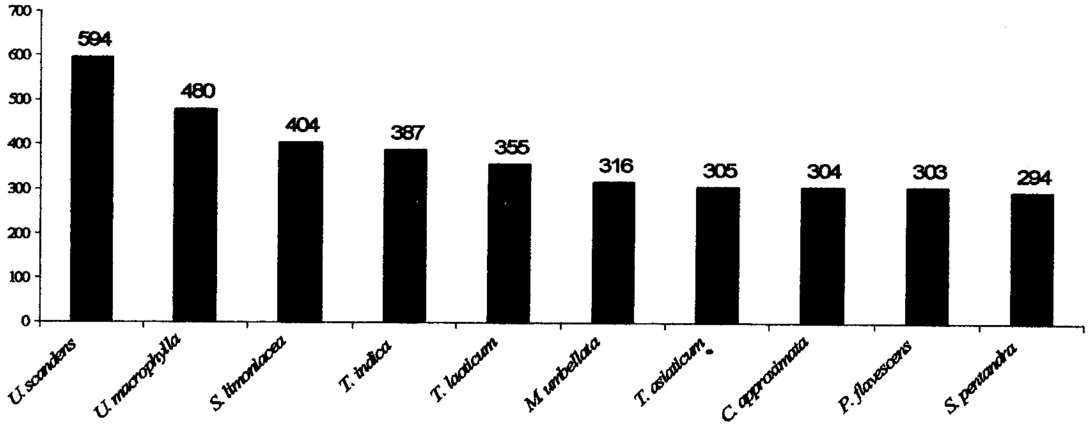

Figure 9 The number of stems per species for the top ten species

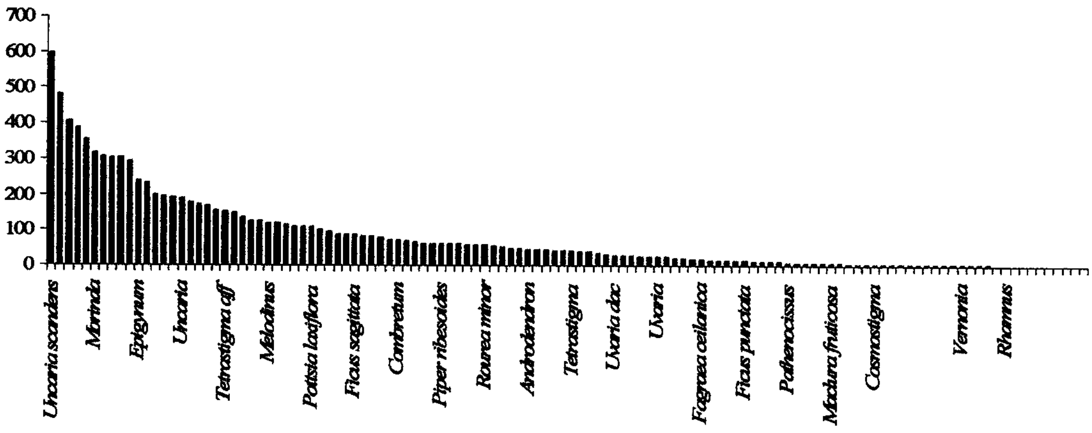

Figure 10 The number of stems per species of the all species

The lianas individual's positions are mapped in the Mo Singto Biodiversity Research Plot for analysis of distribution. The five most abundant species were plotted onto plot maps. The five species were of *Uncaria scandens*, *Uncaria macrophylla*, *Sabia limoniacea*, *Tetracera indica* and *Tetrastigma laoticum*. The results show that *Uncaria scandens* was most dense in the higher area (the lower right of the map, at approximately 780 m), but had low density in upper left of map, but it was dispersed over almost the whole area (figure 12). *Uncaria macrophylla* distribution shows clumping of individuals in lower areas, approximately 730-740 m, and the number of liana individuals decreases with increased elevation. However, the higher elevations still have limited numbers of individuals. Moreover, the lower left part of the map, with elevations than 790 m, contain no individuals (figure 13). The other species were dispersed all over the area. Regarding the species distributions, some areas have higher density for each species; *Sabia limoniacea* was frequently denser in the lower area at approximately 730-740 m elevation (figure 14). The distribution of *Tetracera indica* presents a different distribution when compared with the other high density species. This species was well dispersed and relatively unclumped (figure 15). Another well distributed species was *Tetrastigma laoticum*, but in lower areas it was more dense (figure 16). On the other hand the distribution of *Piper retrofractum* was more restricted (figure 17). This species contained 100 stems and ranked in 32th place of the 114 species. Its distribution was spread between 740 m to 780 m elevation, but was limited, and highly scattered. Elevation does not seem to affect this piper. The highest number of this species occurred in the slope area from the southern part of the plot to the northern part, and the edge of the dispersion was at the camp site (the black triangle). It is clear that liana species differ in their distribution pattern, and some probably respond to environmental factors.

The proportion of the lianas (ramets) in different diameter classes was also studied. Size was categorized into two classes, 3-6 cm and > 6 cm dbh. Analysis of the 40 (20 x 20 m) random sampling plots found that the most of the 516 stems (79 %) were in the 3-6 cm dbh class. In proportion, the ratio was 1:3.8 stems. In the other 40 (20 x 20 m) random sampling plots (lianas ≥ 1cm dbh dataset) the number of stems were classified into three groups, 1-2.9 cm dbh, 3-5.9 cm dbh and ≥ 6 cm dbh. The smallest diameter class (<3 cm dbh) had the highest proportion, which was 63 % of all 1,067 stems. The 3-6 cm dbh class was found 30 % and 7% represented ≥ 6 cm dbh class. The proportion between size classes was 1:4.1:8.5. Figure 11 shows a plot of log N (density) versus 1-cm classes, an increase in size classes lead to a fewer number of individuals. The number of stems slightly and regularly decreased with increasing liana diameter. After at the 8 cm diameter class, the number of individuals rapidly decreased and the lowest number of stems is found in the 10 cm diameter class. This suggests that most species of lianas do not get larger than about 8 cm in diameter. The biggest dbh size in all censuses was found in *Spatholobus harmandii*, which had a stem 52.8 cm in dbh (figure 18).

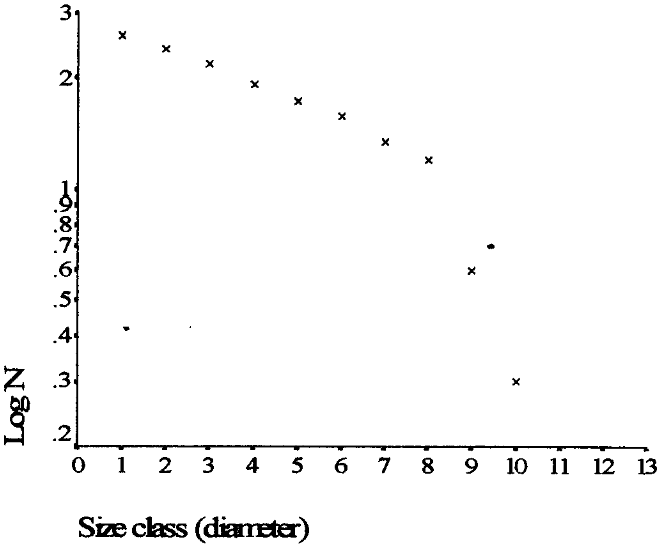

Figure 11 Distributions by 1-cm classes

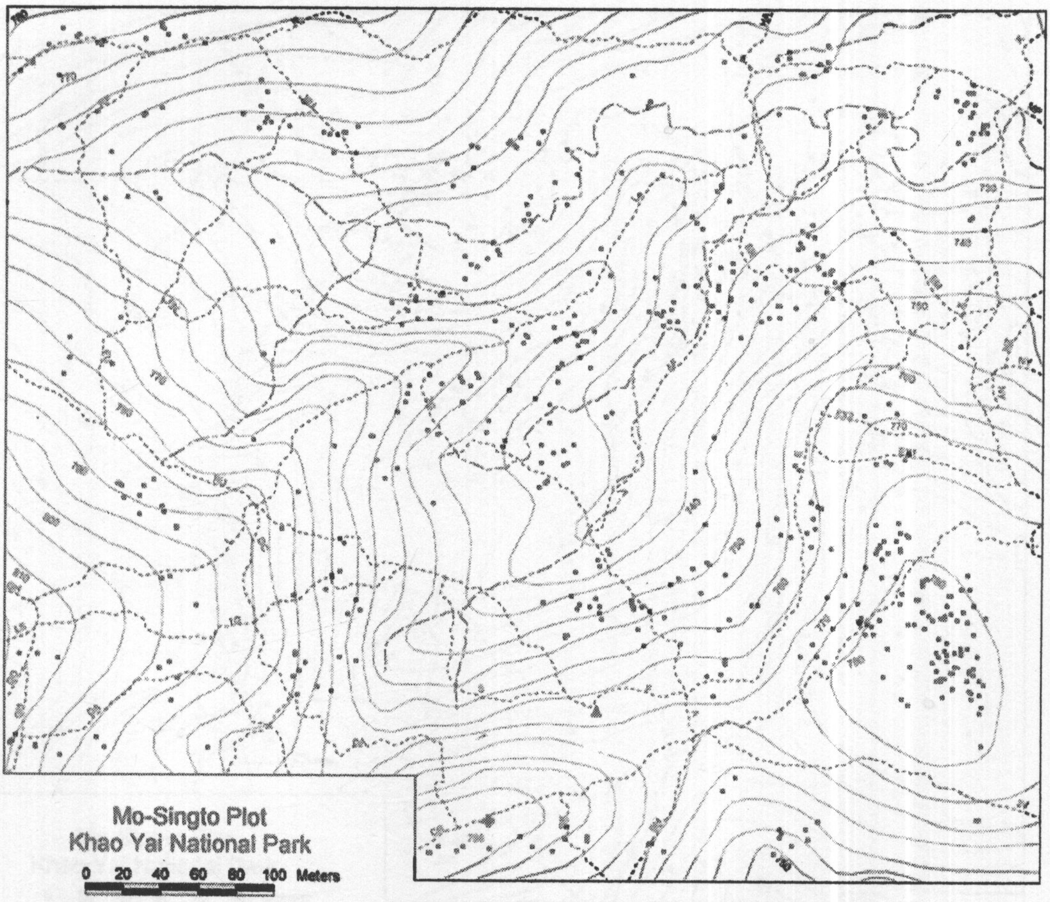

Figure 12 The distribution of *Uncaria scandens* on the Mo Singto Biodiversity Research Plot

