EFFECTS OF MATURE TREES ON SEEDLING ESTABLISHMENT ON DEFORESTED SITES

PUTTIPONG NAVAKITBUMRUNG

MASTER OF SCIENCE
IN BIOLOGY

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A THESIS SUBMITTED TO THE GRADUATE SCHOOL IN
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19 March 2003

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ABSTRACT

In Thailand, accelerated natural regeneration (ANR) of forest on degraded land has not been successful due to lack of knowledge about the natural processes of forest regeneration. The role of remnant trees in disturbed areas has been widely assumed to help to increase seedling recruitment by attracting seed dispersers. This study was carried out to determine the effects of mature isolated trees on tree seedling recruitment in deforested areas and to find out which tree species should be planted to attract seed-dispersing birds. Naturally established tree seedlings were surveyed beneath fifty-one remnant trees (7 species) compared with open areas at deforested areas, south and above of Mae Sa Mai village in Doi Suthep-Pui National Park. Observations of birds visiting trees were done on the remnant trees studied and on

fruiting trees in intact forest. A total of seventy-eight tree seedling species (1,156 individuals) had become established in the study plots. Animals dispersed fifty-seven of the tree species (64.2% of individuals), while wind disperse twenty-one (35.9% of individuals). Most mature remnant trees did not increase seedling recruitment beneath their crowns, except for *Schima wallichii* (DC.) Korth. (Theaceae) ($P<0.05$). The density and species richness of animal-dispersed seedlings beneath mature remnant trees did not depend on the species of the mature trees ($P\geq0.05$). Species with fleshy fruits (*e.g. Callicarpa arborea* Roxb. var. *arborea*, Verbenaceae) were not necessarily more attractive than those with dry fruits (*e.g. Schima wallichii* (DC.) Korth.). There was no relationship between tree size and seedling density established beneath their crowns ($P\geq0.05$). Bigger crowns tended to support a lower species richness of natural seedlings. Growth rates of natural seedlings beneath tree crowns and in open areas were similar ($P\geq0.05$). *Trema orientalis* (L.) Bl. (Ulmaceae) was the fastest growing species of natural seedling. Bird observations showed that *Schima wallichii* (DC.) Korth. (Theaceae) was the remnant tree species that attracted most birds. Three bulbuls species, *Pycnonotus aurigaster* (Sooty-headed Bulbul), *P. flavescens* (Flavescent Bulbul), and *P. jocosus* (Red-whiskered Bulbul) were the most important frugivorous birds that dispersed seeds from intact forests into the deforested site.

ชื่อเรื่องวิทยานิพนธ์ ผลของไม้ยืนต้นเต็มวัยต่อการตั้งตัวของกล้าไม้ในพื้นที่ป่าที่ถูกทำลาย

ชื่อผู้เขียน นายพุฒิพงศ์ นวกิจบำรุง

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บทคัดย่อ

วิธีเร่งกระบวนการฟื้นฟูตามธรรมชาติในพื้นที่ป่าที่ถูกทำลายของประเทศไทย ไม่ประสบความสำเร็จเท่าที่ควร เนื่องจากขาดความรู้ในกระบวนการธรรมชาติของการฟื้นฟูป่า มีข้อสันนิษฐานว่าต้นไม้ยืนต้นที่ยังเหลืออยู่ในป่าที่ถูกทำลาย ดึงดูดสัตว์ที่ช่วยกระจายเมล็ดทำให้มีกล้าไม้ยืนต้นมากขึ้น งานวิจัยนี้มีเป้าหมายเพื่อศึกษา ผลของไม้ยืนต้นที่โตเต็มวัย ที่มีต่อการตั้งตัวของกล้าไม้ยืนต้นธรรมชาติในพื้นที่ป่าถูกทำลาย และหาว่ามีไม้ยืนต้นชนิดใดสามารถนำมาปลูกเพื่อดึงดูดนกที่ช่วยกระจายเมล็ด การศึกษาโดยสำรวจต้นกล้าไม้ชนิดยืนต้นภายใต้ทรงพุ่มไม้ 7 ชนิด รวม 51 ต้น เปรียบเทียบกับกล้าไม้ในแปลงควบคุม ในพื้นที่ป่าถูกทำลายซึ่งอยู่ทางทิศใต้ของหมู่บ้านแม่สาใหม่ อุทยานแห่งชาติดอยสุเทพ-ปุย และสำรวจชนิดนกที่เข้ามาเกาะต้นไม้ที่ศึกษา

BRT 542093

และชนิดนกที่กินผลไม้จากไม้ยืนต้นกำลังติดผลสุกในป่าที่สมบูรณ์ ผลการศึกษาพบกล้าไม้ยืนต้นรวม 78 ชนิด (กล้าไม้ 1,156 ต้น) ในบริเวณที่ศึกษา เป็นกล้าไม้จากสัตว์ช่วยกระจายเมล็ด 57 ชนิด (ร้อยละ 64.2 ของจำนวนกล้าไม้) และเป็นกล้าไม้จากลมกระจายเมล็ด 21 ชนิด (ร้อยละ 35.9 ของจำนวนกล้าไม้) โดยส่วนมากปริมาณกล้าไม้ภายใต้ทรงพุ่มไม่แตกต่างอย่างมีนัยสำคัญกับปริมาณกล้าไม้ในแปลงควบคุม ยกเว้นภายใต้ต้นทะโล้ (*Schima wallichii* (DC.) Korth.) ($P < 0.05$) ความหนาแน่นและจำนวนชนิดของกล้าไม้ยืนต้น ที่มาจากสัตว์ช่วยกระจายเมล็ด ไม่ได้ขึ้นอยู่กับชนิดของไม้ยืนต้น ($P \geq 0.05$) แสดงให้เห็นว่าไม่จำเป็นที่ ไม้ยืนต้นที่ผลิตผลไม้แบบผลสด (ตัวอย่างเช่น ข้าแป้น *Callicarpa arborea* Roxb. var. *arborea*) ดึงดูดสัตว์ช่วยกระจายเมล็ดดีกว่าไม้ยืนต้นที่ผลิตผลไม้แบบผลแห้ง (ตัวอย่างเช่น ทะโล้ *Schima wallichii* (DC.) Korth.) และพบว่าความหนาแน่นของกล้าไม้ยืนต้นภายใต้ทรงพุ่ม ไม่สัมพันธ์อย่างมีนัยสำคัญกับขนาดต้นไม้ยืนต้น ($P \geq 0.05$) แต่พบว่าจำนวนชนิดของกล้าไม้ยืนต้นมีแนวโน้มลดลงเมื่อทรงพุ่มกว้างขึ้น การเปรียบเทียบอัตราการเจริญเติบโตของกล้าไม้ยืนต้นระหว่างภายใต้ทรงพุ่มไม้ยืนต้นกับในแปลงควบคุม พบว่าไม่มีความแตกต่างอย่างมีนัยสำคัญ ($P \geq 0.05$) และกล้าไม้ต้นพังแหรใหญ่ (*Trema orientalis* (L.) Bl.) มีอัตราการเจริญเติบโตสูงสุด ผลการสำรวจนกพบว่า ต้นทะโล้ (*Schima wallichii* (DC.) Korth.) ดึงดูดนกได้มากที่สุด และนกปรอด 3 ชนิด ได้แก่ นกปรอดหัวสีเขม่า นกปรอดหัวตาขาว และนกปรอดหัวสีเขม่า ซึ่งกินผลไม้เป็นอาหาร มีความสำคัญมากในการช่วยกระจายเมล็ดไม้ยืนต้นจากป่าสมบูรณ์มาสู่พื้นที่ป่าถูกทำลาย

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ABBREVIATIONS

ANR	: accelerated natural regeneration
cm	: centimetre
FORRU	: Forest Restoration Research Unit
GBH	: girth at breast height
km^2	: square kilometres
m^2	: square metres
no.	: number
RFD	: Thai Royal Forest Department
RGR	: relative growth rate

CHAPTER 1

INTRODUCTION

Rationale

Degradation of natural resources and the environment is presently one of the most important problems in Thailand. One of the main forms of environmental degradation is deforestation. Thailand's forest cover has been reduced from 53.3% (273,508 km^2) in 1961 to 19% in 2000, averaging about 4,056 km^2 loss per year (RFD, 1995). In reality, remaining natural forest cover might be even lower, *e.g.* 15% (Maxwell, 2001). Forest destruction has been slowed by a commercial logging ban since 1989. The National Forest Policy of Thailand (1985) stated the goal of having 40% of the country under forest with 15% as production forest and 25% as conservation forest, using two approaches: i) protection of remaining forest resources and ii) efficient reforestation. Therefore, forest planting projects were established to support the policy. Although, a lot of deforested areas were recovered, deforestation continues due to illegal logging, agricultural expansion, and forest encroachment (Chatwiroon, 1997).

Tree planting can solve the problem of deforestation (Chatwiroon, 1997). A symposium in Washington, D.C. in June 1996 concluded that all tree plantations facilitate restoration of degraded forests and lands in the tropics (Parrotta *et al.*, 1997). Initially, the Royal Forest Department (RFD) planted fast-growing monoculture plantations, such as pines, teak, and eucalyptus, which are easier to manage than mixed-species plantations. Although, such plantations can facilitate forest restoration, their ecological functions are generally weak (Lamb, 1997; Zhuang, 1997). For example, Karimuna (1995) reported that the species diversity of the ground floras in pine and eucalyptus plantations is less diverse than in evergreen forest. Subsequently, tree planting events, organized by government agencies, companies, villagers, and students have become very popular. One tree planting project was to celebrate the Golden Jubilee of His Majesty King Bhumibol Adulyadey in 1994. The target of this project was to plant 8,000 km^2 of deforested land. This target has not been met (Chatwiroon, 1997) because lack of knowledge about appropriate methods of planting native forest tree seedlings (FORRU, 1998).

Biological diversity has been widely promoted. Planting native trees is recommended for reforestation projects because they promote biodiversity (Lamb, 1997; Robison and Handel, 1993). Although, secondary forest can accrete biodiversity rapidly in the tropics, it may not be of direct value in conservation. It can have other indirect roles, such as providing resources for native animals and buffering and protecting primary forest fragments (Turner *et al.*, 1997). Forest restoration goals are divided in three alternative goals, reclamation, rehabilitation, and restoration. Rehabilitation involves planting mostly native species and some exotic species planted in deforested areas. Reclamation is done only with exotic species, for economic or ecological reasons. Finally, restoration attempts to restore a forest ecosystem to its original condition, with the main objective to preserve biological diversity (Lamb *et al.*, 1997).

The framework species method of forest restoration (Goosem and Tucker, 1995) was first developed in the late 1980's in Queensland, Australia. The method is based on the selection of fast-growing native tree species with dense spreading crowns that shade out weeds. Selected trees must also attract seed-dispersing wildlife and they must be easy to propagate in nurseries. Planting by this method can accelerate forest regeneration and restore biodiversity (FORRU, 1998). The cost of planting is high because an input of labor is required restoration at every stage of the process, from collecting seeds or seedlings, to raising them in nurseries, preparing sites, planting seedlings, and maintaining them afterwards (Lamb *et al.*, 1997). Tree planting is not always an appropriate technology in cash-poor communities. An alternative is to accelerate the natural processes of succession.

Accelerated natural regeneration (ANR) has been practiced in the Philippines (Dugan, 2000). It entails cutting or pressing the weeds around existing, naturally established seedling, protecting the area from fire, and interplanting with desired tree species where necessary. It is important to know what specific factors limit the rate of regeneration in deforested areas in order to devise minimum input strategies to overcome them.

In Thailand, ANR has not been successful, due to lack of knowledge about natural processes of forest regeneration. Although some aspects have been studied, such as limiting factors of natural regeneration (Hardwick *et al.*, 1997), there are many more in need for further research, such as the seed rain and seedling establishment (Hardwick *et al.*, 2000a).

Seed dispersal and seedling establishment are the most critical and sensitive stages in forest regeneration. The roles of different dispersal agents in seedling recruitment are very poorly understood. Consequently, both seed dispersal by birds and the role of isolated trees as perches require attention, as identified in The Chiang Mai Research Agenda for the Restoration of Degraded Forestlands for Wildlife Conservation in Southeast Asia (Elliott *et al.*, 2000a). It is rarely possible to plant all species of trees for ecological restoration, especially in large areas, but natural regeneration may be accelerated by planting a smaller number of trees which act as suitable perches to attractive seed dispersers for enhancing seed rain. More needs to be known about whether or not isolated trees really enhance seedling recruitment. Which remnant tree species are most attractive and what birds disperse seeds? My research investigated the effects of different remnant mature tree species on the establishment of natural seedlings in deforested sites. Furthermore, observations of birds visiting remnant trees in deforested sites and birds visiting fruiting trees in intact forest determined which bird species are important seed dispersers. Such knowledge will help to improve tree species selection for planting to accelerate forest regeneration.

Hypotheses

1. Remnant mature trees attract seed-dispersing birds into deforested areas.

2. There will be a higher density of animal-dispersed seedlings beneath remnant trees than in control areas with no mature trees.

3. The density and species richness of the seedling community beneath mature remnant trees will depend on the species of the mature trees.

Objectives

The main objectives of this study were:

1. To determine the effects of mature remnant trees on tree seedling establishment in deforested areas, and

2. To determine which tree species should be planted to attract frugivorous seed-dispersing birds into deforested sites.

Future implications of this study

The results of this study will provide some basic ecological knowledge on natural forest regeneration. Specifically, the results show the differential role of remnant forest trees on reforestation. The importance of frugivorous seed dispersing birds which use these trees as perches in deforested areas and increase seed deposition beneath them. This knowledge can help to improve tree planting / reforestation design by accelerating natural regeneration (ANR).

Limitations of the study

I studied seven relicts tree species on deforested sites. My information might not be applicable to other tree species. This study focused only on natural tree seedlings that are most important in natural regeneration. Therefore, this study did not analyze other factors involved, such as differences in herbaceous vegetation and soil conditions.

CHAPTER 2

LITERATURE REVIEW

Understanding natural regeneration is very important to improve ANR techniques (Parrotta, 2000). Every step of the process must be studied, such as the seed rain, seed deposition, seed germination, seedling recruitment (Hardwick *et al.*, 1997). My study focused on the effects of remnant trees on seedling establishment in deforested areas. The most important background knowledge for this study concerns seed dispersal, especially by birds, the role of remnant trees, and seedling establishment.

Importance of the seed rain on deforested sites

A main problem that limits forest regeneration in disturbed areas is the lack of a soil seed bank (McClanahan and Wolfe, 1993). Many species of forest plants do not develop persistent seed banks (Ng, 1980). This agrees with the Forest Restoration Research Unit (FORRU, unpublished data). FORRU studied seed germination of native tree species in Doi Suthep-Pui National Park since 1995 at FORRU's nursery, next Doi Suthep-Pui National Park Headquarters. Seeds were sown in modular trays in forest soil without fertilizer. Numbers of seeds germinated were recorded weekly. The results indicated that many tree species lose viability rapidly in the soil seed bank. About 39% of the total species tested (337 species) were non-viable within a month and up to 67% in two months (Figure 1). Therefore, seed banks have a limited value in reforestation (van der Valk and Pederson, 1989). An important factor for the recovery of forests is seed dispersal from sources outside the deforested site. Seeds are dispersed in many ways, by wind, water, and animals (Willson, 1992; Jordano, 1992; Stiles, 1992).

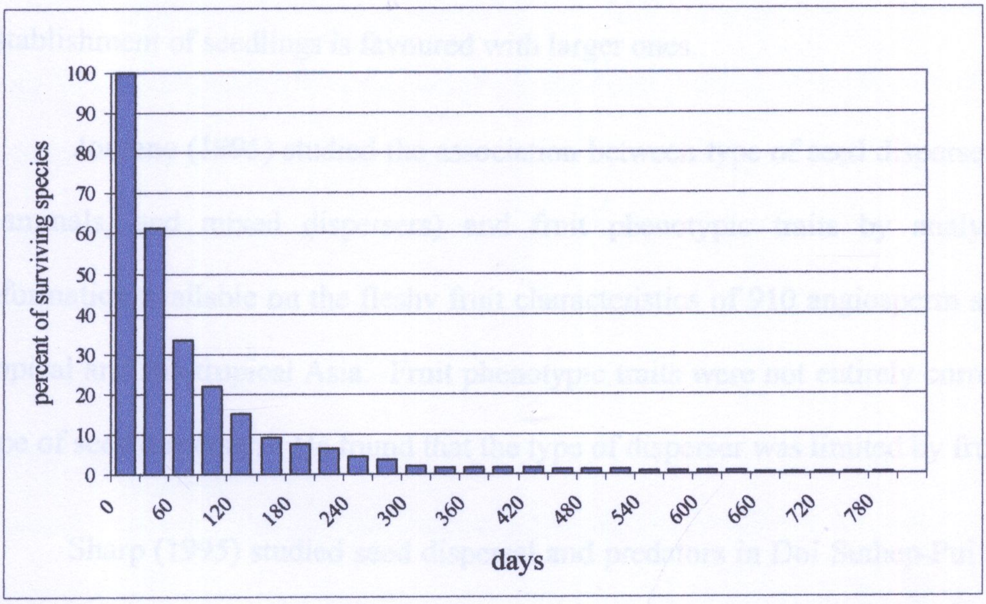


Figure 1 The loss of viability of tree seeds from the seed bank shows that most trees tested have no dormancy

Source: unpublished data, Forest Restoration Research Unit

Seed dispersal

Forster and Janson (1985) compared seed masses of mature tropical forest tree species with different light gap requirements for establishment in Peru. They reported that the species that become established beneath a closed canopy or in small gaps have higher mean seed masses than those that require large gaps. Furthermore, the seed mass of mature forest species is significantly larger than that of pioneer species.

Johnson *et al.* (1985) reported that seed shadows depend upon both seed size and bird species carrying out dispersal. Hedge *et al.* (1991) investigated the relationship of seed size in the bird-dispersed tree *Santalum album* L. (Santalaceae) in India. They found that dispersal efficiency is favoured in small seeds, while establishment of seedlings is favoured with larger ones.

Jordano (1995) studied the association between type of seed dispersers (birds, mammals, and mixed dispersers) and fruit phenotypic traits by analyzing the information available on the fleshy fruit characteristics of 910 angiosperm species in tropical and sub-tropical Asia. Fruit phenotypic traits were not entirely correlative to type of seed dispersers. He found that the type of disperser was limited by fruit size.

Sharp (1995) studied seed dispersal and predators in Doi Suthep-Pui National Park, Thailand. Small, flat, light-weight, and usually winged fruits/seeds could disperse farther into gaps, while bigger ones could spread only a few meters from the parent trees. Furthermore, the species diversity of fruits/seeds declined with distance from forest edges.

Wunderle (1997) investigated the role of animal seed dispersal in accelerating native forest regeneration on degraded tropical lands. He concluded that the efficacy of animal seed dispersal to restoration sites can be limited by the degree of isolation from a seed source, absence of animal seed dispersers in the region, and by large seed size.

Corlett (1998b) investigated seed dispersal by vertebrates in the Indomalayan Region. He reported that small fruits and large, soft fruits that have many small seeds are eaten by a wide range of seed dispersal agents. Larger seeds and fruits are eaten by fewer dispersers and most depend on a few species of mammals and birds, which are highly vulnerable to hunting, fragmentation, and habitat loss.

Dalling *et al.* (1998) studied patterns of seed rains, seed abundance in the soil, and seed mortality of two common pioneer trees, *Miconia argentea* DC. (Melastomataceae) and *Cecropia insignis* Liebm. (Moraceae), on Barro Colorado Island, Panama. The below-crown seed bank in the top soil (up to 3 cm deep) accounted for only 23% of seed rain for *Miconia*, and only 2% for *Cecropia*. Seed densities of both species in the seed bank decline with distance from the crown. The annual loss of *Miconia* seeds was >90% below the crown and declined to 65% at 30 m from the crown. The annual loss of *Cecropia* was >90% at all distances. They concluded that seed losses in the seed bank could largely be attributed to mortality from pathogenic fungi.

Hamann and Curio (1998) studied interactions between frugivores and fleshy fruit trees in a Philippine rainforest. They grouped tree species into early-, mid-, and late-successional species. Early-successional tree species were visited by a wide range of frugivores, but mid- and late-successional tree species were mostly visited by hornbills and pigeons. Consequently, late-successional tree species are the most specialized with respect to dispersers and most sensitive to extinction.

Traveset (1998) reviewed the effects of different seed dispersers (42 bird species, 28 non-flying mammals, 10-15 bats, 12 reptiles, and 2 fishes) on seed germination of nearly 200 plant species after passage through the digestive tract of these animals. She found that seed dispersers commonly have an effect on the germinability of seeds and the rate of germination in about 50% of the plant species they consume. Enhancement of germination occurred about twice as often as inhibition.

Martínez-Garza and González-Montagut (2002) studied the spatial distribution of fleshy-fruited species that disperse to tropical pastures at different distances from forest border in Mexico. They collected a total of 12,647 seeds from 38 fleshy-fruited species which are dispersed to pastures, 30% (32 species) were bird-dispersed seeds only, 20% (3 species) were bat-dispersed seeds, and 50% (3 species) were dispersed by both birds and bats.

Frugivorous birds

Seed dispersal agents have been widely studied, but most interesting is seed-dispersal by birds. Frugivorous birds are known to be important seed dispersers, facilitating regeneration of degraded natural forests (Elliott *et at.*, 1997). Many authors have described the benefits of frugivorous birds on forest restoration over other seed dispersal agents (Howe, 1986). Frugivorous birds benefit the plants by 1) dispersing many seeds into gaps, 2) by increasing the diameter of the seed shadow over that effected gravity, and 3) by increasing the probability that seeds will be deposited at the site of a future treefall gap (Hoppes, 1988).

Howe and Kerckhove (1979) observed feeding assemblages of birds in a Costa Rican dry-forest population of *Casearia corymbosa* H.B.K. (Flacourtiaceae). The Yellow-green Vireo (*Vireo flavoviridis*) was the most reliable disperser throughout the season, accounting for 65% of the arillate seeds removed. Other common visitors were the Streaked Flycatcher (*Myiodynastes maculatus*) 12%, Golden-fronted Woodpecker (*Melanerpes aurifrons*) 9%, Pale-throated flycatcher (*Myiarchus nuttingi*) 8%.

Howe and Kerckhove (1981) observed birds and mammals visiting individual plants in a Panamanian population of the rainforest tree *Virola surinamensis* (Rol.) Warb. (Myristicaceae) (wild nutmeg). They found that consistent differences in seed size could result in dramatic differences in dispersal. Food selection will alternatively favor small seed size and high dispersability in years when frugivores are abundant and large seed size and enhanced seedling vigor in the parental stand, when fruit-eating birds are scarce. Small-seeded plants are likely to colonize new sites whereas large-seeded individuals are likely to produce offspring that fare well in competition with other seedlings near parent trees.

Pratt and Stiles (1983) showed that diet, courtship, and breeding behavior of frugivorous birds influence how long they spend among fruiting plants. Furthermore, the correlation between fruit type and frugivorous birds has implications for seed dispersal. Their results showed that fruit pigeons (Superb fruit dove, White-breasted fruit dove, and Mountain pigeon) and bowerbirds (Black-eared catbird, MacGregor's bowerbird) excrete more seeds beneath parent trees than birds of paradise (Lawes's parotia, Trumpet manucode, Superb bird of paradise, Magnificent bird of paradise, and Blue bird of paradise). The fruit pigeons and bowerbirds make long visits to the plants and the birds of paradise make short visits.

Howe *et al.* (1985) demonstrated that large birds, such as Guans (*Penelop purpurascens*) and toucans (*Ramphastos sulfuratus* and *R. swainsonii*) in South

America can disperse seeds of the rainforest tree *Virola surinamensis* (Rol.) Warb. (Myristicaceae) more than 20 meters. Furthermore, dispersal by these large birds is more favorable for seedling survival than by smaller birds, such trogons (*Trogon massena*) and motmots (*Baryphthengus martii*), which regurgitate seeds under or near the tree crown.

This agrees with the report of Johnson *et al.* (1985), who reported that regurgitated seeds generally spent less time in a bird than defecated seeds, facilitating more rapid dispersal. Smaller birds defecate only small seeds and regurgitate some small seeds as well as all large ones, whereas larger birds defecate all small seeds and many larger ones.

Hoppes (1988) investigated spatial patterns of seedfall for several species of bird-dispersed plant in an Illinois (USA) maple-hackberry woodland. He found that around individual fruiting plants, seedfall declined with distance from the seed source. Small seeds were dispersed farther and were much more likely to be dispersed into adjacent treefall gaps than large ones. Furthermore, natural seedfall around a treefall gap was highest at the edge of the gap, lower in the center of the gap, and lowest in undisturbed forest.

Dean *et al.*, (1990) found that although, birds dispersed seeds by feeding, many birds dispersed seeds as nest material. They studied the dispersal of seeds as nest material by birds and found that seeds of 55 plant species are incorporated into the nests of 31 common bird species in semiarid shrubland of the southern Karoo, South Africa. Nest lining and structural materials include many viable seeds. Furthermore, they postulated that seeds with cottony coverings on indehiscent fruits on woolly or branched peduncles are adapted for direct dispersal by birds as nest material.

Robinson and Handel (1993) investigated forest restoration in New York, USA by planting trees and shrubs of 17 species to attract avian seed dispersers. One year after planting the plantation spread and increased in diversity, with 20 additional species. They found a total of 1,079 woody seedlings, of which 95% came from sources outside the plantation. Most seedlings (71%) were fleshy fruits, dispersed by birds from nearby woodland fringes. The density of new recruits of each species is dependent on the distance from the nearest potential seed source.

Debussche and Isenmann (1994) studied the composition and spatial patterns of the seed rain, produced by bird dispersers, in patchy Mediterranean vegetation in France. They collected the seeds of 38 fleshy-fruited plants. Twenty-five species were dispersed by the bird *Sylvia atricapilla*, which disperses the most diverse and mixed seed rain of the various bird dispersers. The species richness of the seed rain increased with seed density, ranging from 3-21 species per 0.25 m^2. The maximum density (up to 829 per 0.25 m^2) of seeds was observed under the canopy of isolated trees and saplings in old fields, which are favoured perching places for the dispersers. The minimum density (down to 12 per 0.25 m^2) was observed outside of the canopy of these same trees and saplings. The bird dispersers thus trigger dynamic processes initiated by pioneer woody plants in Mediterranean old field successions. Furthermore, dispersal of fleshy-fruited plants by birds was more significant in the mid-stages of succession, when both have homogeneous structure.

