EFFECTS OF FOREST RESTORATION AGE ON SPECIES DIVERSITY OF THE EPIPHYTIC BRYOPHYTE COMMUNITY

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An Undergraduate Thesis in Partial Fulfillment of the Requirements
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Undergraduate Thesis entitled "Effects of forest restoration age on species diversity of the epiphytic bryophyte community"
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บทคัดย่อ

ปัจจุบันมีการฟื้นฟูป่าเพื่อทดแทนพื้นที่ป่าที่ถูกทำลาย ส่งผลให้เกิดป่าฟื้นฟูที่มีความหลากหลายของสิ่งมีชีวิตแตกต่างจากป่าธรรมชาติ รวมถึงความหลากหลายของไบรโอไฟต์อิงอาศัยด้วยเช่นกัน ดังนั้นงานวิจัยนี้จึงทำการศึกษาความหลากชนิดและเปรียบเทียบชุมชีพไบรโอไฟต์อิงอาศัยในพื้นที่แปลงป่าปลูกพรรณไม้โครงสร้างของหน่วยวิจัยฟื้นฟูป่า มหาวิทยาลัยเชียงใหม่ ที่มีอายุป่าฟื้นฟู 21 ปี (ปลูกปี 2541) และ 13 ปี (ปลูกปี 2549) กับป่าธรรมชาติดงเซ็ง บ้านแม่สาใหม่ อำเภอแม่ริม จังหวัดเชียงใหม่ โดยทำการสำรวจในเดือนมิถุนายน 2562 พบไบรโอไฟต์อิงอาศัย 15 ชนิด 14 สกุล 12 วงศ์ เจริญบนเปลือกของต้น *Archidendron clypearia* (Jack) I.C.Nielsen (มะขามแป), *Erythrina stricta* Roxb. (ทองหลางป่า) และ *Sarcosperma arboreum* Hook.f. (มะยาง) ประกอบด้วยมอสส์ที่มีการเจริญแบบตั้งตรง 4 ชนิด (ร้อยละ 26.67) มอสส์ที่มีการเจริญแบบทอดนอน 5 ชนิด (ร้อยละ 33.33) รวมทั้งลิเวอร์เวิร์ตประเภทใบ 6 ชนิด (ร้อยละ 40.00) โดยความหลากชนิดของไบรโอไฟต์อิงอาศัยไม่แตกต่างกันในป่าปลูกทั้งสองอายุ แต่อย่างไรก็ตามดัชนีความเหมือนของชุมชีพไบรโอไฟต์อิงอาศัยในแปลงป่าปลูกที่มีอายุมากมีค่ามากกว่าแปลงป่าปลูกอายุน้อย เมื่อเปรียบเทียบกับแปลงป่าธรรมชาติ ดังนั้นถ้าป่าปลูกมีอายุมากขึ้นอาจส่งผลให้ความหลากชนิดของไบรโอไฟต์อิงอาศัยมีความใกล้เคียงกับป่าธรรมชาติมากขึ้นด้วย

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ABSTRACT

Forest restoration is re-establishing the forest in disturbance areas. This is resulting in the difference of biodiversity between restoration and natural forest, also the diversity of epiphytic bryophytes. Thus, this research determined the species diversity and compared epiphytic bryophyte community among framework species restoration plots of Forest Restoration Research Unit (FORRU), Chiang Mai University aged 21, 13 years and Dong Seng Natural Forest, Mae Sa Mai Village, Mae Rim District, Chiang Mai Province. The surveys were carried in June 2019. Fifteen species 14 genera 12 families of epiphytic bryophytes found on the bark of *Archidendron clypearia* (Jack) I.C.Nielsen (Thai name: Mah Kham Pae), *Erythrina stricta* Roxb. (Thai name: Tawng Lahng Bah) and *Sarcosperma arboreum* Hook.f. (Thai name: Mah Yang). Epiphytic bryophytes were divided into 3 groups, i.e., acrocarpous mosses 4 species (26.67%), pleurocarpous mosses 5 species (33.33%) and leafy liverworts 6 species (40.00%). Species richness of epiphytic bryophytes was not different in two forest restoration ages. However, the similarity index of the epiphytic bryophyte community in older restoration forests was higher than the young restoration forest when compared to the natural forest. Therefore, if the restoration forest becomes older, the epiphytic bryophytes species in the restoration forest will also more similar to the natural forest.

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CHAPTER 1
INTRODUCTION

1.1 Introduction

"Forest restoration" is re-establishment of the forest that will be similar to an original forest ecosystem before deforestation occurred. It aims to restore former levels of ecosystem structure and function. The success of forest restoration can be measured from the returning of the multi-layer canopy, increasing numbers of returning species and improving soil conditions (The Forest Restoration Research Unit [FORRU], 2006).

Bryophytes are small, non-vascular tissue plants can be biological indicators because they are usually found in an abundant environment and help to retain moisture. Although bryophytes, comparing to fungi, algae, or angiosperm, may have much lower economic value, they also are pioneer plants that could grow in high areas above sea level, flooded areas, even wastelands. When bryophytes died, they accumulate into humus soil then other land plants can grow to be the forest. Epiphytic bryophyte is a type of bryophytes that grows on another plant but not parasitizing it. Tree bark also important habitats for epiphytic bryophytes, in addition, their diversity is positively increasing by tree density and host tree DBH (Oishi, 2012).

The framework species plots of Forest Restoration Research Unit (FORRU), Mae Sa Mai Village, Doi Suthep-Pui National Park, Chiang Mai Province were forest restoration plots. The plots had been established by Department of Biology, Faculty of Science, Chiang Mai University in 1998 and 2006 to reforest abandoned fields (Pakkad et al., 2002). The areas were increasing in abundant of trees and wildlife (Elliott et al., 2004) and starting to have epiphytic bryophyte species that can be one of the indicators about the abundant of area. While Dong Seng Forest was a natural forest near the framework species plots. The forest restoration is resulting in the difference of biodiversity between natural and restoration forest; therefore, these areas were surveyed to compare the species diversity of epiphytic bryophyte communities in natural forest and forest restoration plots for improving the database, knowledge and to emphasize the importance of forest restoration to epiphytic bryophyte diversity.

1.2 Objectives

1.2.1 To determine the species composition of epiphytic bryophytes at Dong Seng Forest and framework species plots of Forest Restoration Research Unit, Mae Sa Mai Village, Mae Rim District, Chiang Mai Province

1.2.2 To compare epiphytic bryophyte communities among natural forest and various restoration ages of framework species plots

1.3 Research scope

The purpose of this study is to survey epiphytic bryophytes and compare epiphytic bryophyte communities between Dong Seng Forest that is the natural forest with two framework species plots of FORRU that were started reforestation in 1998 and 2006. Both natural forest and restoration plots are near Mae Sa Mai Village, Mae Rim District, Chiang Mai Province.

1.4 Hypotheses

1.4.1 Species richness of epiphytic bryophytes will be increasing in older age framework species plots.

1.4.2 Similarity index of epiphytic bryophyte communities in older age framework species plots will be more increased when compared to the non-disturbance forest.

1.5 Benefits

1.5.1 To gain species composition of epiphytic bryophytes at Dong Seng Forest and framework species plots of Forest Restoration Research Unit, Mae Sa Mai Village, Doi Suthep-Pui National Park, Chiang Mai Province

1.5.2 Using diversity index to indicate improving abundance of epiphytic bryophytes in the restoration forest

1.5.3 Estimate abundance of forest restoration using epiphytic bryophytes as an indicator

CHAPTER 2
LITERATURE REVIEWS

2.1 Bryophytes

Bryophytes are small, non-vascular tissue plants that attach to the ground and their habitats with rhizoids. They grow in cluster patterns under the shade and moist habitat such as, on soil, rock, or bark. Some species are found in thallus form growing attach to their habitats, some in the leafy form with caulidium and phyllidium structure (Rattanayan, 1998).

Bryophytes are classified by botanists into 3 major groups or division; mosses (Division Bryophyta), liverworts (Division Marchantiophyta), and hornworts (Division Anthocerotophyta) (Goffinet and Shaw, 2008). Furthermore, mosses can be classified into two major groups by using gametophyte and sporophyte growing. There are composed of “acrocarpous mosses” that have an erect stem with sporophyte growing on a terminal of the main stem and “pleurocarpous mosses” that main stems are always creeping while sporophytes are produced on short, lateral branches. Liverworts also can be classified into two major groups by gametophytes structure. There are “thalloid liverworts” and “leafy liverworts” which have thalloid gametophyte and leafy gametophyte structure respectively (Rattanayan, 1998).

Like all land plants, bryophytes have an alternation of generation through two-phase of the life cycle including the gametophyte phase with haploid (n) chromosomes that is dominant in all bryophyte species, and the sporophyte phase with diploid (2n) chromosomes that is depended on the gametophyte (Figure 2.1).

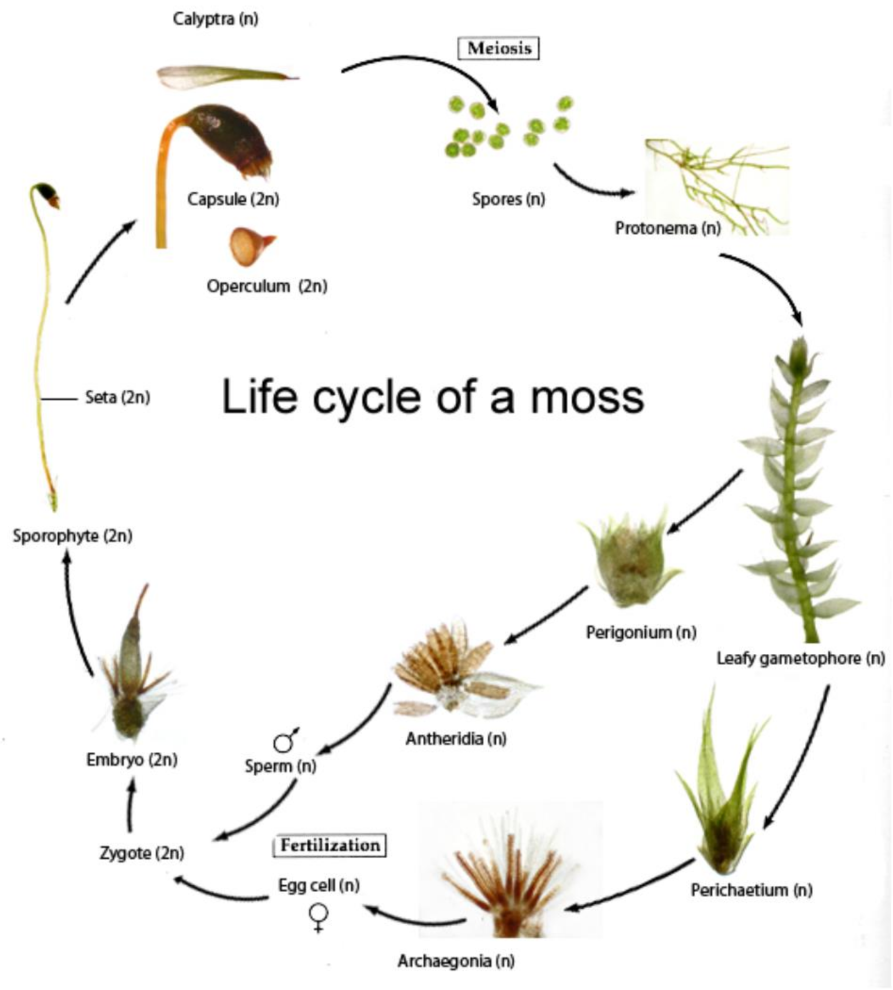

Figure 2.1 Life cycle of a moss (Tan and Ho, 2008)

Bryophytes are consisting of 177 families 1,822 genera 34,556 species around the world (The Plant List, 2013). 89 families 280 genera 1,006 species of bryophytes have been reported in Thailand (He, 2019; Lai et al., 2008). These plants can be biological indicators because they are usually found in an abundant environment and help to retain moisture. They play an important role in the water balance of ecosystems in the forest by storing large amounts of water. Just like every organism, bryophytes have an ecological function such as providing micro-habitat for small animals, insects, micro-organisms, can be food for some beetles, and be the seedling bed for seed germination (Frahm et al., 1996). Although bryophytes comparing to fungi, algae, or angiosperm, may have much lower economic value, they also pioneer plants that could grow in high areas above sea level, flooded areas, even wastelands. When bryophytes died, they accumulate into humus soil that promote other land plants to grow to be the forest. Furthermore, they can reduce erosion along streams and absorb water (Pitpan, 1996).

Epiphytic bryophyte is a type of bryophytes that grows on another plant but not parasitizing it. They receive the nutrient from an environment such as nutrients from the rain, canopy leachate, and rotten bark. These reasons make epiphytic bryophytes present in many areas. Their diversity is positively increasing by tree density and host tree DBH (Oishi, 2012). The roughness and characteristic of host bark also were factors for epiphytic bryophyte diversity (González-Mancebo et al., 2003; Shen et al., 2018; Song et al., 2015). However, epiphytic bryophytes rather not found in the high shade because of lacking enough light for their growing, neither on acidic bark tree (e.g. some pine tree), nor high pollution area (Manachit, 2006).