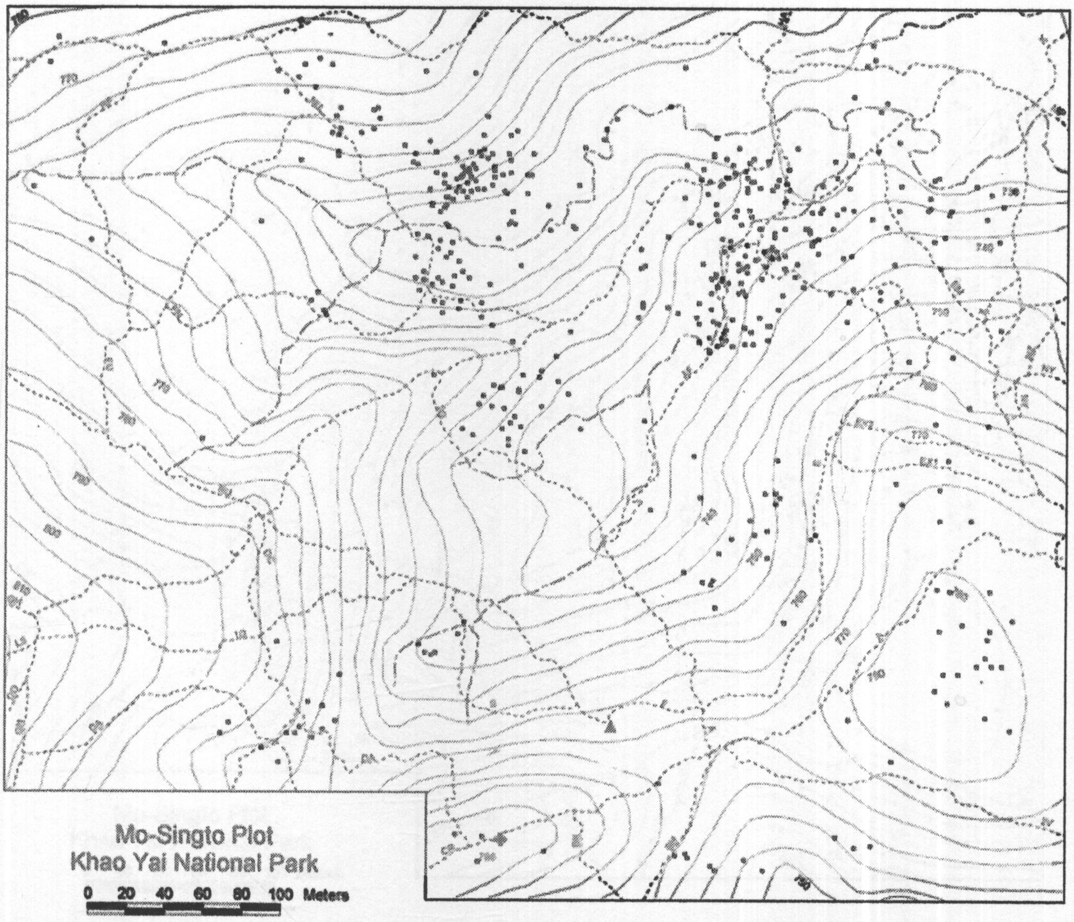

Figure 13 The distribution of *Uncaria macrophylla* on the Mo Singto Biodiversity Research Plot

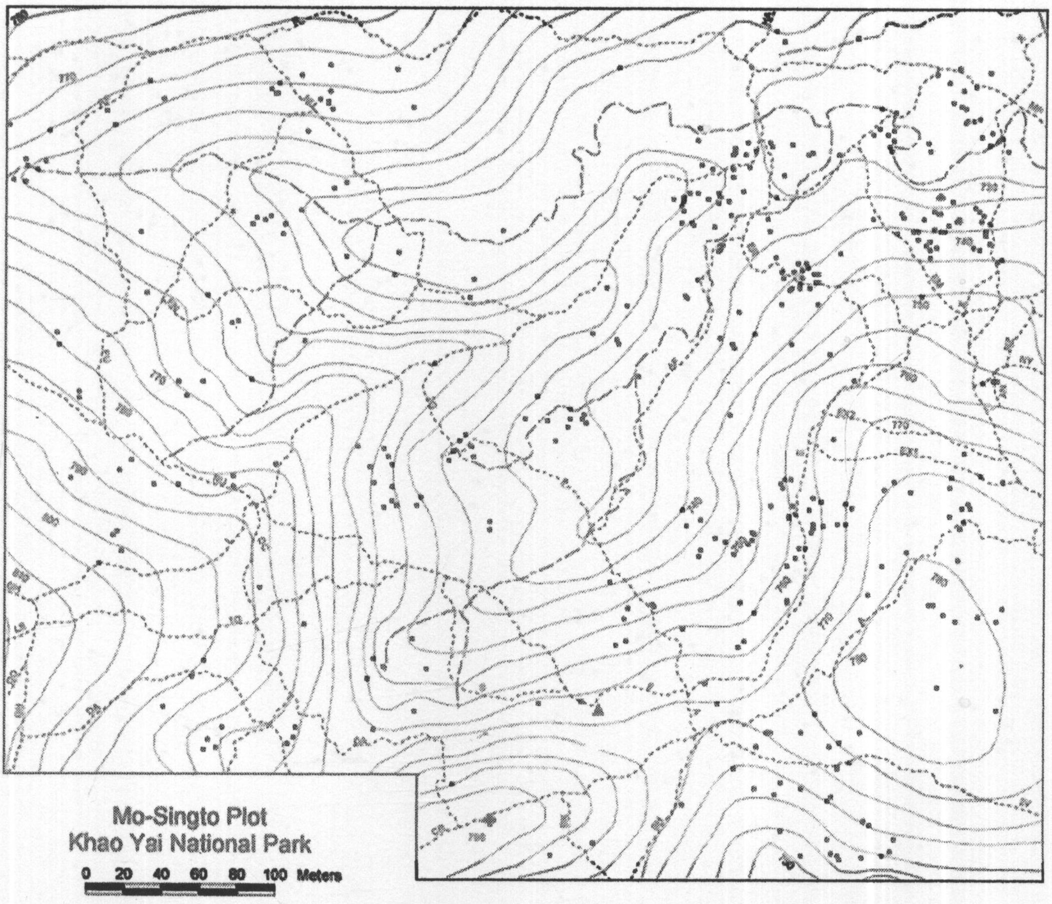

Figure 14 The distribution of *Sabia limoniacea* on the Mo Singto Biodiversity Research Plot

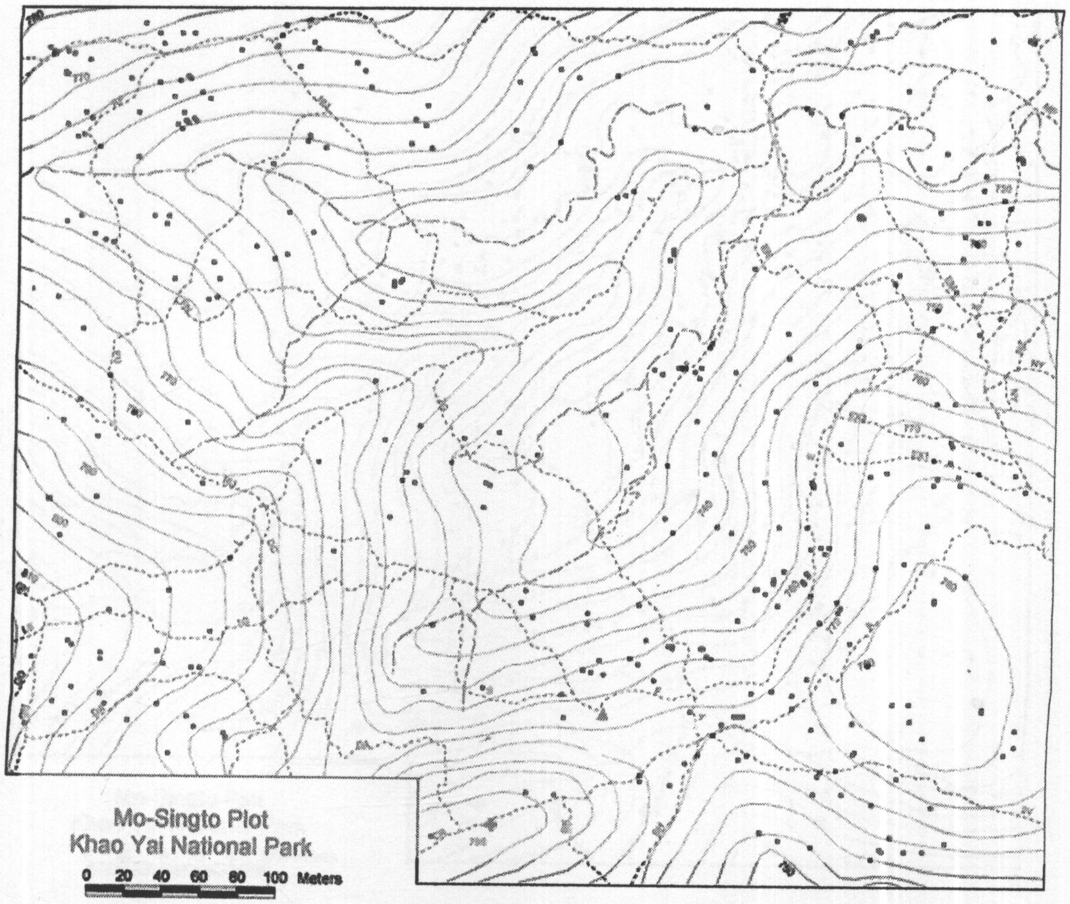

Figure 15 The distribution of *Tetracera indica* on the Mo Singto Biodiversity Research Plot

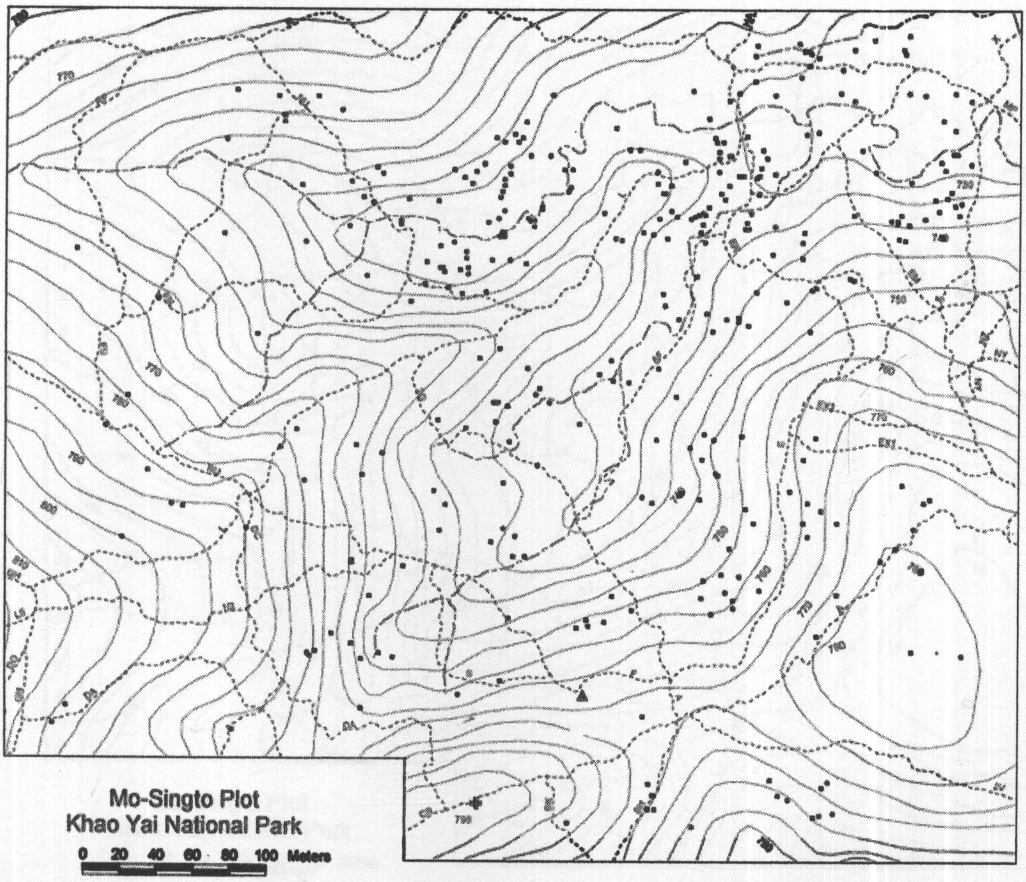

Figure 16 The distribution of *Tetrastigma laoticum* on the Mo Singto Biodiversity Research Plot