Whittaker and Jones (1994) studied the role of frugivorous bats and birds in the rebuilding of a tropical forest on Krakatau Island, Indonesia, which was devastated by a volcanic eruption in 1883. They found that 124 species of plant had been introduced endogenously by birds and bats from a total of 137 zoochorous species. Besides, birds have a dispersal role for a more diversity of plants than do bats, for which available records indicated a restriction largely to trees and shrubs.

Parrotta (1995) studied the influence of overstory composition on understory colonization by native species in a plantation of the exotic trees *Casuarina equisetifolia* L. (Casuarinaceae), *Eucalyptus robusta* Sm. (Myrtaceae), and *Leucaena leucocephala* (Lam.) de Wit (Leguminosae, Mimosoideae), on a degraded tropical site in Puerto Rico. He found that 19 secondary forest species established in the plantation understories. Most of these species (90%) and the total seedling population (97%) are zoochorous, indicating the importance of frugivorous bats and particularly birds as facilitators of secondary forest species colonization. Understory species richness and seedling densities are affected by overstory composition.

Nepstad *et al.* (1996) compared tree establishment in abandoned pastures and mature forest in eastern Amazonia. They found that tree seed deposition in abandoned pastures was higher beneath trees (999 m^{-2} yr^{-1}). Tree seed deposition by birds was low in the open vegetation of the abandoned pastures (2 m^{-2} yr^{-1}).

Corlett (1996) studied the characteristics of vertebrate-dispersed fruits in Hong Kong. He concluded that bird-dispersed species cover the full range of fruit characteristics, except for fruits that are too large to swallow and too hard to peck. This agrees with the report of Tucker and Murphy (1997), who concluded that fruit size and type suggest that birds are responsible for most of the effective seed dispersal in Queensland.

Corlett (1998a) observed birds feeding in Hong Kong shrubland and recorded 42 bird species (22 residents, 20 migrants) eating fruits. At least 92 fruiting species were eaten by birds, the most important seed-dispersal agents being the Red-whiskered Bulbul (*Pycnonotus jocosus*), the Light-vented Bulbul (*P. sinensis*), and the Japanese White-eye (*Zosterops japonicus*).

Remnant trees in deforested areas

The role of remnant trees in disturbed areas has been widely discussed. Many studies have shown the benefits of such trees for accelerated natural regeneration (ANR) by attracting seed dispersers (Wunderle, 1997). These trees are associated with higher seed deposition and seedling beneath their crowns than in open areas.

Guevara *et al.* (1986) determined the role of remnant forest trees in tropical secondary succession in Mexico. They found that remnant large forest trees form "regeneration nuclei", because passing and resident frugivorous birds use them as perching sites. They recorded 29 woody species and 2 climbers beneath 7 remnant trees, and 86% of those plants are bird dispersed.

McClanahan and Wolfe (1993) investigated accelerated forest succession in a fragmented landscape by birds using perches as bird-attracting structures, in Florida, USA. They recorded more seeds and a higher diversity beneath perches (340 seeds m^{-2} yr^{-1}), which was 150 times greater than in sites without perches, however less than 0.06% of the dispersed seeds survived to become seedlings. Perches attracted birds and increased seed deposition, but the harsh conditions and/or high predation on seeds appeared to reduce seedling recruitment. Nonetheless, abundance and diversity of bird-dispersed plants was higher under perches. Therefore, perch structures have a limited ability to enhance plant diversity in secondary successions.

Verdú and García-Fayos (1996) also demonstrated that perches, trees, and shrubs not only attract seed-dispersing birds, but also produce favourable micro-environmental conditions for seed germination and seedling establishment. Soil moisture content after rainfall is always greater beneath trees, providing favourable water potentials for seed germination maintained for a longer time.

Toh *et al.* (1999) studied the role of isolated trees in a degraded sub-tropical rainforest in southern Queensland, Australia. They reported that low trees (<3 m high) act as the initial focus for the activities of seed-dispersing birds, while taller trees (>6 m high) act as bird perches. There was no relationship between remnant tree size and seedling density beneath their crowns. The diversity of tree seedlings beneath the trees increases with both the height and crown area of the trees. Most seedlings can establish around remnant trees, but only some of these can survive through to maturity.

Hau (1999) studied tree seed dispersal on degraded hillsides in Hong Kong. He collected a total of 2,417 tree seeds (17 species), 10,097 shrub seeds (14 species), 132 climber seeds (5 species), and 78 herb seeds (5 species). Most seeds (>94%) collected by seed traps under treelets are dispersed by frugivorous birds.

Galindo-González *et al.* (2000) investigated the seed rain under isolated fig trees in pastures in a tropical rainforest in Mexico. They reported that the seed rain is dominated by zoochorous species (89%). Birds and bats are important seed dispersers in pastures because they disperse seeds of pioneer and primary species connect forest fragments, and maintain plant diversity. They assist to restore woody vegetation in disturbed areas in tropical forests.

Carrière *et al.* (2002a) studied the seed rain beneath remnant trees in a slash-and-burn agricultural system in southern Cameroon. They found that the seed rain beneath remnant trees is 25 times higher than in open areas, 10 m away from the edges of their crowns, while mean species richness of the monthly seed rain is three times higher. Both fleshy-fruited and wind-dispersed species of remnant trees attracted seed-dispersing animals, which greatly raised the seed rain. The attraction did not depend only on presence of fleshy fruits.

Carrière *et al.* (2002b) investigated this site further and found that plant diversity around all age classes (3-20 years) of remnant trees was not significantly different between the positions, beneath and away from their crowns. Most individuals of naturally establishing trees belonged to species with animal-dispersal seeds. These accounted for a larger proportion of recruits beneath remnant trees (75%) than away from remnant trees (64%). In contrast, wind-dispersed species comprised a smaller proportion of recruits beneath remnant trees (11.7%) than away from them (23.6%). They concluded that increased seed rain by attraction of perching animals influences regeneration patterns. Furthermore, the regeneration beneath remnant trees of an animal-dispersed (*Pycnanthus angolensis* (Welw.) Warb., Myristicaceae) and a wind-dispersed (*Triplochiton scleroxylon* K. Schum., Sterculiaceae) species was similar.

Seedling establishment

Post-dispersal processes such as seed predation, seed germination, and seedling establishment are dependent and affect seedling distribution (Verdú and García-Fayos, 1998). For seedling establishment, research has concentrated an various factors, such as competition with herbaceous weeds, seed size, and nutrient availability. The probability of survival varies significantly among species, between habitat, forest type, and fruit types (Osunkoya, 1994). In addition, much research has indicated a higher abundance of seedlings, especially of animal-dispersed plants, under tree crowns than in open areas.

Maguire and Forman (1983) studied the effects of herbs on tree seedling distribution patterns in West Virginia, USA. They concluded that herb patches have a major influence in determining the density and distribution of seedlings of common tree species. However, the distribution of the herb patches is controlled by both the tree canopy and other herb patches.

Nepstad *et al.* (1990) studied tree seedling establishment in a highly degraded pasture in Brazil. They found that establishment is limited by a lack of seed dispersal, predation of seeds and seedlings, and seasonal drought. Bats and birds disperse small seeds of pioneer trees, but leaf-cutter ants and small rodents eat most of them. Furthermore, if the seeds germinate, seedling predators or drought eliminates most of them.

Debussche and Isenmann (1994) studied the composition and spatial patterns of the seedlings of fleshy-fruited plants in patchy Mediterranean vegetation in France. Their results indicated that establishment of fleshy-fruited plants is favored when seeds are deposited under pioneer woody plants rather than in open areas.

Leishman and Westoby (1994) studied the role of seed size on seedling establishment on dry soils in Australia. Their results indicated that seed size is positively associated with survival time of seedlings under dry conditions. Large seeds provide an advantage for seedling establishment when soil moisture is low, such as in deforest sites. Furthermore, Leishman *et al.* (1995) suggested that seed size is more important than environmental conditions for seedling establishment.

Huante *et al.* (1995) determined nutrient availability and growth rates of 34 woody species in a deciduous forest in Mexico. They recorded the highest relative growth rate (RGR) in the high nutrient treatment. Relationship between RGR and seed biomass among the species was weak. Under both low and high nutrients, RGR was highly correlated with specific leaf area (SLA), suggesting the importance of both the total leaf area produced and leaf morphological characteristics in determining the RGR.

Nepstad *et al.* (1996) compared tree establishment in abandoned pasture and mature forest in the eastern Amazonia. They found that tree seedlings and sprout emergence was 20 times lower in the abandoned pasture than in forest understory and forest gaps.

Adhikari (1996) found a relationship between tree seedling establishment and herbaceous vegetation in degraded areas of Doi Suthep-Pui National Park, northern Thailand. He reported that tree seedling diversity is highest in *Eupatorium adenophorum* Spreng. (Compositae)-dominated sites, followed by *Imperata cylindrica* (L.) P. Beauv. var. *major* (Nees) C.E. Hubb. *ex* Hubb. & Vaugh. (Gramineae)-dominated sites and *Pteridium aquilinum* (L.) Kuhn ssp. *aquilinum* var. *wightianum* (Ag.) Try. (Dennstaedtiaceae)-dominated sites. Furthermore, the *Eupatorium* sites had lowest seedling mortality (21.7% over 10 months) followed by the *Pteridium* sites (25.7%) and the *Imperata* sites (30%). Most tree seedling species had better growth rate in the *Eupatorium* sites. There were no significant associations between any of the tree seedling species found in both of the *Imperata* sites and the *Pteridium* sites. Seedlings of three species (*Castanopsis diversifolia* (Kurz) King *ex* Hk. f., Fagaceae; *Leea indica* (Burm. f.) Merr., Leeaceae; and *Phoebe lanceolata* (Wall. *ex* Nees) Nees, Lauraceae) showed significant association with the *Eupatorium*-dominated site. He suggested that the dominant ground flora does not provide a reliable indication of the tree seedling community or of soil conditions.

Previous research at the study site

In the study site, a deforested area above Mae Sa Mai village, previous research has focused on reforestation.

Elliott *et al.* (1997) surveyed naturally established seedlings or saplings (>30 cm tall, gbh < 10 cm) in 1,600 m^2 of plots in this deforested area. They found 174 natural seedlings of 36 species and a density of 0.12 seedlings / m^2.

Kuarak and Hitchcock (1998) compared the number of bird dispersed seedlings beneath the canopies of remnant trees (14 individual trees, 9 species) and in control plots, away from their crowns. They found that *Schima wallichii* (DC.) Korth. (Theaceae) and *Albizia chinensis* (Obs.) Merr. (Leguminosae, Mimosoideae) were the most important remnant trees that promoted seed dispersal by birds, there were abundant bird-dispersed tree seedling beneath their crowns over in control plots. Furthermore, they observed birds feeding on 17 fruiting trees species in mature forest. They found that only 8 species, *Bischofia javanica* Bl., *Macaranga denticulata* (Bl.) M.-A. (both Euphorbiaceae), *Eugenia fruticosa* (DC.) Roxb. (Myrtaceae), *Eurya acuminata* DC. var. *wallichiana* Dyer (Theaceae), *Ficus altissima* Bl., *Ficus glaberrima* Bl. var. *glaberrima, Ficus microcarpa* L. f. var. *microcarpa forma microcarpa* (Moraceae), and *Hovenia dulcis* Thunb. (Rhamnaceae) are clearly attractive to birds. The most important bird visitors were Black-crested Bulbul *Pycnonotus melanicterus* and Striated Yuhina *Yuhina castaniceps*, which had the longest visits to fruiting trees.

Chanthorn (1999) observed birds from December 1997 to January 1998 in the reforested area at this study site. In 60 hours of the observations he recorded 35 bird species (33 species in non-planted plots and 16 species in planted plots). Most of the birds were insectivores, such as Grey breasted Prinia, Long-tailed Shrike, and Pied Bushchat. There was a low proportion of frugivorous birds, of which the Red-whiskered Bulbul was the most abundant. Furthermore, he observed birds feeding in four fruiting trees species, *Ilex umbellulata* (Wall.) Loesn. (Aquifoliaceae), *Antidesma montamum* Bl. (Euphorbiaceae), *Nyssa javanica* (Bl.) Wang. (Nyssaceae) and *Ficus* sp. (Moraceae) during July-October 1998 in evergreen forest of Doi Suthep-Pui

National Park. In twenty hours, a total of 12 bird species were recorded, Black-crested Bulbul, Mountain Bulbul, Puff-throated Bulbul, Ashy Bulbul, Blue-throated Barbet, Red-whiskered Bulbul, Soothy-headed Bulbul, Asian fairy Bluebird, Flavescent Bulbul, Blue-winged Leafbird, Common Tailorbird, and Blacked-naped Monarch. Of these, only five species (Red-whiskered Bulbul, Soothy-headed Bulbul, Flavescent Bulbul, Blue-throated Barbet, and Common Tailorbird) were also found in the reforested area at the study site.

Khopai (2000) studied effects of forest restoration activities on the species diversity of ground flora and tree seedlings in the reforested site. She reported a total of 49 species of naturally established trees (> 1 m in height) in her research plots. The most abundant species were *Litsea cubeba* (Lour.) Pers. var. *cubeba* (Lauraceae), *Acacia megaladena* Desv. var. *megaladena*, *Albizia chinensis* (Osb.) Merr. (Leguminosae, Mimosoideae), *Antidesma acidum* Retz., *Glochidion sphaerogynum* (M.-A.) Kurz (both Euphorbiaceae), *Gmelina arborea* Roxb. (Verbenaceae), and *Markhamia stipulata* (Wall.) Seem. *ex* K. Sch. var. *kerrii* Sprague (Bignoniaceae).

Scott *et al.* (2000) studied the effects of artificial perches and local vegetation on bird-dispersed seed deposition in regenerating sites. They found that the species richness and density of bird-dispersed seeds are significantly higher below perches than in control plots, which lack perches. The majority of bird-dispersed tree seeds were *Antidesma acidum* Retz. (Euphorbiaceae). During 72 hours of bird observations, they recorded a total of 8 bird species visiting perches (29 visits). They were largely insectivorous birds (Grey Bushchat, Grey-breasted Prinia, Olive-backed Pipet, Pied Bushchat, Asian Brown Flycatcher, and Yellow-eyed Babbler) and some frugivorous birds (Sooty-headed Bulbul and Red-whiskered Bulbul). The total species richness of birds visiting perches was higher in the naturally regenerating plots. They suggested that perches are a useful technique to increase seed deposition by birds. Furthermore, the absence of nearby forest and the presence and specific characteristics of fruiting trees have a significant impact on attractiveness to seed-dispersing birds.

These research projects produced an understanding of natural succession and knowledge for ANR. Although much research has indicated the benefits of remnant trees to reforestation in assisting seed dispersal by animals, there are many gaps in this knowledge, such as the effects of different remnant tree species on seedling establishment. This study will help provide a more detailed idea of the role of remnant trees and their role in helping improve ANR techniques.

CHAPTER 3

STUDY SITE

Background

Doi Suthep-Pui National Park is situated to the west of Chiang Mai City, northern Thailand (18°50′ N, 98°50′ E). The park was established on 14 April 1981. The highest peak, Doi Pui, has an elevation of 1,685 m above sea level. The park covers an area 261 km^2 (Figure 2). Deciduous and evergreen are the two basic kinds of forest which are roughly separated at about 950 m elevation (Maxwell, 1988; Maxwell and Elliott, 2001). Nong Hoi Highland Agriculture Research Station is the nearest weather station to the study site, which is directly north of Mae Sa Mai at about 1,000 m elevation. The annual rainfall recorded there was 1,854 mm in 2000 and 2,071.2 mm in 2001. Average annual temperatures were 24.3 °C in 2000 and 24.5 °C in 2001 (Figure 3). The average minimum temperatures were 16.3 °C in 2000 and 17 °C in 2001 while average maximum temperatures were 35.1 °C in 2000 and 34.5 °C in 2001 (Figure 4). The park has exceptionally high biodiversity (Elliott *et al.*, 1989; Maxwell and Elliott, 2001). A total of 2,247 species of vascular plant have been recorded, 21.6% of which are tree species (Maxwell, 2001). Animal species include 326 bird species (Round, 1984), 61 mammal species, 28 amphibian species, 50 reptile species, >500 butterfly species, and >300 moth species (Elliott and Maxwell, 1995).

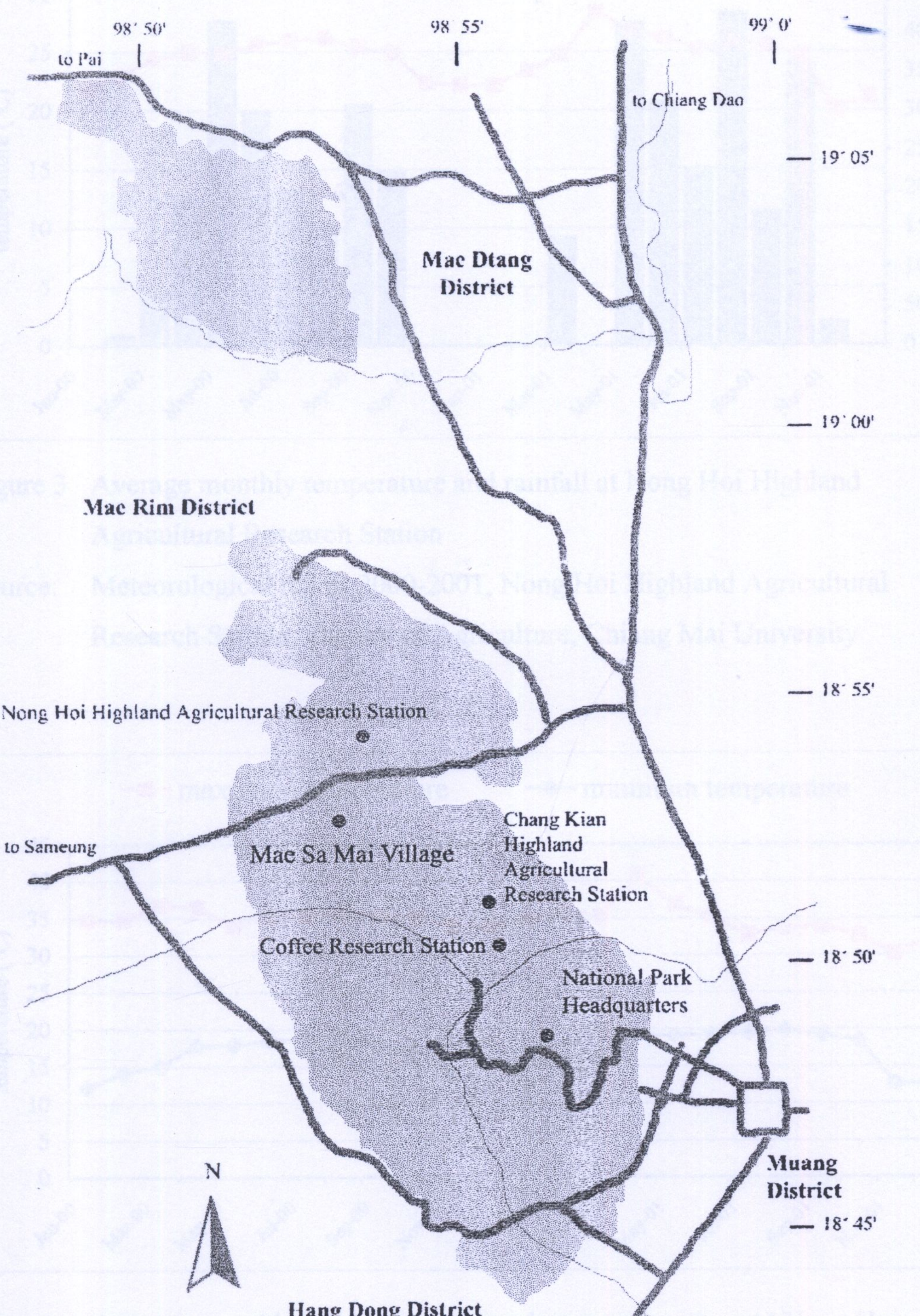


Figure 2 Map of Doi Suthep-Pui National Park, Chiang Mai

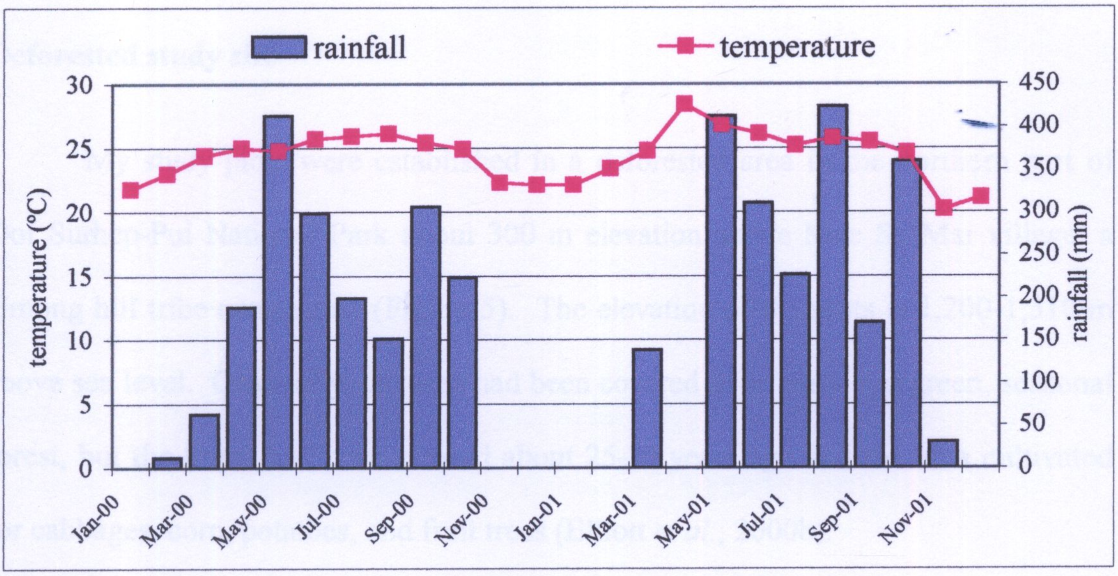


Figure 3 Average monthly temperature and rainfall at Nong Hoi Highland Agricultural Research Station

Source: Meteorological report 2000-2001, Nong Hoi Highland Agricultural Research Station, Faculty of Agriculture, Chiang Mai University

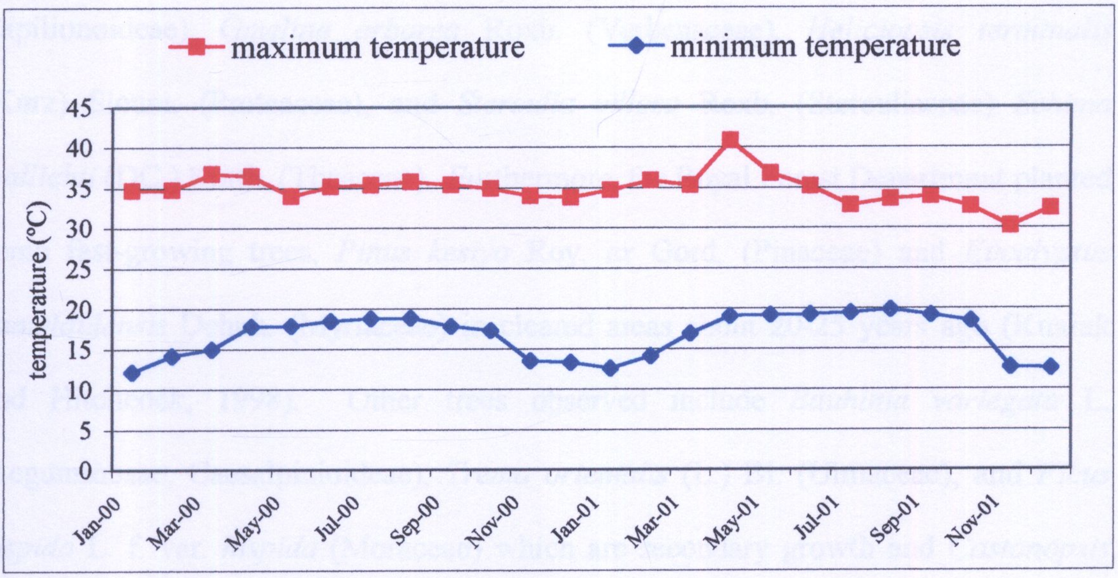


Figure 4 Average monthly minimum and maximum temperature at Nong Hoi Highland Agricultural Research Station

Source: Meteorological report 2000-2001, Nong Hoi Highland Agricultural Research Station, Faculty of Agriculture, Chiang Mai University

Deforested study site

My study plots were established in a deforested area in the northern part of Doi Süthep-Pui National Park about 300 m elevation above Mae Sa Mai village, a Hmong hill tribe community (Figure 5). The elevation of the plots is 1,200-1,310 m above sea level. Originally, the area had been covered in primary evergreen, seasonal forest, but the forest had been cleared about 25-30 years ago and the area cultivated for cabbages, corn, potatoes, and fruit trees (Elliott *et al.*, 2000b).

Although most mature trees were cut for village construction and preparing cultivated areas some trees remain along the dirt roads between fields. These include *Albizia chinensis* (Osb.) Merr. (Leguminosae, Mimosoideae), *Callicarpa arborea* Roxb. var. *arborea* (Verbenaceae), *Erythrina stricta* Roxb. (Leguminosae, Papilionoideae), *Gmelina arborea* Roxb. (Verbenaceae), *Heliciopsis terminalis* (Kurz) Sleum. (Proteaceae), and *Sterculia villosa* Roxb. (Sterculiaceae) *Schima wallichii* (DC.) Korth. (Theaceae). Furthermore, the Royal Forest Department planted some fast-growing trees, *Pinus kesiya* Roy. *ex* Gord. (Pinaceae) and *Eucalyptus camaldulensis* Dehnh. (Myrtaceae) in cleared areas about 20-25 years ago (Kuarak and Hitchcock, 1998). Other trees observed include *Bauhinia variegata* L. (Leguminosae, Caesalpinioideae), *Trema orientalis* (L.) Bl. (Ulmaceae), and *Ficus hispida* L. f. var. *hispida* (Moraceae) which are secondary growth and *Castanopsis diversifolia* (Kurz) King *ex* Hk. f. (Fagaceae) is primary growth.