2.2 Bark roughness of host

Bark roughness of host was determined adapted from Song et al. (2005) as follow:

2.2.1 Low : very smooth or smooth but with fissures (Figure 2.2)

2.2.2 Medium : shallowly furrowed (Figure 2.3)

2.2.3 High : deeply fissured or abundant crevices across the surface (Figure 2.4)

Figure 2.2 Low roughness barks (Sungkaew, 2019)

Figure 2.3 Medium roughness barks (Sungkaew, 2019)

Figure 2.4 High roughness barks (Sungkaew, 2019)

2.3 Life forms of bryophytes

When bryophytes grow on the substrate, almost exhibit colonial life form more rather than present individual shoots or thalli. Each species presents a characteristic depend on their family, genus or species. Many species show the plasticity of life forms according to the environmental condition. This research classified the life forms of each species according to the description of Bates (1998) as follow:

2.3.1 Turfs: many loosely or closely packed vertical stems with limited branching such as many Pottiaceae, Dicranaceae, etc. (Figure 2.5A)

2.3.2 Cushions: dome-shaped colonies formed by regeneration from a central point of origin such that gradually increase in both height and radius and the component shoots vary in orientation from vertical to horizontal, by many acrocarpous and pleurocarpous mosses but not liverworts. (Figure 2.5B)

2.3.3 Dendroids: creeping stem along the substratum, then becoming erect, and finally develop an apical cluster of lateral branches bearing the main photosynthetic leaves, or else a rosette of large apical leaves, such as some acrocarpous and pleurocarpous mosses (e.g. *Hypopterygium*), thalloid Metzegeriales. (Figure 2.5C)

2.3.4 Pendants: mainly epiphytes in which the main shoots hang down from the point of attachment and bear many short, horizontal, lateral branched, such as Meteoriaceae, Phyllogoniaceae, etc. (Figure 2.5D)

2.3.5 Mats: branched or unbranched shoots that creep over the substratum and often closely attached by rhizoids, such as Hypnaceae, *Frullania*, *Radula*, many Lejuneaceae. (Figure 2.5E)

2.3.6 Wefts: loosely intertwining, usually richly branched, often with rather few rhizoidal attachments, usually robust pleurocarpous mosses, such as Racopilaceae, Thuidiaceae, and leafy liverworts. (Figure 2.5F)

2.3.7 Fans: shoots arising from vertical bark or rocks, branch repeatedly in the horizontal plane to form flattened photosynthetic surfaces, sometimes downcurved to towards their apices; leaves arrange in two lateral ranks, such as Neckeraceae, some *Plagiochila*, etc. (Figure 2.5G)

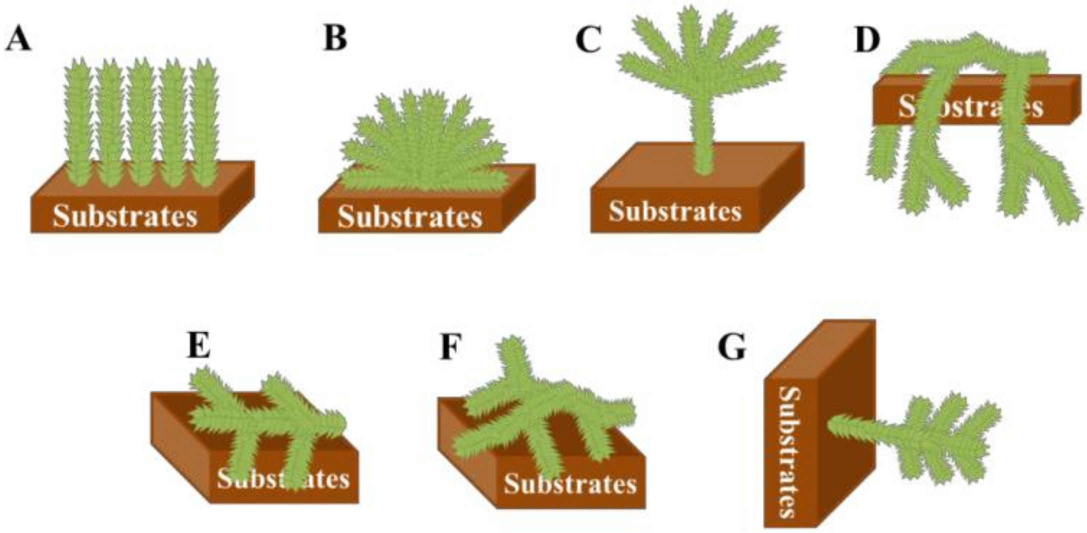

Figure 2.5 Life forms of bryophytes (Ajintaiyasil, 2017)

A. Turfs B. Cushions C. Dendroids D. Pendants

E. Mats F. Wefts G. Fans

Bryophyte life forms have interpreted as adaptations for maximizing water use efficiency, but some researches recognized the relationships between life forms and other physical factors of substrata, such as moisture and light intensity. For example, densely packed cushions often present in more dry habitats than other forms, which may result from receiving less light than widely spaced individuals. According to Figure 2.6, “Wet” refers to habitat that has less desiccation stress than “Dry”, life forms in parenthesis occur infrequently, a) life form on very freely draining, inclined surfaces, b) life forms on level surfaces, and c) extremely dense or branched version.

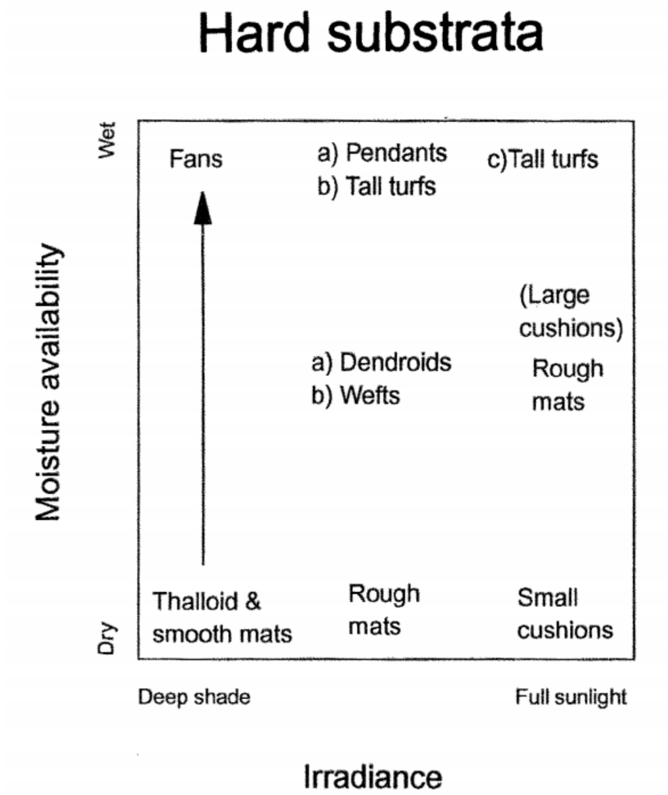

Figure 2.6 Relationship of bryophyte life forms to gradients of moisture and irradiance on hard substrata (not on soils) (Bates, 1998).

2.4 Bryophyte study in Thailand

Bryophyte study in Thailand was started in 1899-1900, when E.J. Schmidt, Danish botanist, collected bryophytes from Chang Island, Trad province. During 1902-1932 A.F.G. Kerr, Irish doctor turned botanist, collected a lot of bryophytes around Thailand (Sukkharak and Chantanaorrapint, 2014) then Dixon (1932) studied specimens from A.F.G. Kerr collection with literature and published the first mosses list of Thailand concluding 220 species of mosses and Dixon (1935) improved to 300 species. During 1950-1970 had lots of bryophyte study in Thailand by Thai botanists collaborated with Danish and Japanese botanists, such as Ch. Charoenphol, B. Hansen, K. Larsen, T. Santisuk, T. Smitinand, T. Sorensen and E. Warncke collected mosses about 7,000 specimens. These specimens were revised by botanists at Missouri Botanical Garden and these were becoming primary resources of mosses collection by Missouri Botanical Garden untill now (Vongkuna, 2003).

Santanachote and Rattanayan (1999) surveyed and collected mosses at Suthep-Pui National Park, Chiang Mai Province revealed 25 families 54 species and 2 varieties of mosses, almost at an elevation of 1,400-1,685 m above sea level and growing as epiphytes on the tree. Species richness of mosses in each family rather low and Simpson's diversity index was calculated to equal 0.02 indicated easily damaged ecosystem. From Weeranakin (2001) recorded about epiphytic mosses on *Pinus kesiya* Royle ex Gord. at Doi Suthep-Pui, 13 genera of mosses have consisted of 7 genera in acrocarpous mosses (54%) and 6 genera in pleurocarpous mosses (46%), which *Calymperes* and *Leucobryum* were the dominant genera. Moreover, Simpson's diversity index indicated at 0.44 meaning medium diversity of epiphytic mosses. Boonphathip (2001) studied epiphytic mosses on *Cupressus torulosa* D. Don at Doi Pui and observed 16 genera of mosses composed of acrocarpous mosses 6 genera (38%) and pleurocarpous mosses 10 genera (62%), the dominant genera were *Racopilum* and *Macrothamnium* and Simpson's diversity index was equal to 0.289 indicated high diversity of epiphytic mosses.

Furthermore, there were reported mosses outside conservation area such as; Tripiyarat (2002) surveyed bryophytes and their habitats on the wall at U-Mong Temple, Chiang Mai Province at an elevation of 350 m above sea level uncovered 6 groups of bryophytes growing on 5 plant species, *Hyophila involuta* (Hook.) Jaeg. was mostly around the tunnel and pagoda, *Isopterygium serrulatum* Fleisch. was located around the drainage channel and *Fissidens papillosus* Lac. was near the car park.

Chantanaorrapint (2002) studied diversity of bryophytes at the Summit of Khao Luang, Huai Yang Waterfall National Park, Prachuap Khiri Khan Province at an elevation 1,000-1,200 m above sea level found bryophytes 26 families 51 genera 81 species consisted of 1 species hornwort, 42 species mosses and 38 species liverworts (2 species thalloid liverworts and 36 species leafy liverworts. Lejeuneaceae is found to be main family that 7 genera with 11 species were being collected and classified. Vongkuna (2003) surveyed epiphytic mosses on tree at Ru See Cave, Doi Suthep-Pui National Park, Chiang Mai at elevation 1,050 m, in evergreen forest with high humidity and near water source area, could be classified into mosses 6 families 6 genera 12 species which composed of acrocarpous mosses 8 species (67%) and pleurocarpous mosses 4 species (33%). The dominant species in relative frequency is *Calymperes* sp.

(Calymperaceae). Moreover *Pinnatella alopecuroides* (Hook.) Flesieh. is the dominant species in relative dry weight and Simpson's diversity index is equal 0.2748 indicated a high diversity of mosses.

Kornochalert (2004) surveyed epiphytic bryophytes at San Ku, Doi Suthep-Pui National Park, Chiang Mai Province at elevation 1,600 m, in evergreen forest with high humidity near the summit of Doi Pui, and found that 9 families with 11 genera 11 species of which consisted of leafy liverworts 3 species (27%), acrocarpous mosses 2 species (18%) and pleurocarpous mosses 6 species (55%) were observed and classified. The dominant species in relative frequency is *Meteorium miquelianum* (C. Müll.) Fleisch. in Broth. subsp. *miquelianum* (Meteoriaceae). Moreover *Macromitrium turgidum* Dix. (Orthotrichaceae) is the dominant species in relative dry weight and Simpson's diversity index is equal to 0.26 indicated rather high diversity of bryophytes.

Furthermore, Nathi (2009) surveyed mosses diversity in Kew Mae Pan and Ang Ka Areas, Doi Inthanon National Park, Chiang Mai Province and found that 27 families 59 genera 101 species of mosses in Sematophyllaceae is the most in terms of species composition (16 species) followed by Fissidentaceae and Meteoriaceae (10 species in each family). Moreover, *Distichophyllum carinatum* Dixon & W. E. Nicholson, a moss species, is threatened with extinction of IUCN red list name also revealed.

Hassama (2015) studied species richness and vertical distribution of bryophytes at Chao Pa Waterfall, Trang Province come across bryophytes 20 families 54 genera 114 species composed of mosses 61 species, leafy liverworts 2 species and thallous liverworts 51 species. These bryophytes were almost epiphytic and some on ground or rock by the most in terms of species composition is Lejeuneaceae (14 genera 34 species) followed by Calymperaceae (6 genera 16 species), Fissidentaceae, Neckeraceae and Radulaceae (8 species in each family), respectively. Vertical distribution of bryophytes on *Saraca indica* L. 6 plants obtained 63 species of bryophytes (26 species of mosses and 37 species of liverworts) and bryophyte communities were varied in different high of trees by less moss diversity but more liverwort diversity when observed at higher on trees. Recently, Printarakul (2015) revised all bryophyte flora of Doi Suthep-Pui National Park, Chiang Mai Province including all 350 species which 49 taxa were new records for Thailand. Moreover, the dichotomous key and descriptions of many bryophytes species from this report were also used in this thesis. Lastly, He (2019) has online checklists of 620 mosses species that present in Thailand.