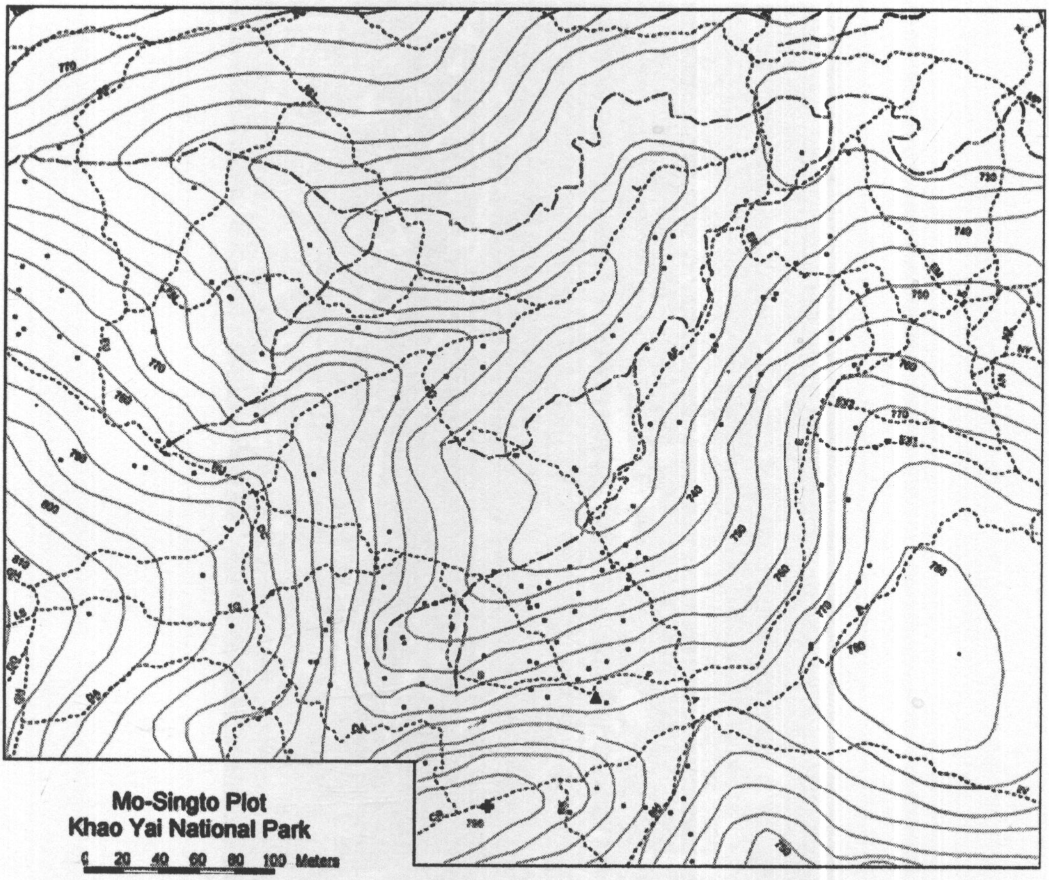

Figure 17 The distribution of *Piper retrofractum* on the Mo Singto Biodiversity Research Plot

Figure 18 The biggest stem in the inventory (*Spatholobus harmandii* stem)

Liana diversity and density

Inventory of the ≥ 1 cm dbh lianas (genets) found that the valley habitat contained 252 stems and 61 species within 10 sampling plots; the slope area had slightly lower density and diversity, or 227 stems and 57 species per 10 sampling plots. The highest density occurred in the hilltop habitat: 309 stems and 61 species per 10 sampling plots. On the other hand, the maximum species diversity was found in the secondary forest habitat, which had 67 species and 288 stems per 10 sampling plots. The survey results are presented in table 2.

Table 2 The census data for lianas >1 cm dbh (genets)

Habitat	Observed	plot									
		1	2	3	4	5	6	7	8	9	10
Valley	N (stems)	22	6	14	21	30	31	28	29	20	51
	Cumm. N	22	28	42	63	93	124	152	181	201	252
	S (species)	16	4	10	14	17	17	13	12	16	21
	Accum. S	16	19	26	32	39	46	48	50	56	61
Slope	N (stems)	26	28	12	15	45	10	16	11	34	30
	Cumm. N	26	54	66	81	126	136	152	163	197	227
	S (species)	14	15	10	11	19	8	11	8	14	18
	Accum. S	14	23	25	30	39	42	46	46	52	57
		1	2	3	4	5	6	7	8	9	10
Hilltop	N (stems)	61	20	23	35	19	30	41	19	26	35
	Cumm. N	61	81	104	139	158	188	229	248	274	309
	S (species)	29	11	10	19	14	17	20	13	14	19
	Accum. S	29	34	37	47	51	52	55	56	58	61

Table 2 (continued)

Habitat	Observed	plot									
2° forest	N (stems)	37	27	31	15	34	18	27	28	36	35
	Cumm. N	37	64	95	110	144	162	189	217	253	288
	S (species)	21	12	17	11	15	10	15	15	20	22
	Accum. S	21	29	34	39	41	44	48	53	58	67

Liana mean density

The liana mean density was used for comparison of density among 4 habitats. The results show that the slope habitat had lowest density, 22.8 ± 2.35 stems per plot. The valley habitat had similar mean density to the slope site, which was 25.2 ± 2.27 stems per plot. The secondary forest habitat had highest mean density, which was 28.8 ± 1.32 stems per plot. However, the mean density of the hilltop habitat, 30.9 ± 2.23 stems was similar to the secondary forest. The density (stems per sample plot) was compared among habitats with ANOVA. The results of boxplot analysis and ANOVA showed no significant differences among the four habitats (figure 19 and table 3). Before ANOVA analysis, the dataset required standardization. The variance-mean ratio among plots was examined. The ratio was approximately 1.0, so the square root was used for normalization.

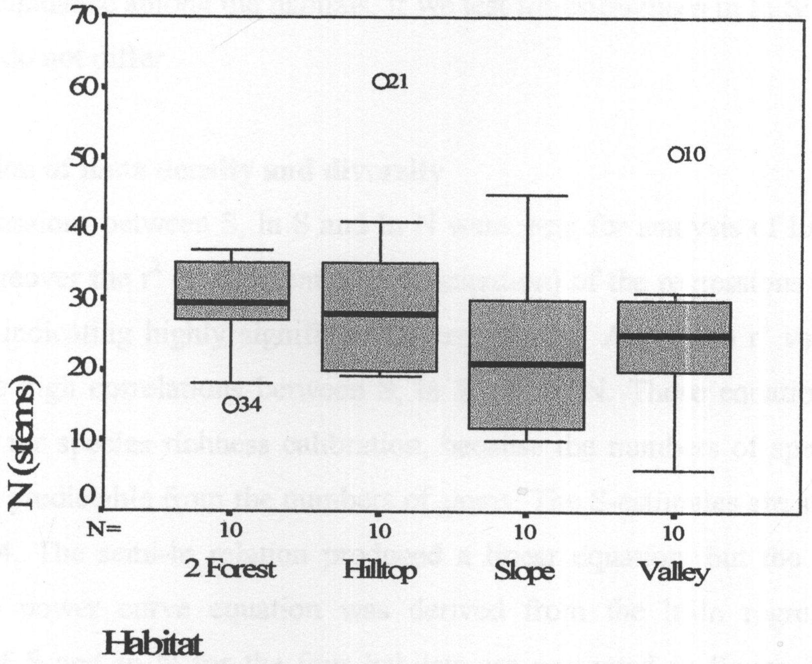

Figure 19 Boxplot of lianas density among the habitats

Table 3 The ANOVA of lianas density in 4 habitats

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.516	3	1.505	1.260	.303
Within Groups	43.016	36	1.195		
Total	47.532	39			

The mean liana diversity was calculated from all sampling plots from the observed number of species (within same habitat site). The results show that the hilltop habitat had highest mean diversity value, 16.6 ± 5.56 species per plot. The mean diversity was lowest in the slope habitat, which had 12.8 ± 3.85 species per plot and was slightly higher in the valley habitat, which had 14.0 ± 4.67 species per plot. The secondary forest habitat also had high mean diversity, 15.8 ± 4.18 species per plot. However these differences in species richness were simply due to differences in the overall abundance among the habitats. If we test for differences in ln S/ ln N, the 4 habitat types do not differ.

Regression of liana density and diversity

The regressions between S, ln S and ln N were used for analysis of liana species richness. Moreover the r^2 (coefficient of determination) of the regressions was nearly equal to 1.0 indicating highly significant determinations. All of the r^2 values in the table indicate high correlations between S, ln S and ln N. These equations provide suitable data for species richness calibration, because the numbers of species in the habitats were predictable from the numbers of stems. The S-estimates are summarized in the table 4. The semi-ln relation produced a linear equation, but the line is not straight. The power curve equation was derived from the ln-ln regression. The regressions of S and ln N for the four habitats are presented in figure 20, and the regression of ln S and ln N for the four habitats are shown in figure 21. The regressions were compared with ANCOVA. The comparison between the habitats was based on the ln-ln equations of all 40 sampling plots. The ANCOVA result showed no significantly differences between S corrected for N among four habitats. The key variable was the N (number of stems), used in the S-estimated equation, was found significant in the analysis. The ANCOVA results are presented in the table 5. In addition the semi-ln plot cannot be used because the relation is not linear-straight. The ln S / ln N analysis is more valid.