The areas are mostly mono-cultivated and have many fallow places, abandoned and dominated by weedy herbaceous vegetation, including grasses

(*Pennisetum polystachyon* (L.) Schult., *Imperata cylindrica* (L.) P. Beauv. var. *major* (Nees) C.E. Hubb. *ex* Hubb. & Vaugh., *Thysanolaena latifolia* (Roxb. *ex* Horn.) Honda, and *Phragmites vallatoria* (Pluk. *ex* L.) Veldk., all Gramineae; *Pteridium aquilinum* (L.) Kuhn) ssp. *aquilinum* var. *wightianum* (Ag.) Try., Dennstaedtiaceae; *Bidens pilosa* L. var. *minor* (Bl.) Sherff, *Ageratum conyzoides* L., *Eupatorium odoratum* L., *E. adenophorum* Spreng., all Compositae; and *Commelina diffusa* Burm. f., Commelinaceae) (Elliott *et al.*, 1997; Elliott *et al.*, 2000b).

Elliott *et al.* (2000b) reported the soil characteristics in the study area and compared this with soil from undisturbed evergreen forest at a similar elevation (Table 1). The results showed that the soil in the study site is significantly more acidic, with much less organic matter, nitrogen, silt, and clay but more sand.

Table 1 Soil characteristics of the study site (n=16) compared with those in undisturbed primary evergreen forest (Reusee Cave, east side of Doi Suthep, elevation 1,100 m about 9 km from the study site) (n=20)

	degraded area		*evergreen forest*		t-test [1]
	mean	*SD*	mean	*SD*	p values
pH	5.44	0.423	6.22	0.545	0.001
organic matter (%)	5.35	0.997	7.30	2.480	0.010
nitrogen (%)	0.26	0.045	0.37	0.121	0.002
potassium (ppm)	274.84	137.637	295.67	72.093	ns [2]
moisture at field capacity (%)	34.76	2.571	35.35	4.363	ns [2]
sand (%)	68.52	6.290	52.13	17.872	0.010
silt (%)	18.26	3.090	22.04	5.473	0.020
clay (%)	13.22	3.880	25.83	16.343	0.010

[1] Two-tailed student's t-test, variances assumed equal, [2] ns = not significant at $p>0.05$

Source: Elliott *et al.* (2000b)

Most parts of this area are situated in the forest-planting project to celebrate His Majesty King Bhumibol Adulyadej's Golden Jubilee. The target area encompasses 0.32 km^2 (200 rai) of deforested land. Tree planting started in 1996 by the Forest Restoration Research Unit (FORRU), Chiang Mai University. This tree-planting program was implemented in collaboration with Mae Sa Mai villagers to plant and maintain the planting plots. Furthermore, the villagers make fire breaks and keep watch for forest fires every dry season, but fires still occur almost every dry season (Elliott *et al.*, 1997; Elliott *et al.*, 2000b; FORRU, 1998).

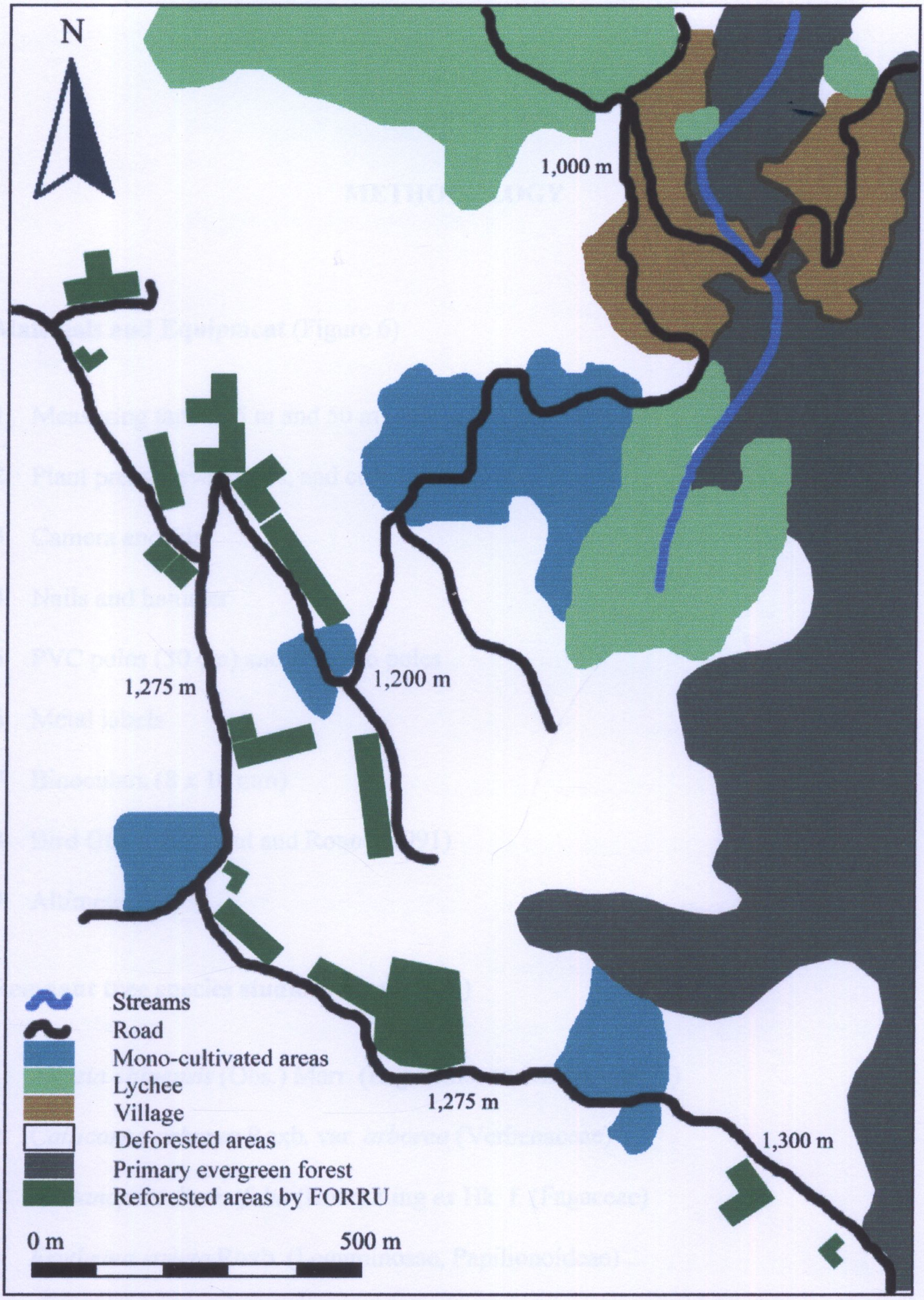


Figure 5 Land use map showing the deforested sites in Doi Suthep-Pui National Park, and Mae Sa Mai village

CHAPTER 4

METHODOLOGY

Materials and Equipment (Figure 6)

1. Measuring tape (1.5 m and 50 m)
2. Plant press, newspapers, and cutters
3. Camera and film
4. Nails and hammer
5. PVC poles (30 cm) and Bamboo poles
6. Metal labels
7. Binoculars (8 x 10 mm)
8. Bird Guide (Lekagul and Round, 1991)
9. Altimeter (m)

Remnant tree species studied (Figure 7-13)

1. *Albizia chinensis* (Obs.) Merr. (Leguminosae, Mimosoideae)
2. *Callicarpa arborea* Roxb. var. *arborea* (Verbenaceae)
3. *Castanopsis diversifolia* (Kurz) King *ex* Hk. f. (Fagaceae)
4. *Erythrina stricta* Roxb. (Leguminosae, Papilionoideae)
5. *Eucalyptus camaldulensis* Dehnh. (Myrtaceae)
6. *Pinus kesiya* Roy. *ex* Gord. (Pinaceae)
7. *Schima wallichii* (DC.) Korth. (Theaceae)

Method

Study of tree seedling establishment

Tree selection for research

Seven species of remnant tree that were present in the deforested sites were chosen, based on various characteristics: six native species and one exotic species (*Eucalyptus camaldulensis* Dehnh.): different fruit types. They were isolated from other tree crowns and had no big trees beneath their crowns.

Sampling plots

A total of 102 plots, 51 beneath the trees studied and 51 in open areas, away from tree crowns were demarcated. Circular plots, dependent on the width of canopies of these trees, were established, along with control plots (containing no trees) nearby each tree. Fifty-one pairs of plots consisted of 6-pairs of both *Albizia chinenesis*-plots and *Erythrina stricta*-plots, 7-pairs of *Callicarpa arborea*-plots, and 8-pairs of *Castanopsis diversifolia*-plots, *Eucalyptus camaldulensis*-plots, *Pinus kesiya*-plots, and *Schima wallichii*-plots. The trees sizes and plots areas are listed in Appendix A.

Data collection

All naturally established tree seedlings present in each plot were surveyed, excluding seedlings from the remnant trees studied. Seedlings were labeled, identified, and classified according to their seed-dispersal method (by wind or animals). Furthermore, seedling heights were recorded to determine relative growth rates. The first survey was made in the dry season, March-May 2000, and the second for measuring seedling height during the next dry season, March-May 2001. Seedlings were identified by comparing them with seedlings in FORRU nursery and with seedling vouchers in Chiang Mai University Herbarium. Unknown seedlings were identificied by J.F. Maxwell, curator of CMU Herbarium.

Bird observations

Bird observations in the remnant trees

Observations were made during March 2001 – May 2001 from the ground at about 15-30 m from each remnant tree. Observation periods were divided 4 daily periods, 0600-0900, 0900-1200, 1200-1500, and 1500-1800 hrs. using 8 x 40 binoculars. The bird species observed, number of birds, time of visit, and their behavior were recorded.

Bird observations in fruiting trees in intact forest

Observations of birds feeding in fruiting trees was done during March – December 2002. Observations were made from ground, about 15-20 m from fruiting trees in mature forest. Birds were observed for 3 hours in the morning and 3 hours in evening. The fruiting tree species, location, bird feeding species, number of birds, time of visiting (minute), and their behavior were also recorded.

Data analysis

Data were analyzed by 2 main methods. Ecological indices were calculated by using a basic computer program (Ludwig and Reynold, 1998). Secondly, data were analyzed using the Excel spreadsheet program and SPSS computer programs.

Ecological Indices

Ecological indices of tree seedlings consisted of species richness (N0), species diversity (N1, N2), and evenness (*E*5) were calculated for each plot by using the SPDIVERS.BAS programe. Resemblance in species composition among plots was also analyzed by similarity or distance coefficients.

Species/area curves

Calculations were done by using the Excel spreadsheet programe, which has the following formula.

$$S(a) = S - \sum_{i=1}^{S} (1 - a)^{n_i}$$

where: $S(a)$ = expected number of species in a fraction (a) of the total area surveyed, (a = 0 to 1)

S = total number of species encountered

n_i = number of individuals of the ith species

Rarefraction

Calculation for rarefraction was made by RAREFRAC.BAS programe and created charts in Excel spreadsheet programe.

$$E(S_n) = \sum_{i=1}^{S} \left[1 - \left(\frac{\binom{N-n_i}{n}}{\binom{N}{n}} \right) \right]$$

where: $E(S_n)$	=	number of species expected in a sample of n individuals
N	=	total number of individuals
S	=	total number of species encountered
n_i	=	number of individuals of the i^{th} species

Species richness

N0	=	Total number of species

Species diversity (Hill's number)

N1	=	$e^{H'}$
N2	=	$1/\lambda$

where: N1 = number of abundant species in the sample

N2	=	number of very abundant species in the sample
H'	=	Shannon's index
λ	=	Simpson's index

Shannon's index (H')

$$H' = \sum_{i=1}^{s} p_i \ln p_I$$

Simpson's Index (λ)

$$\lambda = \sum_{i=1}^{s} p_i^2$$

where: p_i = proportion of individuals of the i^{th} species

$$p_i = n_i / N$$

where:

n_i	=	number of individuals of the i^{th} species
N	=	total number of individuals
s	=	total number of species

Evenness (Modified Hill's index)

$$E5 = \frac{(1/\lambda) - 1}{e^{H'} - 1}$$

Similarity coefficient by Sorensen's index

Calculation was made by Excel spreadsheet program by using following formula.

$$\text{Sorensen's index} = \frac{2C}{A + B}$$

where: C = number of species found in both sampling units (SUs)

A = total number of species in the first SU

B = total number of species in the second SU

Difference coefficient by Chord Distance (CRD)

Calculation was made by using SUDIST.BAS program which the formular is:

$$CRD_{jk} = \sqrt{2\,(1 - ccos_{jk})}$$

where: CRD_{jk} = Chord distance between the j^{th}SU and k^{th}SU range from 0 to $2^{1/2}$

$ccos_{jk}$ = Chord cosine

$$ccos_{jk} = \frac{\sum (X_{ij}\, X_{ik})}{\sqrt{\sum X_{ij}^2 \,.\, \sum X_{ik}^2}}$$

where: X_{ij} = number of individuals of the i^{th} species in the j^{th} SU

X_{ik} = number of individuals of the i^{th} species in the k^{th} SU

Statistical Analysis

Density (no./ m^2) and species richness (no.species/ m^2) of seedlings were tested for differences among pair-plots (beneath the studied tree crown and control) for each studied tree species and for each dispersal agent by using *t*-Tests with the Excel spreadsheet program. Non-parametric tests, the *Kruskal-Wallis* test and the *Mann-Whitney* test were used to test for differences among the studied tree species for each dispersal agent by using SPSS program. Regression analysis using in Excel spreadsheet program, was used to test for relationships between remnant tree size and seedling density.

Relative growth rate (RGR)

The relative growth rate (% RGR $year^{-1}$) of each individual tree seedlings was analyzed by using the height of seedlings.

$$RGR = \frac{[\ln h2 - \ln h1]}{[t2 - t1]} \times 100 \times 365$$

where: *h1* = height (cm) of seedling in first monitoring

h2 = height (cm) of seedling in last monitoring

t2 - t2 = number of days between the monitoring

Figure 6 Materials and equipment

Figure 7 *Albizia chinensis* (Obs.) Merr. (Leguminosae, Mimosoideae)

Figure 8 *Callicarpa arborea* Roxb. var. *arborea* (Verbenaceae)

Figure 9 *Castanopsis diversifolia* (Kurz) King *ex* Hk. f. (Fagaceae)

Figure 10 *Erythrina stricta* Roxb. (Leguminosae, Papilionoideae)

Figure 11 *Eucalyptus camaldulensis* Dehnh. (Myrtaceae)

Figure 12 *Pinus kesiya* Roy. *ex* Gord. (Pinaceae)

Figure 13 *Schima wallichii* (DC.) Korth. (Theaceae)

CHAPER 5

RESULTS

Seedling establishment

A total of 78 tree seedling species (1,156 individuals) had established in the studied plots (Appendix B). Most seedlings, 57 tree species (64.2% of individuals) were dispersed by animals (birds and small mammals), whilst 21 tree species were dispersed seeds by wind (Table 2). Plots beneath tree crowns supported more tree seedling species and individuals (72 species, 648 seedlings) than control plots (60 species, 508 individuals).

Table 2 Number of seedlings and number of seedling species divided by dispersal means in all plots

Dispersal means	Under tree crown		Control		Total	
	no.of seedlings	no.of species	no.of seedlings	no.of species	No.of seedlings	no.of species
wind	215 (33.2%)	19 (26.4%)	200 (39.4%)	19 (31.7%)	415 (35.9%)	21 (26.9%)
birds and wind	22 (3.4%)	3 (4.2%)	10 (1.9%)	2 (3.3%)	32 (2.8%)	3 (3.8%)
birds	73 (11.3%)	5 (6.9%)	53 (10.4%)	5 (8.3%)	126 (10.9%)	6 (7.7%)
birds and small mammals	216 (33.3%)	22 (30.6%)	157 (30.9%)	20 (33.3%)	373 (32.3%)	25 (32.1%)
small mammals	122 (18.8%)	23 (31.9%)	88 (17.3%)	14 (23.3%)	210 (18.2%)	23 (29.5%)
Total	648	72	508	60	1156	78

The most abundant seedling species in all plots combined were *Dalbergia ovata* Grah. *ex* Bth. (Leguminosae, Papilionoideae) (127 seedlings, 11.0%), *Schima wallichii* (DC.) Korth. (Theaceae) (83 seedlings, 7.2%), *Litsea cubeba* (Lour.) Pers. var. *cubeba* (Lauraceae) (76 seedlings, 6.6%), *Rhus chinensis* Mill. (Anacardiaceae) (64 seedlings, 5.5%) and *Litsea monopetala* (Roxb.) Pers. (Lauraceae) (55 seedlings, 4.8%). In plots underneath tree crowns, the most abundant species were *Dalbergia ovata* Grah. *ex* Bth. (Leguminosae, Papilionoideae) (80 seedlings, 12.3%), *Litsea cubeba* (Lour.) Pers. var. *cubeba* (Lauraceae) (43 seedlings, 6.6%) and *Litsea monopetala* (Roxb.) Pers. (Lauraceae) (42 seedlings, 6.5%). In the control plots, the most abundant species were *Schima wallichii* (DC.) Korth. (Theaceae) (58 seedlings, 11.4%), *Dalbergia ovata* Grah. *ex* Bth. (Leguminosae, Papilionoideae) (47 seedlings, 9.2%) and *Litsea cubeba* (Lour.) Pers. var. *cubeba* (Lauraceae) (33 seedlings, 6.5%) (Table 3).

Table 3 Number of seedlings found in each species from all isolated tree species combined

no.	Botanical name	Family name	Seed dispersal mechanism	Under tree crowns	Controls	Total
1	*Glochidion acuminatum* M.-A. var. *siamense* A.S.	Euphorbiaceae	wind, animal	3	2	5
2	*Glochidion kerrii* Craib	Euphorbiaceae	wind, animal	1	0	1
3	*Glochidion sphaerogynum* (M.-A.) Kurz	Euphorbiaceae	wind, animal	18	8	26
4	*Albizia chinensis* (Osb.) Merr.	Leguminosae, Mimosoideae	wind	10	5	15
5	*Albizia odoratissima* (L. f.) Bth.	Leguminosae, Mimosoideae	wind	4	5	9
6	*Archidendron clypearia* (Jack) Niels. ssp. *clypearia* var. *clypearia*	Leguminosae, Mimosoideae	wind	2	3	5
7	*Bauhinia variegata* L.	Leguminosae, Caesalpinioideae	wind	20	19	39
8	*Cratoxylum cochinchinense* (Lour.) Bl.	Guttiferae, Hypericaceae	wind	0	2	2
9	*Dalbergia cultrata* Grah. *ex* Bth.	Leguminosae, Papilionoideae	wind	6	8	14
10	*Dalbergia ovata* Grah. *ex* Bth.	Leguminosae, Papilionoideae	wind	80	47	127
11	*Engelhardia spicata* Lechen. *ex* Bl. var. *spicata*	Juglandaceae	wind	3	2	5
12	*Erythrina stricta* Roxb.	Leguminosae, Papilionoideae	wind	8	1	9
13	*Firmiana colorata* (Roxb.) R. Br.	Sterculiaceae	wind	2	0	2
14	*Ilex umbellulata* (Wall.) Loesn.	Aquifoliaceae	wind	0	1	1
15	*Kydia calycina* Roxb.	Malvaceae	wind	4	4	8
16	*Mallotus philippensis* (Lmk.) M.-A.	Euphorbiaceae	wind	1	7	8
17	*Markhamia stipulata* (Wall.) Seem. *ex* K. Sch. var. *kerrii* Sprague	Bignoniaceae	wind	7	4	11
18	*Melochia umbellata* (Houtt.) Stapf	Sterculiaceae	wind	2	0	2
19	*Oroxylum indicum* (L.) Kurz	Bignoniaceae	wind	5	4	9
20	*Schima wallichii* (DC.) Korth.	Theaceae	wind	25	58	83

Table 3 (continued)

no.	Botanical name	Family name	Seed dispersal mechanism	Under tree crowns	Controls	Total
21	*Stereospermum colais* (B.-H. *ex* Dillw.) Mabb.	Bignoniaceae	wind	15	5	20
22	*Toona ciliata* M. Roem.	Meliaceae	wind	4	4	8
23	*Vernonia volkameriifolia* DC. var. *volkameriifolia*	Compositae	wind	5	3	8
24	*Wendlandia tinctoria* (Roxb.) DC. ssp. *floribunda* (Craib) Cowan	Rubiaceae	wind	12	18	30
25	*Alangium kurzii* Craib	Alangiaceae	animal	2	0	2
26	*Alseodaphne andersonii* (King *ex* Hk. f.) Kosterm.	Lauraceae	animal	1	1	2
27	*Anneslea fragrans* Wall.	Theaceae	animal	9	2	11
28	*Antidesma acidum* Retz.	Euphorbiaceae	animal	24	27	51
29	*Antidesma bunius* (L.) Spreng. var. *bunius*	Euphorbiaceae	animal	8	5	13
30	*Aporusa villosa* (Wall. *ex* Lindl.) Baill.	Euphorbiaceae	animal	31	18	49
31	*Artocarpus lakoocha* Roxb.	Moraceae	animal	6	10	16
32	*Artocarpus lanceolata* Trec.	Moraceae	animal	3	3	6
33	*Baccaurea ramiflora* Lour.	Euphorbiaceae	animal	1	1	2
34	*Beilschmiedia* aff. *intermedia* Allen	Lauraceae	animal	1	0	1
35	*Callicarpa arborea* Roxb. var. *arborea*	Verbenaceae	animal	1	0	1
36	*Canarium subulatum* Guill.	Burseraceae	animal	1	0	1
37	*Canthium parvifolium* Roxb.	Rubiaceae	animal	10	14	24
38	*Castanopsis acuminatissima* (Bl.) A. DC.	Fagaceae	animal	8	1	9
39	*Castanopsis argyrophylla* King *ex* Hk. f.	Fagaceae	animal	4	0	4
40	*Castanopsis diversifolia* (Kurz) King *ex* Hk. f.	Fagaceae	animal	12	9	21

Table 3 (continued)

no.	Botanical name	Family name	Seed dispersal mechanism	Under tree crowns	Controls	Total
41	*Cinnamomum longipetiolatum* H.W. Li	Lauraceae	animal	3	2	5
42	*Dillenia parviflora* Griff. var. *kerrii* (Craib) Hoogl.	Dilleniaceae	animal	4	2	6
43	*Dimocarpus longan* Lour. ssp. *longan* var. *longan*	Sapindaceae	animal	2	0	2
44	*Diospyros glandulosa* Lace	Ebenaceae	animal	9	7	16
45	*Elaeocarpus lanceifolius* Roxb.	Elaeocarpaceae	animal	3	2	5
46	*Eugenia claviflora* Roxb.	Myrtaceae	animal	11	18	29
47	*Eugenia fruticosa* (DC.) Roxb.	Myrtaceae	animal	8	7	15
48	*Eurya acumminata* DC. var. *wallichiana* Dyer	Theaceae	animal	3	2	5
49	*Ficus fistulosa* Reinw. *ex* Bl. var. *fistulosa*	Moraceae	animal	0	1	1
50	*Ficus hispida* L. f. var. *hispida*	Moraceae	animal	1	1	2
51	*Ficus semicordata* B.-H. *ex* J.E. Sm. var. *semicordata*	Moraceae	animal	1	0	1
52	*Ficus subulata* Bl. var. *subulata*	Moraceae	animal	1	0	1
53	*Garuga pinnata* Roxb.	Burseraceae	animal	2	2	4
54	*Gluta obovata* Craib	Anacardiaceae	animal	1	2	3
55	*Gmelina arborea* Roxb.	Verbenaceae	animal	3	6	9
56	*Grewia eriocarpa* Juss.	Tiliaceae	animal	0	1	1
57	*Helicia nilagirica* Bedd.	Proteaceae	animal	6	3	9
58	*Horsfieldia thorelii* Lec.	Myristicaceae	animal	1	0	1
59	*Lithocarpus fenestratus* (Roxb.) Rehd.	Fagaceae	animal	1	0	1
60	*Litsea cubeba* (Lour.) Pers. var. *cubeba*	Lauraceae	animal	43	33	76

Table 3 (continued)

no.	Botanical name	Family name	Seed dispersal mechanism	Under tree crowns	Controls	Total
61	*Litsea glutinosa* (Lour.) C.B. Rob. var. *glutinosa*	Lauraceae	animal	1	1	2
62	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	animal	42	13	55
63	*Litsea salicifolia* Nees *ex* Roxb.	Lauraceae	animal	1	0	1
64	*Machilus bombycina* King *ex* Hk. f.	Lauraceae	animal	12	11	23
65	*Maesa ramentacea* (Roxb.) A. DC.	Myrsinaceae	animal	0	3	3
66	*Michelia baillonii* Pierre	Magnoliaceae	animal	1	1	2
67	*Phoebe lanceolata* (Wall. *ex* Nees) Nees	Lauraceae	animal	4	6	10
68	*Phyllanthus emblica* L.	Euphorbiaceae	animal	20	11	31
69	*Planchonella punctata* Flet.	Sapotaceae	animal	1	0	1
70	*Protium serratum* (Wall. *ex* Colebr.) Engl.	Burseraceae	animal	1	0	1
71	*Rhus chinensis* Mill.	Anacardiaceae	animal	37	27	64
72	*Sapindus rarak* DC.	Sapindaceae	animal	1	0	1
73	*Saurauia roxburghii* Wall.	Saurauiaceae	animal	5	1	6
74	*Fluggea virosa* (Roxb. *ex* Willd.) Voigt	Euphorbiaceae	animal	1	0	1
75	*Sterculia villosa* Roxb.	Sterculiaceae	animal	27	26	53
76	*Styrax benzoides* Craib	Styracaceae	animal	9	5	14
77	*Trema orientalis* (L.) Bl.	Ulmaceae	animal	0	1	1
78	*Turpinia pomifera* (Roxb.) Wall. *ex* DC.	Staphyleaceae	animal	23	12	35
	Total			648	508	1,156

Comparison between recruitment beneath tree crown and control

A comparison of tree seedling recruitment beneath tree crowns and in control plots was carried out by using *t*-tests on seedling density and species richness.

Although mean seedling density and species richness beneath tree crowns were higher than in control plots for all tree species (except *Albizia chinensis*) the differences were statistical significant (P<0.05) only for seedling density in the *Schima wallichii*-plots (P=0.02) and for species richness in the *Eucalyptus camaldulensis*-plots (P=0.01).