From the continuous study and research, more bryophytes were known, also continuously increasing bryophyte species lists in Thailand. So that, if there will be more researches, there would be more database, the new record or new species that would be benefits to biodiversity and ecological database of Thailand.

2.5 Forest restoration by framework species method

"Forest restoration" means the re-establishment of forest plant and animal species which are similar to an original forest ecosystem before deforestation occurred. The key tree species are planted to restore the former levels of ecosystem structure and functioning species. The success of forest restoration can be measured from returning of a multi-layered canopy, increasing numbers of returning species, improving soil conditions (FORRU, 2006).

The forest restoration has numerous benefits such as, increase the market value of biodiversity and carbon storage, moreover; in many tropical countries clean water supplies depend on forest conservation. The soil beneath forests provides the natural process of water filter and preservation of dry season water.

The framework species method uses planting a few, carefully selected tree species that rapidly grow and increase diversity. Mixtures of 20-30 indigenous forest tree species are planted. After the trees grow, they will attract wild animals and seed dispersers. Then, the forest becomes cooler, more humid, and weed-free.

This technique was excellent in Australia, also Thailand (Elliott, 2013). Moreover, it has been successfully modified to restore seasonally dry tropical forests to in northern Thailand (Elliott et al., 2003) and potentially worked well within a few kilometres of forest remnants (FORRU, 2008). However, if the tropical forests were once destroyed, they can never be recovered. Although some primary forest species can be restored, their long evolution progress was broken, and some species may become extinct. Furthermore, forest restoration is expensive and cannot guarantee the outcome.

2.6 Study site

The plantation plots of FORRU were positioned in abandoned fields from cultivation, 2-3 km far from the village. The soil before forest planting was more sand, acidic and less organic matter compare to another evergreen forest area at a similar elevation because of forest degradation and fire. The forest was then recovered by using the framework species method every year since 1998, then forests become more abundant (Elliott et al., 2004). While the Dong Seng Forest is a natural forest that has been protected by Hmong tribe villagers in the area for a long time ago, so the forest contains a lot of big trees and seedlings which are not disturbed. (Figure 2.7)

Figure 2.7 Dong Seng natural forest (Jinto, 2009)

Dong Seng Forest and the framework species 1998 plot, 2006 plot of FORRU were selected in this study because the areas were near to each other (Figure 2.8-2.10). Thus, the environmental conditions were not much different in each forest plots. The areas are at 18° 52’N, 98° 51’E an elevation of 1,207-1,310 m above sea level, consists of 3 main seasons: rainy season (May to October), dry season (November to January) and hot season (February to April). The average annual rainfall was 1,140.2 mm. The minimum temperature is 15.0 °C in January and the maximum 39.9 °C in April (Figure 2.11-2.13).

Figure 2.8 Study site map (Google Earth); show 3 forest plots in red border

A. The framework species 1998 plot of FORRU

B. The framework species 2006 plot of FORRU

C. Dong Seng natural forest

Figure 2.9 The framework species 1998 plot of FORRU (FORRU, 2006)

A. in 1998 (before forest restoration), B. in 2004 (6 years after planting), C. nowadays

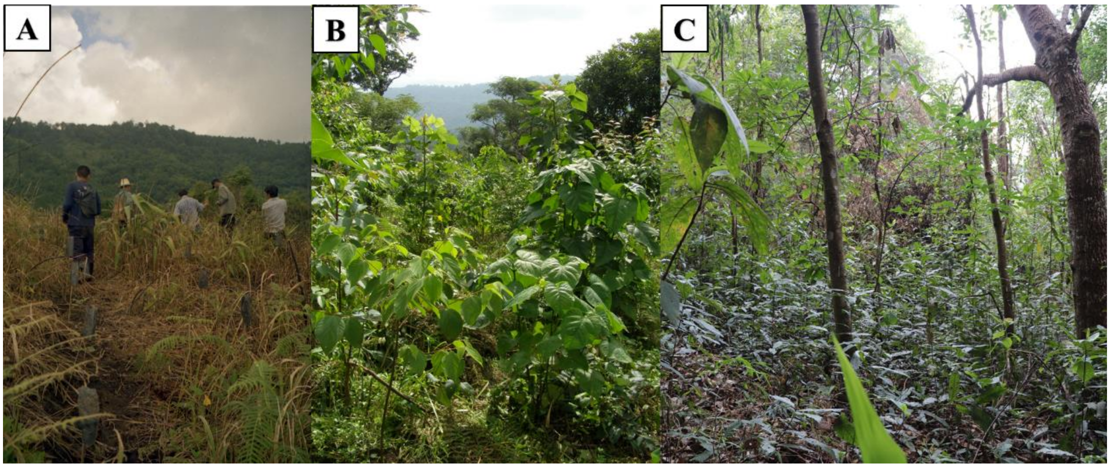

Figure 2.10 The framework species 2006 plot of FORRU

A. in 2006 (before forest restoration), B. in 2007 (1 year after planting), C. nowadays

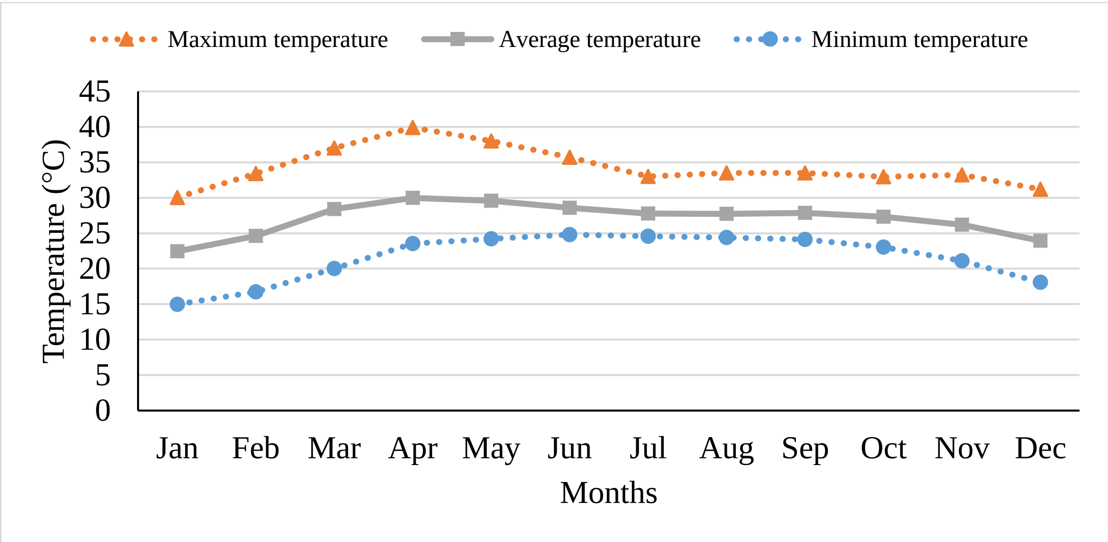

Figure 2.11 Maximum, average and minimum temperature from 2014-2018 at 314 m above sea level, Chiang Mai (Northern Meteorological Center, 2019)

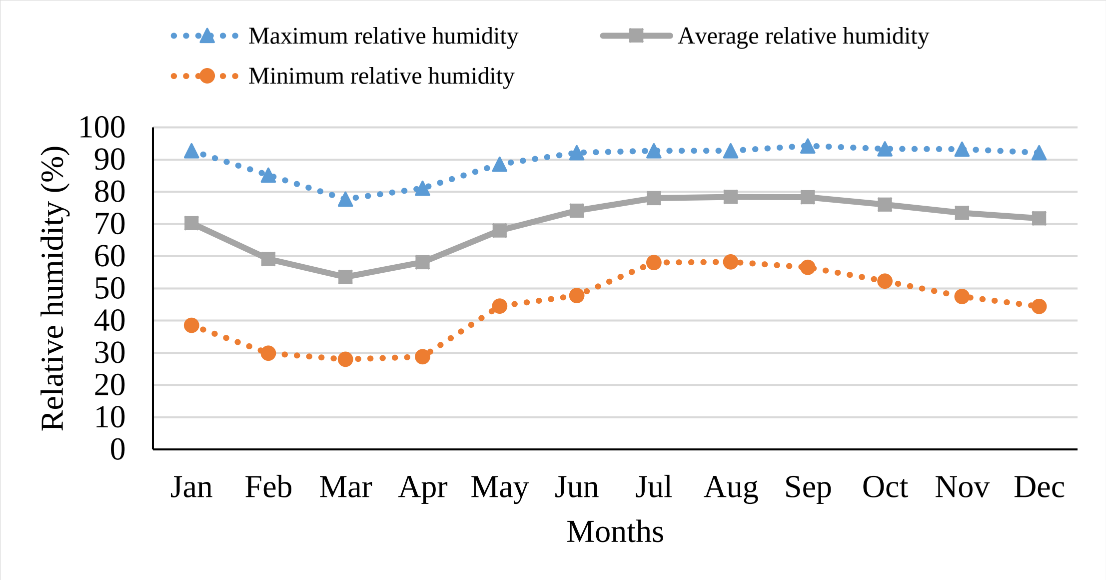

Figure 2.12 Maximum, average and minimum relative humidity from 2014-2018 at 314 m above sea level, Chiang Mai (Northern Meteorological Center, 2019)

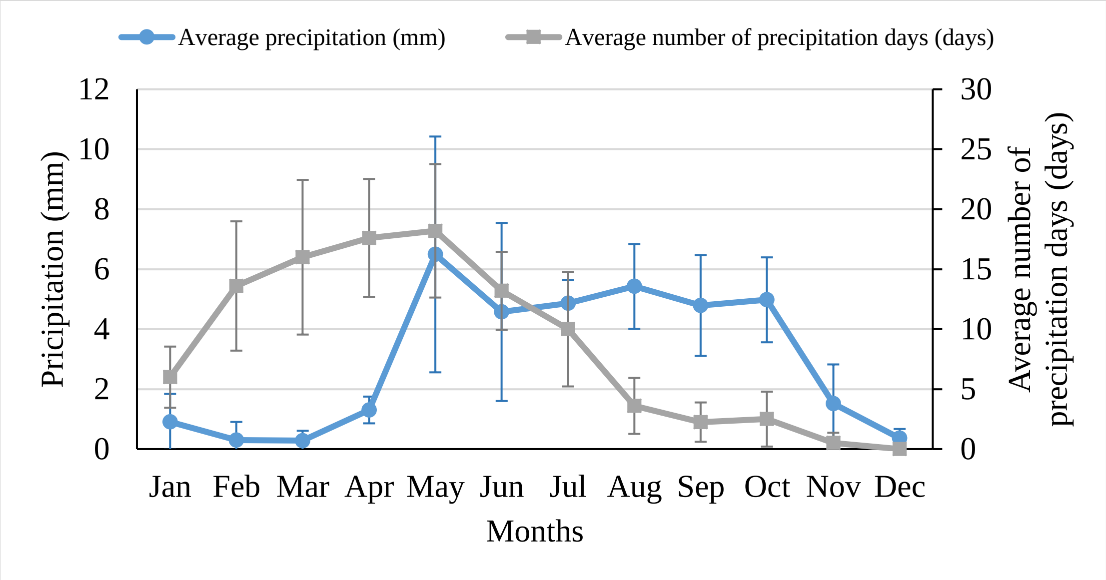

Figure 2.13 Average precipitation and number of precipitation days from 2014-2018 at 314 m above sea level, Chiang Mai (Northern Meteorological Center, 2019)

CHAPTER 3
MATERIALS AND METHODS

3.1 Materials

3.1.1 Specimen collecting equipment

1) paper bags 10 x 15 cm
2) pocketknife
3) field note
4) pencil
5) plastic bags
6) Global Position System (GPS) receiver
7) compass
8) hand lens
9) digital camera
10) frame quadrat 10 x 10 cm with 100 equal-sized standard grids
11) measuring tape
12) rope
13) thermometer and hygrometer
14) densiometer

3.1.2 Identification equipment

1) stereo microscope
2) light compound microscope
3) petri dishes
4) slides and cover glasses
5) razor blades
6) dropper
7) distilled water
8) dissecting needles
9) fine forceps
10) small brush
11) stationary such as paper, pencil, rubber, pen

12) related taxonomic literature as follows:
Gangulee (1972), Gangulee (1978), Gangulee (1980),
Gradstein (2011), Lai (1976), Printarakul (2015), Wijk (1958),
Wongkuna (2010), etc.

3.2 Methods

3.2.1 preliminary survey the framework species plots of FORRU (1998 and 2006 plot) as well as Dong Seng natural forest plot.

3.2.2 Epiphytic bryophyte specimens in three forest plots were collected from three host species including *Archidendron clypearia* (Jack) I.C.Nielsen (Fabaceae, Thai name: Mah Kham Pae), *Erythrina stricta* Roxb. (Fabaceae, Thai name: Tawng Lahng Bah) and *Sarcosperma arboreum* Hook.f. (Sapotaceae, Thai name: Mah Yang). Each host species was also selected 3 trees per host by the largest DBH size according to the research unit database (Figure 3.1).