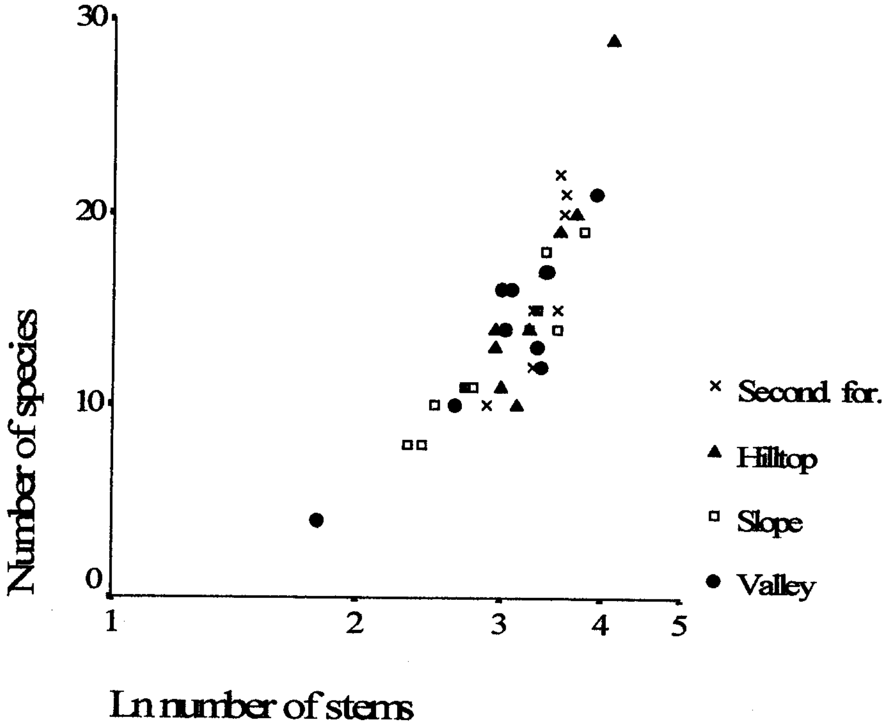

Figure 20 S versus ln N plot for four habitats

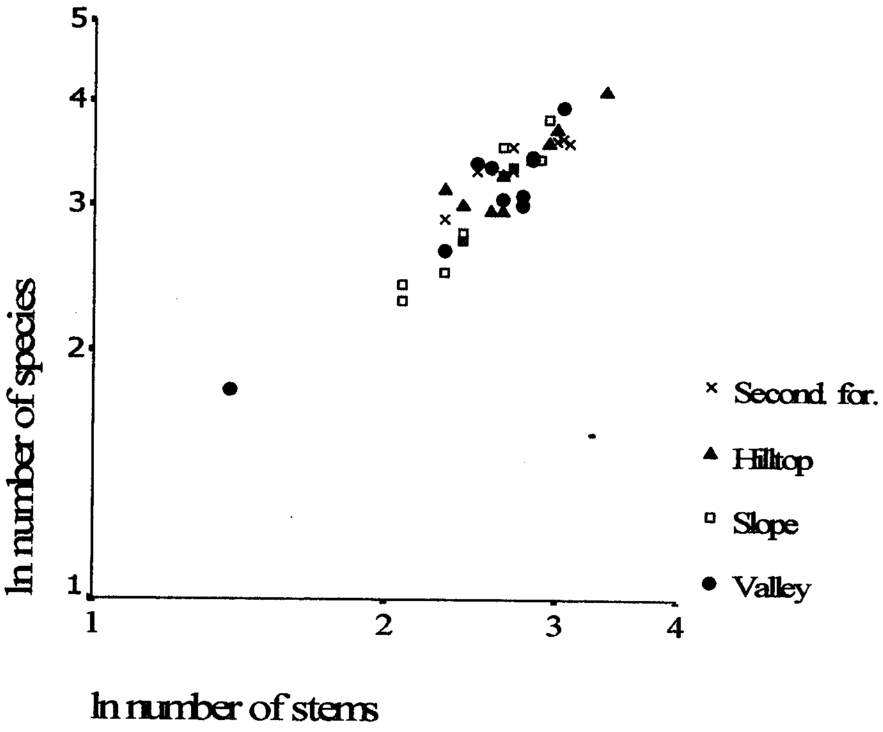

Figure 21 Ln-ln plot, ln S versus ln N for four habitats

Table 4 The equation from the regression process

Habitat	Regression type	Equation	R^2
Total	Semi-ln	S = (lnN x 8.85)-13.50	0.78
	Ln-ln	$S = 0.97N^{0.86}$	0.85
Valley	Semi-ln	S = (lnN x 7.32)-8.73	0.81
	Ln-ln	$S = 0.84N^{0.98}$	0.89
Slope	Semi-ln	S = (lnN x 6.90)-7.90	0.90
	Ln-ln	$S = 1.21N^{0.67}$	0.92
Hilltop	Semi-ln	S = (lnN x 13.65)-29.30	0.87
	Ln-ln	$S = 0.91N^{0.91}$	0.79
2° forest	Semi-ln	S = (lnN x 11.61)-22.78	0.70
	Ln-ln	$S = 0.91N^{0.91}$	0.76

Table 5 The ANCOVA of diversity for 4 habitats by ln-ln equation

Dependent Variable: S : ln-ln

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1363.374(a)	4	340.843	5185.975	.000
Intercept	26.796	1	26.796	407.712	.000
N	1247.658	1	1247.658	18983.273	.000
HABITAT	.157	3	.052	.799	.503
Error	2.300	35	.066		
Total	11974.374	40			
Corrected Total	1365.674	39			

a R Squared = .998 (Adjusted R Squared = .998)

SHE analysis

The SHE analysis of all habitats was done by constructing graphs of various functions in relation to the cumulative number of individuals. The ln S, ln E, H and ln E/ lnS values were used, in which H and E are derived from the Shannon's H and Buzas and Gibson's E (or Shannon H-ln S). The results show that data of all habitats conform to a log series distribution, which is presented in figures 22-26. The summarized SHE analysis data are presented in table 6. The calculation of indices revealed that ln S and H values were highest for the secondary forest (4.20 and 3.70) and lowest for the slope habitat (4.04 and 3.59). On the other hand, ln E/ln S and ln E values tended to be highest for hilltop habitat (-0.85 and -3.51) and lowest for the secondary forest (-1.20 and-5.05). However all of SHE analysis found that ln S and H lines were relatively constant, but tended to increase slightly, whereas ln E/ln S and ln E line both tended to decline. These trends indicate that the data are closest to the log series distribution, in which the value of H remains constant with increasing N.

Table 6 The SHE analysis for the 4 habitat sites

Habitat		Plot									
		1	2	3	4	5	6	7	8	9	10
Valley	ln S	2.77	2.94	3.26	3.46	3.66	3.83	3.87	3.91	4.02	4.11
	H	2.62	2.84	3.21	3.27	3.43	3.60	3.54	3.47	3.55	3.64
	(lnE/lnS) x 10	-0.44	-0.35	-0.42	-0.56	-0.64	-0.60	-0.85	-1.13	-1.18	-1.14
	(lnE) x 10	-1.22	-1.04	-1.38	-1.96	-2.33	-2.29	-3.31	-4.42	-4.75	-4.71
Slope	ln S	2.64	3.13	3.22	3.40	3.66	3.74	3.83	3.83	3.95	4.04
	H	2.42	2.75	2.83	2.99	3.23	3.33	3.46	3.47	3.55	3.59
	(lnE/lnS) x 10	-0.83	-1.23	-1.21	-1.21	-1.18	-1.09	-0.96	-0.94	-1.01	-1.12
	(lnE) x 10	-2.19	-3.85	-3.89	-4.11	-4.33	-4.08	-3.69	-3.59	-4.01	-4.53

Table 6 (continued)

Habitat		Plot									
		1	2	3	4	5	6	7	8	9	10
Hilltop	ln S	3.37	3.53	3.61	3.85	3.93	3.95	4.01	4.02	4.06	4.11
	H	3.16	3.29	3.38	3.56	3.62	3.63	3.66	3.67	3.71	3.76
	(lnE/lnS) x 10	-0.61	-0.67	-0.64	-0.75	-0.79	-0.81	-0.87	-0.88	-0.86	-0.85
	(lnE) x 10	-2.07	-2.36	-2.31	-2.90	-3.12	-3.21	-3.47	-3.55	-3.50	-3.51
2° forest	ln S	3.04	3.37	3.53	3.66	3.76	3.78	3.89	3.97	4.06	4.20
	H	2.84	3.07	3.17	3.29	3.40	3.36	3.47	3.46	3.60	3.70
	(lnE/lnS) x 10	-0.67	-0.88	-1.01	-1.02	-0.96	-1.12	-1.08	-1.28	-1.13	-1.20
	(lnE) x 10	-2.04	-2.97	-3.56	-3.73	-3.61	-4.24	-4.22	-5.10	-4.60	-5.05

Habitat		plot									
		4	8	12	16	20	24	28	32	36	40
Total	ln S	2.64	3.04	3.43	3.61	3.81	3.93	3.95	4.06	4.16	4.20
	H	2.56	2.76	3.03	3.23	3.46	3.63	3.65	3.78	3.87	3.90
	(lnE/lnS) x 10	-0.30	-0.93	-1.18	-1.05	-0.91	-0.77	-0.76	-0.69	-0.69	-0.72
	(lnE) x 10	-0.79	-2.85	-4.04	-3.81	-3.47	-3.02	-3.01	-2.80	-2.89	-3.05