Table 4 Average density (no./m^2) and species richness (no.species/m^2) of total seedlings in each studied tree plots

Species	n	Density				Species richness			
		Beneath tree		Control		Beneath tree		Control	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Albizia chinensis	6	0.153	0.061	0.155	0.122	0.108	0.032	0.074	0.054
Callicarpa arborea	7	0.209	0.131	0.206	0.168	0.154	0.092	0.152	0.136
Castanopsis diversifolia	8	0.224	0.165	0.170	0.076	0.122	0.099	0.098	0.036
Erythrina stricta	6	0.399	0.157	0.369	0.216	0.247	0.091	0.212	0.134
Eucalyptus camaldulensis	8	0.268	0.121	0.198	0.245	0.097 *	0.041	0.057 *	0.047
Pinus kesiya	8	0.156	0.139	0.135	0.165	0.116	0.087	0.089	0.085
Schima wallichii	8	0.372 *	0.210	0.199 *	0.123	0.161	0.042	0.133	0.074

Remark: * significant differences (P<0.05)

Considering only wind-dispersed seedling species (Table 5) seedling density beneath tree crowns was higher than in control plots for the *Castanopsis diversifolia*, *Erythrina stricta* and *Schima wallichii*-plots, but the difference was significant ($P < 0.05$) only in the *Erythrina stricta*-plots ($P=0.04$). Mean seedling density beneath the tree crowns was lower than in the control plots for all other tree species plots, but not significantly so. Mean seedling species richness was high beneath the crowns of most remnant tree species (except for only *Pinus kesiya* and *Schima wallichii*). However, the differences between tree crown plots and control plots were not statistically significant.

Table 5 Average density (no./m^2) and species richness (no.species/m^2) of wind-dispersed seedlings in each studied tree plots

Species	n	Density				Species richness			
		Beneath tree		Control		Beneath tree		Control	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Albizia chinensis	6	0.069	0.064	0.086	0.113	0.041 *	0.032	0.026 *	0.025
Callicarpa arborea	7	0.065	0.037	0.070	0.049	0.052	0.032	0.049	0.037
Castanopsis diversifolia	8	0.072	0.053	0.058	0.041	0.044	0.035	0.036	0.019
Erythrina stricta	6	0.219 *	0.147	0.077 *	0.043	0.108 *	0.060	0.044 *	0.018
Eucalyptus camaldulensis	8	0.068	0.084	0.109	0.160	0.023	0.022	0.021	0.019
Pinus kesiya	8	0.031	0.036	0.044	0.049	0.031	0.036	0.035	0.027
Schima wallichii	8	0.143	0.170	0.079	0.054	0.037	0.019	0.038	0.021

Remark: * significant differences ($P<0.05$)

Considering only animal-dispersed seedling species (Table 6) seedling density beneath tree crowns was higher than in control plots for all of remnant tree species except for *Erythrina stricta*. However, the difference was significant ($P<0.05$) only for *Schima wallichii* ($P=0.008$). Mean seedling species richness beneath the tree crowns was higher than in the control plots, also except for only *Erythrina stricta*. For three species of remnant tree, this difference was statistically significant ($P<0.05$), *Eucalyptus camaldulensis* ($P=0.0006$), *Pinus kesiya* ($P=0.02$), and *Schima wallichii* ($P=0.04$).

Table 6 Average density (no./m^2) and species richness (no.species/m^2) of animal-dispersed seedlings in each studied tree plots

Species	n	Density				Species richness			
		Beneath tree		Control		Beneath tree		Control	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Albizia chinensis	6	0.084	0.049	0.068	0.049	0.067	0.025	0.048	0.042
Callicarpa arborea	7	0.148	0.117	0.138	0.135	0.106	0.072	0.104	0.104
Castanopsis diversifolia	8	0.172	0.134	0.125	0.079	0.091	0.076	0.071	0.031
Erythrina stricta	6	0.197	0.119	0.292	0.225	0.156	0.072	0.168	0.121
Eucalyptus camaldulensis	8	0.202	0.137	0.089	0.111	0.075 *	0.024	0.036 *	0.033
Pinus kesiya	8	0.132	0.140	0.091	0.125	0.094 *	0.085	0.055 *	0.070
Schima wallichii	8	0.232 *	0.076	0.120 *	0.080	0.126 *	0.035	0.097 *	0.064

Remark: * significant differences ($P<0.05$)

The mean ratios of animal / wind -dispersed seedling (Table 7) individuals were higher beneath tree crowns than in control plots for all remnant tree species studied except *Erythrina stricta*. However, the differences were insignificant ($P \geq 0.05$). For seedling species richness, the ratios were higher beneath tree crowns than in control plots for all of remnant tree species, except *Erythrina stricta*. However, these differences were statistically significant ($P<0.05$) only for *Eucalyptus camaldulensis* ($P=0.03$).

Table 7 Mean ratios of animal / wind seedlings using number of individuals and number of species

Species	n	Individual				Species richness			
		Beneath tree		Control		Beneath tree		Control	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Albizia chinensis	4	1.952	2.309	0.956	0.931	3.021	4.028	1.542	1.329
Callicarpa arborea	6	2.786	3.208	1.601	1.372	2.375	2.312	1.944	1.421
Castanopsis diversifolia	7	2.485	0.926	1.812	1.087	2.152	0.516	1.928	0.937
Erythrina stricta	6	1.506	1.611	4.889	3.908	2.212	2.436	3.750	1.475
Eucalyptus camaldulensis	4	2.088	2.048	1.684	1.664	2.875 *	1.315	1.625 *	0.478
Pinus kesiya	4	2.917	3.625	0.833	1.106	2.167	2.285	0.917	1.258
Schima wallichii	8	2.726	1.453	2.069	1.833	4.292	2.250	2.858	1.670

Remark: * significant differences ($P<0.05$)

Ecological indices

Maximum species richness (N0=17) occurred beneath the crown of a *Castanopsis diversifolia* tree (7) (Table 8). Minimum species richness (N0=0) occurred underneath the crown of a *Pinus kesiya* (4) and one of the control plots of *Eucalyptus camaldulensis* (3). Mean species richness of tree seedlings, for each species of isolated tree was highest underneath *Castanopsis diversifolia* crowns (N=39) and lowest in the control plots near to *Eucalyptus camaldulensis* trees (N0=14).

Species diversity was highest (N1=25.16,N2=29.62) underneath *Castanopsis diversifolia* and *Albizia chinensis* crowns, while highest evenness (E5=1.32) occurred underneath *Albizia chinensis* and *Pinus kesiya* crowns. For the control plots, species diversity was highest in the *Callicarpa arborea*-control plots (N1=26.75,N2=40.83), but evenness was highest in the *Pinus kesiya*-control plots (E5=1.63).

Table 8 Ecological indices of natural tree seedlings in each plots

Mature tree species	Under tree crown				Control			
	Richness	Diversity		Evenness	Richness	Diversity		Evenness
	N0	N1	N2	E5	N0	N1	N2	E5
Albizia chinensis (1)	3*				2*			
Albizia chinensis (2)	11	10.02	22.75	2.41	4	3.59	5.25	1.64
Albizia chinensis (3)	4	3.36	4.00	1.27	3	2.75	3.75	1.57
Albizia chinensis (4)	10	8.67	12.21	1.46	4	1.78	1.38	0.48
Albizia chinensis (5)	2*				1*			
Albizia chinensis (6)	8	7.58	22.50	3.27	10	9.44	25.99	2.96
Albizia chinensis	**27**	**22.69**	**29.62**	**1.32**	**19**	**8.48**	**4.27**	**0.44**
Callicarpa arborea var. *arborea* (1)	6	4.86	6.00	1.29	8	7.58	22.50	3.27
Callicarpa arborea var. *arborea* (2)	4*				3*			
Callicarpa arborea var. *arborea* (3)	3	2.83	6.00	2.73	5	3.99	4.67	1.22
Callicarpa arborea var. *arborea* (4)	8	7.58	22.50	3.27	8	7.19	13.75	2.06
Callicarpa arborea var. *arborea* (5)	6	5.29	9.34	1.94	1*			
Callicarpa arborea var. *arborea* (6)	2	1.65	1.67	1.03	1*			
Callicarpa arborea var. *arborea* (7)	9	7.56	11.00	1.52	9	8.48	22.00	2.80
Callicarpa arborea* var. *arborea	**26**	**19.52**	**20.09**	**1.03**	**31**	**26.75**	**40.83**	**1.55**
Castanopsis diversifolia (1)	12	9.82	12.16	1.26	9	4.99	3.39	0.59
Castanopsis diversifolia (2)	11	7.84	6.99	0.88	14	9.01	6.92	0.74
Castanopsis diversifolia (3)	9	5.65	4.48	0.75	5	2.29	1.71	0.55
Castanopsis diversifolia (4)	8	7.54	18.33	2.65	8	7.24	13.19	1.96
Castanopsis diversifolia (5)	6	5.34	7.33	1.46	7	6.73	27.99	4.71
Castanopsis diversifolia (6)	10	7.67	8.00	1.05	7	6.34	11.00	1.87
Castanopsis diversifolia (7)	17	12.68	11.81	0.92	8	7.72	36.00	5.21
Castanopsis diversifolia (8)	3	2.83	6.00	2.73	12	10.49	17.00	1.68
Castanopsis diversifolia	**39**	**25.16**	**20.48**	**0.81**	**38**	**23.11**	**16.19**	**0.69**

Table 8 (continued)

Mature tree species	Under tree crown				Control			
	Richness	Diversity		Evenness	Richness	Diversity		Evenness
	N0	N1	N2	E5	N0	N1	N2	E5
Erythrina stricta (1)	11	9.72	17.14	1.85	5	4.17	5.14	1.31
Erythrina stricta (2)	13	11.08	15.33	1.42	5	3.67	3.43	0.91
Erythrina stricta (3)	4*				13	9.57	9.24	0.96
Erythrina stricta (4)	8	7.19	13.75	2.06	5	4.76	14.99	3.72
Erythrina stricta (5)	3	2.38	2.50	1.09	5	4.46	6.99	1.74
Erythrina stricta (6)	10	7.07	6.13	0.84	4	3.58	5.25	1.64
Erythrina stricta	**28**	**21.41**	**22.19**	**1.04**	**22**	**14.89**	**13.72**	**0.92**
Eucalyptus camaldulensis (1)	5	4.17	5.14	1.31	2	1.65	1.67	1.03
Eucalyptus camaldulensis (2)	1*				1*			
Eucalyptus camaldulensis (3)	2	1.29	1.67	0.57	0**			
Eucalyptus camaldulensis (4)	6	4.36	4.12	0.93	2	1.89	3.00	2.25
Eucalyptus camaldulensis (5)	5	4.76	14.99	3.72	6	3.83	3.25	0.79
Eucalyptus camaldulensis (6)	2	1.75	2.00	1.32	1*			
Eucalyptus camaldulensis (7)	5	2.84	2.17	0.63	3	1.59	1.32	0.54
Eucalyptus camaldulensis (8)	8	5.26	4.42	0.80	5	4.14	4.62	1.15
Eucalyptus camaldulensis	**15**	**7.92**	**6.06**	**0.73**	**14**	**6.96**	**5.36**	**0.73**
Pinus kesiya (1)	5	3.99	4.67	1.22	5	4.46	6.99	1.74
Pinus kesiya (2)	11	10.11	19.43	2.02	11	9.49	13.57	1.48
Pinus kesiya (3)	3*				2	1.89	3.00	2.25
Pinus kesiya (4)	0**				2*			
Pinus kesiya (5)	4*				2*			
Pinus kesiya (6)	1*				1*			
Pinus kesiya (7)	5	4.76	9.33	2.22	2	1.89	3.00	2.25
Pinus kesiya (8)	4*				2*			
Pinus kesiya	**24**	**19.97**	**26.05**	**1.32**	**23**	**20.49**	**32.79**	**1.63**

Table 8 (continued)

Mature tree species	Under tree crown				Control			
	Richness	Diversity		Evenness	Richness	Diversity		Evenness
	N0	N1	N2	E5	N0	N1	N2	E5
Schima wallichii (1)	9	3.68	2.25	0.47	8	5.34	4.77	0.87
Schima wallichii (2)	4	3.78	7.49	2.34	4*			
Schima wallichii (3)	13	10.81	13.80	1.30	10	8.85	13.59	1.60
Schima wallichii (4)	8	7.72	36.00	5.21	10	8.14	10.00	1.26
Schima wallichii (5)	15	12.46	15.16	1.24	5	4.71	10.50	2.56
Schima wallichii (6)	8	5.85	5.25	0.88	5	3.99	4.67	1.22
Schima wallichii (7)	12	8.48	7.88	0.92	5	4.76	14.99	3.72
Schima wallichii (8)	6	5.45	9.00 .	1.79	6*			
Schima wallichii	**36**	**17.18**	**9.51**	**0.53**	**33**	**21.69**	**17.16**	**0.78**
Total	72	**36.61**	**24.39**	**0.66**	**60**	**32.88**	**23.02**	**0.69**

* one seedling per one species, therefore can't calculate diversity and evenness

** no seedlings

Species/area curves

Species/area curves were used to compare the expected number of seedling species beneath tree crowns and in control plots. The species/area curves for wind-dispersed, animal-dispersed, and total seedlings are shown in Figures 14-34. Most species/area curves beneath tree crowns indicate higher numbers of species than in control plots, except all charts of *Callicarpa arborea*-plots and charts of wind-dispersed seedling species in the *Castanopsis diversifolia* and *Pinus kesiya*-plots, for which the species/area curves are higher in control. However, all differences between the curves are very small.

Figure 14 Species/area curves of wind-dispersed seedlings in *Albizia chinensis* plots

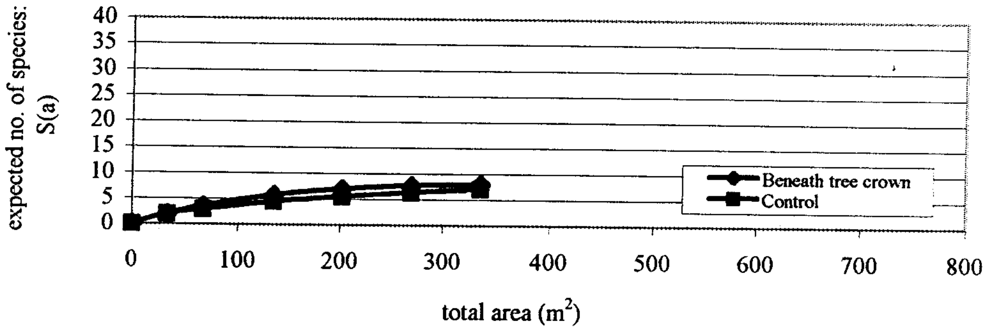


Figure 15 Species/area curves of animal-dispersed seedlings in *Albizia chinensis* plots

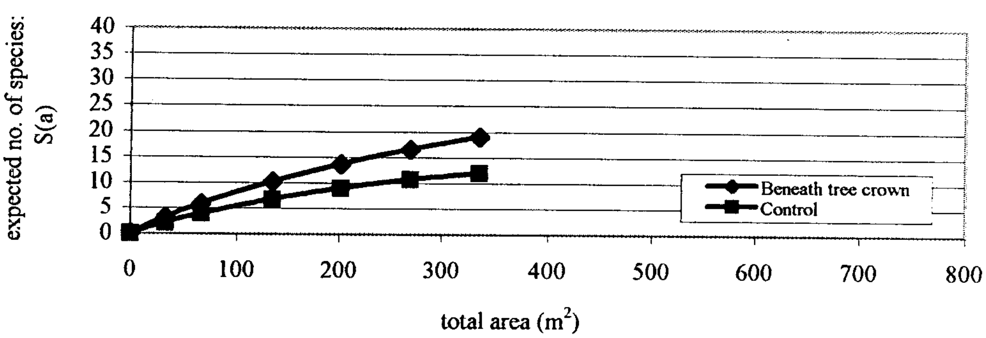


Figure 16 Species/area curves of natural tree seedlings in *Albizia chinensis* plots

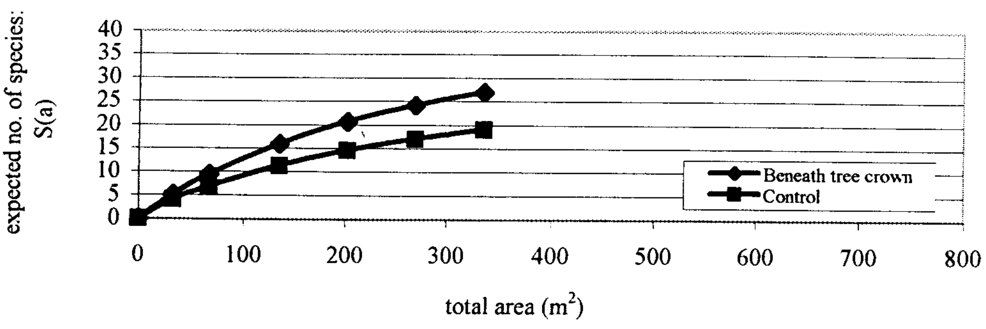


Figure 17 Species/area curves of wind-dispersed seedlings in *Callicarpa arborea* var. *arborea* plots

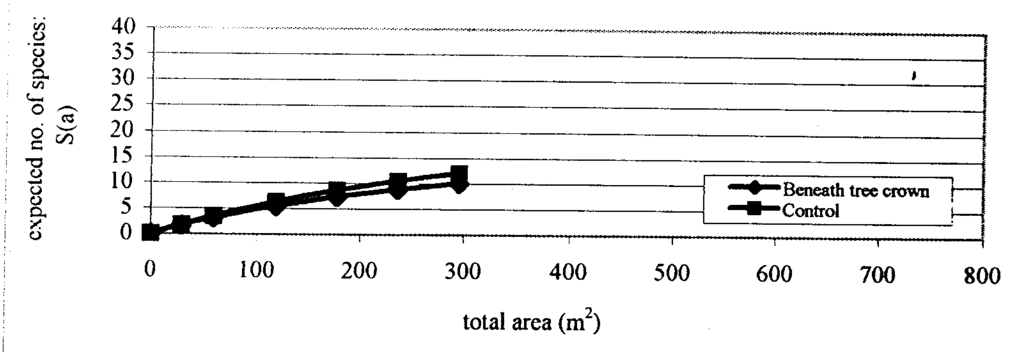


Figure 18 Species/area curves of animal-dispersed seedlings in *Callicarpa arborea* var. *arborea* plots

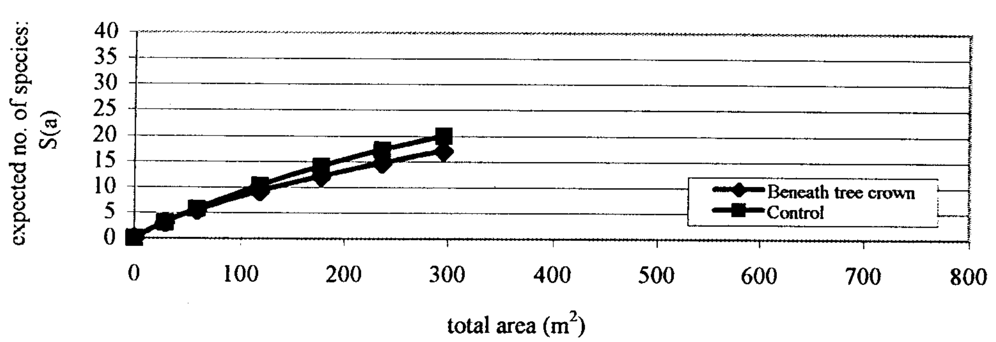


Figure 19 Species/area curves of natural tree seedlings in *Callicarpa arborea* var. *arborea* plots

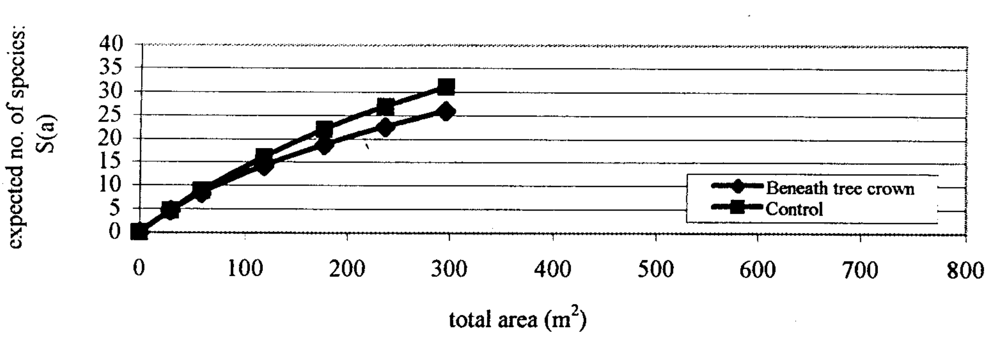


Figure 20 Species/area curves of wind-dispersed seedlings in *Castanopsis diversifolia* plots

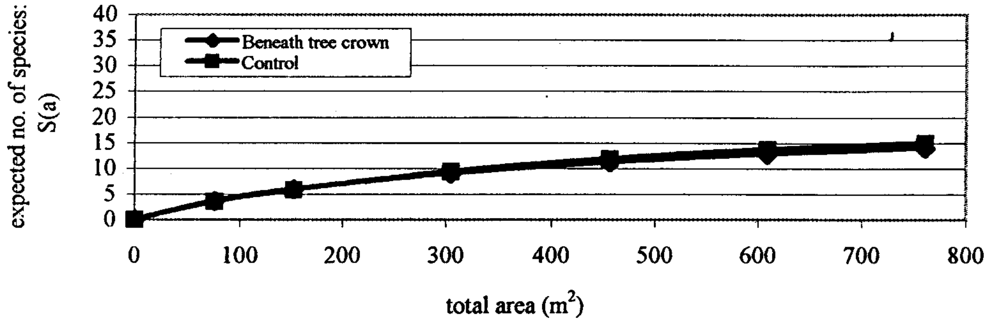


Figure 21 Species/area curves of animal-dispersed seedlings in *Castanopsis diversifolia* plots

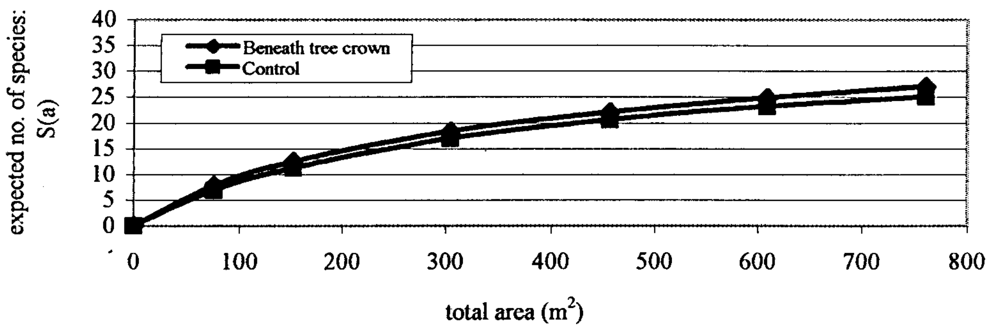


Figure 22 Species/area curves of natural tree seedlings in *Castanopsis diversifolia* plots

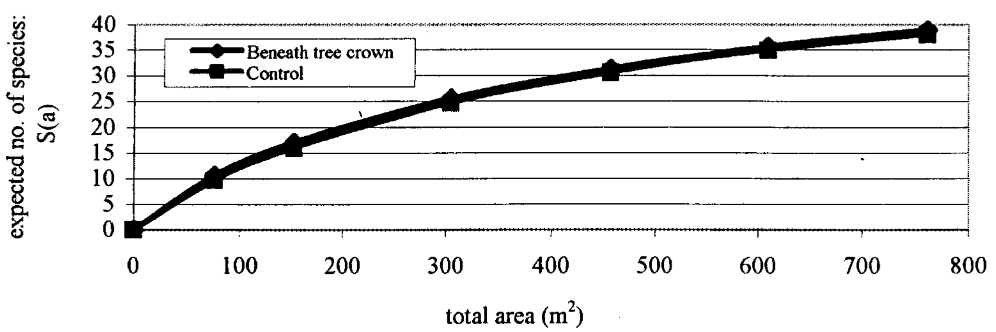


Figure 23 Species/area curves of wind-dispersed seedlings in *Erythrina stricta* plots

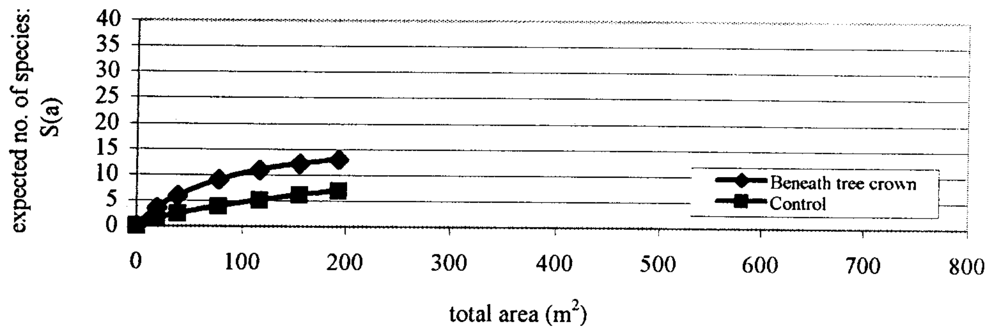


Figure 24 Species/area curves of animal-dispersed seedlings in *Erythrina stricta* plots

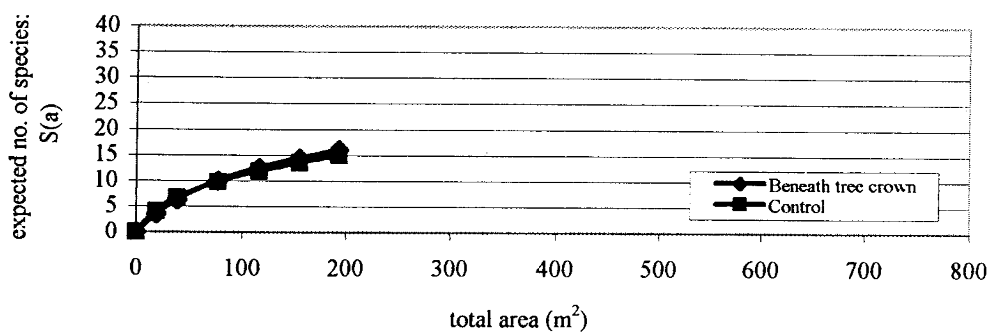


Figure 25 Species/area curves of natural tree seedlings in *Erythrina stricta* plots