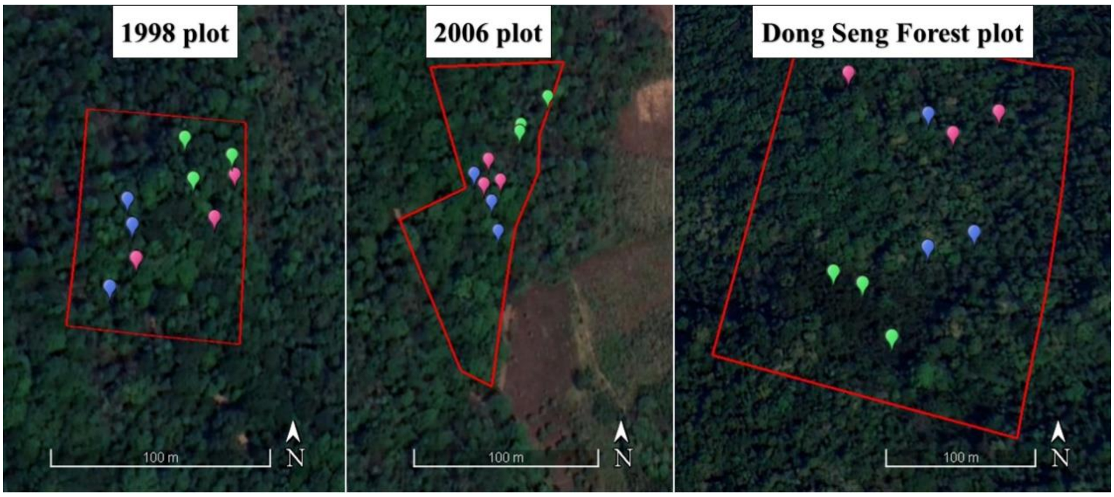

Figure 3.1 Position of host species from 3 plots

= *Archidendron clypearia* (Jack) I.C.Nielsen

= *Erythrina stricta* Roxb.

= *Sarcosperma arboreum* Hook.f.

3.2.3 Epiphytic bryophytes were investigated at the height that the bryophyte colony has maximum coverage in 4 directions (N, S, E, and W) for each individual tree. Then, put 10 cm x 10 cm frame quadrat with 100 equal-sized standard grids for 4 directions of individual trees, also collected physical and biological data needed:

1) Physical data
   a. altitude
   b. GPS coordinates
2) Biological data
   a. canopy closure (%) of each plot
   b. canopy height of each host
   c. canopy diameter of each host
   d. GBH of each host
   e. bark roughness of host species was determined adapted from Song et al. (2005), using “low” = very smooth or smooth but with fissures; “medium” = shallowly furrowed; “high” = deeply fissured or abundant crevices across the surface.
   f. grid height above the ground in each direction of individual hosts
   g. life form of bryophyte growing according to Bates (1998)
   h. % cover and % frequency of each epiphytic bryophyte species

3.2.3 Bryophyte specimens were identified in the laboratory using dichotomous keys in related taxonomic literature. All specimens were verified by comparison to the specimens at CMUB herbarium (Department of Biology, Faculty of Science, Chiang Mai University). The classification system of bryophytes in this thesis follows Goffinet and Shaw (2008).

3.2.4 The results were analyzed using Two-way ANOVA with Tukey’s post-hoc in PAST 3.26 to test mean different of altitude, canopy diameter, canopy height, GBH, and grid height of each host in three forest plots

3.2.5 Diversity indices of epiphytic bryophytes in three forest plots were calculated and compared using Microsoft Excel version 16.0 and PAST 3.26 programs, as follow:

1) Species richness (S): a total number of species in each plot

2) Simpson's index or dominance index (D): calculated from the number of different species in three plots. The lower values of this index represent greater species diversity. D ranges from 0 (all species are equally present) to 1 (one species dominates the plot completely).

   Simpson's index (Simpson, 1949) formula as:

$$D = \frac{\sum_i n_i(n_i - 1)}{n(n-1)}$$

   Where: D = Simpson's index or dominance

   n_i = total frequency of individual bryophyte species i in the plots

   n = total frequency of all bryophyte species in the plots

3) Simpson's diversity index (1-D) is also provided. Higher values of these indices represent greater diversity. Simpson's diversity index (1-D) ranges from 0 (low diversity) to 1 (the highest diversity).

4) Shannon-Weiner index (H) was adapted from Simpson's index by Shannon and Weaver (1949). Varies from 0 for communities with only a single species to high values for communities with many species, each with few individuals.

Shannon-Weiner index (H) formula as:

$$H = -\sum_i \frac{n_i}{n} \ln \frac{n_i}{n}$$

Where: H = Shannon-Weiner index

n_i = total frequency of individual bryophyte species i in the plots

n = total frequency of all bryophyte species in the plots

5) Buzas and Gibson's evenness (Buzas and Gibson, 1969): e^H/S

If the bryophytes species are equally distributed the ratio will equal to 1

6) Relative coverage (R_{cov}) is the proportion of the substrate occupied by each bryophyte species, formula as:

$$R_{cov} = C_i/\Sigma C \times 100\%$$

Where: R_{cov} = the relative coverage

C_i = the coverage of the species in the plots

ΣC = the total coverage of all species in the plots

7) Relative frequency (R_{fre}) is the chance of finding a species in the plots, formula as:

$$R_{fre} = f_i/\Sigma F \times 100\%$$

Where: R_{cov} = the relative frequency

f_i = the frequency of the species in the plots

ΣF = the total frequency of all species in the plots

8) Importance value index (IVI) of each epiphytic bryophyte species calculated from: $IVI = (R_{cov} + R_{fre})/2$

9) Sørensen similarity coefficient (Sørensen, 1948) calculated by present/absent of each species and shared bryophyte species between each plot, formula as:

$$\text{Sørensen similarity coefficient} = \frac{2a}{2a + b + c}$$

Where: a = total numbers of species shared by the two plots

b = total numbers of species present only in the first plot

c = total numbers of species present only in the second plot

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Forest plots' profile

Dong Seng natural forest plot, as well as, the framework species plots of FORRU (1998 and 2006 plot) were surveyed in June 2019 for collecting epiphytic bryophyte specimens, also physical and biological data of individual host species. The results are as follows in Table 4.1. Bark roughness of three host species was determined following Song et al. (2005) and displayed in Figure 4.1.

Table 4.1 Physical and biological data of three host species in three forest plots

Host species	Forest plots		
	Dong Seng	1998	2006
***Archidendron clypearia* (Jack) I.C.Nielsen**			
Average altitude	1219	1302	1247
Average canopy diameter (m)	3.72	4.90	4.19
Average canopy height (m)	11	17	16
Average GBH (cm)	58	130	53
Average grid height (cm)	71	10	20
Bark roughness	low	low	low
***Erythrina stricta* Roxb.**			
Average altitude	1224	1305	1237
Average canopy diameter (m)	5.73	2.78	5.38
Average canopy height (m)	26	15	20
Average GBH (cm)	127	77	118
Average grid height (cm)	150	26	15
Bark roughness	high	high	high

Table 4.1 (cont.)

Host species	**Forest plots**		
	Dong Seng	**1998**	**2006**
Sarcosperma arboreum **Hook.f.**			
Average altitude	1177	1300	1240
Average canopy diameter (m)	9.59	4.81	4.03
Average canopy height (m)	16	13	12
Average GBH (cm)	109	67	65
Average grid height (cm)	96	17	0
Bark roughness	medium	medium	medium
All host species			
Average altitude	**1206**	**1302**	**1242**
Average canopy diameter (m)	**6.45**	**4.30**	**4.52**
Average canopy height (m)	**17**	**15**	**16**
Average GBH (cm)	**97**	**97**	**77**
Average grid height (cm)	**99**	**16**	**12**
Canopy closure (%)	**98.70**	**96.88**	**95.14**

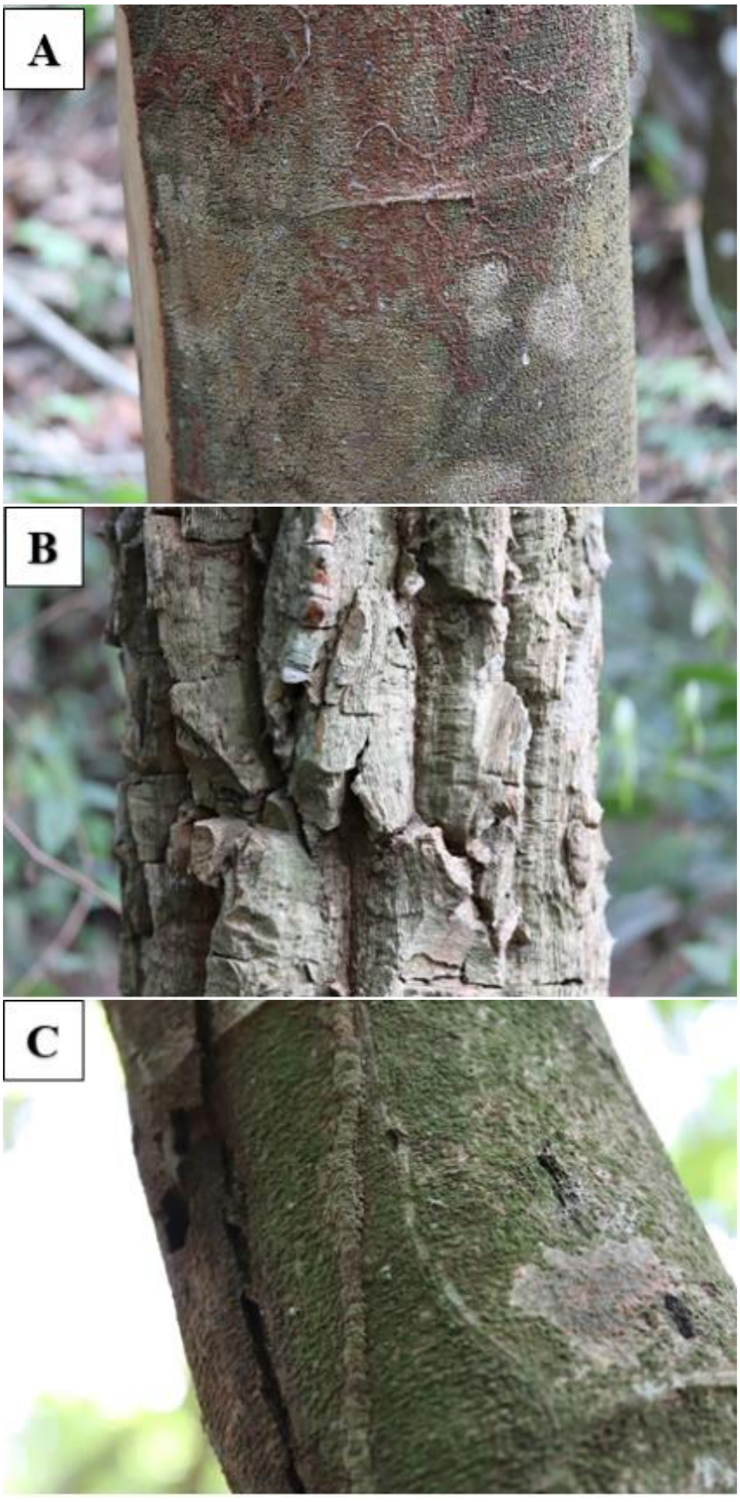

Figure 4.1 Bark of host species

A. *Archidendron clypearia* (Jack) I.C.Nielsen

B. *Erythrina stricta* Roxb.

C. *Sarcosperma arboretum* Hook.f.

Altitude, canopy diameter, canopy height, GBH, grid height of each host in three forest plots were analyzed using Two-way ANOVA to test mean different. Two-way ANOVAs result indicated no significant difference ($p>0.05$) of altitude, canopy diameter, canopy height, and GBH of each host in three forests. While there was a present of significant differences ($p<0.05$) on grid height above the ground between Dong Seng plot and the framework species plots of FORRU (both 1998 and 2006 plot). Moreover, canopy closure was increasing when the forest became older and highest in natural forest.

The grid height above the ground in Dong Seng plot was significantly higher than in 1998 and 2006 plot positively related to the ages of the forest. Furthermore, there was a trend that the 1998 plot had higher bryophytes above the ground than the 2006 plot. This result is similar to Fritz (2009) finding that tree age was also an important factor for the vertical distribution of epiphytes, probably because of a higher microhabitat quality.

4.2 Bryophyte species composition

Epiphytic bryophytes 15 species 14 genera 12 families were totally found in this study including acrocarpous mosses 4 species (26.67 %), pleurocarpous mosses 5 species (33.33%), and leafy liverworts 6 species (40.00%). The list of all bryophyte species was shown in Table 4.2.