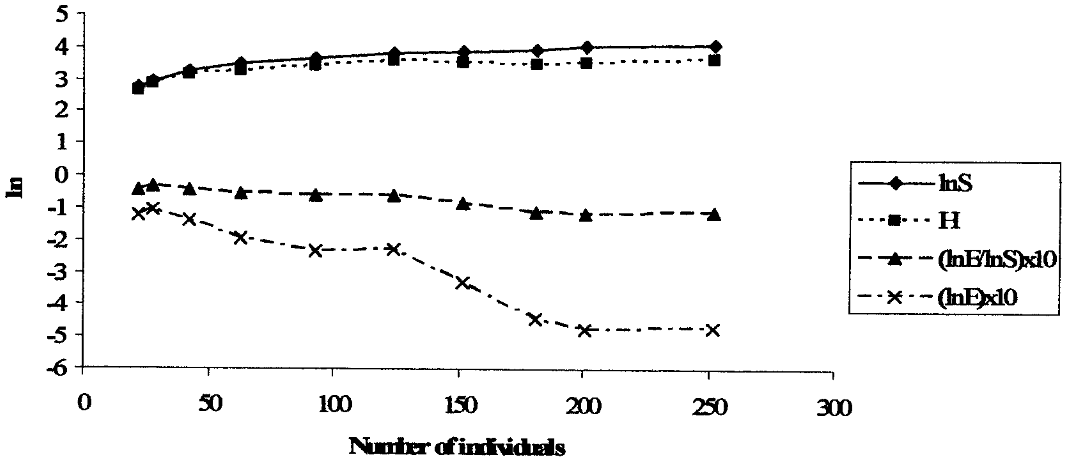

Figure 22 SHE analysis plot for the valley habitat

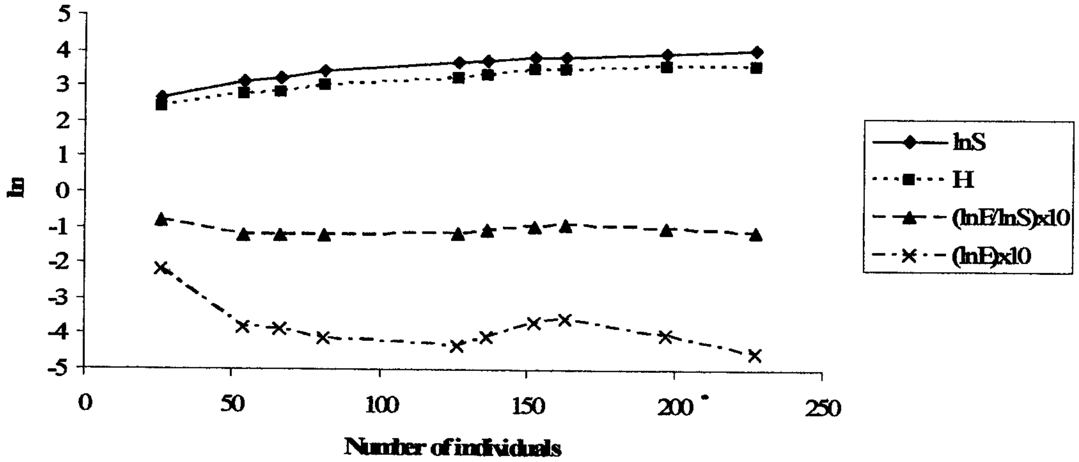

Figure 23 SHE analysis plot for the slope habitat

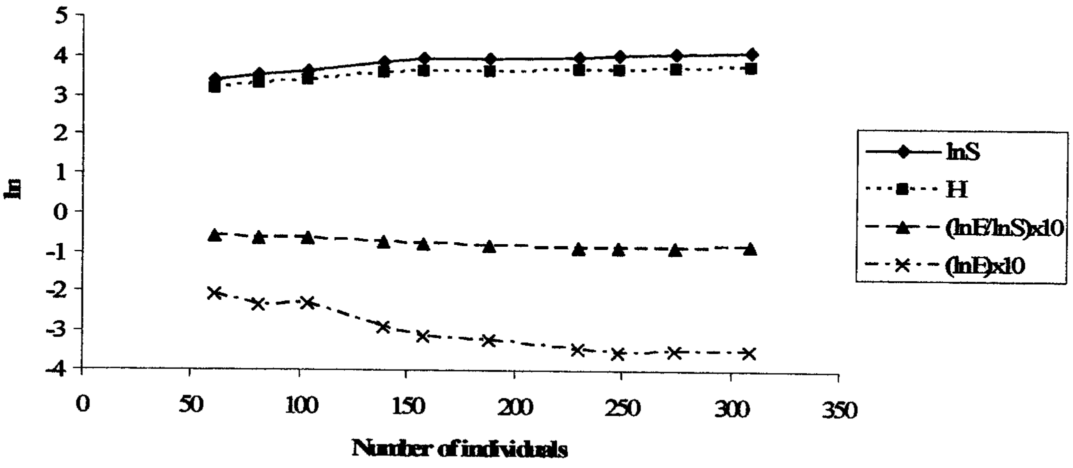

Figure 24 SHE analysis plot for the hill top habitat

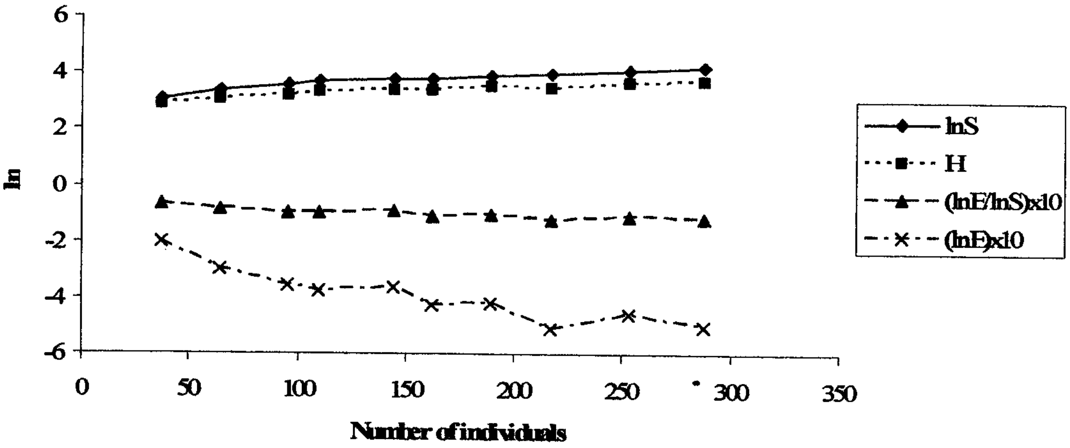

Figure 25 SHE analysis plot for the secondary forest habitat

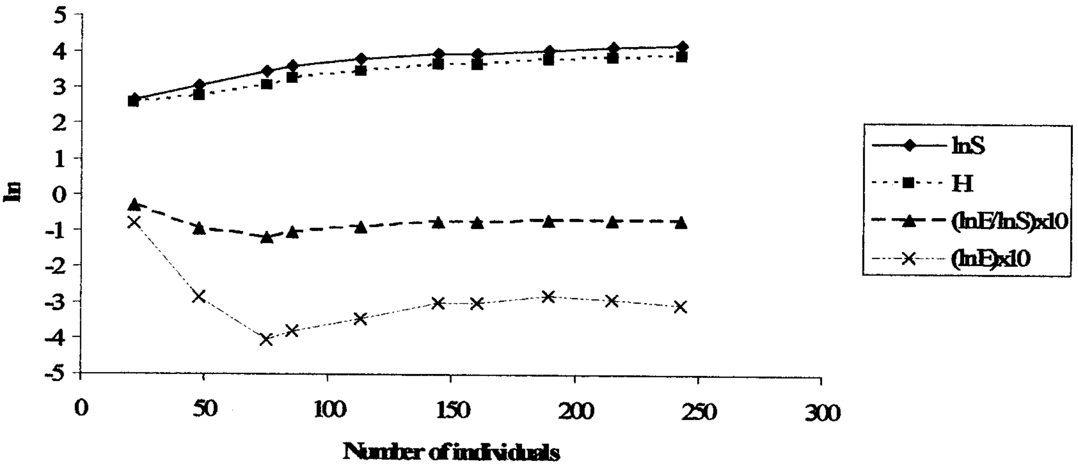

Figure 26 SHE analysis plot for the total 40 plots

Fisher's alpha

The fisher's alpha is an important species diversity index for the log series distribution. The study found that the secondary forest habitat had highest α value, which was 27.43. The lowest α value was found in the hill top habitat, which was 22.77. However the valley habitat and slope habitat had intermediate α values, which were 25.59 and 24.46 respectively. The value of α for the aggregated 40 plots was 24.07.

The summary of density and diversity results is presented in table 7. However, the result can add understanding for explaining the character of density and diversity of the 1.6 hectares area (40 x 20 x 20 m). The total pooled was derived from the calculation all 40 sampling plots, which not similar to SHE analysis of total area of 1.6 ha. The SHE analysis of total 1.6 ha gathered from random 10 sampling plots and performed SHE analysis.

Table 7 Summary table of density and diversity studies

	Area				Total
	Valley habitat	Slope habitat	Hilltop habitat	2° Forest habitat	Pooled
Mean density[1]	25.2 ± 2.27	22.8 ± 2.35	30.9 ± 2.23	28.8 ± 1.32	26.9 ± 11.28
Mean diversity[2]	14.0 ± 4.67	12.8 ± 3.85	16.6 ± 5.56	15.8 ± 4.18	14.8 ± 4.68
N	252	227	309	288	1076
S	61	57	61	67	92
H	3.64	3.59	3.76	3.70	3.96
ln S	4.11	4.04	4.11	4.20	4.52
ln E	-0.47	-0.45	-0.35	-0.50	-0.56
Log series α	25.59	24.46	22.77	27.43	24.07
Log series x	0.91	0.90	0.93	0.91	0.98

[1] stems per plot, [2] species per plot

Species-area curve

The data on lianas ≥ 1 cm dbh in the 40 sampling plots were used for construction of a species-area curve. The regression of ln S (species) on ln A (area) was done to obtain the S estimated as a function of area. The regression between ln S and ln A produced the equation of power curve ($S = cA^z$) where S was estimated species, A was area and c and z are constants. The power curve equation from the regression was $S = 1.04A^{0.42}$ and r^2 is 0.97. However, the S estimated result was not good as presented in the semi-ln equation. The equation of semi-ln regression provided $S = -141.28 + \ln(a) \times 23.88$ and r^2 is 0.97. The asymptote point originated at the 82 species, but S value of the curve still increased when enlarged the size of area. The species-area curve of lianas ≥ 1 cm dbh presented in the figure 27.

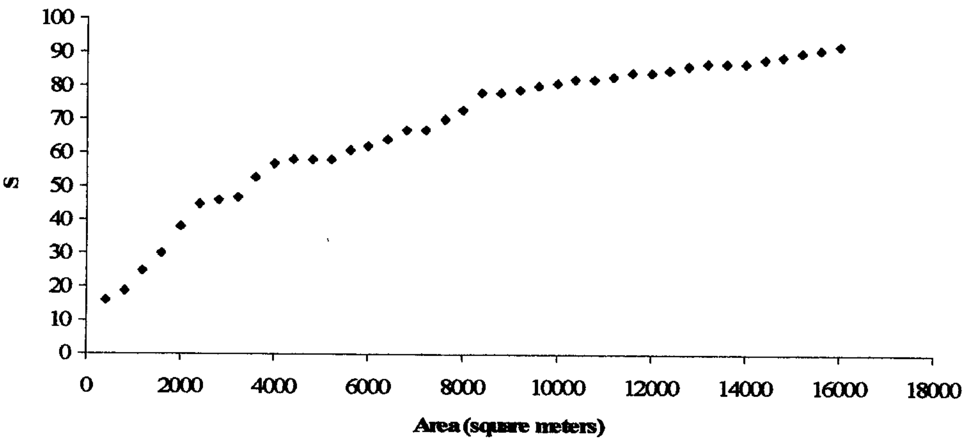

Figure 27 The species-area curve of lianas ≥ 1 cm dbh

Lianas and their environmental factors

The dataset for lianas ≥ 1 cm dbh was used to analyze how environmental factors determine liana diversity and density. The 40 sampling plots were combined. The dataset is presented in table 8. Liana diversity and density values were regressed with environmental factors. The dependent variables were diversity and density. The environmental factors were used as independent variables. The multiple regression was done in two cycles using different dependent variables.

Table 8 The density and diversity of ≥1 cm dbh liana per sampling plot

plot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Density (stems)	20	62	30	19	34	41	23	35	27	22	17	28	11	16	37	31	11	45	27	10
Diversity (species)	13	29	18	15	18	20	10	19	15	14	12	15	9	11	15	19	8	19	16	8
plot	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Density (stems)	52	20	29	6	22	28	30	21	14	35	38	27	31	16	35	37	20	28	36	18
Diversity (species)	22	16	12	5	16	13	17	14	11	19	22	12	17	12	18	21	12	16	22	15

The environmental data were collected from 40 sampling plots. The major field measured variables were forest height, elevation, slope, the number of available host trees, and collected soil variables. Soil samples were taken for soil analysis, which gave soil texture, pH, organic matter, phosphorus, potassium, cation exchange capacity. Moreover the canopy distinctiveness was derived from the point-intercept height measurements. The dataset of constraint factors is presented tables 9 and 10.

Table 9 The soil characters for constraint factors data

Plot name	Sand fraction (%)	Silt fraction (%0	Clay fraction (%)	pH	Organic matter ($g\ kg^{-1}$)	Phosphorus ($mg\ kg^{-1}$)	Potassium ($mg\ kg^{-1}$)	C.E.C. ($cmol\ kg^{-1}$)
1	30.54	47.5	21.96	5.63	6.8	3.5	177.6	12.36
2	28.69	46.14	25.17	5.42	5.72	5.8	180.2	13.54
3	21.77	45.19	33.04	5.93	5.32	5.55	216.6	16.72
4	42.5	35	22.5	4.9	3.41	4	111.1	11.51
5	32.5	47.5	20	5.38	8.15	4.58	115.7	10.45
6	23.64	48.68	24.89	4.69	5.75	1.95	97	14.48
7	26.43	48.68	24.89	4.74	8.4	9.48	165.8	13.17
8	47.31	33.98	18.71	5	7.3	5.14	175.2	11.15
9	32.3	41.91	25.79	4.74	4.35	4.88	99	13.43
10	44.1	30.5	25.4	5.02	5.9	5.24	95.61	13.64
11	27.7	43.9	28.4	4.73	6.69	7.63	154.3	15.12
12	23.64	50.36	26	4.6	5.13	2.04	72	14.46
13	42.5	35	22.5	4.1	9.49	5.71	80.5	11.59
14	25.56	58.21	16.23	4.54	5.95	3.04	64.16	10.37
15	22.5	45	32.5	5.23	6.29	5.55	278.4	16.38
16	42.5	40	17.5	4.5	6.46	3.53	135.1	10.76
17	25	36.5	38.5	4.79	5.41	4.2	122.5	17.54
18	22.66	43.83	33.51	4.28	9.66	5.03	112	16.29
19	13.2	54.07	32.73	4.04	11.05	4.58	93.41	15.87
20	12.21	49.06	38.73	4.56	6.17	3.54	103.6	17.32
21	28.1	43	28.9	4.48	6.93	4.95	130.9	15.46
22	29.32	38.5	32.18	4.17	10.39	5.18	78.93	17.14
23	31.02	55.28	13.7	4.34	9.25	4.08	83.59	9.84
24	20.64	48	31.36	4.52	7.31	4.43	100.1	16.97
25	13.15	44.4	42.45	4.25	11.12	5.2	105.6	18.47
26	20.3	44.2	35.5	4.5	7.01	4.69	121.6	17.65
27	29.36	54.15	16.49	4.34	11.36	7.55	151.4	10.41
28	42	31.15	26.85	4.66	5.97	1.81	125.6	14.35
29	14.33	51.04	34.63	4.31	8.09	3.63	118.8	18.14
30	27.89	56.96	15.15	4.45	6.68	4.13	73.56	10.35
31	10.74	55.16	34.1	5.36	7.84	4.79	182	16.38
32	17.5	52.5	30	5.25	6.93	3.35	146.4	15.43

Table 9 (continued)