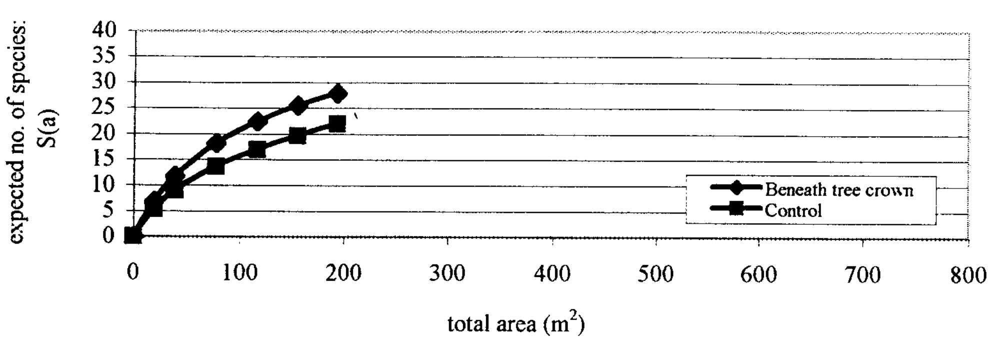


Figure 26 Species/area curves of wind-dispersed seedlings in *Eucalyptus camaldulensis* plots

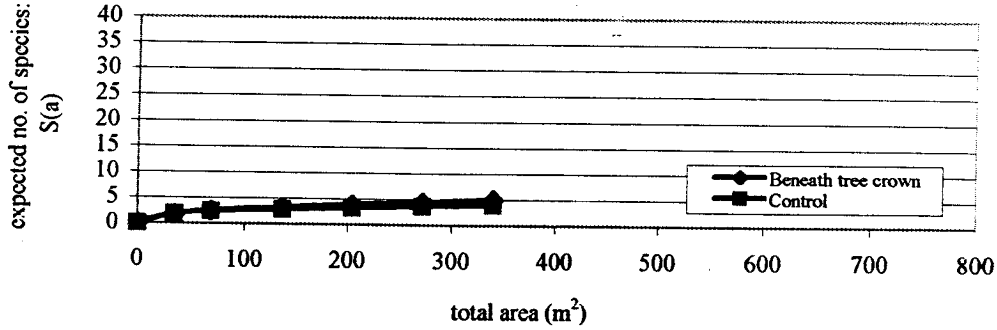


Figure 27 Species/area curves of animal-dispersed seedlings in *Eucalyptus camaldulensis* plots

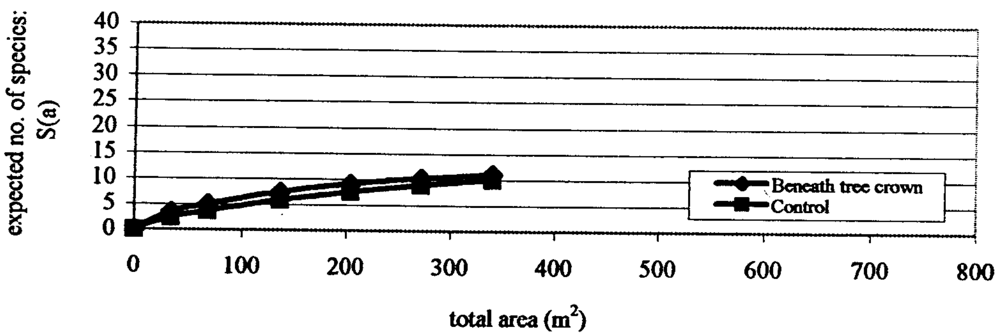


Figure 28 Species/area curves of natural tree seedlings in *Eucalyptus camaldulensis* plots

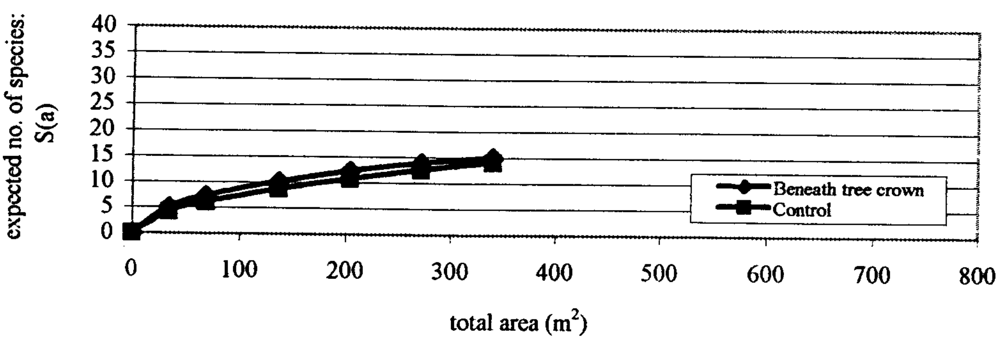


Figure 29 Species/area curves of wind-dispersed seedlings in *Pinus kesiya* plots

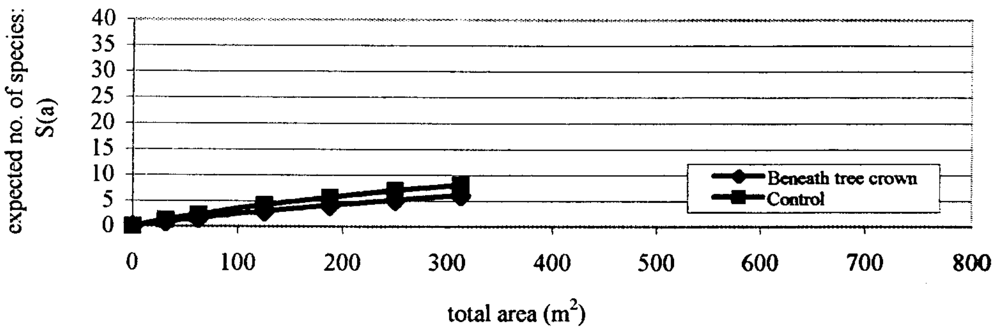


Figure 30 Species/area curves of animal-dispersed seedlings in *Pinus kesiya* plots

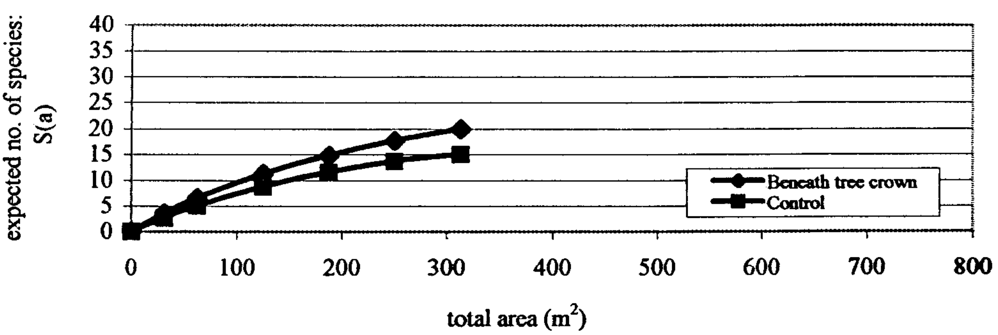


Figure 31 Species/area curves of natural tree seedlings in *Pinus kesiya* plots

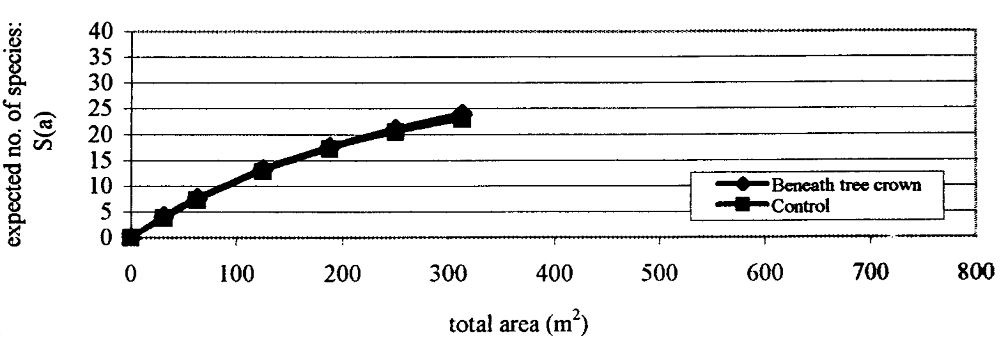


Figure 32 Species/area curves of wind-dispersed seedlings in *Schima wallichii* plots

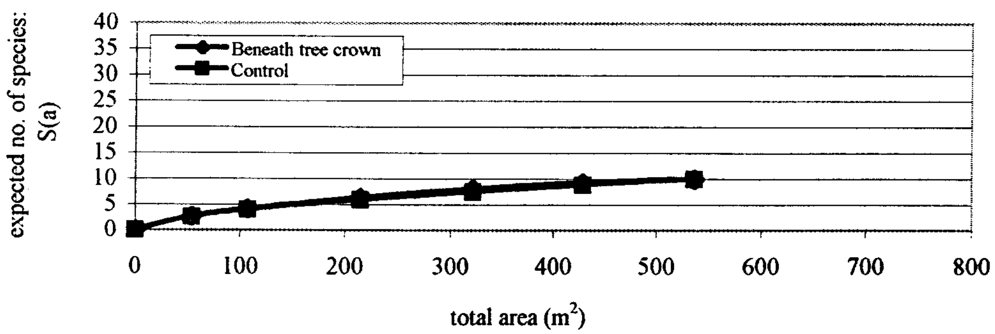


Figure 33 Species/area curves of animal-dispersed seedlings in *Schima wallichii* plots

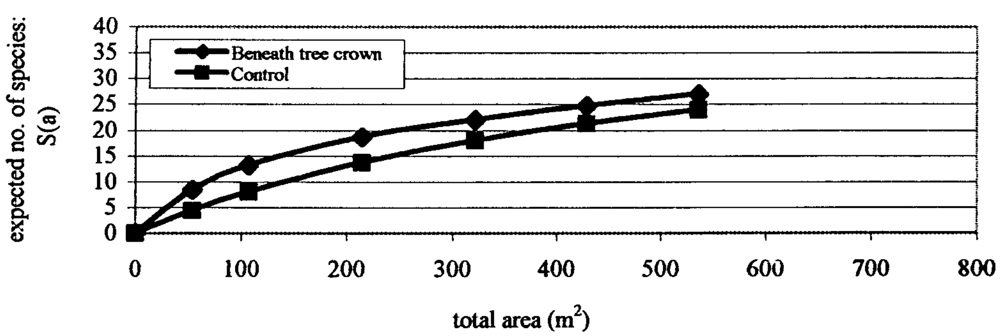
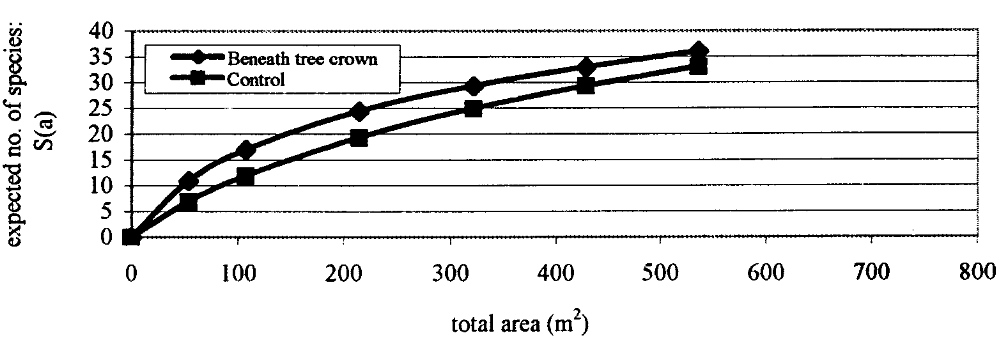


Figure 34 Species/area curves of natural tree seedlings in *Schima wallichii* plots



Rarefraction

The rarefraction method is used to calculate expected number of seeding species from different communities if all samples of the seedling community plots were reduced to a standard number of individuals. Since, in this study, seedling density varied greatly among plots, and plot size varied according to the dimensions of the tree crowns, it is a more appropriate technique than standard species/area curves. Rarefraction curves were used to compare expected numbers of seedling species beneath the tree crowns and in the control plots. Separate curves for wind-dispersed, animal-dispersed, and total seedlings are shown in Figures 35-55. Most charts show similar relationships between numbers of individuals and number of species beneath the tree crowns and in control plots. The expected numbers of seedling species beneath tree crowns was higher than in control plots in charts of wind-dispersed seedlings in *Albizia chinensis*-plots, animal-dispersed seedlings in *Erythrina stricta*-plots, and total seedlings in *Albizia chinensis* and *Erythrina stricata*-plots. The opposite result was found in all charts of *Schima wallichii*-plots and for animal-dispersed seedlings and total seedlings in the *Callicarpa arborea*-plots.

Figure 35 Rarefraction curves of wind-dispersed seedlings in *Albizia chinensis* plots

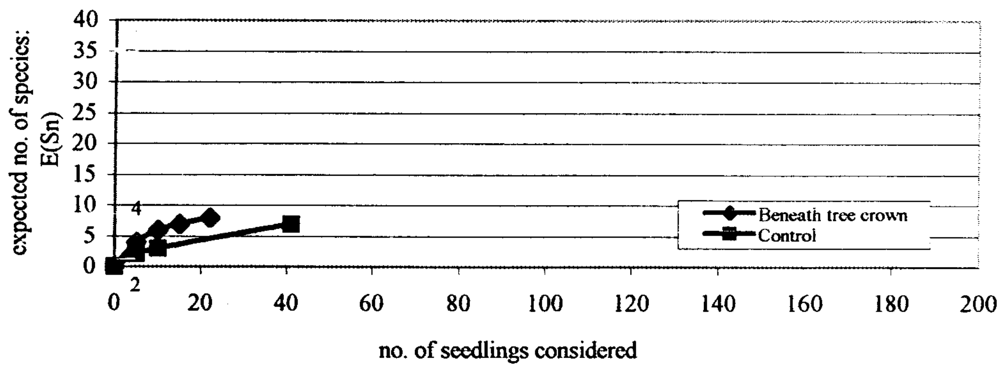


Figure 36 Rarefraction curves of animal-dispersed seedlings in *Albizia chinensis* plots

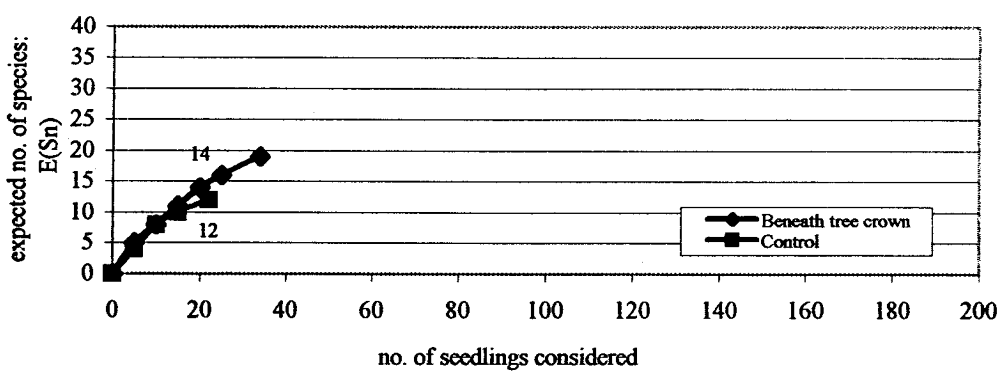


Figure 37 Rarefraction curves of natural tree seedlings in *Albizia chinensis* plots

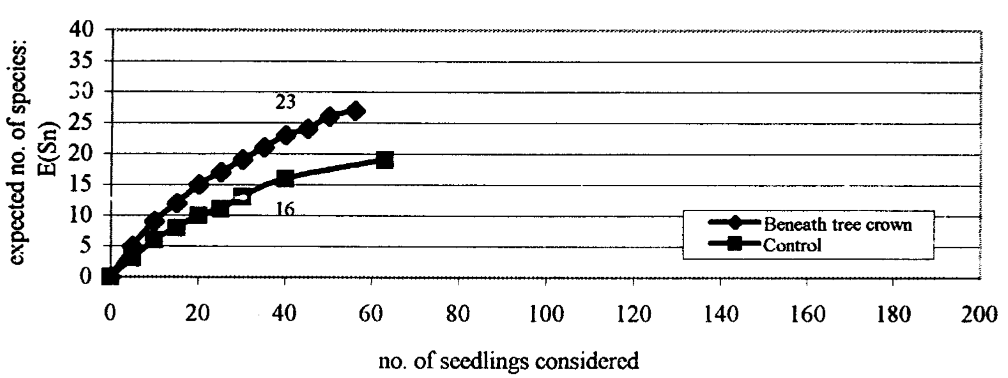


Figure 38 Rarefraction curves of wind-dispersed seedlings in *Callicarpa arborea* var. *arborea* plots

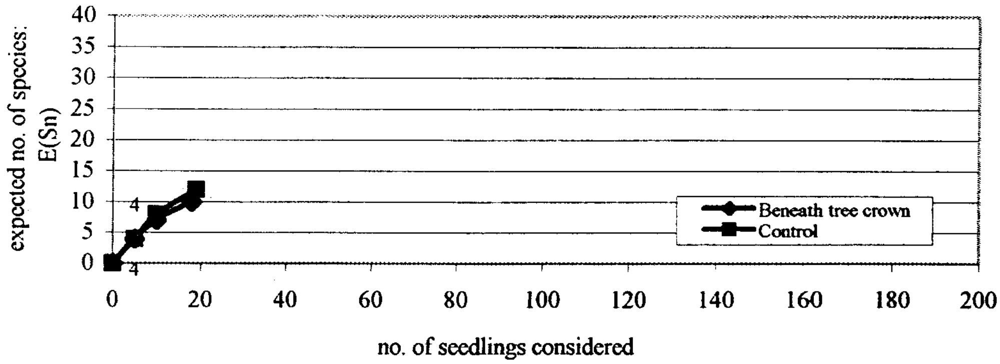


Figure 39 Rarefraction curves of animal-dispersed seedlings in *Callicarpa arborea* var. *arborea* plots

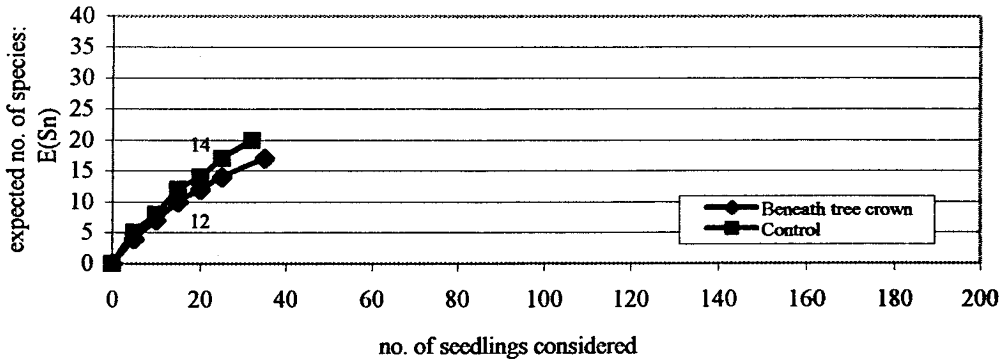


Figure 40 Rarefraction curves of natural tree seedlings in *Callicarpa arborea* var. *arborea* plots

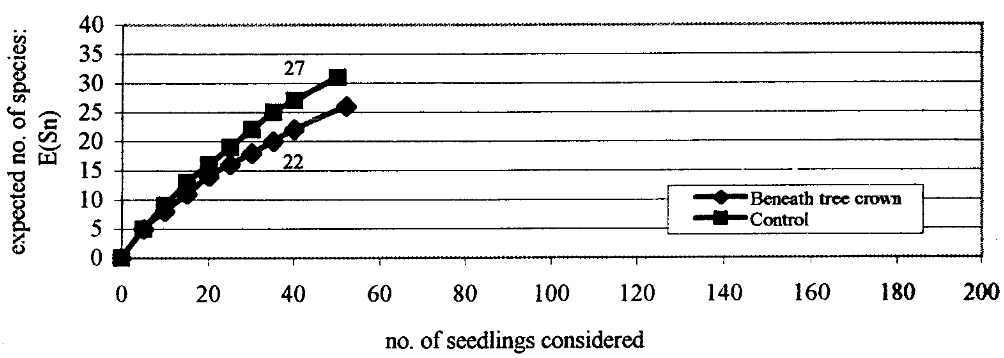


Figure 41 Rarefraction curves of wind-dispersed seedlings in *Castanopsis diversifolia* plots

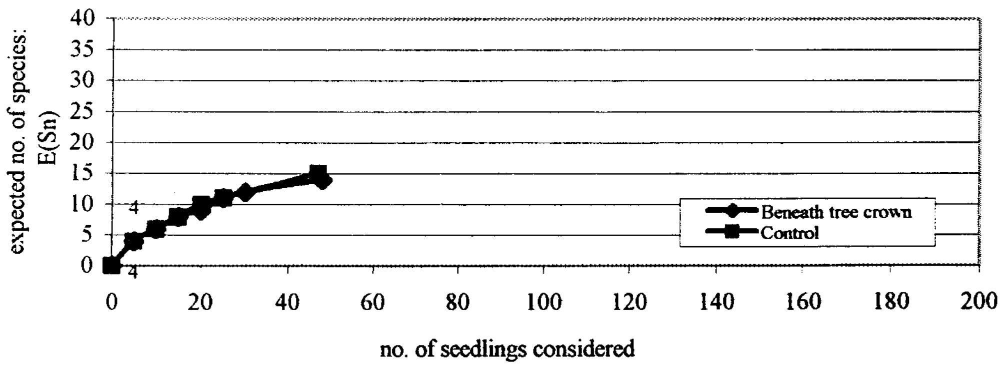


Figure 42 Rarefraction curves of animal-dispersed seedlings in *Castanopsis diversifolia* plots

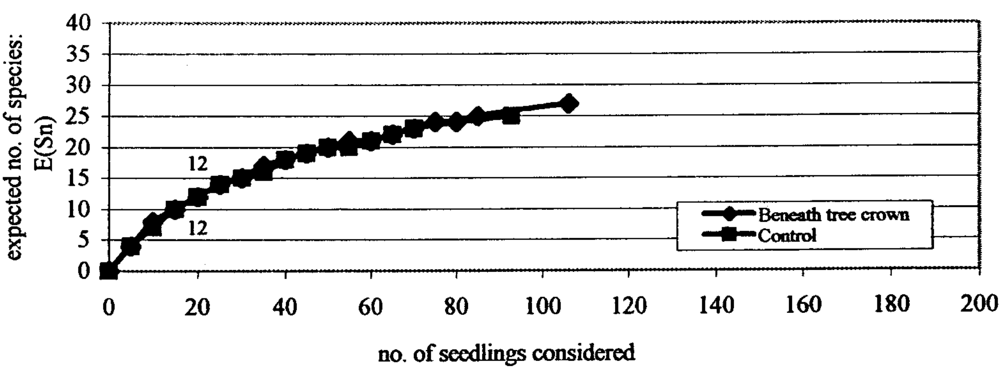


Figure 43 Rarefraction curves of natural tree seedlings in *Castanopsis diversifolia* plots

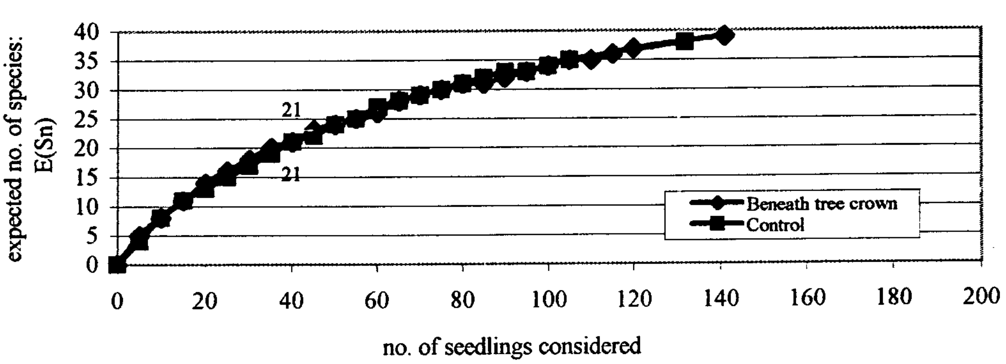


Figure 44 Rarefraction curves of wind-dispersed seedlings in *Erythrina stricta* plots

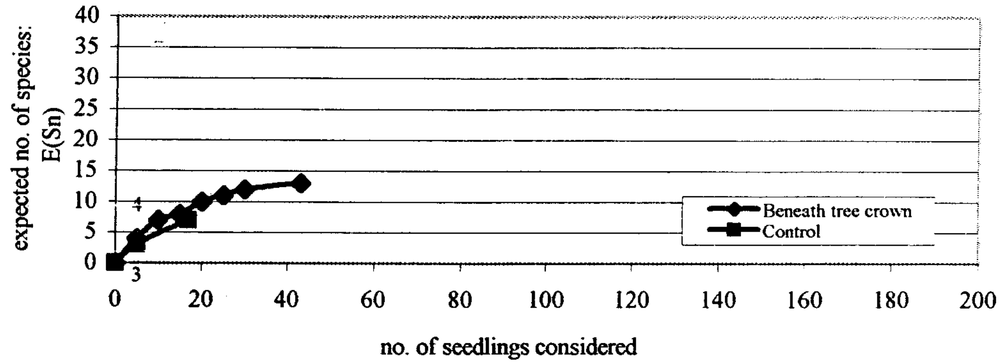


Figure 45 Rarefraction curves of animal-dispersed seedlings in *Erythrina stricta* plots

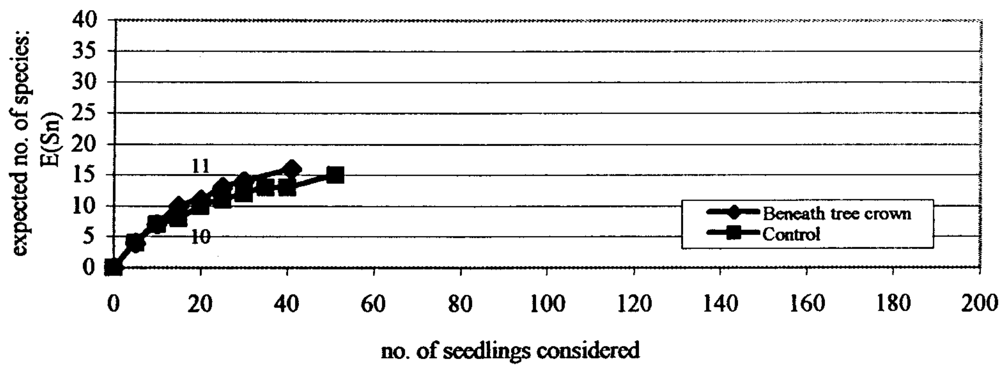


Figure 46 Rarefraction curves of natural tree seedlings in *Erythrina stricta* plots