Table 4.2 Lists of all bryophyte species found in the study area

Bryophyte group	**Scientific name**	**Family**	**Life form**
Acrocarpous mosses	*Fissidens hollianus* Dozy & Molk.	Fissidentaceae	Fans
	Fissidens zollingeri Mont.	Fissidentaceae	Fans
(26.67 %)	*Leucobryum aduncum* var. *scalare* (Müll. Hal. ex M. Fleisch.) A. Eddy	Dicranaceae	Turfs
	Octoblepharum benitotanii N. Salazar & Chantanaorr.	Calymperaceae	Turfs
Pleurocarpous mosses	*Entodontopsis anceps* (Bosch & Sande Lac.) W.R. Buck & Ireland	Stereophyllaceae	Mats
	Isopterygium lignicola (Mitt.) A. Jaeger	Hypnaceae	Mats
(33.33 %)	*Pelekium gratum* (P. Beauv.) Touw	Thuidiaceae	Wefts
	Racopilum orthocarpum Wilson ex Mitt.	Racopilaceae	Mats
	Trichosteleum stigmosum Mitt.	Sematophyllaceae	Mats
Leafy liverworts	*Cephalozia hamatiloba* Steph.	Cephaloziaceae	Mats
	Chiloscyphus kurzii (Sande Lac.) J.J. Engel & R.M. Schust.	Lophocoleaceae	Mats
(40.00 %)	*Cololejeunea planissima* (Mitt.) Abeyw.	Lejeuneaceae	Mats
	Frullania shanensis Svihla	Frullaniaceae	Mats
	Lejeunea tuberculosa Steph.	Lejeuneaceae	Mats
	Plagiochila junghuhniana Sande Lac.	Plagiochilaceae	Fans

Importance value indices (IVI) of each epiphytic bryophyte species on three host species in Dong Seng Forest, 1998 and 2006 plots were calculated from the average of relative coverage (R_{cov}) and relative frequency (R_{fre}). Then, IVIs of each epiphytic bryophyte species on every host was average to determine the dominant bryophyte species in three forest plots (Table 4.3 and Figure 4.2). Moreover, R_{cov}, R_{fre}, and IVIs of each epiphytic bryophyte species on three host species were also shown in Appendix A, B, and C, respectively.

Table 4.3 Average important value index of all epiphytic bryophyte species on all host species in Dong Seng Forest, 1998 and 2006 plots

Epiphytic bryophyte species	Average important value index (%) in forest plots (mean ± S.D.)		
	Dong Seng	**1998**	**2006**
Acrocarpous mosses			
Fissidens hollianus	4.90 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Fissidens zollingeri	0.00 ± 0.00	0.00 ± 0.00	7.13 ± 1.68
Leucobryum aduncum var. *scalare*	0.00 ± 0.00	8.42 ± 0.00	8.31 ± 0.00
Octoblepharum benitotanii	9.99 ± 14.12	38.47 ± 16.93	24.33 ± 8.47
Pleurocarpous mosses			
Entodontopsis anceps	0.00 ± 0.00	12.05 ± 20.88	7.10 ± 3.98
Isopterygium lignicola	15.65 ± 20.07	13.60 ± 12.99	8.22 ± 14.23
Pelekium gratum	18.26 ± 8.76	5.26 ± 7.44	31.71 ± 27.95
Racopilum orthocarpum	0.00 ± 0.00	0.00 ± 0.00	6.29 ± 0.00
Trichosteleum stigmosum	0.00 ± 0.00	16.25 ± 0.00	0.00 ± 0.00
Leafy liverworts			
Cephalozia hamatiloba	0.00 ± 0.00	0.00 ± 0.00	17.20 ± 0.00
Chiloscyphus kurzii	17.15 ± 8.77	0.00 ± 0.00	0.00 ± 0.00
Cololejeunea planissima	4.73 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Frullania shanensis	35.34 ± 2.66	11.02 ± 11.58	0.00 ± 0.00
Lejeunea tuberculosa	7.41 ± 12.83	17.35 ± 15.92	8.63 ± 14.91
Plagiochila junghuhniana	6.25 ± 0.86	0.00 ± 6.25	0.00 ± 0.00

Note: The average important value index equals 0.00 ± 0.00 means the species is absent in that forest plot.

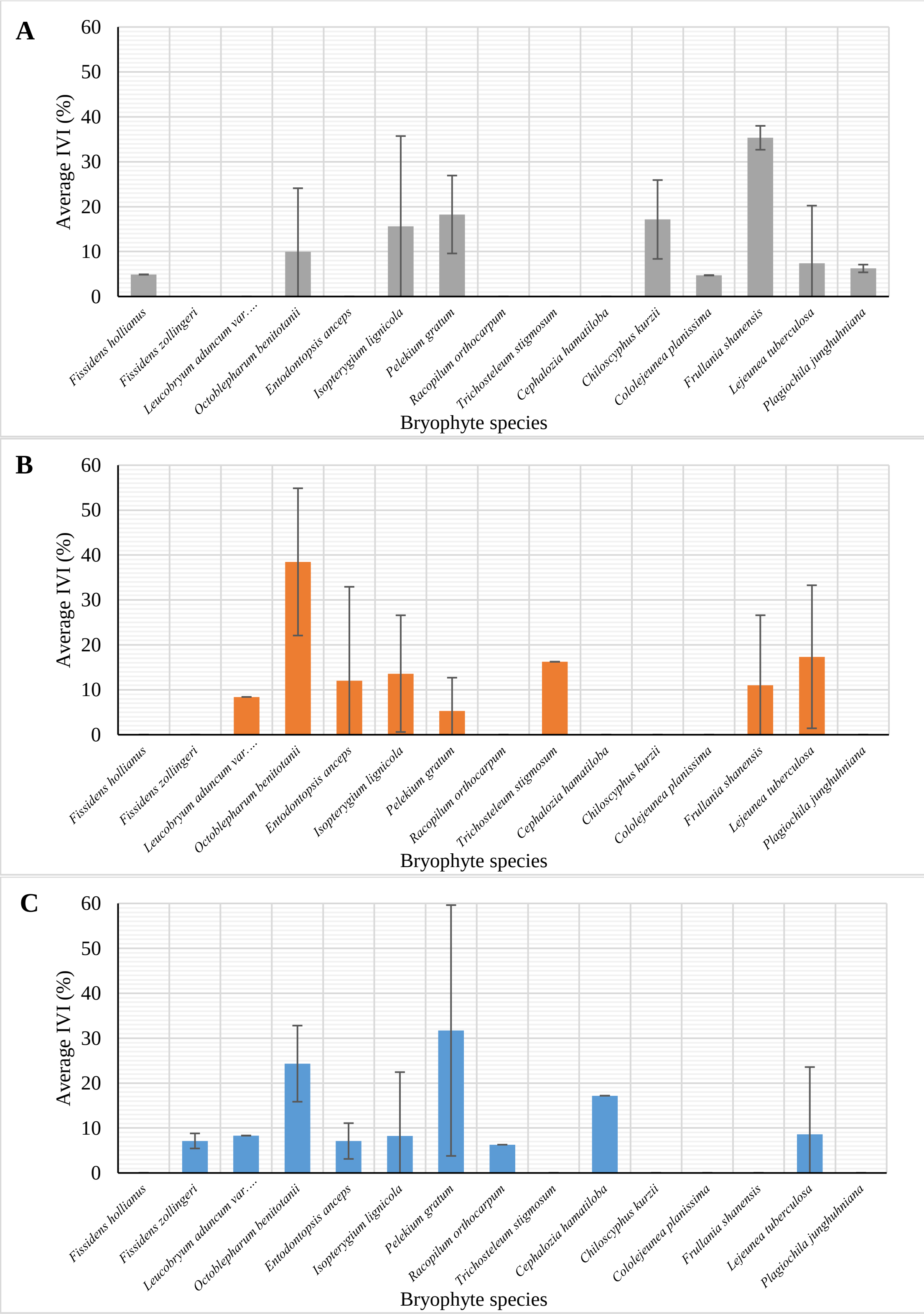

Figure 4.2 Average important value index (IVI) of all epiphytic bryophyte species on all host species A. Dong Seng Forest, B. 1998 plot and C. 2006 plot

According to Table 4.3 and Figure 4.2, the three most dominant bryophyte species recorded in Dong Seng plots were *Frullania shanensis* Svihla (IVI: 35.34%, Figure 4.3A), *Pelekium gratum* (P. Beauv.) Touw (IVI: 18.26%, Figure 4.3B) and *Chiloscyphus kurzii* (Sande Lac.) J.J. Engel & R.M. Schust. (IVI: 17.15%, Figure 4.3C), while *Octoblepharum benitotanii* N. Salazar & Chantanaorr. (IVI: 38.47%, Figure 4.4A), *Lejeunea tuberculosa* Steph. (IVI: 17.35%, Figure 4.4B) and *Trichosteleum stigmosum* Mitt. (Sande Lac.) J.J. Engel & R.M. Schust. (IVI: 16.25%, Figure 4.4C) were dominant in the 1998 plot. In 2006 plot, dominant species included *Pelekium gratum* (P. Beauv.) Touw (IVI: 31.71%, Figure 4.5A), *Octoblepharum benitotanii* N. Salazar & Chantanaorr. (IVI: 24.33%, Figure 4.5B) and *Cephalozia hamatiloba* Steph. (IVI: 17.20%, Figure 4.5C).

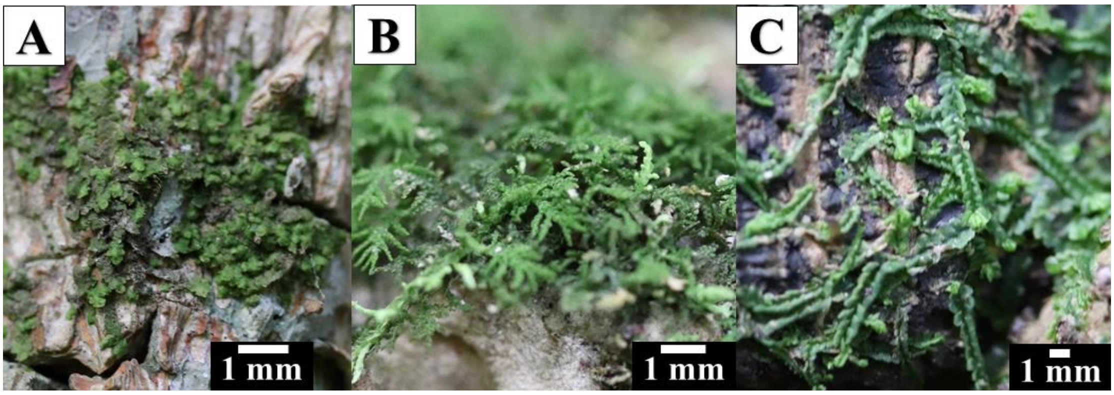

Figure 4.3 Dominant bryophyte species in Dong Seng plot

A. *Frullania shanensis* B. *Pelekium gratum* C. *Chiloscyphus kurzii*

Figure 4.4 Dominant bryophyte species in 1998 plot

A. *Octoblepharum benitotanii* B. *Lejeunea tuberculosa* C. *Trichosteleum stigmosum*

Figure 4.5 Dominant bryophyte species in 2006 plot

A. *Pelekium gratum* B. *Octoblepharum benitotanii* C. *Cephalozia hamatiloba*

The dominant species in 2006 plot, *Pelekium gratum* (P. Beauv.) Touw and *Octoblepharum benitotanii* N. Salazar & Chantanaorr., also common species found in Dong Seng plot and 1998 plot respectively. *P. gratum* and *O. benitotanii* (as *Thuidium meyenianum* (Hampe) Dozy & Molk. in Gangulee, 1980) are often growing on tree trunks, branches, or rotten wood. They are widespread species in Southeast Asia including Thailand (Tan and Printarakul, 2018; Chantanaorrapint and Allen, 2018) and dominant species in this study. While *Frullania shanensis* Svihla was dominant species in Dong Seng Forest, which also found in 1998 plot but not present in 2006 plot. Increasing of this species might be indicator of abundance in restoration forest. However, the study on more various host species still need for confirmation.

4.3 Epiphytic bryophyte diversity indices

Epiphytic bryophyte species were found 9, 8 and 9 species in Dong Seng, 1998 and 2006 plots respectively. The list of epiphytic bryophyte species that occurred in each forest plots was present in Table 4.4. Then, diversity indices as follow: Species richness (S), Simpson's index or dominance index (D), Simpson's diversity index (1-D), Shannon-Weiner index (H), Buzas and Gibson's evenness were calculated (Table 4.5).

Table 4.4 Epiphytic bryophyte species that occurred in three forest plots

Epiphytic bryophyte species	Forest plots		
	Dong Seng	**1998**	**2006**
Acrocarpous mosses			
Fissidens hollianus	✓		
Fissidens zollingeri			✓
Leucobryum aduncum var. *scalare*		✓	✓
Octoblepharum benitotanii	✓	✓	✓
Pleurocarpous mosses			
Entodontopsis anceps		✓	✓
Isopterygium lignicola	✓	✓	✓
Pelekium gratum	✓	✓	✓
Racopilum orthocarpum			✓
Trichosteleum stigmosum		✓	
Leafy liverworts			
Cephalozia hamatiloba			✓
Chiloscyphus kurzii	✓		
Cololejeunea planissima	✓		
Frullania shanensis	✓	✓	
Lejeunea tuberculosa	✓	✓	✓
Plagiochila junghuhniana	✓		
Species richness (S)	9	8	9

Table 4.5 Epiphytic bryophyte diversity indices in three forest plots

Diversity indices	Forest plots		
	Dong Seng	**1998**	**2006**
Species richness (S)	9	8	9
Simpson's index or dominance (D)	0.120	0.159	0.095
Simpson's diversity index (1-D)	0.880	0.841	0.905
Shannon-Weiner index (H)	1.876	1.764	1.905
Buzas and Gibson's evenness	0.725	0.730	0.747

The species richness of epiphytic bryophytes was not much different in each plot. The lowest species richness, Simpson's diversity index (1-D) and Shannon-Weiner index (H) in 1998 plot might be an error from few samplings. While the highest values in the 2006 plot might come from higher humidity of host bark than other plots, which observed from high humus soil in this plot.