Plot name	Sand fraction (%)	Silt fraction (%0	Clay fraction (%)	pH	Organic matter ($g\ kg^{-1}$)	Phosphorus ($mg\ kg^{-1}$)	Potassium ($mg\ kg^{-1}$)	C.E.C. ($cmol\ kg^{-1}$)
33	33.02	30.92	36.06	5.22	6.97	2.63	130.1	17.15
34	30.47	33.42	36.11	5.08	6.61	3.35	114.3	17.91
35	25.58	37.77	36.65	5.05	5.98	2.8	105	17.49
36	15.23	44.87	39.9	5.2	5.87	2.38	93.73	18.52
37	27.67	40.69	31.64	5.11	8.49	3.19	144.4	15.48
38	25.32	39.15	35.53	5.12	7.17	1.63	145.5	16.74
39	23.5	39	37.5	4.88	8.75	4.3	179.3	17.13
40	15.64	44.99	39.37	5.25	6.79	7.41	150.6	18.68

Table 10 The non-soil environmental factors data

Plot name	Forest height (m)	elevation (m)	Slope (degree)	Trees>70 cm dbh (stems)	Trees<70 cm dbh (stems)	Canopy distinctive-ness
1	21.5	742	8	1	17	1.11
2	29	746	16	1	8	1.16
3	19.5	711	16	0	10	2.34
4	29.4	702	19	0	18	1.8
5	33.4	702	14	0	18	1.39
6	22.3	743	8	0	21	1.59
7	23.8	708	8	1	14	1.8
8	22.5	707	8	2	21	1.27
9	27.6	702	6	0	20	1.02
10	15.7	744	24	1	14	2.41
11	15.3	722	16	0	22	2.51
12	21.6	747	24	0	21	2.01
13	22.3	716	19	1	37	1.07
14	12.9	704	8	0	19	2.31
15	13.6	720	14	0	21	1.98
16	19.2	763	19	1	12	1.85
17	9.2	774	14	0	14	1.89
18	15	792	10	1	18	1.77
19	9.2	713	25	0	38	1.35
20	14	777	18	0	21	2.29
21	13.6	723	10	0	26	1.77
22	13.9	724	0	3	40	0.5
23	16.9	784	23	0	32	2.25
24	19.2	738	9	0	25	1.98

Table 10 (continued)

Plot name	Forest height (m)	elevation (m)	Slope (degree)	Trees>70 cm dbh (stems)	Trees<70 cm dbh (stems)	Canopy distinctiveness
25	9.2	793	6	1	15	2.25
26	12	792	8	0	27	2.37
27	8.9	721	12	1	33	2.46
28	23.1	760	9	1	24	1.56
29	10.6	791	6	2	27	1.11
30	11.7	792	23	0	27	1.92
31	12.5	728	10	0	52	1.32
32	8.5	730	17	0	24	2.46
33	13.8	735	16	0	28	1.44
34	8.6	738	16	0	31	0.99
35	9.3	742	13	0	38	1.16
36	8.8	745	17	0	27	1.51
37	10.9	751	14	0	25	1.06
38	15.5	754	17	0	32	1.23
39	9.4	744	27	0	27	1.39
40	10.8	737	16	1	22	1.77

Multiple regression between liana density and environmental factors

The result found that the regression between density and environmental factors had a low coefficient of determination (r^2), which was 0.31. The environmental factors explained the changing of liana density 31 %. The Durbin-Watson value was 1.71, which showed that the standard error was more independent. The r^2 and Durbin-Watson value presented in table 11. However, ANOVA indicated that there was no significant relation between environmental factors and liana density (table 12). Moreover, the one by one test of the relation between liana density and environmental factors also found no significant relation between two the types of variables. The beta also had low values; the highest beta value was for number of trees < 70 cm dbh. This value presented that number of host trees < 70 cm dbh had the highest relation with liana density but this relation was not strong or significant. The beta and significant values are presented in table 13.

Table 11 Model summary of regression between density and environmental factors

R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
.556(a)	.310	-.077	4.83758	1.710

a Predictors: (Constant), trees>70cmdbh, potassium, forest height, silt, canopy distinctiveness, elevation, slope, organic, phosphorus, clay, trees<70cmdbh, pH, cec, sand

Table 12 ANOVA of regression between density and environmental factors

	Sum of Squares	df	Mean Square	F	Sig.
Regression	262.321	14	18.737	.801	.661(a)
Residual	585.054	25	23.402		
Total	847.375	39			

a Predictors: (Constant), trees>70cmdbh, potassium, forest height, silt, canopy distinctiveness, elevation, slope, organic, phosphorus, clay, trees<70cmdbh, pH, cec, sand

Table 13 Coefficients table of regression between density and environmental factors

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	227.809	203.275		1.121	.273	-190.844	646.463
forest height	-.074	.196	-.105	-.375	.710	-.477	.330
elevation	-.019	.038	-.114	-.495	.625	-.097	.059
slope	-.061	.157	-.081	-.387	.702	-.384	.262
sand	-2.026	2.008	-4.047	-1.009	.323	-6.162	2.110
silt	-2.114	2.017	-3.410	-1.048	.305	-6.267	2.040
clay	-2.062	1.927	-3.425	-1.070	.295	-6.032	1.907
pH	-.692	3.006	-.066	-.230	.820	-6.883	5.500
organic	-.367	.727	-.144	-.505	.618	-1.864	1.130
phosphorus	.499	.705	.180	.707	.486	-.954	1.952
potassium	.012	.027	.108	.428	.673	-.044	.068
cec	.283	1.580	.168	.179	.859	-2.971	3.537
canopy distinctiveness	2.360	2.345	.261	1.006	.324	-2.470	7.189
trees<70cmdbh	.226	.134	.436	1.686	.104	-.050	.502
trees>70cmdbh	-1.085	1.813	-.166	-.598	.555	-4.818	2.649

Multiple regression between liana diversity and environmental factors

The regression between liana diversity and environmental factors also found a result similar to that with liana density. The environmental factors explained variation in liana diversity 29 %, (r^2 =0.29). The standard error was highly independent, and the Durbin-Watson value was 2.1 (table 14). The relation of lianas diversity and environmental factors was non-significant (table 15). The one by one test also found that there was no relation between liana diversity and environmental factors. The cation exchange capacity was highly relation with liana diversity, which the beta was 0.73, but it not strong to changing significant value (table 16).

Table 14 Model summary of regression between diversity and environmental factors

R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
.543(a)	.295	-.100	12.318	2.081

a Predictors: (Constant), trees>70cmdbh, potassium, forest height, silt, canopy distinctiveness, elevation, slope, organic, phosphorus, clay, trees<70cmdbh, pH, cec, sand

Table 15 ANOVA of regression between diversity and environmental factors

	Sum of Squares	df	Mean Square	F	Sig.
Regression	1587.467	14	113.391	.747	.711(a)
Residual	3793.308	25	151.732		
Total	5380.775	39			

a Predictors: (Constant), trees>70cmdbh, potassium, forest height, silt, canopy distinctiveness, elevation, slope, organic, phosphorus, clay, trees<70cmdbh, pH, cec, sand

Table 16 Coefficients table of regression between diversity and environmental factors

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	506.706	517.602		.979	.337	-559.316	1572.727
forest height	-.328	.498	-.185	-.657	.517	-1.354	.699
elevation	-.060	.096	-.145	-.628	.536	-.259	.138
slope	.169	.399	.089	.423	.676	-.654	.992
sand	-4.662	5.113	-3.695	-.912	.371	-15.192	5.869
silt	-4.799	5.135	-3.072	-.935	.359	-15.375	5.777
clay	-5.800	4.908	-3.822	-1.182	.248	-15.908	4.308
pH	.223	7.655	.008	.029	.977	-15.542	15.988
organic	-.170	1.851	-.026	-.092	.928	-3.981	3.642
phosphorus	1.270	1.796	.181	.707	.486	-2.430	4.969
potassium	.029	.069	.107	.418	.679	-.114	.172
cec	3.117	4.024	.732	.775	.446	-5.170	11.403
canopy distinctiveness	5.377	5.971	.236	.901	.376	-6.920	17.674
trees<70cmdbh	.396	.341	.303	1.160	.257	-.307	1.098
trees>70cmdbh	-1.875	4.616	-.114	-.406	.688	-11.381	7.632

CHAPTER V
DISCUSSION

Floristic composition

Previous studies have found the number of families per area were different among regions. Gentry (13) found that the 20 Amazonian forests had average 18 families (climbers > 2.5 cm diameter in 0.1 ha) and that 8 families dominated the flora. These major families were Bignoniaceae, Leguminosae, Hippocrateaceae, Menispermaceae, Sapindaceae, Malpighiaceae, Connaraceae and Dilleniaceae. The 41 other families were less common overall in Amazonian sites. African liana communities included an average of 18 families and the major families were Apocyanaceae, Leguminosae, Hippocreteaceae, Dichapetalaceae, Icacinaceae, Combretaceae and Connaraceae. In Borneo, at least 17 families occur and the most prevalent were Annonaceae, Apocynaceae, Loganiaceae, Leguminosae, Connaraceae, Dilleniaceae, and Rubiaceae. Moreover, tropical Asia (including New Guinea) had 50 families and the dominant families were Annonaceae, Leguminosae, Palmae, Connaraceae, Apocyanaceae, Rubiaceae and Moraceae. This study found that the Leguminosae, Apocyanaceae, Rubiaceae, Annonaceae, and Moraceae were the most speciose and the total on the plot was 35 families and 116 species. Gentry (13) concluded that the most prevalent Asian lianas were Annonaceae and palms. This study has found that the liana community was dominated by Leguminosae, Apocynaceae and Rubiaceae, but this study did not include the monocotyledons, so the Palmae was not in the ranking. On the other hand personal observations indicated that there were approximately 4 species of rattan in the Mo Singto site; if the rattans are included in the study then they will still be low in diversity. However, the result was similar to Gentry's African dataset, and suggests that the Asian liana flora is similar to that of Africa (in which Apocyanaceae and Leguminosae are prevalent). Putz and Chai's study (20) found that the major families in Lambir National Park, Malaysia, were Leguminosae (11 species) and Annonaceae (9 species), a result quite similar to this study, in which 13 species of Leguminosae and 8 species of Annonaceae were found. However, the ranking of Annonaceae was different, as this study found Annonaceae in 4th place. On the other hand, the Indian site (43) presented a different result; the Rhamnaceae, Asclepiadaceae and Verbeanaceae were most speciose. In Neotropical forests a different floristic composition occurs, in which results the predominant families are Bignoniaceae and Leguminosae (13, and 46). The floristic composition in this study was similar to other close Asia sites (such as Lambir site) and Africa sites in the order of major families, but the lower ranked families are different at the Mo Singto site. Moreover certain families, such as Sabiaceae, Oleaceae and Tiliaceae are found only in old world areas (13). The flora at Mo Singto is most similar to that of other old world areas, and contrasts with the New World sites.

With respect to density, the family ranking is different. The study found that the Rubiaceae had the highest number of stems and the second and third ranked families (Apocynaceae, and Leguminosae) had much lower abundance. This situation also occurred in Nabe-Nielsen's study in Yasuní, Ecuador (44). The diversity ranking of Nabe-Nielsen's study found the most prevalent families to be Sapindaceae and Leguminosae, but the highest ranking families based on density were Leguminosae and Celastraceae. The density and species rank order plot showed that high density species much fewer than low density species, as described by the logarithmic series.