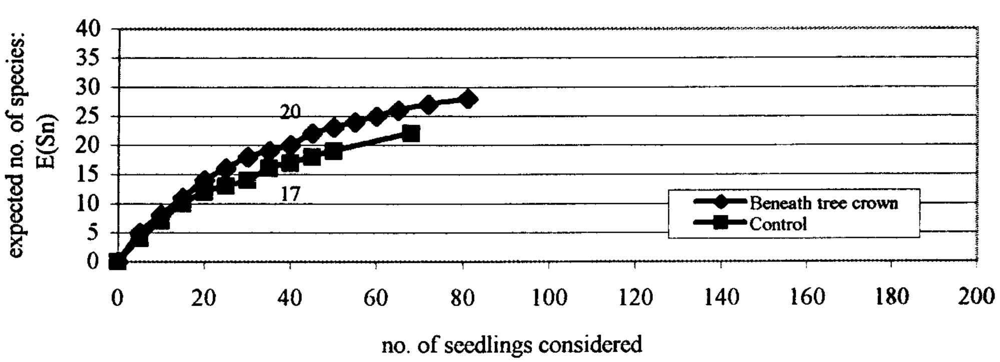


Figure 47 Rarefraction curves of wind-dispersed seedlings in *Eucalyptus camaldulensis* plots

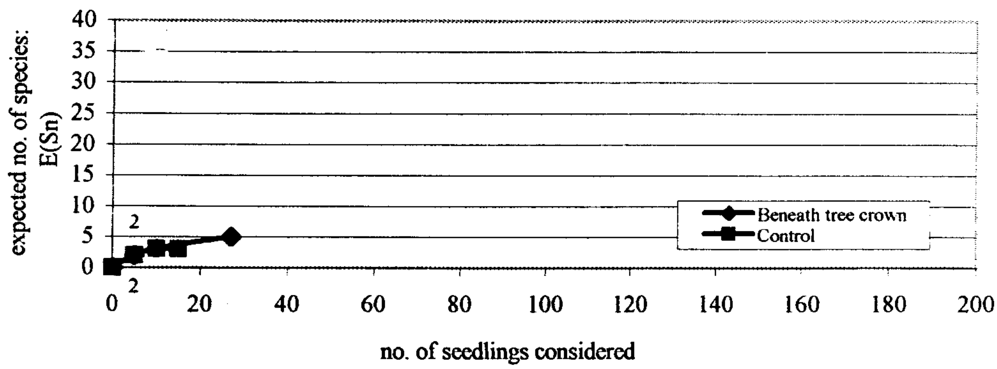


Figure 48 Rarefraction curves of animal-dispersed seedlings in *Eucalyptus camaldulensis* plots

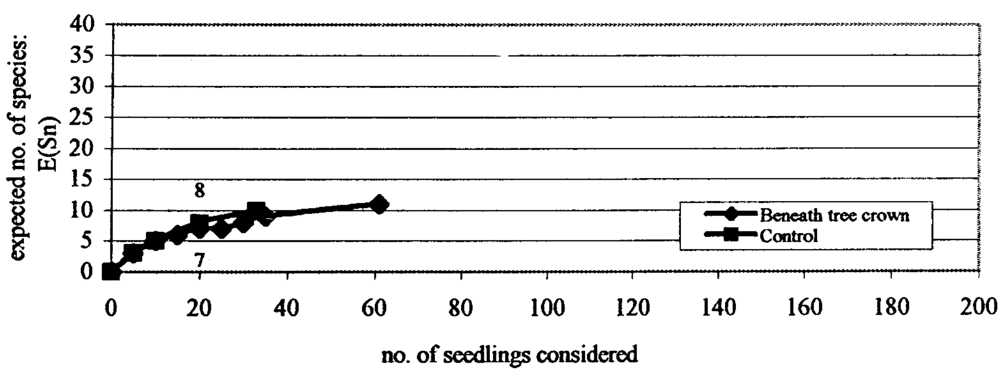


Figure 49 Rarefraction curves of natural tree seedlings in *Eucalyptus camaldulensis* plots

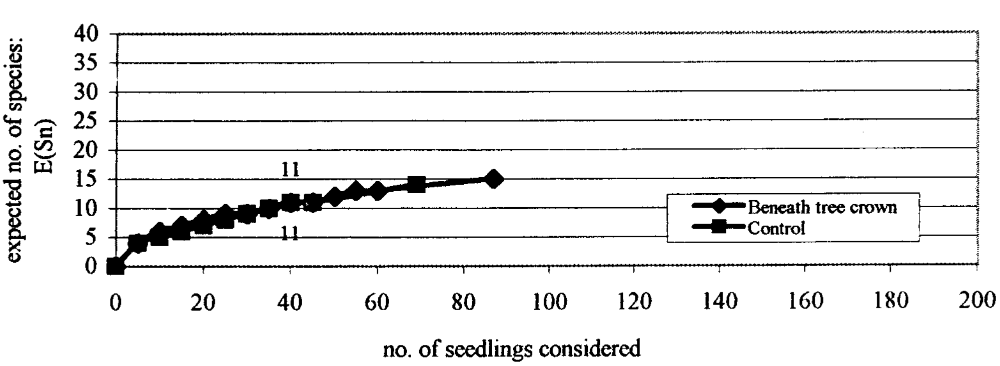


Figure 50 Rarefraction curves of wind-dispersed seedlings in *Pinus kesiya* plots

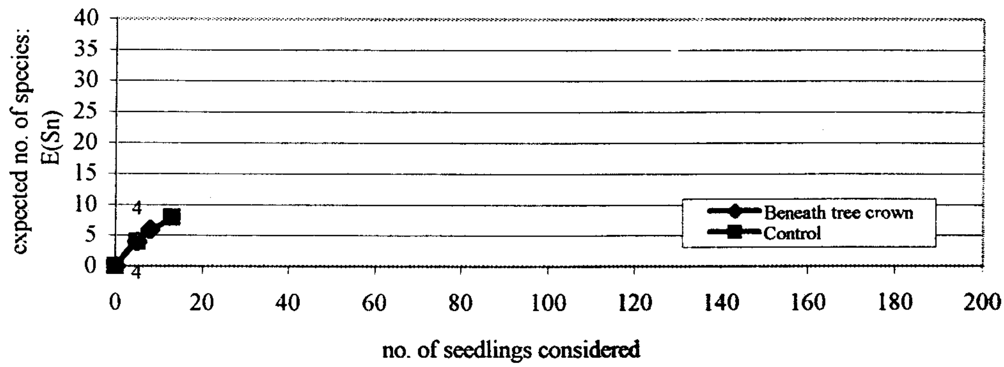


Figure 51 Rarefraction curves of animal-dispersed seedlings in *Pinus kesiya* plots

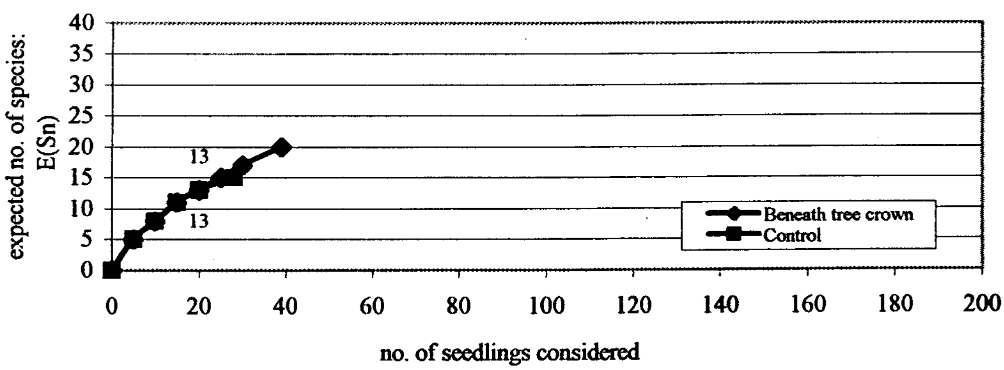


Figure 52 Rarefraction curves of natural tree seedlings in *Pinus kesiya* plots

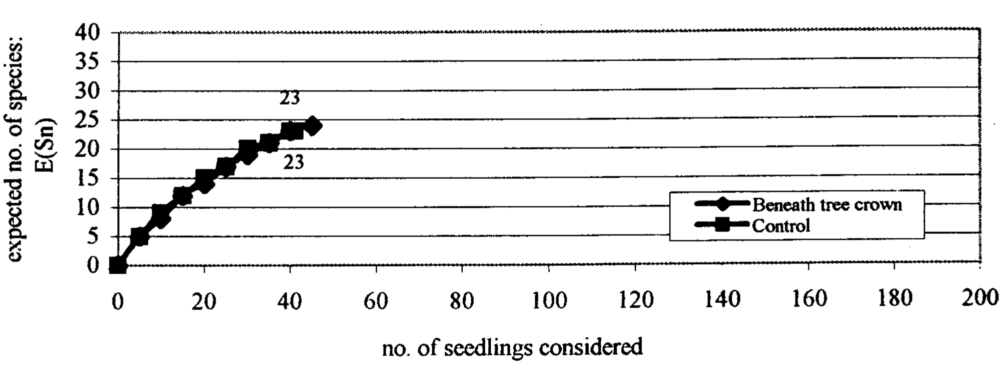


Figure 53 Rarefraction curves of wind-dispersed seedlings in *Schima wallichii* plots

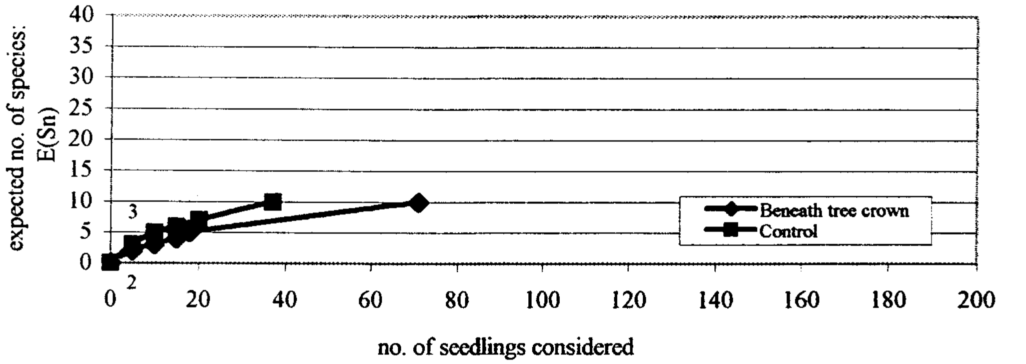


Figure 54 Rarefraction curves of animal-dispersed seedlings in *Schima wallichii* plots

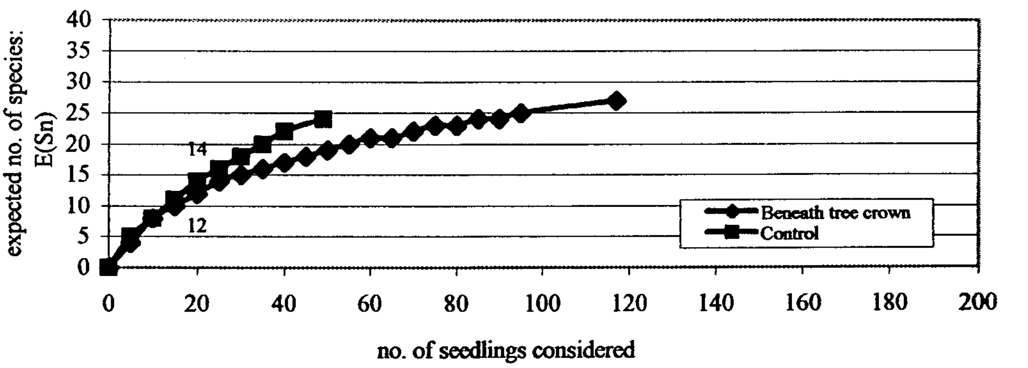
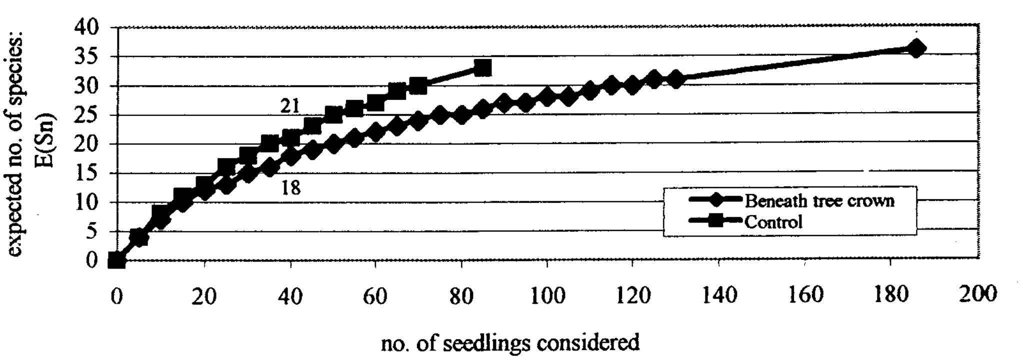


Figure 55 Rarefraction curves of natural tree seedlings in *Schima wallichii* plots



Similarity and difference indices

Sorensen's index was used to compare the species composition of the seedling communities beneath tree crowns and in control plots (Table 9). The maximum value of this coefficient is 1, when two communities have same species and the minimum value is 0, when there are no common species.

Therefore, a low value of Sorensen's index would indicate that remnant tree crowns have a large influence on the species composition of the tree seedling community establishing in deforested areas. The lowest values of Sorensen's index (below 0.5) were obtained with 2 species (*Albizia chinensis* and *Eucalyptus camaldulensis*).

The data were also tested using the difference coefficient, Chord distance, which, unlike Sorensen's index, takes into account the relative abundance of the different species (Table 9). The highest value of Chord distance is 1.41, whilst the lowest value is 0. Therefore, values of above 0.7 would indicate a substantial effect of tree crowns in altering the species composition of the tree seedling community. Chord distance values of above 0.7 were attained with *Albizia chinensis, Callicarpa arborea, Erythrina stricta, Eucalyptus camaldulensis*, and *Pinus kesiya.*

Table 9 Similarity coefficient (Sorensen's index) and difference coefficient (Chord distance; CRD) of natural seedling communities between tree crowns and control plots

Mature tree species	no. of seedling species			Sorensen	CRD
	Beneath tree	Control	Both (C)		
Albizia chinensis (1)	3	2	1	0.40	1.09
Albizia chinensis (2)	11	4	2	0.27	0.89
Albizia chinensis (3)	4	3	2	0.57	1.20
Albizia chinensis (4)	10	4	2	0.29	1.39
Albizia chinensis (5)	2	1	1	0.67	0.77
Albizia chinensis (6)	8	10	2	0.22	1.01
Albizia chinensis	**27**	**19**	**10**	**0.43**	**1.12**
Callicarpa arborea var. *arborea* (1)	6	8	3	0.43	1.14
Callicarpa arborea var. *arborea* (2)	4	3	0	0.00	1.41
Callicarpa arborea var. *arborea* (3)	3	5	0	0.00	1.41
Callicarpa arborea var. *arborea* (4)	8	8	1	0.13	1.37
Callicarpa arborea var. *arborea* (5)	6	1	1	0.29	0.63
Callicarpa arborea var. *arborea* (6)	2	1	1	0.67	0.24
Callicarpa arborea var. *arborea* (7)	9	9	2	0.22	1.02
Callicarpa arborea* var. *arborea	**26**	**31**	**16**	**0.56**	**0.91**
Castanopsis diversifolia (1)	12	9	4	0.38	1.02
Castanopsis diversifolia (2)	11	14	6	0.48	0.47
Castanopsis diversifolia (3)	9	5	1	0.14	0.54
Castanopsis diversifolia (4)	8	8	3	0.38	1.13
Castanopsis diversifolia (5)	6	7	1	0.15	1.33
Castanopsis diversifolia (6)	10	7	4	0.47	1.23
Castanopsis diversifolia (7)	17	8	5	0.40	1.25
Castanopsis diversifolia (8)	3	12	2	0.27	1.26
Castanopsis diversifolia	**39**	**38**	**30**	**0.78**	**0.49**
Erythrina stricta (1)	11	5	2	0.25	1.27
Erythrina stricta (2)	13	5	5	0.56	0.86
Erythrina stricta (3)	4	13	3	0.35	1.28
Erythrina stricta (4)	8	5	4	0.62	0.73
Erythrina stricta (5)	3	5	1	0.25	1.24
Erythrina stricta (6)	10	4	3	0.43	1.24
Erythrina stricta	**28**	**22**	**16**	**0.64**	**0.72**

Table 9 (continued)

Mature tree species	no. of seedling species			Sorensen	CRD
	Beneath tree	Control	Both (C)		
Eucalyptus camaldulensis (1)	5	2	2	0.57	0.42
Eucalyptus camaldulensis (2)	1	1	0	0.00	1.41
Eucalyptus camaldulensis (3)	2	0	0	0.00	
Eucalyptus camaldulensis (4)	6	2	1	0.25	1.32
Eucalyptus camaldulensis (5)	5	6	3	0.55	0.98
Eucalyptus camaldulensis (6)	2	1	0	0.00	1.41
Eucalyptus camaldulensis (7)	5	3	2	0.50	0.21
Eucalyptus camaldulensis (8)	8	5	2	0.31	0.68
Eucalyptus camaldulensis	**15**	**14**	**8**	**0.55**	**0.73**
Pinus kesiya (1)	5	5	1	0.20	1.29
Pinus kesiya (2)	11	11	3	0.27	1.28
Pinus kesiya (3)	3	2	0	0.00	1.41
Pinus kesiya (4)	0	2	0	0.00	
Pinus kesiya (5)	4	2	1	0.33	1.14
Pinus kesiya (6)	1	1	0	0.00	1.41
Pinus kesiya (7)	5	2	0	0.00	1.41
Pinus kesiya (8)	4	2	1	0.33	1.14
Pinus kesiya	**24**	**23**	**11**	**0.47**	**1.18**
Schima wallichii (1)	9	8	6	0.71	0.54
Schima wallichii (2)	4	4	2	0.50	0.86
Schima wallichii (3)	13	10	7	0.61	1.07
Schima wallichii (4)	8	10	3	0.33	1.27
Schima wallichii (5)	15	5	2	0.20	1.35
Schima wallichii (6)	8	5	3	0.46	0.50
Schima wallichii (7)	12	5	3	0.35	1.27
Schima wallichii (8)	6	6	2	0.33	1.13
Schima wallichii	**36**	**33**	**25**	**0.72**	**0.63**
Total	**72**	**60**	**54**	**0.82**	**0.50**

Krusal Wallis-test, used to test for statistical differences in mean Sorensen's index and mean Chord distance of natural seedling communities between tree crowns and control plots among remnant tree species (Table 10), showed no statistically significant differences ($P \geq 0.05$).

Table 10 Mean Sorensen's index and mean Chord distance of natural seedling communities between tree crowns and control plots

Species	Sorensen ^ns^			Chord distance ^ns^		
	n	Mean	SD	N	Mean	SD
Albizia chinensis	6	0.402	0.180	6	1.058	0.221
Callicarpa arborea	7	0.247	0.241	7	1.031	0.447
Castanopsis diversifolia	8	0.334	0.132	8	1.029	0.337
Erythrina stricta	6	0.409	0.154	6	1.103	0.243
Eucalyptus camaldulensis	8	0.272	0.251	7	0.919	0.492
Pinus kesiya	8	0.142	0.158	7	1.297	0.121
Schima wallichii	8	0.437	0.165	8	0.999	0.332
Total	51	0.315	0.203	49	1.060	0.337

Remark: ns = no significant differences ($P \geq 0.05$)

Effect of the species of remnant tree on seedling establishment

A comparison of seedling communities among the remnant tree species was analyzed by using a *Kruskal Wallis*-test and a *Mann Whitney*-test on seedling density and species richness.

A *Kruskal Wallis*-test was used to test for statistical differences in the density and the species richness of seedling establishment beneath the tree crowns and in the control plots among the 7 remnant tree species. In this study, the differences of seedling density and species composition varied according to seed-dispersal mechanism, wind and animal. The differences beneath the tree canopies were statistically significant ($P<0.05$) for density and species component of wind-dispersed seedlings, but not significant ($P\geq0.05$) for density and species component of animal-dispersed seedlings (Table 11). Furthermore, the differences in the control plots among the 7 remnant tree species were statistically significant ($P<0.05$) in species component of animal-dispersed seedlings.

Table 11 Summary results of *Kruskal Wallis*-test on density (no./m^2) and species richness (no.species/m^2) of seedling establishment among the 7 species of isolated tree studied

Dispersed type	Beneath tree crown		Control	
	Density	Species Richness	Density	Species Richness
wind-dispersed seedling	P=0.032	P=0.033	ns	ns
animal-dispersed seedling	ns	ns	ns	P=0.026
Total seedling	P=0.014	P=0.012	ns	P=0.024

Remark: ns = no significant differences ($P\geq0.05$)

The *Mann Whitney*-test was used to test for significant differences in density and species richness between pairs of remnant tree species. Average density of seedlings beneath remnant tree species studied was highest beneath *Erythrina sticta* and lowest beneath *Albizia chinensis* and *Pinus kesiya* (Table 12). The density of animal-dispersed seedlings was highest beneath *Schima wallichii* and lowest beneath *Albizia chinensis*, but the differences were insignificant (P≥0.05). The density of wind-dispersed seedlings was highest beneath *Erythrina stricta* and lowest beneath *Pinus kesiya*, and the differences were statistically significant (P<0.05).

Table 12 Summary results of *Mann Whitney*-test on average density (no./m^2) of seedling establishment beneath isolated tree species (P<0.05)

Species	Dispersal means		Total
	Wind	Animal ^{ns}	
Albizia chinensis	0.069 bc	0.084	0.153 c
Callicarpa arborea	0.065 bc	0.148	0.209 bc
Castanopsis diversifolia	0.072 b	0.172	0.224 abc
Erythrina stricta	0.219 a	0.197	0.399 a
Eucalyptus camaldulensis	0.068 bc	0.202	0.268 abc
Pinus kesiya	0.031 c	0.132	0.156 c
Schima wallichii	0.143 ab	0.232	0.372 ab

Remark: ns = no significant differences (P≥0.05)

Mean species richness of seedlings beneath the studied trees was highest beneath *Erythrina sticta* and lowest beneath *Eucalyptus camaldulensis* (Table 13). The diversity of animal-dispersed seedlings was highest beneath *Erythrina stricta* and lowest beneath *Albizia chinensis*, but the differences were insignificant (P≥0.05). The species richness of wind-dispersed seedlings was highest beneath *Erythrina stricta* and lowest beneath *Eucalyptus camaldulensis*, the differences were statistically significant (P<0.05).

Table 13 Summary results of *Mann Whitney*-test on average species richness (no.species/m^2) of seedling establishment beneath isolated tree species (P <0.05)

Species	Dispersal means		Total
	Wind	Animal ^{ns}	
Albizia chinensis	0.041 b	0.067	0.108 c
Callicarpa arborea	0.052 ab	0.106	0.154 abc
Castanopsis diversifolia	0.044 b	0.091	0.122 bc
Erythrina stricta	0.108 a	0.156	0.247 a
Eucalyptus camaldulensis	0.023 b	0.075	0.097 c
Pinus kesiya	0.031 b	0.094	0.116 bc
Schima wallichii	0.037 b	0.126	0.161 ab

Remark: ns = no significant differences (P≥0.05)

Considering among control plots of the 7 species of remnant trees studied, the differences among remnant species in seedling density were insignificant (P≥0.05) (Table 14). The differences of species richness were almost insignificant. Differences among remnant species in species richness of establishing seedlings were significant (P<0.05) (Table 15). However, this was due almost entirely to the very high number of animal-dispersed species in control plots of *Erytrina stricta.*

Table 14 Summary results of *Mann Whitney*-test on average density (no./m^2) of seedling establishment between control plots of remnant tree species (P <0.05)

Species	Dispersal means		Total ^{ns}
	Wind ^{ns}	Animal ^{ns}	
Albizia chinensis	0.086	0.068	0.155
Callicarpa arborea	0.070	0.138	0.206
Castanopsis diversifolia	0.058	0.125	0.170
Erythrina stricta	0.077	0.292	0.369
Eucalyptus camaldulensis	0.109	0.089	0.198
Pinus kesiya	0.044	0.091	0.135
Schima wallichii	0.079	0.120	0.199

Remark: ns = no significant differences (P≥0.05)

Table 15 Summary results of *Mann Whitney*-test on average species richness (no.species/m^2) of seedling establishment between control plots of remnant tree species ($P<0.05$)

Species	Dispersal means		Total
	Wind ^{ns}	Animal	
Albizia chinensis	0.026	0.048 b	0.074 b
Callicarpa arborea	0.049	0.104 ab	0.152 ab
Castanopsis diversifolia	0.036	0.071 ab	0.098 b
Erythrina stricta	0.044	0.168 a	0.212 a
Eucalyptus camaldulensis	0.021	0.036 b	0.057 b
Pinus kesiya	0.035	0.055 b	0.089 b
Schima wallichii	0.038	0.097 ab	0.133 ab

Remark: ns = no significant differences ($P\geq0.05$)

Effects of the sizes of remnant trees on seedling establishment

Relationships between remnant tree size with seedling establishment were analyzed by linear regression. Linear- regression charts of each studied tree species were made to determine the relationships and statistical analysis. Results varied greatly according to parameters of tree size, seed-dispersed mechanism, and species of remnant tree.

Most analyses showed no relations between any parameters of tree size with density or species richness of seedlings (Table 16). However, there were some significant inverse relationships beneath *Castanopsis diversifolia*, *Eucalyptus camaldulensis*, and *Schima wallichii*.

Table 16 Summary results of linear-regression test between remnant tree size with density (no./m^2) and species richness (no.species/m^2) of natural seedling establishment beneath similar remnant tree species

Species	Density			Species richness		
	Height	GBH	Canopy width	Height	GBH	Canopy width
Albizia chinensis	ns	ns	ns	ns	ns	ns
Callicarpa arborea	ns	ns	ns	ns	ns	ns
Castanopsis diversifolia	ns	ns	P=0.006(-)	ns	ns	P=0.007(-)
Erythrina stricta	ns	ns	ns	ns	ns	ns
Eucalyptus camaldulensis	ns	P=0.038(-)	ns	ns	ns	ns
Pinus kesiya	ns	ns	ns	ns	ns	ns
Schima wallichii	ns	ns	ns	ns	P=0.032(-)	P=0.027(-)
Total	ns	ns	ns	ns	ns	P=0.009(-)

Remark: ns = no significant differences (P≥0.05)

(-) = inverse linear regression

Considering only wind-dispersed seedlings (Table 17) most analyses indicated no statistical relationships except a relationship between canopy width of *Castanopsis diversifolia* and species richness of seedlings.