Buzas and Gibson's evenness indices are similar in each plot. This means the distribution of epiphytic bryophytes in each plot shows not much different. These diversity indices show that the diversity of epiphytic bryophytes in the restoration forest is similar to the natural forest.

4.4 Epiphytic bryophyte similarity

The Sørensen similarity coefficients were also calculated to compare epiphytic bryophyte communities among various restoration ages of framework species plots and natural forest. The epiphytic bryophytes of 1998 and 2006 plots were most similar, whereas epiphytic bryophytes of Dong Seng and 2006 plots were least similar (Table 4.6). There were the reasons from both 1998 and 2006 plots were forest restoration plots, moreover; these two plots were nearer to each other than the Dong Seng plot. On the contrary, 1998 and 2006 plots were far from the Dong Seng plot, so these plots were less similar to the Dong Seng plot. In addition, the 2006 plot was least similar when compared to the Dong Seng plot. This youngest forest plot maybe needs to spend more time for bryophytes from outside or even 1998 plot to spread in the area by spore dispersion.

Table 4.6 Number of shared species (upper right) and Sørensen similarity coefficient (lower left) between the three forest plots

Forest plots	**Dong Seng**	**1998**	**2006**
			Number of shared species
Dong Seng	-	5	4
1998	0.588	-	6
2006	0.444	0.706	-
	Sørensen similarity coefficient		

4.5 Epiphytic bryophyte coverage and grid height above the ground

The relationship between epiphytic bryophyte coverage and grid height that the bryophyte colony has maximum coverage on three host species was also studied in this research. Increasing the height above the ground every 1 meter, there was a trend to decrease 4.85 percent coverage of bryophytes. Although the R^2 value was quite low (Figure 4.6), there was the previous study that humidity was high at tree base because the trees intercepted the rainfall and naturally collected moisture there. Carbon dioxide (CO_2) could also be high near the tree base from the respiration of organisms in the soil (Trynoski and Glime, 1982). Hence, near the tree base could be optimal for bryophytes growing. Furthermore, if we continuously collect the data in the same area, the bryophytes will more growth and lead to a decreasing slope of the following graph.

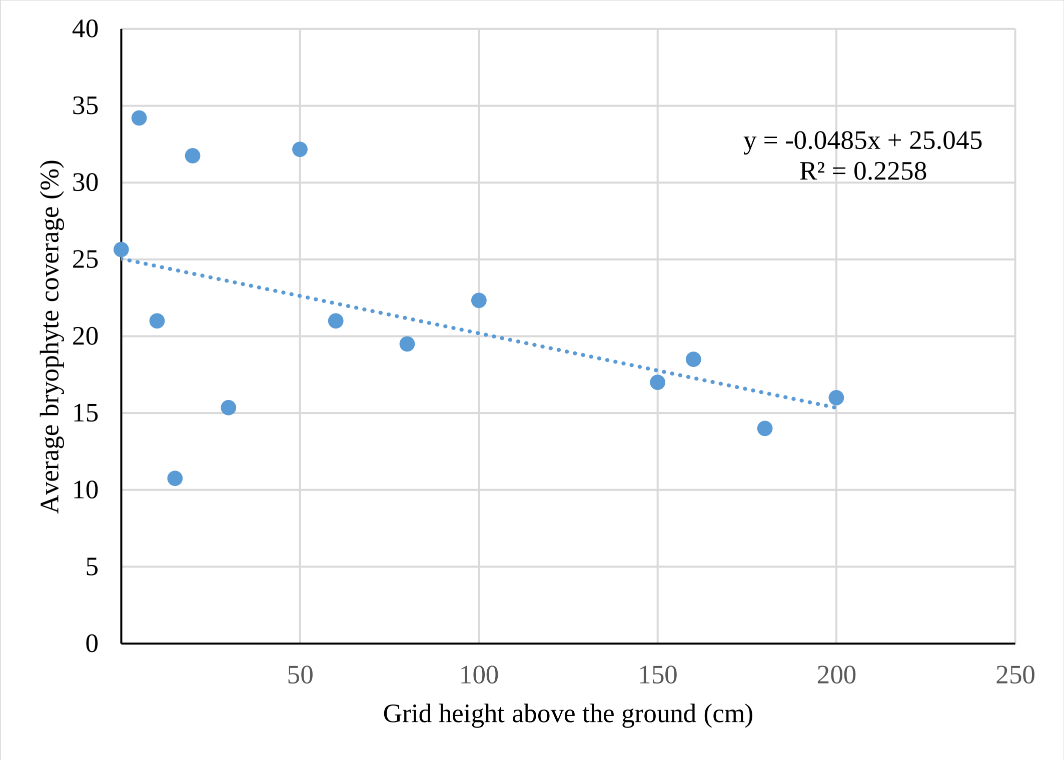

Figure 4.6 Graph of relationship between grid height above the ground and epiphytic bryophyte coverage

4.6 Epiphytic bryophyte species and host species

If the epiphytic bryophyte species were considered to occurrence on host species which had various on bark roughness as Table 4.7, some species were specific to host species as follows: *Fissidens hollianus* Dozy & Molk., *Racopilum orthocarpum* Wilson ex Mitt., *Trichosteleum stigmosum* Mitt., *Cephalozia hamatiloba* Steph. and *Cololejeunea planissima* (Mitt.) Abeyw. Whereas some species could grow on various host bark roughness e.g. *Entodontopsis anceps* (Bosch & Sande Lac.) W.R. Buck & Ireland, *Isopterygium lignicola* (Mitt.) A. Jaeger. Several former researches reported that bark roughness and bark characteristic of hosts were important factors for bryophyte species composition (González-Mancebo et al., 2003; Shen et al., 2018; Song et al., 2015).

Table 4.7 Epiphytic bryophyte species on three host species and their life forms

Epiphytic bryophyte species	Life form	Host species		
		Archidendron clypearia	***Erythrina stricta***	***Sarcosperma arboreum***
Bark roughness of hosts		Low	High	Medium
Acrocarpous mosses				
Fissidens hollianus	Fans			✓
Fissidens zollingeri	Fans		✓	✓
Leucobryum aduncum var. *scalare*	Turfs	✓		
Octoblepharum benitotanii	Turfs	✓		✓
Pleurocarpous mosses				
Entodontopsis anceps	Mats	✓	✓	✓
Isopterygium lignicola	Mats	✓	✓	✓
Pelekium gratum	Wefts		✓	✓
Racopilum orthocarpum	Mats			✓
Trichosteleum stigmosum	Mats			✓
Leafy liverworts				
Cephalozia hamatiloba	Mats			✓
Chiloscyphus kurzii	Mats	✓		✓
Cololejeunea planissima	Mats		✓	
Frullania shanensis	Mats		✓	✓
Lejeunea tuberculosa	Mats	✓	✓	✓
Plagiochila junghuhniana	Fans	✓		✓
Total		7	7	13

4.7 Epiphytic bryophyte life form composition

Moreover, almost of epiphytic bryophytes that occurred in this study were life form of mats which composed of some pleurocarpous mosses and leafy liverworts. This life form bryophytes' stems were always flattened on the substrata. Fans and mats also show in association with deeply shaded habitat (Bates, 1998). In addition, *Sarcosperma arboreum* Hook.f. was host species which has the highest observation of epiphytic bryophytes species in this study (Table 4.8 and Figure 4.7).

This might be the result of high humidity on the bark of this host species. However, these still need more study for confirmation because of low frequency in some species. There also should be collected the data about bark humidity.

Table 4.8 Number of epiphytic bryophyte species in three forest plots were classified by their life forms and three host species

Host species & Epiphytic bryophyte life forms		Number of epiphytic bryophyte species in forest plots		
		Dong Seng	**1998**	**2006**
Archidendron clypearia	(Bark roughness: low)	**4**	**4**	**5**
Fans		1	0	0
Mats		2	2	3
Turfs		1	2	2
Erythrina stricta	(Bark roughness: high)	**4**	**5**	**3**
Fans		0	0	1
Mats		3	4	1
Wefts		1	1	1
Sarcosperma arboretum	(Bark roughness: medium)	**6**	**4**	**6**
Fans		2	0	1
Mats		3	3	3
Turfs		0	1	1
Wefts		1	0	1
Total		**9**	**8**	**9**
Fans		**2**	**0**	**1**
Mats		**5**	**5**	**5**
Turfs		**1**	**2**	**2**
Wefts		**1**	**1**	**1**

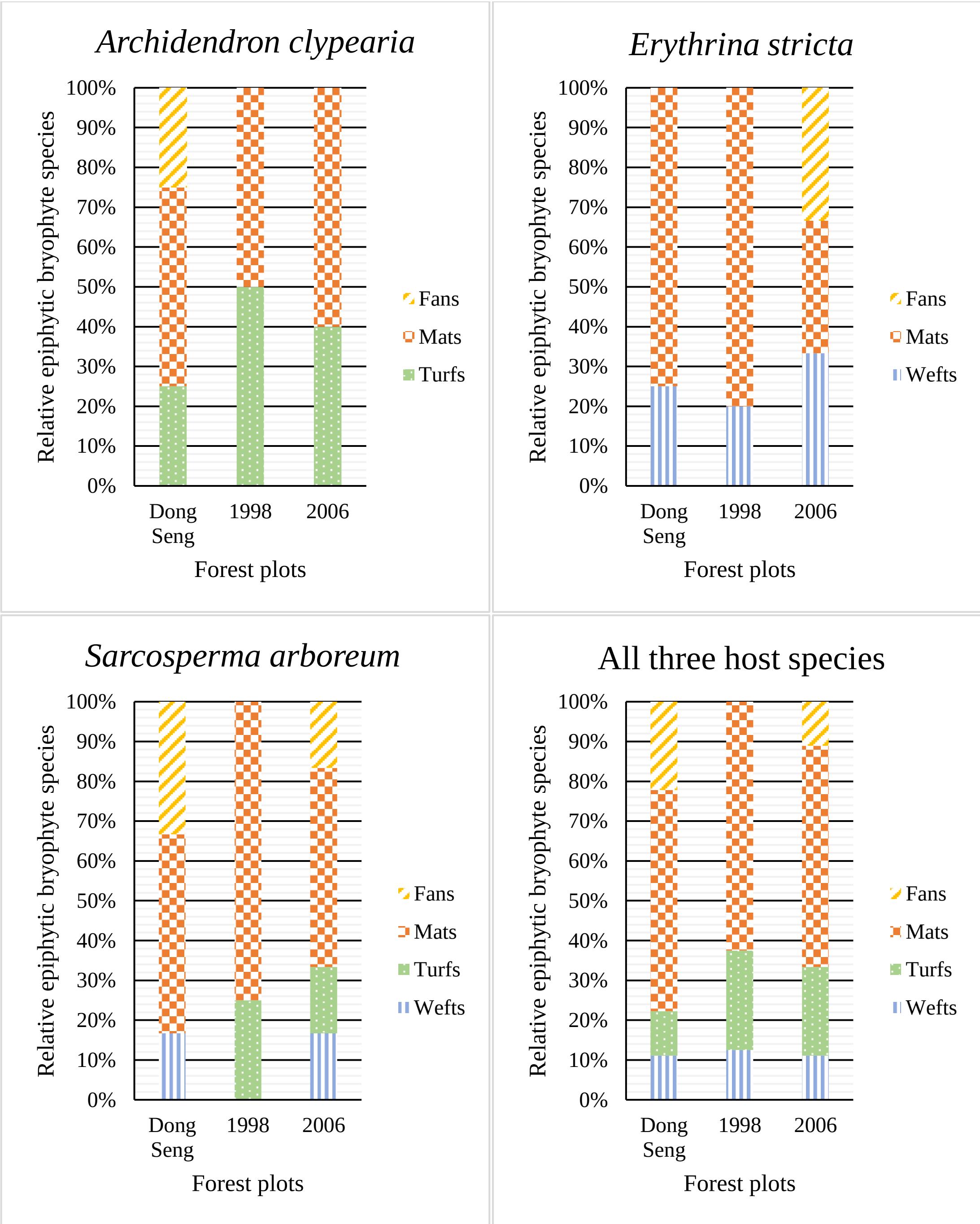

Figure 4.7 Graph of relative epiphytic bryophyte species in three forest plots

4.8 Epiphytic bryophyte species and grid direction

This study also recorded the grid direction for sampling bryophytes. To calculate the relative coverage of each epiphytic bryophytes found on the north (N), south (S), east (E), and west (W) directions of exposure in all three forest plots and hosts, as follow in Table 4.9 and Figure 4.8.