The distribution maps showed that some lianas were strongly affected by the environmental factors, such as *Uncaria macrophylla* and *Piper retrofractum*. On the other hand, in *Tetracera indica* and *Sabia limoniacea*, the environmental factors were less important in determining distribution. The well distributed species tended to reproduce by vegetative propagation more than seeding systems, such as *Uncaria scandens*, *Tetracera indica* and *Tetrastigma laoticum*. Vegetative propagation supported wide dispersion, either favored habitat or not. In the beginning of propagation, ramets still connected to genet and also received the nutrients and water supply from origin stem. After that ramets growth and can support themselves, and finally split to be new stems. Moreover, there was the resource partitioning in same genus. The *Uncaria sandens* well growth in the higher elevation. On the other hand, *Uncaria macrophylla* favored to growth in low level. Not only the altitude determined distribution of this species but the gap also regulated distribution. The clumped distribution of this species was associated with the gaps in the Mo Singto Biodiversity Research plots.

The study of the size distribution of lianas by dbh showed that the small diameter lianas (1-3 cm dbh) had a higher proportion of stems. The medium diameter lianas (> 3- 6 cm dbh) had almost 50 % less compared with the small size class. Lianas (> 6 cm dbh) were 25 % less compared with medium size. Moreover the proportion can be presented in the simple way, which is 1:4:8 represented for the large size, medium size and small size respectively. The size class proportions imply that only 50 % of the small size can survive and grow to medium size, after that they can survive only 25 % of the medium size (12.5 % of small stems). The 1-cm classes' distributions indicated that small size classes lead to reduce survivorship. This empirical relation was consistent with the study of Mascaro et al. (71), which found that the smallest lianas (< 2 cm dbh) had higher mortality rate per year than the larger lianas individuals (> 5 cm dbh). However the study found genetically small diameter size lianas, such as *Tetrastigma cruciatum*, which do not reach large size. This species was only found in the < 3 cm class. Then the size class distribution hypothesis can be obscured by variations among species in growth. The liana plot monitoring and recensus can answer this question. This assumes constant growth rates over age classes.

Liana diversity and density

The liana diversity and density study focused on the >1 cm girth lianas. The 4 habitats sites in the Mo Singto Biodiversity Research Plot were compared with respect to diversity and density. The boxplot analysis of density showed similar density among the 4 habitats. ANOVA showed no significant differences among habitats. The result implies that 4 habitats had different gradients of constraint factors, but provided similar carrying capacity for lianas. The differences in the 4 habitat sites in this study show differences in the combination of limiting factors. The slope habitat site has a more dynamic soil surface, in which soil erosion or landsides often occur. These local conditions limit the host trees and soil nutrients available although this area has plenty of light available. The valley site contains higher availability of the soil nutrients and moisture, but suitable host trees and light were depleted. Brockelman (65) found that the valley site in Mo Singto area had many tall canopy trees, and the canopy was thick.

The light beam hardly penetrated to the forest floor. Moreover, the bigger diameter host tree also decreases the liana density in this habitat. Clark and Clark (54) suggested that the trees ≥ 70 cm dbh were usually found without lianas. The stem twiner lianas did not climb the big trees easily. On the other hand, tendril species are not obstructed by tree dbh. The hilltop site had many lower canopy trees and the light condition was good. However, the soil nutrients and the moisture of this habitat were lower than the valley site. The secondary growth habitat had many small trees. The light beam penetrated to the ground. These various conditions provided places for the specialist lianas. Some places were suitable for twiners, the other places appropriate for root climbers. The lack of suitable places for liana settlement determined the high number of rare species.

The regression of S or ln S on ln N provided species richness values as a function of density and allowed comparison among 4 habitats. ANCOVA was used for comparison of those regressions among habitats. The result showed that the ln S/ ln N index was similar for the 4 habitats. The species richness was not regulated independently by environmental factors, but was determined by overall abundance. The similarity of density and diversity of 4 habitats shows that lianas ≥ 1 cm dbh averaged 26.9 ± 11.28 stems, and 14.80 ± 4.68 species, per 0.04 ha. The result is not strictly compareable to other study sites, because the other studies are based on different lianas dbh sizes and study areas.

SHE analysis is one of numerous diversity indices and proposed for solving some problem in measured the diversity. The most frequently used diversity index is H (heterogeneity index), whatever Shannon and Wiener, and Simpson methods. All of these indices of H combined the species richness and evenness in single measurement. However the different number of species and number of individual can provide the same values of H. This problem had been interfered the community structure comparison. The diversity in SHE analysis can separate the species richness and evenness out for recognize the difference between two communities. Moreover the accumulation of number of individuals in SHE analysis can evaluate the diversity when the number of individuals changes. The distribution pattern was gathered without construct log abundance on species rank curve. SHE analysis provides H and ln S and ln E, and ready for used to explain diversity though H value. If H value was difficult to compare among communities, there are also more split values (ln S and ln E) available for use.

SHE analysis found that the all habitats were characterized by the logarithmic series distribution, in which H values were quite constant and ln E values decreased with increasing N. However, the density and diversity of lianas were not very different among the 4 habitats. Then species richness (ln S) for Mo Sinto Site was better measured from the aggregation of 40 sampling plots, which was 4.52 per 1.6 ha. Moreover the ln evenness (ln E) was -0.56 per 1.6 ha, and the heterogeneity index (H) was 3.96. The logarithmic series community had comparatively few common species and large numbers of rare species. The most suitable diversity index for this area is probably the Fisher's alpha. Fisher's α was used for predicting the number of species and the number of individuals in each species within the particular area. Moreover, Fisher's α was close to the number of species from the data. The study result found that the Fisher's α for ≥ 1 cm dbh lianas (within the 1.6 ha) was 24.07 and log series x was 0.98.

The ≥ 1 cm dbh lianas species area curve presented a stairway shape in the beginning and approached an asymptote with addition of more area. The stairway shape represents patches, and slope of the curve indicates the fine or coarse of numbers of species, which fine represented more evenness than coarse. The curve of this study represented quite coarse gain species. The species area curve showed that the area had different patches sizes. Patches were occupied by particular species. The result was harmonious with the logarithmic series distribution, in which rare species are numerous. The specialists of particular areas formed patches, and produced the stair way shape in the species-area curve.

Lianas and their environmental factors

The multiple regressions between liana diversity and density, and their environmental factors were not found any significant relation. The 30 sampling plots were randomly selected in same forest type (tropical seasonal evergreen forest), which had no relation between liana diversity and density, and environmental factors. This result is consistant with Gentry's study (13), in which he found the mean abundance and diversity in the lowland tropical moist and wet forests were similar. The result indicates that environmental factors did not greatly affect the liana community. On the contrary, the liana niches were wider than the differences of environmental factors among habitats. However, this study included 10 more sampling plots from secondary forest but there did not affect the results of multiple regressions. Gentry (13) also found that liana density and diversity within the same continents was similar and were not strongly affected by environmental factors. Moreover this secondary forest was located adjacent to the main area of tropical seasonal evergreen forest of the plot, in which the soil parent material should be similar and provide the same soil type. Regarding liana species, there were not different species pooled between two forest types, and constructed the same diversity values. However, the soil parent material and species pooled ideas need more studies for confirm these hypotheses. Recalling the distribution maps, some species were restricted in distribution by some environmental factors, such as elevation and gaps. If the multiple regression was done only on those species, a significant relation must occur. On the other hand, the wide dispersion of most species overcame there effects. Regarding beta values, the regression between liana density and environmental factors found that the number of trees < 70 cm dbh had highest beta value. This result implies that the small diameter host trees could be the important factor for liana density. Further study should be done on relations between diameter of host trees and liana density. Moreover the regression between liana diversity and environmental factors provided the highest beta value of cation exchange capacity. The cation exchange capacity value relates to nutrient rich soil, in which a high cation exchange capacity implies soil holding more nutrients (in cation form). Forthcoming studies will also deal with liana diversity and C.E.C. to gain more knowledge about liana and their environmental factors.

CHAPTER VI
CONCLUSION

The floristic composition of ≥ 3 cm dbh lianas in Mo Singto Biodiversity Research Plot was contrasted with the New World sites. The predominant families were similar to other Old World tropical areas. The Leguminosae and Apocynaceae were most speciose in this site. On the other hand the predominant families were not in the highest rank if considered in terms of numbers of stems per family. The most abundant family was Rubiaceae. The 28.56 ha plot contained 9510 stems, which included 35 families, 116 species, excluding 6 unknown species.

The distribution map indicated that environmental factors determined distribution of some liana species. The related species were separated distribution by resource partitioning. The well distribution species tended to reproduce by vegetative propagation more than seeding.

The proportions of small stems (1-3 cm dbh), medium stems (> 3-6 cm dbh) and large stems (> 6 cm dbh) were 8:4:1 respectively. The distributions of size classes trend to depend on survivorship more than genetically small diameter size lianas.

The lianas ≥ 1 cm dbh in Mo Singto Biodiversity Research Plot had 26.9 ± 11.28 stems and 14.80 ± 4.68 species per 0.04 ha. The number of stems determined the number of species, which was similar in the 4 habitats. The lianas in Mo Singto site conformed to the logarithmic series distribution. The lianas community had log series alpha 24.07 and log series x was 0.98 in the 1.6 ha area.

The study area contained various patch sizes, and coarse gains species in the particular patch. The number of species in the patch depended on the density of lianas, the increasing of number of stems caused increase in the number of new species. The evidence was confirmed by the ANCOVA, in which the number of species was related to the number of stems wherever the habitat type.

The ≥ 1 cm dbh liana diversity and density are not determined by environmental factors. This relation gathered from the multiple regression method. The randomized samples or specific selection, such as considered only the wide disperse species should yield the different result.

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APPENDIX

APPENDIX

Table 1 Species list of ≥ 3 cm dbh lianas (genets) in survey of the 28.56 ha, Mo Singto area

Family	Scientific name	Total stems
Annonaceae	*Artabotrys sp.*	2
Annonaceae	*Cyathostemma micranthum* (A. DC.) Sincl.	171
Annonaceae	*Desmos dumosus* (Roxb.) Saff. var. glabrior	87
Annonaceae	*Fissistigma parviflorum* (Scheff.) Merr.	122
Annonaceae	*Uvaria cordata* (Dun.) Alst.	82
Annonaceae	*Uvaria dac* Pierre ex Fin. & Gagnep.	28
Annonaceae	*Uvaria fauveliana* (Pierre ex Fin. & Gagnep.) Ast.	23
Annonaceae	*Uvaria hirsuta* Jack	59
Apocynaceae	*Aganosma cymosa* (Roxb.)G. Don	48
Apocynaceae	*Aganosma schlecteriana* H. Lev.	15
Apocynaceae	*Anodendron affine* (Hook. & Arn.) Druce	6
Apocynaceae	*Anodendron paniculatum* A. DC.	45
Apocynaceae	*Epigynum griffithianum* Wight	239
Apocynaceae	*Melodinus cambodiensis* Pierre ex Spire	119
Apocynaceae	*Melodinus cochinchinensis* (Lour.) Merr.	3
Apocynaceae	*Parameria laevigata* (Juss.) Mold.	82
Apocynaceae	*Pottsia laxiflora* (Bl.) O. K.	107
Apocynaceae	*Strophanthus caudatus* (L.) Kurz	44
Apocynaceae	*Trachelospermum asiaticum* (Sieb. & Zucc.) Nakai [2]	305
Apocynaceae	*Urceola micrantha* (Wall. ex G. Don) Midd.	231
Araliaceae	*Schefflera elliptica* (Bl.) Harms[2]	20
Asclepiadaceae	*Gymnema inodorum* (Lour.) Decne.	7

Table 1 (continued)