Table 17 Summary results of linear-regression test between remnant tree size with density (no./m^2) and species richness (no.species/m^2) of wind-dispersed seedlings beneath similar remnant tree species

Species	Density			Species richness		
	Height	GBH	Canopy width	Height	GBH	Canopy width
Albizia chinensis	ns	ns	ns	ns	ns	ns
Callicarpa arborea	ns	ns	ns	ns	ns	ns
Castanopsis diversifolia	ns	ns	ns	ns	ns	P=0.014(-)
Erythrina stricta	ns	ns	ns	ns	ns	ns
Eucalyptus camaldulensis	ns	ns	ns	ns	ns	ns
Pinus kesiya	ns	ns	ns	ns	ns	ns
Schima wallichii	ns	ns	ns	ns	ns	ns
Total	ns	ns	ns	ns	ns	ns

Remark: ns = no significant differences ($P \geq 0.05$)
(-) = inverse linear regression

Considering only animal-dispersed seedlings (Table 18) most analyses indicated no statistical relationships between tree size with density or species richness of seedlings except some relationships beneath *Albizia chinensis*, *Castanopsis diversifolia*, and *Schima wallichii*.

Table 18 Summary results of linear-regression test between remnant tree size with density (no./m^2) and species richness (no.species/m^2) of animal-dispersed seedlings beneath similar remnant tree species

Species	Density			Species richness		
	Height	GBH	Canopy width	Height	GBH	Canopy width
Albizia chinensis	ns	ns	P=0.03(+)	ns	ns	ns
Callicarpa arborea	ns	ns	ns	ns	ns	ns
Castanopsis diversifolia	ns	ns	P=0.003(-)	ns	ns	P=0.005(-)
Erythrina stricta	ns	ns	ns	ns	ns	ns
Eucalyptus camaldulensis	ns	ns	ns	ns	ns	ns
Pinus kesiya	ns	ns	ns	ns	ns	ns
Schima wallichii	ns	ns	ns	ns	P=0.003(-)	P=0.025(-)
Total	ns	ns	ns	ns	ns	P=0.025(-)

Remark: ns = no significant differences ($P \geq 0.05$)

(-) = inverse linear regression

(+) = relative linear regression

Relative growth rate (RGR)

Relative growth rates of different natural tree seedling species were calculated by using remainder of seedling height (cm). The RGR results did not include all recorded seedlings due to random sampling of seedlings for monitoring in some plots and the loss of some seedlings during the study period. Average RGR's of 58 seedling species (339 seedlings) are presented in Appendix E. The average RGR's combined from beneath remnant trees and in control plots are reported in Table 19. The range of average RGR was 5.23 – 228.24 (% / year). Height RGR of seedling species was highest for *Trema orientalis* (L.) Bl. (Ulmaceae), 228.24 (% / year) followed by *Callicarpa arborea* Roxb. var. *arborea* (Verbenaceae), 114.83 (% / year), and lowest for *Ficus fistulosa* Reinw. *ex* Bl. var. *fistulosa* (Moraceae), 5.23 (% / year).

Frequency of histograms of average RGR values displayed in Figures 56-58. Most seedling species (39 species) recruited beneath remnant tree crowns had wide ranges in average RGR (10-60 % / year) (Figure 56). In the control plots, the number of seedling species peaked clearly at 13 species, which had average RGR's of 20-30 % / year (Figure 57).

Table 19 Average relative growth rate (% per year) of naturally established tree seedlings

No.	Botanical Name	Family	Under tree crown			Control			Total		
			n	Mean	SD	n	Mean	SD	n	Mean	SD
1	*Alseodaphne andersonii* (King *ex* Hk. f.) Kosterm.	Lauraceae	1	54.69	-				1	54.69	-
2	*Anneslea fragrans* Wall.	Theaceae				1	26.83	-	1	26.83	-
3	*Antidesma acidum* Retz.	Euphorbiaceae	7	60.49	34.60	1	39.60	-	8	57.88	32.88
4	*Antidesma bunius* (L.) Spreng. var. *bunius*	Euphorbiaceae	3	72.75	24.86	3	30.96	17.67	6	51.85	29.94
5	*Aporusa villosa* (Wall. *ex* lindl.) Baill.	Euphorbiaceae	13	38.21	21.47	4	28.09	8.72	17	35.83	19.48
6	*Archidendron clypearia* (Jack) Niels. ssp. *clypearia* var. *clypearia*	Leguminosae, Mimosoideae				1	90.43	-	1	90.43	-
7	*Artocarpus lakoocha* Roxb.	Moraceae	3	18.50	16.55	6	28.75	6.69	9	25.34	11.08
8	*Artocarpus lanceolata* Trec.	Moraceae	3	43.45	36.15	1	32.66	-	4	40.75	30.01
9	*Baccaurea ramiflora* Lour.	Euphorbiaceae				1	32.63	-	1	32.63	-
10	*Bauhinia variegata* L.	Leguminosae, Caesalpinioideae	2	45.11	53.48				2	45.11	53.48
11	*Beilschmiedia* aff. *intermedia* Allen	Lauraceae	1	39.60	-				1	39.60	-
12	*Callicarpa arborea* Roxb. var. *arborea*	Verbenaceae	1	114.83	-				1	114.83	-
13	*Canarium subulatum* Guill.	Burseraceae	1	17.20	-				1	17.20	-
14	*Canthium parvifolium* Roxb.	Rubiaceae	3	41.77	25.61	3	27.39	5.06	6	34.58	18.29
15	*Castanopsis acuminatissima* (Bl.) A. DC.	Fagaceae				1	31.54	-	1	31.54	-
16	*Castanopsis argyrophylla* King *ex* Hk. f.	Fagaceae	3	55.54	23.46				3	55.54	23.46
17	*Castanopsis diversifolia* (Kurz) King *ex* Hk. f.	Fagaceae				1	65.37	-	1	65.37	-
18	*Cinnamomum longipetiolatum* H.W. Li	Lauraceae	2	58.12	39.39	1	54.09	-	3	56.78	27.95
19	*Dalbergia cultrata* Grah. *ex* Bth.	Leguminosae, Papilionoideae				2	14.10	15.94	2	14.10	15.94
20	*Dalbergia ovata* Grah. *ex* Bth.	Leguminosae, Papilionoideae	37	57.20	22.85	15	58.11	25.86	52	57.46	23.50

Table 19 (continued)

No.	Botanical Name	Family	Under tree crown			Control			Total		
			n	Mean	SD	n	Mean	SD	n	Mean	SD
21	*Dillenia parviflora* Griff. var. *kerrii* (Craib) Hoogl.	Dilleniaceae	1	11.43	-				1	11.43	-
22	*Dimocarpus longan* Lour. ssp. *longan* var. *longan*	Sapindaceae	1	24.00	-				1	24.00	-
23	*Diospyros glandulosa* Lace	Ebenaceae	4	44.91	33.26	1	31.89	-	5	42.31	29.38
24	*Elaeocarpus lanceifolius* Roxb.	Elaeocarpaceae	2	91.42	83.27				2	91.42	83.27
25	*Eugenia claviflora* Roxb.	Myrtaceae	2	43.84	32.24	1	50.45	-	3	46.05	23.11
26	*Eugenia fruticosa* (DC.) Roxb.	Myrtaceae	3	57.31	26.82	6	57.33	12.77	9	57.33	16.78
27	*Eurya acumminata* DC. var. *wallichiana* Dyer	Theaceae	2	33.06	30.59	2	87.26	45.59	4	60.16	44.54
28	*Ficus fistulosa* Reinw. *ex* Bl. var. *fistulosa*	Moraceae				1	5.23	-	1	5.23	-
29	*Ficus hispida* L. f. var. *hispida*	Moraceae				1	19.08	-	1	19.08	-
30	*Ficus semicordata* B.-H. *ex* J.E. Sm. var. *semicordata*	Moraceae	1	67.81	-				1	67.81	-
31	*Ficus subulata* Bl. var. *subulata*	Moraceae	1	54.69	-				1	54.69	-
32	*Firmiana colorata* (Roxb.) R. Br.	Sterculiaceae	1	28.10	-				1	28.10	-
33	*Glochidion acuminatum* M.-A. var. *siamense* A.S.	Euphorbiaceae	2	18.50	10.96				2	18.50	10.96
34	*Glochidion sphaerogynum* (M.-A.) Kurz	Euphorbiaceae	4	39.51	8.92				4	39.51	8.92
35	*Gluta obovata* Craib	Anacardiaceae	1	26.44	-	2	55.70	15.25	3	45.95	20.05
36	*Gmelina arborea* Roxb.	Verbenaceae	1	26.25	-				1	26.25	-
37	*Helicia nilagirica* Bedd.	Proteaceae	2	32.58	0.04				2	32.58	0.04
38	*Ilex umbellulata* (Wall.) Loesn.	Aquifoliaceae				1	45.96	-	1	45.96	-
39	*Litsea cubeba* (Lour.) Pers. var. *cubeba*	Lauraceae	21	51.03	37.27	9	61.36	42.92	30	54.13	38.59
40	*Litsea glutinosa* (Lour.) C.B. Rob. var. *glutinosa*	Lauraceae				1	18.07	-	1	18.07	-

Table 19 (continued)

No.	Botanical Name	Family	Under tree crown			Control			Total		
			n	Mean	SD	n	Mean	SD	n	Mean	SD
41	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	15	50.75	39.19	3	87.98	28.79	18	56.95	39.57
42	*Machilus bombycina* King *ex* Hk. f.	Lauraceae	2	73.60	11.63	6	29.73	15.49	8	40.70	24.56
43	*Mallotus philippensis* (Lmk.) M.-A.	Euphorbiaceae	1	39.36	-	5	26.64	25.47	6	28.76	23.36
44	*Markhamia stipulata* (Wall.) Seem. *ex* K. Sch. var. *kerrii* Spraque	Bignoniaceae	4	25.00	19.31	2	22.52	23.12	6	24.17	18.23
45	*Phoebe lanceolata* (Wall. *ex* Nees) Nees	Lauraceae	1	47.06	-	2	69.98	28.84	3	62.34	24.31
46	*Phyllanthus emblica* L.	Euphorbiaceae	8	53.78	21.94	1	16.68	-	9	49.66	23.96
47	*Rhus chinensis* Mill.	Anacardiaceae	12	34.37	18.72	1	4.69	-	13	32.09	19.72
48	*Sapindus rarak* DC.	Sapindaceae	1	17.70	-				1	17.70	-
49	*Saurauia roxburghii* Wall.	Saurauiaceae	2	53.46	44.96				2	53.46	44.96
50	*Schima wallichii* (DC.) Korth.	Theaceae	9	60.81	45.19	31	66.31	31.75	40	65.07	34.64
51	*Sterculia villosa* Roxb.	Sterculiaceae	3	23.15	19.98	3	27.56	12.78	6	25.36	15.20
52	*Stereospermum colais* (B.-H. *ex* Dillw.) Mabb.	Bignoniaceae	4	89.56	38.23				4	89.56	38.23
53	*Styrax benzoides* Craib	Styracaceae	2	39.99	31.52	4	34.26	31.50	6	36.17	28.34
54	*Toona ciliata* M. Roem.	Meliaceae	2	33.64	16.94	3	39.86	26.91	5	37.38	21.11
55	*Trema orientalis* (L.) Bl.	Ulmaceae				1	228.24	-	1	228.24	-
56	*Turpinia pomifera* (Roxb.) Wall. *ex* DC.	Staphyleaceae	2	45.14	34.07	2	52.31	30.08	4	48.72	26.56
57	*Vernonia volkameriifolia* DC. var. *volkameriifolia*	Compositae	2	83.65	40.60				2	83.65	40.60
58	*Wendlandia tinctoria* (Roxb.) DC. ssp. *floribunda* (Craib) Cowan	Rubiaceae	2	38.50	3.01	8	61.48	25.21	10	56.89	24.28
	Total		201	49.47	30.76	138	51.36	33.89	339	50.24	32.04

Figure 56 Frequency of seedling species beneath remnant tree crowns separated by periods of average RGR

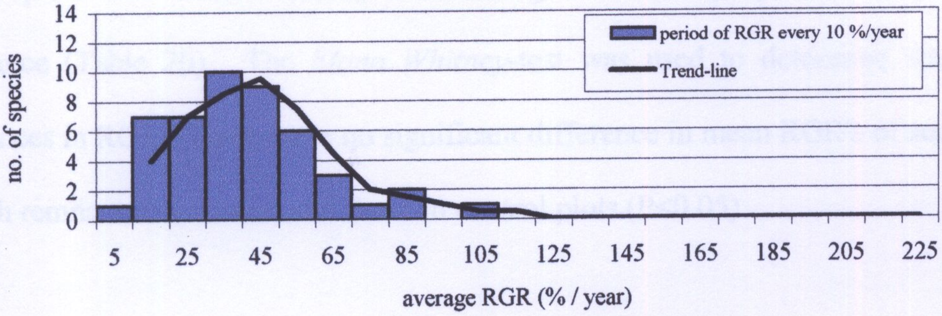


Figure 57 Frequency of seedling species in control plots separated by periods of average RGR

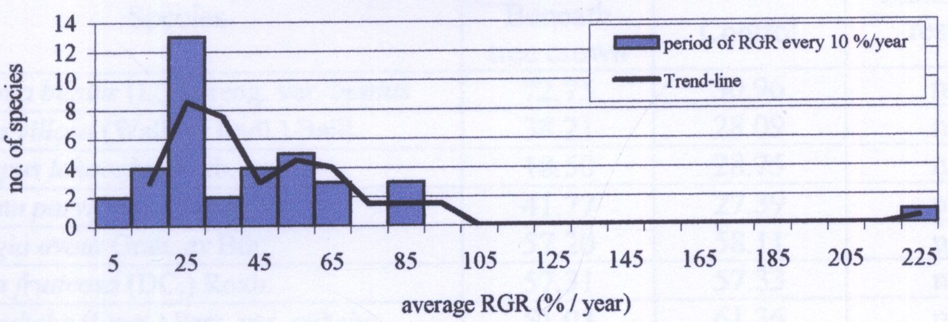
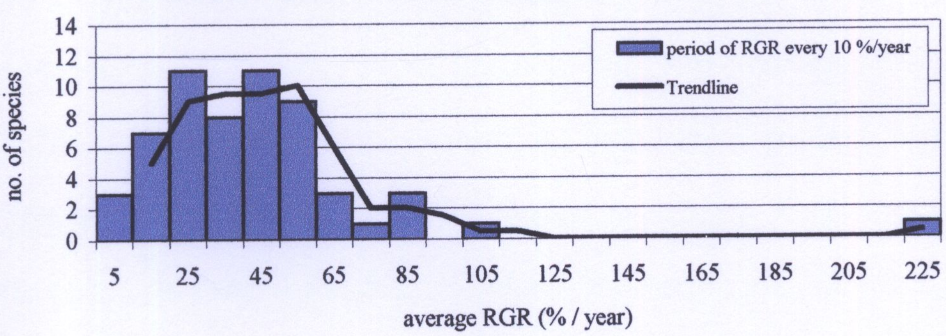


Figure 58 Frequency of seedling species in both, beneath tree crowns and control plots separated by periods of average RGR



A comparison of average RGR of tree seedlings beneath tree crowns and in control plots was carried out by considering 10 seedling species, which were abundance (Table 20). The *Mann Whitney*-test was used to determine statistical differences in RGR. There were no significant difference in mean RGR's of seedlings beneath remnant tree crowns and those in control plots ($P<0.05$).

Table 20 *Mann Whitney*-test on average RGR's of 10 seedling species between beneath remnant tree crowns and in control plots

Species	Mean RGR (% / year)		Statisticai result
	Beneath tree crown	Control	
Antidesma bunius (L.) Spreng. var. *bunius*	72.75	30.96	ns
Aporusa villosa (Wall. *ex* lindl.) Baill.	38.21	28.09	ns
Artocarpus lakoocha Roxb.	18.50	28.75	ns
Canthium parvifolium Roxb.	41.77	27.39	ns
Dalbergia ovata Grah. *ex* Bth.	57.20	58.11	ns
Eugenia fruticosa (DC.) Roxb.	57.31	57.33	ns
Litsea cubeba (Lour.) Pers. var. *cubeba*	51.03	61.36	ns
Litsea monopetala (Roxb.) Pers.	50.75	87.98	ns
Schima wallichii (DC.) Korth.	60.81	66.31	ns
Sterculia villosa Roxb.	23.15	27.56	ns

Remark: ns = no significant differences ($P\geq0.05$)

Bird observations

Bird visitations to the remnant trees studied

During two hundred and thirty-one hours of observations at remnant trees in a deforested site, thirteen species of bird were observed visiting the trees studied (Table 21). Considering all trees combined, the Inornate Warbler visited the longest followed by the Flavescent Bulbul. The Inornate Wabler was the most prevalent visitor in most of tree species studied, *Albizia chinensis* (Obs.) Merr. (Leguminosae, Mimosoideae), *Erythrina stricta* Roxb. (Leguminosae, Papilionoideae), *Eucalyptus camaldulensis* Dehnh. (Myrtaceae), *Pinus kesiya* Roy. *ex* Gord. (Pinaceae), and *Schima wallichii* (DC.) Korth. (Theaceae), whereas for *Callicarpa arborea* Roxb. var. *arborea* (Verbenaceae) it was the Flavescent Bulbul and for *Castanopsis diversifolia* (Kurz) King *ex* Hk. f. (Fagaceae) it was the Burmese Shrike. *Schima wallichii* was most attractive remnant tree species to birds.

Most birds observed were insectivorous (6 species), general or omnivorous (5 species) and a few were carnivorous (2 species) (Appendix F). Insectivorous birds were the most dominant group in *Albizia chinensis* (Obs.) Merr. (Leguminosae, Mimosoideae), *Erythrina stricta* Roxb. (Leguminosae, Papilionoideae) and *Schima wallichii* (DC.) Korth. (Theaceae). Omnivorous birds, which eat both insects and fruits were the longest visiting group in *Callicarpa arborea* Roxb. var. *arborea* (Verbenaceae), *Eucalyptus camaldulensis* Dehnh. (Myrtaceae), and *Pinus kesiya* Roy. *ex* Gord. (Pinaceae). Whilst carnivorous birds predominated in *Castanopsis diversifolia* (Kurz) King *ex* Hk. f. (Fagaceae) (Table 22).

Table 21 Ratios of minutes bird observed / total observation miniutes for each tree species

Scientific Name	Common Name	*Albizia chinensis*	*Callicarpa arborea* var. *arborea*	*Castanopsis diversifolia*	*Erythrina stricta*	*Eucalyptus camaldulensis*	*Pinus kesiya*	*Schima wallichii*	Total
Aegithina tiphia	Common Iora	0.0014	0.0014		0.0049	0.0014	0.0007	0.0056	0.0022
Chrysococcyx maculatus	Asian Emerald Cuckoo		0.0005						0.0001
Lanius collurioides	Burmese Shrike	0.0005	0.0005	0.0272	0.0007	0.0007	0.0004		0.0032
Lanius schach	Long-tailed Shrike							0.0048	0.0009
Pericrocotus cinnamomeus	Small Minivet							0.0274	0.0050
Phaenicophaeus tristis	Green-billed Malkoha							0.0004	0.0001
Phylloscopus inornatus	Inornate Warbler	0.0116	0.0028	0.0007	0.0188	0.0049	0.0085	0.0913	0.0230
Pteruthius melanotis	White-browed Shrike-Babbler	0.0005					0.0007	0.0091	0.0019
Pycnonotus atriceps	Black-headed Bulbul		0.0005						0.0001
Pycnonotus aurigaster	Sooty-headed Bulbul	0.0037	0.0019	0.0007	0.0028	0.0014	0.0052	0.0183	0.0057
Pycnonotus flavescens	Flavescent Bulbul	0.0019	0.0120	0.0007	0.0021	0.0035	0.0037	0.0331	0.0096
Pycnonotus jocosus	Red-whiskered Bulbul	0.0015	0.0042	0.0007	0.0069	0.0035	0.0025	0.0079	0.0040
Sitta frontalis	Velvet-fronted Nuthatch					0.0007		0.0012	0.0003
	Total	0.0209	0.0236	0.0300	0.0361	0.0160	0.0218	0.1990	0.0559

Table 22 Percent of individual visit minutes by each bird group (according to diet) in the trees studied

Bird types	*Albizia chinensis1*	*Callicarpa arborea*	*Castanopsis diversityolia*	*Erythrina stricta*	*Eucalyptus camaldulensis*	*Pinus kesiya*	*Schima wallichii*	Total
Carnivorous bird	2.2	1.9	90.7	1.9	4.3	1.7	2.4	7.2
Insectivorous bird	64.2	19.6	2.3	65.4	43.5	45.9	67.6	58.1
Omnivorous bird	33.6	78.4	6.9	32.7	52.2	52.4	29.9	34.6
% total	100	100	100	100	100	100	100	100

Bird behavior, while they visited the trees could be divided in to three main activities. First, birds perched for a moment and then flew out. This behavior was observed for all bird species. Some birds dropped faeces. Secondly, birds visited for feeding which took longer, depending on the abundance of food. Sooty-headed Bulbul, Flavescent Bulbul, Red-whiskered Bulbul spent a long time in fruiting trees, of *Callicarpa arborea* var. *arborea* (6). Common Iora, Small Minivet, Inornat Warbler, White-browed Shrike-Babbler, Sooty-headed Bulbul, Flavescent Bulbul, Red-whiskered Bulbul, and Velvet-fronted Nuthatch spent a long time foraging for caterpillars or adult insects in almost all trees. Lastly, birds visited trees to defend their territories. Burmese Shrike spent a long time visiting *Castanopsis diversifolia* (3) without feeding and the Long-tailed Shrike spent a long time visiting *Schima wallichii* (3) and *Schima wallichii* (5). Both birds, which are carnivorous, often called and attacked other birds coming in their territories. Nests of both birds were found nearby.

Bird feeding on fruiting trees in intact forest

Birds were observed in fruiting trees of one individual of *Aporusa octandra* (B.-H. *ex* D. Don) Vick. var. *octandra* (Euphorbiaceae), one *Bischofia javanica* Bl. (Euphorbiaceae), two *Callicarpa arborea* Roxb. var. *arborea* (Verbenaceae), one *Debregeasia longifolia* (Burm. f.) Wedd. (Urticaceae), and one *Heynea trijuga* Roxb. *ex* Sims (Meliaceae). *Aporusa octandra* (B.-H. *ex* D. Don) Vick. var. *octandra* (Euphorbiaceae) was located at the National Park Headquarters (FORRU tree number s205) and two *Callicarpa arborea* Roxb. var. *arborea* (Verbenaceae) trees were located along the road near the National Park Headquarters. *Debregeasia longifolia* (Burm. f.) Wedd. (Urticaceae) and *Heynea trijuga* Roxb. *ex* Sims (Meliaceae) were located at the Coffee Research Station. *Bischofia javanica* Bl. (Euphorbiaceae) is located near the Chang Kian Highland Agriculture Research Station.

During fifty-four hours of observations seventeen bird-species visited the trees (Table 23). Most birds were omnivorous, except the Black-throated Sunbird (nectar/insectivorous), Common Iora, Inornate Warbler (insectivorous), Burmese Shrike, Blue Whistling Thrush (carnivorous), and Wedge-tailed Pigeon (frugivorous). Black-crested Bulbul visited the longest time on *Aporusa octandra* and *Bischofia javanica*. Red-whiskered Bulbul visited the longest time on *Debregeasia longifolia* and *Heynea trijuga*. Flavescent Bulbul visited the longest time on *Callicarpa arborea*. *Bischofia javanica* was most attractive to birds ate them fruits compare with other trees. Red-whiskered Bulbul ate fruits widely by feeding every fruiting tree studied.

Table 23 Ratios of minutes bird observed / total observation minutes for each fruiting tree species

Scientific Name	Common Name	*Aporusa octandra*	*Bischofia javanica*	*Callicarpa arborea* var. *arborea*	*Debregeasia longifolia*	*Heynea trijuca*	Total
Aegithina tiphia	Common Iora			0.00417			0.00093
Aethopyga saturata	Black-throated Sunbird					0.00069	0.00015
Chloropsis aurifrons	Golden-fronted Leafbird	0.00185					0.00031
Chloropsis hardwickii	Orange-bellied Leafbird		0.00417				0.00093
Criniger pallidus	Puff-throated Bulbul		0.92361			0.01667	0.20895
Hypsipetes flavala	Ashy Bulbul		0.03194				0.00710
Hypsipetes mcclellandii	Mountain Bulbul	0.00185					0.00031
Lanius collurioides	Burmese Shrike			0.00139			0.00031
Megalaima asiatica	Blue-throated Barbet		0.00028				0.00006
Myiophoneus caeruleus	Blue Whistling Thrush		0.00139				0.00031
Phylloscopus inornatus	Inornate Warbler			0.00278			0.00062
Pycnonotus aurigaster	Sooty-headed Bulbul	0.03593		0.00417			0.00691
Pycnonotus flavescens	Flavescent Bulbul		0.09722	0.03611			0.02963
Pycnonotus jocosus	Red-whiskered Bulbul	0.24667	0.69444	0.00556	0.19222	0.43292	0.32491
Pycnonotus melanicterus	Black-crested Bulbul	0.27259	1.3875				0.35377
Treron sphenura	Wedge-tailed Pigeon		0.08472				0.01883
Zosterops palpebrosus	Oriental White-eye	0.00074					0.00012
	Total	0.55963	3.22528	0.05417	0.19222	0.45028	0.95414

Most birds visited the trees to feed on fleshy fruits, except the Common Iora and Inornate Warbler, which foraged for insects, while Burmese Shrike and Blue Whistling Thrush only perched for a moment. Black-throated Sunbird visited *Heynea trijuga* to pick white arils and then flew out, only once.

Aporusa octandra (B.-H. *ex* D. Don) Vick. var. *octandra* (Euphorbiaceae) fruits during March to May. The fruit type is a septicidal capsule, light green-yellow when ripe. The fruit size is about 10 mm x 8 mm x 8 mm. The birds ate the fruits by using their bills to rip open the green epicarp and then pecked out the orange aril, including the seeds which were swallowed immediately. Whilst foraging for ripe fruit, some birds defecated. Most birds spent a few minutes feeding, ate about 1-4 arils, and then flew away. Red-whiskered Bulbuls often visited in flocks of 5-10 individuals for a few minutes. Sooty-headed Bulbuls often visited as individuals and fed for a few minutes. Black-crested Bulbuls visited in small flocks of 2-3 individuals, but spent the longest time in *Aporusa octandra* var. *octandra* compared with other bulbuls.