Table 4.9 Relative coverage of epiphytic bryophyte species on hosts in different directions

Epiphytic bryophyte species	Relative coverage (%)			
	N	**S**	**E**	**W**
Acrocarpous mosses				
Fissidens hollianus	0.00	0.00	100.00	0.00
Fissidens zollingeri	66.67	33.33	0.00	0.00
Leucobryum aduncum var. *scalare*	47.83	43.48	0.00	8.70
Octoblepharum benitotanii	30.33	17.42	20.55	31.70
Pleurocarpous mosses				
Entodontopsis anceps	48.08	26.92	25.00	0.00
Isopterygium lignicola	25.77	30.77	28.85	14.62
Pelekium gratum	8.84	26.10	51.00	14.06
Racopilum orthocarpum	0.00	0.00	100.00	0.00
Trichosteleum stigmosum	0.00	40.43	0.00	59.57
Leafy liverworts				
Cephalozia hamatiloba	44.00	0.00	56.00	0.00
Chiloscyphus kurzii	100.00	0.00	0.00	0.00
Cololejeunea planissima	0.00	0.00	0.00	100.00
Frullania shanensis	23.58	11.35	39.30	25.76
Lejeunea tuberculosa	27.53	18.12	22.65	31.71
Plagiochila junghuhniana	0.00	58.33	41.67	0.00

The dominant bryophytes species in this study such as *Frullania shanensis* Svihla, *Pelekium gratum* (P. Beauv.) Touw, *Octoblepharum benitotanii* N. Salazar & Chantanaorr. and *Lejeunea tuberculosa* Steph. were growing in every direction. So, these species were not specific to the direction of exposure. This was the reason why these species could be found frequently and high coverage. Whereas some species such as *Chiloscyphus kurzii* (Sande Lac.) J.J. Engel & R.M. Schust. was more preferring to grow on the north, might be specific to north direction. However, some species that grow in only one or two directions do not always specific to that direction because of not enough samplings in this study. Although this still needs to have further study for confirmation, there were some literature told that they found some bryophytes more sensitive than others to the direction of exposure. Some authors said bryophyte distribution related to the direction of windward or leeward, but habitat differences were more important environmental variables (Trynoski and Glime, 1982). Consequently, some researches use representative direction for collecting epiphytic bryophyte specimens (Shen et al., 2018; Song et al., 2015).

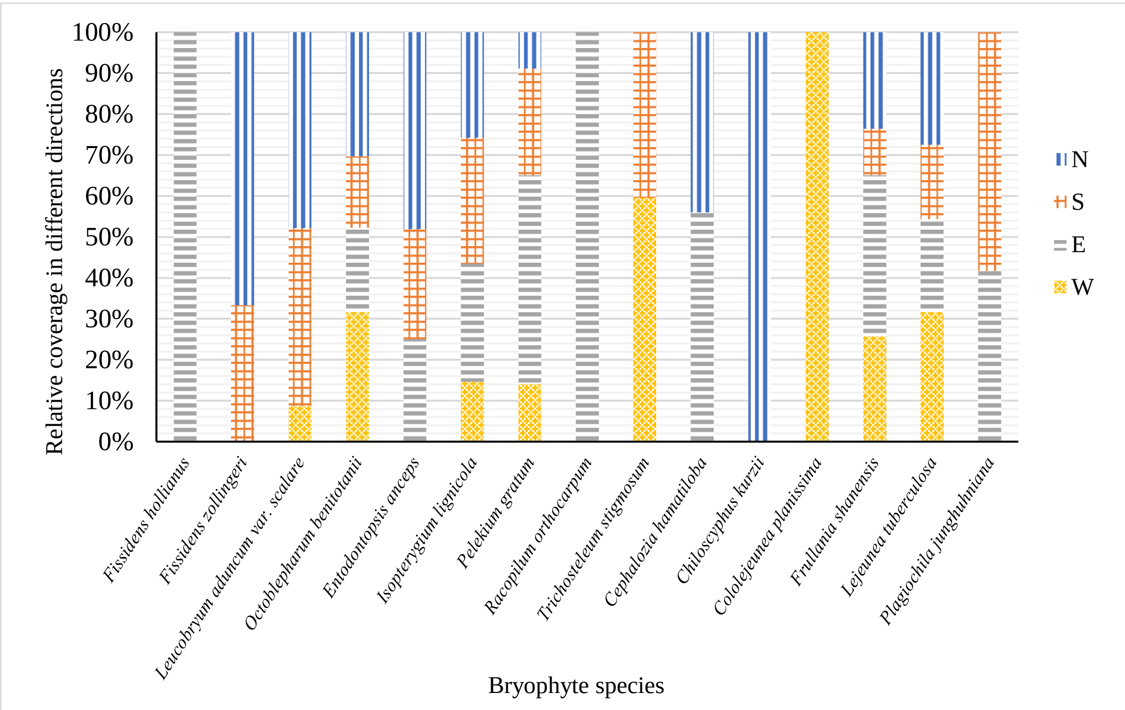

Figure 4.8 Graph of relative coverage of epiphytic bryophyte species on hosts in different directions

CHAPTER 5
CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

Species richness of epiphytic bryophytes was not different in two forest restoration ages (1998 plot = 8 species, 2006 plot = 9 species). However, the similarity index of the epiphytic bryophyte community in older restoration forest (0.588) was higher than the young restoration forest (0.444), when compared to the natural forest. Therefore, if the restoration forest becomes older, the epiphytic bryophytes species in the restoration forest will also more similar to the natural forest.

Furthermore, this study also provided information that epiphytic bryophytes have a trend to decrease their coverage when the height above the ground increase. While the species richness of epiphytic bryophytes was highest (13 species) in medium bark roughness (*Sarcosperma arboreum* Hook.f.) and almost all of their life forms were mats (9 species). In terms of grid directions, were different in each epiphytic bryophyte species and still need further study.

5.2 Recommendation

5.2.1 Increase replication of each host species

5.2.2 Study on more various host bark types

5.2.3 Spend long period survey for studying the change of bryophyte community

5.2.4 Measure humidity of host bark

REFERENCES

REFERENCES

Ajintaiyasil, P. (2017). **Diversity of Mosses in Phu Kradueng National Park, Loei Province.** Master's Thesis. Department of Botany, Faculty of Science, Chulalongkorn University, Thailand.

Bates, J. W. (1998). Is 'Life-Form' a Useful Concept in Bryophyte Ecology? **Oikos,** 82(2), 223-237.

Boonphathip, W. (2001). **Ecological Study of Epiphytic Mosses on *Cupressus torulosa* D. Don at Doi Pui, Chiang Mai Province.** Independent Study Bachelor's Degree. Department of Biology, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand. (in Thai).

Buzas, M. A., & Gibson, T. G. (1969). Species Diversity: Benthonic Foraminifera in Western North Atlantic. **Science,** 163(3862), 72–75.

Chantanaorrapint, S. (2002). **Bryophytes Diversity at the Summit of Khao Luang, Huai Yang Waterfall National Park, Prachuap Khiri Khan Province.** Master's Thesis. Department of Botany, Faculty of Science, Chulalongkorn University, Thailand. (in Thai).

Chantanaorrapint, S. and Allen, N. S. (2018). *Octoblepharum benitotanii* (Octoblepharaceae) a new species from the Old World Tropics. **Philippine Journal of Systematic Biology,** 12(1), 58-66.

Dixon, H. N. (1932). On the moss flora of Siam. **J. Siam Soc. Nat. Hist.,** 9, 1-51.

Dixon, H. N. (1935). Further contributions to the moss flora of Siam. **J. Siam Soc. Nat. Hist.,** 10, 1-30.

Elliott, S., Anusarnsunthorn, V., Maxwell, J. F., Gale, G., Toktang, T., Kuarak, C., Navakitbumrung, P., Pakkad, G., Tunjai, P., Thaiying, J., and Blakesley, D. (2004). How to plant a forest. **Proc. Ann. Biodiversity Research and Training Symposium.** Oct 2004.

Elliott, S., Blakesley, D., and Hardwick, K. (2013). **Restoring Tropical Forests: a practical guide.** Kew: Royal Botanical Gardens.

Elliott, S., Navakitbumrung, P.,Kuarak, C., Zangkum, S., Anusarnsunthorn, V. and Blakesley, D. (2003). Selecting framework tree species for restoring seasonally dry tropical forests in northern Thailand based on field performance. **Forest Ecology and Management,** 184: 177-191.

Frahm, J. P., Frey, W., Kürschner, H., and Menzel, M. (1996). **Mosses and Liverworts of Mount Kinabalu.** Malaysia: Sabah Parks Trustees.

Fritz, Ö. (2009). Vertical distribution of epiphytic bryophytes and lichens emphasizes the importance of old beeches in conservation. **Biodiversity and Conservation,** 18(2), 289–304.

Gangulee, H. C. (1972). **Mosses of Eastern India and adjacent regions: A monograph (Vol. 1).** Calcutta: BSI.

Gangulee, H. C. (1978). **Mosses of Eastern India and adjacent regions: A monograph (Vol. 2).** Calcutta: BSI.

Gangulee, H. C. (1980). **Mosses of Eastern India and adjacent regions: A monograph (Vol. 3).** Calcutta: BSI.

Gradstein, S. R. (2011). **Guide to the liverworts and hornworts of Java.** Indonesia: SEAMEO-Biotrop.

Goffinet, B. and Shaw, A. J. (2008). **Bryophyte Biology**. (2nd ed.). New York: Cambridge University Press.

González-Mancebo, J. M., Losada-Lima, A., & McAlister, S. (2003). Host Specificity of Epiphytic Bryophyte Communities of a Laurel Forest on Tenerife (Canary Islands, Spain). **The Bryologist,** 106(3), 383–394.

Hassama, B. (2015). **Species Richness and Vertical Distribution of Bryophytes at Chao Pa Waterfall, Trang Province.** Master's Thesis. Graduate School, Prince of Songkla University, Thailand. (in Thai).

He, S. (2019). **The moss flora of Thailand: an annotated checklist and atlas of the mosses of Thailand.** Retrieved October 14, 2019, from http://www.mobot.org/MOBOT/moss/Thailand/

Jinto, P. (2009). **Trees and Ground Flora Diversity of Framework Species Plantation Plots and Dong Seng Forest, Mae Rim District, Chiang Mai Province.** Master's Thesis. Department of Biology, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand. (in Thai).

Kornochalert, S. (2004). **Ecological Study of Epiphytic Bryophytes at San Ku, Doi Suthep-Pui National Park, Chiang Mai Province.** Independent Study Master's Degree. Department of Biology, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand. (in Thai).

Lai, M. J. (1976). A key to the families of Bryophyta in Taiwan. **Taiwania,** 21, 73-82.

Lai, M. J., Zhu, R. L., and Chantanaorrapint, S. (2008). Liverworts and hornworts of Thailand: an updated checklist and bryofloristic accounts. **Ann. Bot. Fennici,** 45, 321-341.

Manachit, S. (2006). **Diversity of Bryophytes in the Area of Sirindhorn Observatory, Doi Suthep-Pui National Park, Chiang Mai Province.** Master's Thesis. Department of Biology, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand. (in Thai).

Nathi, Y. (2009). **Mosses Diversity in Kew Mae Pan and Ang Ka Areas, Doi Inthanon National Park, Chiang Mai Province.** Master's Thesis. Department of Botany, Faculty of Science, Chulalongkorn University, Thailand.

Northern Meteorological Center. (2019). **Chiang Mai Climate Statistics.** Retrieved October 10, 2019, from http://www.cmmet.tmd.go.th/forecast/climate.xls

Oishi, Y. (2012). Decreased Epiphytic Bryophyte Diversity on Mt. Odaigahara, Japan: Causes and Implications. In G. A. Lameed (Ed.), **Biodiversity Enrichment in a Diverse World** (pp. 153-170). Croatia: Intech.

Pakkad, G., Elliott, S., Anusarnsunthorn, V., James, C., and Blakesley, D. (2002). Forest restoration planting in northern Thailand. In Koskela, S., Appanah, S., Anderson, A. P., and Markopoulos, M. D. (Eds.), **Proceedings of the Southeast Asian Moving Workshop on Conservation, Management and Utilization of Forest Genetic Resources** (pp. 143-153). Bangkok: FORSPA.

Pitpan, N. (1996). **A Study on Taxonomy, Morphology, and Ecology of Mosses in Taksin National Park and in Dio Museu of Tak Province.** Master's Thesis. Graduate School, Naresuan University, Phitsanulok, Thailand. (in Thai).

Printarakul, N. (2015). **Bryophyte Flora of Doi Suthep-Pui National Park, Chiang Mai, Thailand**. Ph.D.'s Thesis. Graduate School, Chiang Mai University, Chiang Mai, Thailand.

Rattanayan, S. (1998). **Bryophytes.** Chiang Mai: Nopburee Press Company Printing Design. (in Thai).

Santanachote, K. and Rattanayan, S. (1999). **A Field Survey of Mosses Conducted at Doi Suthep-Pui.** Research Report, Chiang Mai University, Chiang Mai, Thailand. (in Thai).

Shannon, C. E. and Weaver, W. (1949). **The Mathematical Theory of Communication.** Urbana: University of Illinois Press.

Shen, T., Corlett, R. T., Song, L., Ma, W.-Z., Guo, X.-L., Song, Y., & Wu, Y. (2018). Vertical gradient in bryophyte diversity and species composition in tropical and subtropical forests in Yunnan, SW China. **J Veg Sci**, 00, 1-13.

Simpson, E. H. (1949). Measurement of Diversity. **Nature**, 163: 1-688.