Family	Scientific name	Total stems
Asclepiadaceae	*Gymnema sp.*	3
Asclepiadaceae	*Gymnema latifolium* Wall. Ex Wight	7
Asclepiadaceae	*Gymnema thorelii* Cost.	3
Asclepiadaceae	*Telosoma sp.*	4
Asclepiadaceae	*Marsdenia tinctoria* R. Br.	1
Celastraceae	*Celastrus approximata* Craib	304
Celastraceae	*Celastrus paniculatus* Willd	3
Celastraceae	*Reissantia indica* (Willd.) Halle	25
Celastraceae	*Salacia chinensis* L.	167
Combretaceae	*Combretum punctatum* Bl.	71
Combretaceae	*Combretum sp.*	9
Compositae	*Vernonia elaeagnifolia DC.*	3
Compositae	*Vernonia solanifolia* Bth.	11
Connaraceae	*Rourea minor* (Gaertn.) Leenh.	57
Connaraceae	*Roureopsis stenopetala* (Griff.) Schell.	109
Convolvulaceae	*Argyreia obtecta* (Choisy) Cl.	72
Convolvulaceae	*Argyria sp.*	49
Convolvulaceae	*Erycibe elliptilimba* Merr. & Chun	148
Convolvulaceae	*Erycibe subspicata* Wall ex G. Don	118
Convolvulaceae	*Neuropeltis racemosa* Wall.	177
Convolvulaceae	*Porana spectabilis* Kruz	2
Cucurbitaceae	*Neoalsomitra integrifolia* (Cogn.) Hutch.	4
Cucurbitaceae	*Trichosanthes ovigera* Bl.	4

Table 1 (continued)

Family	**Scientific name**	**Total stems**
Dilleniaceae	*Tetracera indica* (Houtt. Ex Christm. & Panz.) Merr.	387
Dilleniaceae	*Tetracera loureiri* (Fin. & Gagnep.) Pierre ex Craib	43
Elaeagnaceae	*Elaeagnus conferta* Roxb.	77
Euphorbiaceae	*Phyllanthus reticulatus* Poir.	57
Gnetaceae	*Gnetum macrostachyum* Hk. f.	59
Gnetaceae	*Gnetum montanum* Markgraf	60
Hernandiaceae	*Illigera pierrii* Gagnep.	156
Legumminosae:		
Caesalpinioidae	*Bauhinia glauca* (Wall. Ex Bth.) Bth.	65
Caesalpinioidae	*Caesalpinia crista* L.	6
Caesalpinioidae	*Pterolobium microphyllum* Miq.	38
Mimosoideae	*Acacia megaladena* Desv.	24
Mimosoideae	*Entada rheedii* Spreng.	1
Papilionoideae	*Callerya cinerea* (Bth.) Schot	22
Papilionoideae	*Dalbergia foliacea* Wall.	15
Papilionoideae	*Dalbergia horrida* (Denn.) Mebb.	113
Papilionoideae	*Dalbergia velutina* Bth.	50
Papilionoideae	*Endosamara racemosa* (Roxb.) Gees.	1
Papilionoideae	*Mucuna macrocarpa* Wall.	192
Papilionoideae	*Pueraria alopecuroides* Craib	1
Papilionoideae	*Spatholobus harmandii* Gagnep.	197
Loganiaceae	*Fagraea ceilanica* Thunb.^{2}	16
Loganiaceae	*Strychnos lanata* Hill	4

Table 1 (continued)

Family	**Scientific name**	**Total stems**
Melastomataceae	*Diplectria barbata* (Bl.) Franken & Roos	124
Menispermaceae	*Diploclisia glaucescens* (Bl.) Diels	109
Menispermaceae	*Hypserpa nitida* Miers	55
Moraceae	*Ficus laevis* Bl.	1
Moraceae	*Ficus punctata* Thunb.	13
Moraceae	*Ficus sagittata* Vahl.	86
Moraceae	*Ficus sp.*	42
Moraceae	*Ficus villosa* Bl.	28
Moraceae	*Maclura cochinchinensis* (Lour.) Corn.	6
Moraceae	*Maclura sp.* [1]	15
Myrsinaceae	*Embelia sessiliflora* Kruz.	9
Oleaceae	*Jasminum lanceolaria* Roxb.	11
Oleaceae	*Jasminum scandens*	2
Piperaceae	*Piper retrofractum* Vahl	100
Piperaceae	*Piper ribesoides* Wall.	59
Polygalaceae	*Securidaca inappendiculata* Hassk.	1
Ranunculaceae	*Naravelia laurifolia* Wall. ex Hk.f. & Th.	1
Rhamnaceae	*Berchemia floribunda* Wall. ex Brongn	14
Rhamnaceae	*Gouania leptostachya* DC.	37
Rhamnaceae	*Rhamnus nipalensis* (Wall.) Laws.	1
Rhamnaceae	*Ventilago denticulata* Willd.	86
Rhamnaceae	*Ventilago harmandiana* Pierre	4

Table 1 (continued)

Family	Scientific name	Total stems
Rhamnaceae	*Ziziphus attopensis* Pierre	41
Rubiaceae	*Caelospermum truncatum* (Wall.) Baill. ex K.	194
Rubiaceae	*Coptospelta flavescens* Korth.	34
Rubiaceae	*Morinda umbellata* L.	316
Rubiaceae	*Morinda villosa* Hk. f.	24
Rubiaceae	*Oxyceros longiflora* (Lmk.) Yama.	134
Rubiaceae	*Uncaria laevigata* Wall. ex G. Don	187
Rubiaceae	*Uncaria macrophylla* Wall.	480
Rubiaceae	*Uncaria scandens* (Sm.) Hutch.	594
Rutaceae	*Paramignya scandens* (Griff.) Craib.	7
Rutaceae	*Toddalia asiatica* (L.) Lmk.	61
Sabiaceae	*Sabia limoniacea* Wall. ex Hk. f. & Th.	404
Thymelaeaceae	*Linostoma pauciflorum* Bl.	55
Tiliaceae	*Grewia laevigata* Vahl	30
Tiliaceae	*Grewia sp.*	27
Urticaceae	*Poikilospermum suaveolens* (Lour.) Merr. [2]	66
Verbenaceac	*Premna corymbosa* (Burm. f.) Rottl. & Willd.	16
Verbenaceac	*Premna flavescens* Ham. ex Cl.	303
Verbenaceac	*Sphenodesme mollis* Craib	1
Verbenaceac	*Sphenodesme pentandra* Jack	294
Vitaceae	*Ampelopsis cantoniensis* Pl.	93
Vitaceae	*Pathenocissus semicordata* (Wall.) Pl.	8

Table 1 (continued)

Family	**Scientific name**	**Total stems**
Vitaceae	*Tetrastigma harmandii* Pl.	39
Vitaceae	*Tetrastigma laoticum* Gagnep.	355
Vitaceae	*Tetrastigma aff. pyriforme* Gagnep.	152
Unknown 6		1
Unknown 8		1
Unknown 9		2
Unknown 19		2
Unknown 38		1
Unknown 39		3

[1] New species not yet named [2] Hemiepiphytes

Table 2 Species list of ≥ 1 cm dbh lianas (genets) in survey of 40 sampling plots

No	Scientific name
1	*Acacia megaladena* Desv.
2	*Aganosma cymosa* (Roxb.)G. Don
3	*Aganosma schlecteriana* H. Lev.
4	*Ampelopsis cantoniensis* Pl.
5	*Anodendron affine* (Hook. & Arn.) Druce
6	*Anodendron paniculatum* A. DC.
7	*Argyreia obtecta* (Choisy) Cl.
8	*Argyria sp.*
9	*Berchemia floribunda* Wall. ex Brongn
10	*Caelospermum truncatum* (Wall.) Baill. ex K.
11	*Caesalpinia crista* L.
12	*Callerya cinerea* (Bth.) Schot
13	*Celastrus approximata* Craib
14	*Celastrus monospermus* Roxb.
15	*Combretum punctatum* Bl.
16	*Combretum sp.*
17	*Coptospelta flavescens* Korth.
18	*Cosmostigma racemosa* (Roxb.) Wight
19	*Cyathostemma micranthum* (A. DC.) Sincl.
20	*Dalbergia foliacea* Wall.
21	*Dalbergia horrida* (Denn.) Mebb.
22	*Desmos dumosus* (Roxb.) Saff. Var. glabrior
23	*Diplectria barbata* (Bl.) Franken & Roos.
24	*Diploclisia glaucescens* (Bl.) Diels
25	*Elaeagnus conferta* Roxb.
26	*Embelia sessiliflora* Kruz.
27	*Epigynum griffithianum* Wight
28	*Erycibe elliptilimba* Merr. & Chun
29	*Erycibe subspicata* Wall ex G. Don

Table 2 (Continued)

No	Scientific name
30	*Fagraea ceilanica* Thunb.
31	*Ficus punctata* Thunb.
32	*Ficus sagittata* Vahl.
33	*Ficus sp.*
34	*Ficus villosa* Bl.
35	*Fissistigma parviflorum* (Scheff.) Merr.
36	*Gnetum macrostachyum* Hk. f.
37	*Gnetum montanum* Markgraf
38	*Gouania leptostachya* DC.
39	*Grewia laevigata* Vahl
40	*Grewia sp.*
41	*Gymnema inodorum* (Lour.) Decne.
42	*Gymnema sp.*
43	*Gymnema thorelii* Cost.
44	*Hypserpa nitida* Miers
45	*Illigera pierrii* Gagnep.
46	*Jasminum lanceolaria* Roxb.
47	*Linostoma pauciflorum* Bl.
48	*Melodinus cambodiensis* Pierre ex Spire
49	*Morinda cochinchinensis DC.*
50	*Morinda umbellata* L.
51	*Morinda villosa* Hk. f.
52	*Mucuna macrocarpa* Wall.
53	*Neuropeltis racemosa* Wall.
54	*Oxyceros longiflora* (Lmk.) Yama.
55	*Parameria laevigata* (Juss.) Mold.
56	*Paramignya scandens* (Griff.) Craib.
57	*Phyllanthus reticulatus* Poir.
58	*Piper retrofractum* Vahl
59	*Piper ribesoides* Wall.

Table 2 (Continued)

No	Scientific name
60	*Poikilospermum suaveolens* (Lour.) Merr.
61	*Pottsia laxiflora* (Bl.) O. K.
62	*Premna flavescens* Ham. ex Cl.
63	*Pterolobium microphyllum* Miq.
64	*Reissantia indica* (Willd.) Halle
65	*Rhamnus nipalensis* (Wall.) Laws.
66	*Rourea minor* (Gaertn.) Leenh.
67	*Roureopsis stenopetala* (Griff.) Schell.
68	*Sabia limoniacea* Wall. ex Hk. f. & Th.
69	*Salacia chinensis* L.
70	*Schefflera elliptica* (Bl.) Harms
71	*Spatholobus harmandii* Gagnep.
72	*Sphenodesme pentandra* Jack
73	*Strophanthus caudatus* (L.) Kurz
74	*Tetracera indica* (Houtt. Ex Christm. & Panz.) Merr.
75	*Tetracera loureiri* (Fin. & Gagnep.) Pierre ex Craib
76	*Tetrastigma aff. pyriforme* Gagnep.
77	*Tetrastigma cruciatum* Craib & Gagnep. [1]
78	*Tetrastigma harmandii* Pl.
79	*Tetrastigma laoticum* Gagnep.
80	*Toddalia asiatica* (L.) Lmk.
81	*Trachelospermum asiaticum* (Sieb. & Zucc.) Nakai
82	*Uncaria laevigata* Wall. ex G. Don
83	*Uncaria macrophylla* Wall.
84	*Uncaria scandens* (Sm.) Hutch.
85	*Urceola micrantha* (Wall. Ex G. Don) Midd.
86	*Uvaria cordata* (Dun.) Alst.
87	*Uvaria dac* Pierre ex Fin. & Gagnep.
88	*Uvaria fauveliana* (Pierre ex Fin. & Gagnep.) Ast.
89	*Uvaria hirsuta* Jack

Table 2 (Continued)

No	Scientific name
90	*Ventilago denticulata* Willd.
91	*Vernonia elaeagnifolia DC.*
92	*Vernonia solanifolia* Bth.

[1] found only in less than 3 cm dbh

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