Song, L. , Ma, W. , Yao, Y. , Liu, W. , Li, S. , Chen, K. , Lu, H. , Cao, M. , Sun, Z. , Tan, Z. and Nakamura, A. (2015), Bole bryophyte diversity and distribution patterns along three altitudinal gradients in Yunnan, China. **J Veg Sci,** 26, 576-587.

Sørensen, T. (1948). A Method of Establishing Groups of Equal Amplitude in Plant Sociology Based on Similarity of Species Content and Its Application to Analyses of the Vegetation on Danish Commons. **Videnski Selskab Biologiske Skrifter,** 5, 1-34.

Sukkharak, P. and Chantanaorrapint, S. (2014). Bryophyte studies in Thailand: past, present, and future. **Cryptogamie, Bryologie,** 35, 5-17.

Sungkaew, S. (2019). **Field Dendrology.** Bangkok: Faculty of Forestry, Kasetsart University. (in Thai).

Tan, B. C. and Ho, B.-C. (2008). **A Guide to the Mosses of Singapore.** Singapore: Science Centre Singapore.

Tan, B. C. and Printarakul, N. (2018). A Small Collection of Thai Mosses Made by J. F. Maxwell at the Herbarium of California Academy of Sciences in United States. **Nat. Hist. Bull. Siam Soc.,** 63(1), 41-45.

The Forest Restoration Research Unit [FORRU], (2006). **How to Plant a Forest: The Principles and Practice of Restoring Tropical Forests.** Chiang Mai: Department of Biology, Faculty of Science, Chiang Mai University.

The Forest Restoration Research Unit [FORRU], (2008). **Research for Restoring Tropical Forest Ecosystems: A Practical Guide.** Chiang Mai: Department of Biology, Faculty of Science, Chiang Mai University.

The Plant List. (2013). **The Bryophytes (Mosses and liverworts).** Retrieved October 14, 2019, from http://www.theplantlist.org/ 1.1/browse/B/

Tripiyarat, B. (2002). **A Field Survey of Bryophytes and Their Habitats on wall at U-Mong Temple, Chiang Mai Province.** Independent Study Bachelor's Degree. Department of Biology, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand. (in Thai).

Trynoski, S. E. and Glime, J. M. (1982). Direction and Height of Bryophytes on Four Species of Northern Trees. **The Bryologist**, 85(3), 281-300.

Vongkuna, K. (2003). **Ecological Study of Epiphytic Mosses at Ru See Cave, Doi Suthep-Pui National Park, Chiang Mai.** Independent Study Master's Degree. Department of Biology, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand. (in Thai).

Weeranakin, J. (2001). **Ecological Study of Epiphytic Mosses on *Pinus kesiya* Royle ex Gord. at Doi Suthep-Pui, Chiang Mai Province.** Independent Study Bachelor's Degree. Department of Biology, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand. (in Thai).

Wijk, R. Van Der. (1958). Precursory studies on Malaysian mosses a preliminary key to the moss genera. **Blumea,** 9, 143-186.

Wongkuna, K. (2010). **Taxonomic revision of *Fissidens* Hedw. (Fissidentaceae, Bryophyta) in Thailand.** Ph.D.'s Thesis. Graduate School, Chiang Mai University, Chiang Mai, Thailand.

APPENDICES

APPENDIX A Relative coverage of epiphytic bryophyte species on *Archidendron clypearia*, *Erythrina stricta* and *Sarcosperma arboreum*

Host species & Epiphytic bryophyte species	Relative coverage (%) in forest plots		
	Dong Seng	1998	2006
***Archidendron clypearia* (Jack) I.C.Nielsen**			
Acrocarpous mosses			
Leucobryum aduncum var. *scalare* (Müll. Hal. ex M. Fleisch.) A. Eddy	0.00	2.55	10.38
Octoblepharum benitotanii N. Salazar & Chantanaorr.	16.87	71.55	17.92
Pleurocarpous mosses			
Entodontopsis anceps (Bosch & Sande Lac.) W.R. Buck & Ireland	0.00	0.00	1.89
Isopterygium lignicola (Mitt.) A. Jaeger	45.78	23.78	36.79
Leafy liverworts			
Chiloscyphus kurzii (Sande Lac.) J.J. Engel & R.M. Schust.	31.33	0.00	0.00
Lejeunea tuberculosa Steph.	0.00	2.12	33.02
Plagiochila junghuhniana Sande Lac.	6.02	0.00	0.00

Host species & Epiphytic bryophyte species	**Relative coverage (%) in forest plots**		
	Dong Seng	**1998**	**2006**
***Erythrina stricta* Roxb.**			
Acrocarpous mosses			
Fissidens zollingeri Mont.	0.00	0.00	8.93
Pleurocarpous mosses			
Entodontopsis anceps (Bosch & Sande Lac.) W.R. Buck & Ireland	0.00	49.24	3.57
Isopterygium lignicola (Mitt.) A. Jaeger	8.99	2.67	0.00
Pelekium gratum (P. Beauv.) Touw	40.45	13.36	87.50
Leafy liverworts			
Cololejeunea planissima (Mitt.) Abeyw.	1.12	0.00	0.00
Frullania shanensis Svihla	49.44	20.99	0.00
Lejeunea tuberculosa Steph.	0.00	13.74	0.00

Host species & Epiphytic bryophyte species	Relative coverage (%) in forest plots		
	Dong Seng	1998	2006
***Sarcosperma arboreum* Hook.f.**			
Acrocarpous mosses			
Fissidens hollianus Dozy & Molk.	2.65	0.00	0.00
Fissidens zollingeri Mont.	0.00	0.00	3.55
Octoblepharum benitotanii N. Salazar & Chantanaorr.	0.00	25.19	43.97
Pleurocarpous mosses			
Entodontopsis anceps (Bosch & Sande Lac.) W.R. Buck & Ireland	0.00	0.00	14.89
Isopterygium lignicola (Mitt.) A. Jaeger	0.00	6.98	0.00
Pelekium gratum (P. Beauv.) Touw	17.11	0.00	15.60
Racopilum orthocarpum Wilson ex Mitt.	0.00	0.00	4.26
Trichosteleum stigmosum Mitt.	0.00	18.22	0.00
Leafy liverworts			
Cephalozia hamatiloba Steph.	0.00	0.00	17.73
Chiloscyphus kurzii (Sande Lac.) J.J. Engel & R.M. Schust.	14.75	0.00	0.00
Frullania shanensis Svihla	38.35	0.00	0.00
Lejeunea tuberculosa Steph.	23.01	49.61	0.00
Plagiochila junghuhniana Sande Lac.	4.13	0.00	0.00

APPENDIX B Relative frequency of epiphytic bryophyte species on *Archidendron clypearia*, *Erythrina stricta* and *Sarcosperma arboretum*

Host species & Epiphytic bryophyte species	**Relative frequency (%) in forest plots**		
	Dong Seng	**1998**	**2006**
***Archidendron clypearia* (Jack) I.C.Nielsen**			
Acrocarpous mosses			
Leucobryum aduncum var. *scalare* (Müll. Hal. ex M. Fleisch.) A. Eddy	0.00	14.29	6.25
Octoblepharum benitotanii N. Salazar & Chantanaorr.	23.08	28.57	18.75
Pleurocarpous mosses			
Entodontopsis anceps (Bosch & Sande Lac.) W.R. Buck & Ireland	0.00	0.00	6.25
Isopterygium lignicola (Mitt.) A. Jaeger	30.77	33.33	12.50
Leafy liverworts			
Chiloscyphus kurzii (Sande Lac.) J.J. Engel & R.M. Schust.	15.38	0.00	0.00
Lejeunea tuberculosa Steph.	0.00	9.52	18.75
Plagiochila junghuhniana Sande Lac.	7.69	0.00	0.00

Host species & Epiphytic bryophyte species	Relative frequency (%) in forest plots		
	Dong Seng	**1998**	**2006**
***Erythrina stricta* Roxb.**			
Acrocarpous mosses			
Fissidens zollingeri Mont.	0.00	0.00	7.69
Pleurocarpous mosses			
Entodontopsis anceps (Bosch & Sande Lac.) W.R. Buck & Ireland	0.00	23.08	7.69
Isopterygium lignicola (Mitt.) A. Jaeger	8.33	7.69	0.00
Pelekium gratum (P. Beauv.) Touw	8.33	7.69	15.38
Leafy liverworts			
Cololejeunea planissima (Mitt.) Abeyw.	8.33	0.00	0.00
Frullania shanensis Svihla	25.00	23.08	0.00
Lejeunea tuberculosa Steph.	0.00	7.69	0.00

Host species & Epiphytic bryophyte species	Relative frequency (%) in forest plots		
	Dong Seng	**1998**	**2006**
***Sarcosperma arboreum* Hook.f.**			
Acrocarpous mosses			
Fissidens hollianus Dozy & Molk.	7.14	0.00	0.00
Fissidens zollingeri Mont.	0.00	0.00	8.33
Octoblepharum benitotanii N. Salazar & Chantanaorr.	0.00	28.57	16.67
Pleurocarpous mosses			
Entodontopsis anceps (Bosch & Sande Lac.) W.R. Buck & Ireland	0.00	0.00	8.33
Isopterygium lignicola (Mitt.) A. Jaeger	0.00	7.14	0.00
Pelekium gratum (P. Beauv.) Touw	7.14	0.00	8.33
Racopilum orthocarpum Wilson ex Mitt.	0.00	0.00	8.33
Trichosteleum stigmosum Mitt.	0.00	14.29	0.00
Leafy liverworts			
Cephalozia hamatiloba Steph.	0.00	0.00	16.67
Chiloscyphus kurzii (Sande Lac.) J.J. Engel & R.M. Schust.	7.14	0.00	0.00
Frullania shanensis Svihla	28.57	0.00	0.00
Lejeunea tuberculosa Steph.	21.43	21.43	0.00
Plagiochila junghuhniana Sande Lac.	7.14	0.00	0.00

APPENDIX C Important value index of epiphytic bryophyte species on *Archidendron clypearia*, *Erythrina stricta* and *Sarcosperma arboretum*

Host species & Epiphytic bryophyte species	**Important value index (%) in forest plots**		
	Dong Seng	**1998**	**2006**
***Archidendron clypearia* (Jack) I.C.Nielsen**			
Acrocarpous mosses			
Leucobryum aduncum var. *scalare* (Müll. Hal. ex M. Fleisch.) A. Eddy	0.00	8.42	8.31
Octoblepharum benitotanii N. Salazar & Chantanaorr.	19.97	50.06	18.34
Pleurocarpous mosses			
Entodontopsis anceps (Bosch & Sande Lac.) W.R. Buck & Ireland	0.00	0.00	4.07
Isopterygium lignicola (Mitt.) A. Jaeger	38.28	28.56	24.65
Leafy liverworts			
Chiloscyphus kurzii (Sande Lac.) J.J. Engel & R.M. Schust.	23.35	0.00	0.00
Lejeunea tuberculosa Steph.	0.00	5.82	25.88
Plagiochila junghuhniana Sande Lac.	6.86	0.00	0.00

Host species & Epiphytic bryophyte species	Important value index (%) in forest plots		
	Dong Seng	**1998**	**2006**
***Erythrina stricta* Roxb.**			
Acrocarpous mosses			
Fissidens zollingeri Mont.	0.00	0.00	8.31
Pleurocarpous mosses			
Entodontopsis anceps (Bosch & Sande Lac.) W.R. Buck & Ireland	0.00	36.16	5.63
Isopterygium lignicola (Mitt.) A. Jaeger	8.66	5.18	0.00
Pelekium gratum (P. Beauv.) Touw	24.39	10.53	51.44
Leafy liverworts			
Cololejeunea planissima (Mitt.) Abeyw.	4.73	0.00	0.00
Frullania shanensis Svihla	37.22	22.03	0.00
Lejeunea tuberculosa Steph.	0.00	10.72	0.00

Host species & Epiphytic bryophyte species	Important value index (%) in forest plots		
	Dong Seng	1998	2006
***Sarcosperma arboreum* Hook.f.**			
Acrocarpous mosses			
Fissidens hollianus Dozy & Molk.	4.90	0.00	0.00
Fissidens zollingeri Mont.	0.00	0.00	5.94
Octoblepharum benitotanii N. Salazar & Chantanaorr.	0.00	26.88	30.32
Pleurocarpous mosses			
Entodontopsis anceps (Bosch & Sande Lac.) W.R. Buck & Ireland	0.00	0.00	11.61
Isopterygium lignicola (Mitt.) A. Jaeger	0.00	7.06	0.00
Pelekium gratum (P. Beauv.) Touw	12.13	0.00	11.97
Racopilum orthocarpum Wilson ex Mitt.	0.00	0.00	6.29
Trichosteleum stigmosum Mitt.	0.00	16.25	0.00
Leafy liverworts			
Cephalozia hamatiloba Steph.	0.00	0.00	17.20
Chiloscyphus kurzii (Sande Lac.) J.J. Engel & R.M. Schust.	10.95	0.00	0.00
Frullania shanensis Svihla	33.46	0.00	0.00
Lejeunea tuberculosa Steph.	22.22	35.52	0.00
Plagiochila junghuhniana Sande Lac.	5.64	0.00	0.00

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