Bischofia javanica Bl. (Euphorbiaceae) fruits from June to February. The fruit type is a slightly fleshy globose drupe, brown-black when ripe. The fruit size is about 7-10 mm diameter. The birds ate whole fruits and some of them defecated while foraging. Red-whiskered Bulbuls often visited in large flocks of 10-15 individuals and spent a few minutes feeding. Puff-throated Bulbuls and Black-crested Bulbuls visited in smaller flocks of 3-7 individuals and spent a very long time in the tree. Wedge-tailed Pigeons visited the fruiting tree alone and spent 15-45 minutes feeding.

Callicarpa arborea Roxb. var. *arborea* (Verbenaceae) fruits from August to October. The fruit type is a globose drupe, dark purple when ripe. The fruit size is about 4 mm diameter. The birds ate whole fruits and some of them dropped faeces while perched in the trees. Most birds visited singly or in groups of 2-3 individuals. They usually spent 1-2 minutes feeding on the fruits.

Debregeasia longifolia (Burm. f.) Wedd. (Urticaceae) fruits from October to March. The fruit is an achene, surrounded by a fleshy receptacle, orange when ripe. The fruit size is about 5 mm diameter. I observed only Red-whiskered Bulbuls visiting this tree. The birds ate whole fruits. Large flocks of Red-whiskered Bulbuls visited this species, but usually separated into small groups of 2-3 whilst foraging. Visits were rare and usually last only a few minutes

Heynea trijuga Roxb. *ex* Sims (Meliaceae) fruits from August to December. The fruit type is a septicidal capsule, globose, fleshy, maroon when ripe. The fruit size is about 12-14 mm diameter. Red-whiskered Bulbuls and Puff-throated Bulbuls ate fruits by using their bills to peck at the white arils, but did not swallow seeds. Red-whiskered Bulbuls visited in large flocks of 10-15 individuals and spent about 4-8 minutes per visit. Puff-throated Bulbuls visited in smaller flocks of about 4 individuals and spent about 3 minutes feeding but were observed only once.

Birds attracted to fruiting trees in the forest were mostly different species to those observed in remnant trees in the deforested area. Although bird species recorded differed between forest and remnant trees, the following species: *Aegithina tiphia* (Common Iora), *Lanius collurioides* (Burmese Shrike), *Phylloscopus inornatus* (Inornate Warbler), *Pycnonotus aurigaster* (Sooty-headed Bulbul), *Pycnonotus* *flavescens* (Flavescent Bulbul), *Pycnonotus jocosus* (Red-whiskered Bulbul) were recorded in both places. Of these bird species, only the latter three species are likely to disperse seeds from forest to deforested areas (the others are mostly insectivores).

CHAPTER 6

DISCUSSION

Seedling establishment

Most seedlings that established in the studied plots were of animal-dispersed species (Table 2). A slightly larger proportion of these seedlings established beneath remnant trees (66.8%) than in control plots (60.6%). On the other hand, a slightly smaller proportion of wind-dispersed seedlings established beneath remnant trees (33.2%) than in control plots (39.4%), agree to Carrière *et al.*, (2002b). Therefore, animal-dispersed species were important for forest regeneration in this disturbed area.

Comparison between beneath tree sites and control sites

Duncan and Chapman (1999) concluded that the seed rain under trees was higher than in open areas. Therefore, it was expected that seedling recruitment beneath isolated trees would be greater than away from their crowns. However this study indicated that establishment of natural seedlings beneath remnant trees was not significantly higher than in control plots. This agrees with a previous study of Carriè re *et al.* (2002b) but contrasts with Guevara *et al.* (1986). Seedling recruitment differed among the remnant tree species and the types of seed dispersal mechanism.

Remnant trees tended to slightly enhance seedling establishment beneath their crowns, but not significantly so compared with controls (Table 4). Only beneath *Schima wallichii* crowns was seedling density significantly higher than in the control plots. Beneath *Eucalyptus camaldulensis* crowns the species richness of seedling was higher significantly than in the control plots. The significant differences that occurred with both tree species were strongly influenced by the abundance of animal-dispersed seedlings (Table 6).

Distribution of wind-dispersed seedlings varied among remnant trees species (Table 5). It was difficult to conclude that wind-dispersed seedlings were more abundant in the control plots or beneath the tree crowns. However, seedling establishment below *Erythrina stricta* and *Albizia chinensis* was higher significantly than in the control plots. Both species are legumes and their crowns produce little shade, which might create suitable conditions for wind-dispersed species. Some of the *Albizia chinensis* trees studied were located in a forest-planting area. Therefore, some seedlings might have been damaged by human activity, so seedling density under *Albizia chinensis* was lower than in control.

All of the remnant tree species tended to attract animals, which are seed dispersers. The establishment of animal-dispersed seedlings beneath the crowns of remnant trees was higher than away from the crowns, except beneath the crowns of *Erythrina stricta* (Table 6). Lower numbers of animal-dispersed seedlings beneath *Erythrina stricta* crowns might be because of low shade beneath their crowns. Animal-dispersed species are usually shade-tolerant (Whitmore, 1989). Accordingly, the abundance of animal-dispersed seedlings was low (Table 6), but the abundance of wind-dispersed seedlings was high (Table 5).

Furthermore, the species component of animal-dispersed seedlings beneath *Pinus kesiya* was higher than in control plots. It is therefore possible that forest regeneration might be faster in *Pinus kesiya* plantations than in areas without plantations as suggested in a previous study by Oberhauser (1997).

Schima wallichii crowns had the greatest effect at increasing seedling recruitment, compared with the control plots, especially for seedling species dispersed by animals, a result also obtained by Kuarak and Hitchcock (1998). This result agrees with the bird-observation data, which showed that many birds visited these trees.

Although, the recruitment of animal-dispersed seedlings beneath remnant trees was higher than in control plots, the result was not statistically significant. It is possible that the influences of remnant trees alone might not be strong enough to enhance the seed rain. Differences of environmental condition between sites beneath and away from remnant trees could lead to variation in seedling establishment (Nepstad *et al.* 1996), including other effects, such as competition, seed-predation (Carrière *et al.*, 2002b), and herb cover (Adhikari, 1996).

Effects of the species of remnant tree on seedling establishment

The density and species richness of natural seedling recruits differed among the species of remnant tree. Variations in seedling establishment were strongly influenced by wind-dispersed tree seedlings, whereas animal-dispersed seedlings had a lesser effect. Moreover, analysis results of only bird-dispersed seedlings also not different as results of animal-dispersed seedlings.

The density and species richness of animal-dispersed seedlings was similar among the species of remnant trees, which agrees with previous studies. Toh *et al.* (1997) and Carrière *et al.* (2002b) concluded that all isolated tree species were equally attractive as a focal point for seedling recruitment, regardless of whether they had fleshy fruits or dry fruits. *Callicarpa arborea* var. *arborea* is a fleshy-fruited tree, but seedling establishment of animal and bird-dispersed trees under its crowns was not different to the other trees studied. It is possible that this tree in addition attracting seed dispersers, might also attract seed and seedling predators.

Erythrina stricta crowns seemed to create suitable conditions for seedling recruitment of wind-dispersed species. Most wind-dispersed seedlings are pioneer species that like to establish in gaps (Whitmore, 1989). The low shade and long leafless period of *Erythrina stricta* might provide for germination and recruitment of wind-dispersed seedlings.

While seedling density and species richness were low under the canopy of *Eucalyptus camaldulensis* (an exotic species), these parameters were not significant different compared with the other tree species studied. Such a result agrees with the previous study of Pommerenke (2000) which was also inconclusive on impact of eucalyptus on forest vegetation composition.

In control areas, away from the crowns of studied trees the seedling density did not differ among the control sites of each species studied. But, the species richness of seedlings, especially animal-dispersed species was significantly different among the control sites. An unusual peak of animal-dispersed species in the control sites near *Erythrina stricta* tree caused a significant difference in seedling richness, among the control sites. Without this, the species richness among the control sites would not have differed significantly if *Erythrina stricta*' control sites had been removed from the analysis. Small mammals dispersed thirteen species of tree seedlings, from a total of 15 animal-dispersed species. It is possible that small mammals dropped tree seeds in the *Erythrina stricta*' control sites before arrival this tree species.

Effects of remnant tree size on seedling establishment

There was no relationship between remnant tree size and the density of tree seedlings, established beneath their crowns. A similar result was obtained by Toh *et al.* (1999). However, the results showed some variation when each parameter of tree size, dispersal mechanism, and remnant tree species were considered.

The parameters of tree size, tree height, GBH, and width of crown showed different results. There was no relationship between tree height of any of the remnant tree species with seedling density, but there was a relationship between GBH and crown width. Therefore, tree height might not influence seedling establishment beneath their crown, whereas crown width and GBH might have more influence.

Crown width determines shade and influences soil moisture content (Verdú and García-Fayos, 1996). Such factors may then influence the density and distribution of tree seedlings (Maguire and Forman, 1983). Increasing the width of *Albizia chinensis* crowns increased seedling density, especially of animal-dispersed species. In general, animal-dispersed seedlings are often climax species, which like to establish in shade, whereas wind-dispersed seedlings are often pioneer species, which are shade-intolerant (Whitmore, 1989). Pathogens are another cause of most seedling mortality (Augspurger, 1983). Animal-dispersed species seem to resist pathogens better than wind-dispersed species (Schupp *et al.*, 1989). Consequently, low shade under *Albizia chinensis* might provide suitable conditions for seedling establishment.

However, the dense evergreen crown of *Castanopsis diversifolia* shaded out weeds and natural seedlings, especially of animal-dispersed species that constitute a large proportion of the seedlings. Most animal-dispersed seedlings might be killed by predators or be disturbed by some mammals that dig soil to forage for food under tree canopies.

Surprisingly, seedling density below *Eucalyptus camaldulensis* crowns decreased with increasing GBH, but there was no significant relationship with crown width. RFD (1997) reported that *Eucalyptus camaldulensis* competed efficiently for soil moisture content and that chemical substances (1,8 - cineole and α – pinene) in Eucalyptus oil from the leaves (terpenes) can inhibit seed germination and plant growth. It is possible that larger trees have a higher efficiency to compete for soil nutrients, and drop more leaves, which inhibit seedling establishment.

Species richness beneath remnant tree crowns increased with all parameters of tree size, height, GBH, and crown width. But species richness per unit area decreased with increasing tree size, which agrees with the results of Toh *et al.* (1999). However, the results showed some variation depending on each parameter of tree size, dispersal mechanism, and remnant tree species considered.

There was no relationship between tree height and species richness per unit area, but there was an inverse relationship with GBH and crown width. Increasing width of *Castanopsis diversifolia* and *Schima wallichii* crowns was associated with a decline in species richness of natural seedlings. Declining seedling density beneath *Castanopsis diversifolia* might cause declining species richness of seedlings. Species richness of establishing tree seedlings declined with increasing GBH and crown width of *Schima wallichii*. This may have been due to the creation of a more homogenous environment beneath the larger *Schima wallichii* trees.

Increasing girth at breast height of *Schima wallichii* was related with decreasing of the species component of animal-dispersed species, as the width of crown, because the GBH of *Schima wallichii* related with the width of their crown ($P < 0.05$).

A previous study indicated that plant diversity beneath a *Eucalyptus* plantation was inversely related to canopy cover (Bone *et al.*, 1997). However, this study did not find such a relationship. Soil properties and micro climatic conditions under Eucalyptus might provide unsuitable conditions for many tree seedling species. Consequently, there were only 15 seedling species found under Eucalyptus crowns, the lowest species richness compared with the other tree species.

Growth rate of natural seedlings

Trema orientalis (L.) Bl. (Ulmaceae) grew very fast compared with other natural tree seedlings (Table 19). This species is a pioneer tree in open, disturbed areas, and secondary growth forest (Maxwell, 2001). Its seeds are dispersed by birds. Moreover, it has been suggested for planting for restoring forest in degraded areas in southern Vietnam (So, 2000). In Thailand, FORRU studied seed germination of this tree in their nursery and reported that the germination rate was low. Before using this species as a framework species, we need to know how to increase the germination rate for seedling production.

This study did not find a clear difference in growth rate of natural seedlings below tree crowns compared with open areas. Tree crowns had no significant effects on RGR. This may have been because the trees were not large enough to permanently shade establishing seedlings. Moreover, other effects such as weed competition and soil conditions might have more influence on the growth rate of natural seedlings.

The role of birds in forest regeneration

Observations of birds visiting isolated trees indicated that very few bird species are able to increase the seed rain in disturbed areas, and the most important species are bulbuls.

Schima wallichii was the most attractive remnant tree species to birds. Although, a large proportion of the birds visiting this species were insectivores, such as *Pericrocotus cinnamomeus* (Small Minivet) and *Phylloscopus inornatus* (Inornate Warbler), this species also greatly attracted *Pycnonotus aurigaster* (Sooty-headed Bulbul) and *Pycnonotus flavescens* (Flavescent Bulbul), which might be the most important birds that enhance seed deposition below their crowns. These results correspond with seedling data in this study. Consequently, planting *Schima wallichii* as a framework species could probably greatly increase the seed rain in deforested areas and accelerate forest regeneration.

During the observation period, *Callicarpa arborea* var. *arborea* produced fleshy fruits which attracted more frugivorous birds than the other trees studied, except for *Schima wallichii.* Willson and Crome (1989) suggested that although the seed rain of animal-dispersed tended to be higher under fruiting trees than non-fruiting trees, the effect of fruit resources also depends greatly on the social, foraging and digestive behavior of frugivorous involved.

Once problem of this study was bird observation visiting to the remnant trees studied only a few months, March to May. Season had strongly influence on trees providing flower/fruits, which attracted birds. Then, the timing of bird observation will affect birds seen.

Comparing bird observations with a previous study (Scott *et al.*, 2000) in the same area, only bulbuls (Sooty-headed Bulbul and Red-whiskered Bulbul) were observed visiting both artificial perches and the trees in this study. This suggests that differences between artificial perches and natural perches have a strong influence on the species of birds visiting. Artificial perches might be attractive to birds, which are not usually shy and like to perch in low places. While complexity of natural perches, such as tree branches might useful to attract many birds visited.

Although isolated trees in deforested areas clearly attract birds and increase the seed rain, however a large proportion of seeds fail to develop into seedlings (McClanahan and Wolfe, 1993; Toh *et al.*, 1999; Hardwick *et al.*, 2000b). Thus, further research is needed to find out how to increase seedling recruitment.

Observations of fruiting trees indicated that the commonest birds which fed on fleshy fruits, were bulbuls. This agrees with Kuarak and Hitchcock (1998) and Sanitjan (2001). Lambert (1989) demonstrated that bulbuls (*Pycnonotus* spp.) can disperse seeds over several kilometers and can retain seeds in their digestive tracts for up to 40 minutes.

Bischofia javanica was very attractive to many birds. This might have been because this tree was located far from human activity and produces a favorite fruit for many bird species. Sanitjan (2001) noted that many birds were observed on fruiting trees, which have fleshy, small, ripe fruits and big crowns.

It was surprise that few birds visited fruiting trees of *Debregeasia longifolia* and *Heynea trijuga.* Both of these fruiting trees were located near a dirt road and human activity. I observed, birds would fly out every time a human came near, so disturbance may have reduced the species observed. The birds observed were often those tolerant of human activity, *e.g. Pycnonotus jocosus* (Red-whiskered Bulbul). These bird species can adapt their behavior and invade man made habitats (Portigo, 1994).

For trees with abundant fruits, *e.g. Bischofia javanica* large bird flocks would visit and break up into smaller groups, whereas trees offering limited food supplies, *e.g. Debregeasia longifolia* and *Heynea trijuga* tended to attract on individuals or very small groups of bird which entered and left in rapid succession. Such behavior reduces competition for food and perch places (Singhakan, 1986).

Three bulbul species, *Pycnonotus aurigaster* (Sooty-headed Bulbul), *P. flavescens* (Flavescent Bulbul), and *P. jocosus* (Red-whiskered Bulbul) were observed at both deforested areas and intact forest. These bulbuls help to accelerate forest regeneration in disturbed areas by consuming seeds in the forests and depositing them under perch trees. However, more needs to be known about what limit these bulbuls as seed dispersers, such as how far they fly between forest and disturbed areas, and what sizes of seeds they can swallow. This knowledge will help to create a better understanding of the role of these bulbuls to improve ANR techniques.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Most remnant mature trees did not increase seedling recruitment beneath their crowns, except for *Schima wallichii* (DC.) Korth. (Theaceae).

2. The density and species richness of animal-dispersed seedlings beneath mature remnant trees did not depend on the species of the mature trees. Species with fleshy fruits (*e.g. Callicarpa arborea* Roxb. var. *arborea*) were not necessarily more attractive than those with dry fruits (*e.g. Schima wallichii* (DC.) Korth.).

3. There was no relationship between tree size and seedling density established beneath their crowns. Bigger crowns tended to support a lower species richness of natural seedlings. Size of remnant trees could not predict seedling recruitment under crowns.

4. Growth rates of natural seedlings between beneath tree crowns and in open areas were similar.

5. *Trema orientalis* (L.) Bl. (Ulmaceae) was the fastest growing species of natural seedling.

6. The remnant tree species that was most attractive to birds was *Schima wallichii* (DC.) Korth. (Theaceae).

7. Three bulbuls birds, *Pycnonotus aurigaster* (Sooty-headed Bulbul), *P. flavescens* (Flavescent Bulbul), and *P. jocosus* (Red-whiskered Bulbul) were the most important frugivorous birds that dispersed seeds from intact forest into the deforested sites.

Recommendations

1. Other factors such as forest fire, seed predators, competition with weeds, and pathogens seem to have great influence on natural seedling recruitment. Consequently, further research to accelerate forest regeneration is necessary to find out how to reduce the mortality of natural seedlings.

2. Growth rate of natural trees should be monitored continuously over a longer period to see more indications of differences of seedling recruitment between beneath tree crowns and in open areas.

3. Further research should determine the effects of isolated planted trees on accelerating forest regeneration in deforested areas.

4. Frugivorous birds definitely help to accelerate forest regeneration in disturbed areas by consuming fruits in the forest and depositing seeds under the perch trees. However, more needs to be known about what limit these birds as seed dispersers.

5. Because only a few frugivorous birds help to accelerate forest regeneration in this deforested site, these birds should be protected from hunting.

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APPENDICES

Appendix A

Remnant trees studied

No.	Remnant trees	Plot code	Elevation (m)	Diameter of plot (m)	GBH (cm)	Hight (m)	Radius of control plot	Habitat
1	*Albizia chinensis* (1)	12	1225	6	55	8	3	open, degraded, deforested area, in FORRU planting area, dominated by *Pteridium aquilinum*, not burned in recent years but weeds cut by FORRU
2	*Albizia chinensis* (2)	13	1225	10	95	12	5	open, degraded, deforested area, in FORRU planting area, dominated by *Pteridium aquilinum*, not buined in recent years but weeds cut by FORRU
3	*Albizia chinensis* (3)	17	1225	7	87	8	3.5	open, degraded, deforested area, in FORRU planting area, dominated by *Pteridium aquilinum*, not burned in recent years but weeds cut by FORRU
4	*Albizia chinensis* (4)	28	1325	11	137	12	5.5	open, degraded, deforested area, bordering RFD planting area, not burned in recent years, dominated by *Microstegium vagan*
5	*Albizia chinensis* (5)	46	1225	7	65	8	3.5	open, degraded, deforested area, in FORRU planting area, dominated by *Imperata cylindrica*, not burned in recent years but cut weeds cut by FORRU
6	*Albizia chinensis* (6)	47	1225	8.5	82	8	4.25	open, degraded, deforested area, bordering cabbage field, not burned in recent years, dominated by *Imperata cylindrica* and *Pteridium aquilinum*

Appendix A (continued)

No.	Remnant trees	Plot code	Elevation (m)	Diameter of plot (m)	GBH (cm)	Hight (m)	Radius of control plot	Habitat
7	*Callicarpa arborea* var. *arborea* (1)	8	1225	5	70	10	2.5	open, degraded, deforested area, bordering FORRU planting area, dominated by *Pteridium aquilinum*, not burned in recent years
8	*Callicarpa arborea* var. *arborea* (2)	9	1225	6	87	15	3	open, degraded, deforested area, in FORRU planting area, dominated by *Pteridium aquilinum*, not burned in recent years but weeds cut by FORRU
9	*Callicarpa arborea* var. *arborea* (3)	11	1225	6.5	65	10	3.25	open, degraded, deforested area, in FORRU planting area, dominated by *Pteridium aquilinum*, not burned in recent years but weeds cut by FORRU
10	*Callicarpa arborea* var. *arborea* (4)	14	1225	6.5	77	15	3.25	open, degraded, deforested area, in FORRU planting area, dominated by *Pteridium aquilinum*, not burned in recent years but weeds cut by FORRU
11	*Callicarpa arborea* var. *arborea* (5)	15	1225	7	60	10	3.5	open, degraded, deforested area, in FORRU planting area, dominated by *Pteridium aquilinum*, not burned in recent years but weeds cut by FORRU
12	*Callicarpa arborea* var. *arborea* (6)	40	1225	9	40	6	4.5	open, degraded, deforested area, in FORRU planting area, dominated by *Pteridium aquilinum*, not burned in recent years but weeds cut by FORRU
13	*Callicarpa arborea* var. *arborea* (7)	48	1225	10	160	12	5	open, degraded, deforested area, bordering cabbage field, not burned in recent years, dominated by *Imperata cylindrica*
14	*Castanopsis diversifolia* (1)	3	1275	9	280	15	4.5	open, degraded, deforested area, not burned in recent years, dominated by *Microstegium vagans*
15	*Castanopsis diversifolia* (2)	4	1275	13	246	15	6.5	open, degraded, deforested area, not burned in recent years, dominated by *Microstegium vagans*

Appendix A (continued)

No.	Remnant trees	Plot code	Elevation (m)	Diameter of plot (m)	GBH (cm)	Hight (m)	Radius of control plot	Habitat
16	*Castanopsis diversifolia* (3)	19	1275	11	270	18	5.5	open, degraded, deforested area, roadside, dominated by *Imperata cylindrica*, not burned in recent years
17	*Castanopsis diversifolia* (4)	20	1275	12	270	18	6	open, degraded, deforested area, roadside, dominated by *Imperata cylindrica*, not burned in recent years
18	*Castanopsis diversifolia* (5)	21	1275	10	150	12	5	open, degraded, deforested area, roadside, dominated by *Imperata cylindrica*, not burned in recent years
19	*Castanopsis diversifolia* (6)	22	1275	11	175	20	5.5	open, degraded, deforested area, roadside, dominated by *Imperata cylindrica*, not burned in recent years
20	*Castanopsis diversifolia* (7)	23	1275	8	265	20	4	open, degraded, deforested area, roadside, dominated by *Imperata cylindrica*, not burned in recent years
21	*Castanopsis diversifolia* (8)	32	1325	13	200	15	6.5	open, degraded, deforested area, ridge in secondary growth area, bordering RFD planting area, not burned in recent years, dominated by *Imperata cylindrica* and *Microstegium vagans*
22	*Erythrina stricta* (1)	25	1300	6	130	11	3	open, degraded, deforested area, not burned in recent years, in RFD planting area
23	*Erythrina stricta* (2)	26	1275	8	153	12	4	open, degraded, deforested area, not burned in recent years, dominated by *Microstegium vagans*
24	*Erythrina stricta* (3)	27	1275	6	96	12	3	open, degraded, deforested area, not burned in recent years, dominated by *Microstegium vagans*
25	*Erythrina stricta* (4)	52	1300	6	52	7	3	open, degraded, deforested area, not burned in recent years, in RFD planting area
26	*Erythrina stricta* (5)	53	1325	5	90	11	2.5	open, degraded, deforested area, not burned in recent years, dominated by *Microstegium vagans*

Appendix A (continued)

No.	Remnant trees	Plot code	Elevation (m)	Diameter of plot (m)	GBH (cm)	Hight (m)	Radius of control plot	Habitat
27	*Erythrina stricta* (6)	54	1250	7	111	12	3.5	open, degraded, deforested area, bordering FORRU planting area, not burned in recent years, dominated by *Eupatorium adenophorum*
28	*Eucalyptus camaldulensis* (1)	7	1300	6.5	95	12	3.25	open, degraded, deforested area, not burned in recent years, dominated by *Pteridium aquilinum* and *Eupatorium adenophorum*
29	*Eucalyptus camaldulensis* (2)	33	1300	6	98	10	3	open, degraded, deforested area, not burned in recent years, dominated by *Pteridium aquilinum* and *Eupatorium adenophorum*
30	*Eucalyptus camaldulensis* (3)	34	1300	6	90	10	3	open, degraded, deforested area, not burned in recent years, dominated by *Pteridium aquilinum* and *Eupatorium adenophorum*
31	*Eucalyptus camaldulensis* (4)	35	1300	8.5	110	12	4.25	open, degraded, deforested area, not burned in recent years, dominated by *Imperata cylindrica* and *Pteridium aquilinum*
32	*Eucalyptus camaldulensis* (5)	36	1300	7	100	10	3.5	open, degraded, deforested area, not burned in recent years, dominated by *Pteridium aquilinum* and *Eupatorium adenophorum*
33	*Eucalyptus camaldulensis* (6)	37	1300	7	118	11	3.5	open, degraded, deforested area, roadside, not burned in recent years, dominate by *Imperata cylindrica* and *Eupatorium adenophorum*
34	*Eucalyptus camaldulensis* (7)	38	1300	7	99	10	3.5	open, degraded, deforested area, roadside, not burned in recent years, dominated by *Pennisetum polystachyon*
35	*Eucalyptus camaldulensis* (8)	39	1300	10	115	12	5	open, degraded, deforested area, roadside, not burned in recent years, dominated by *Imperata cylindrica*

Appendix A (continued)

No.	Remnant trees	Plot code	Elevation (m)	Diameter of plot (m)	GBH (cm)	Hight (m)	Radius of control plot	Habitat
36	*Pinus kesiya* (1)	16	1225	7	115	10	3.5	open, degraded, deforested area, in FORRU planting area, dominated by *Pteridium aquilinum*, not burned in recent years but weeds cut by FORRU
37	*Pinus kesiya* (2)	42	1275	7	109	16	3.5	open, degraded, deforested area, roadside, dominated by *Imperata cylindrica*, not burned in recent years
38	*Pinus kesiya* (3)	43	1250	7	98	12	3.5	open, degraded, deforested area, roadside, dominated by *Imperata cylindrica*, burned in 1999
39	*Pinus kesiya* (4)	44	1250	9	113	12	4.5	open, degraded, deforested area, roadside, dominated by *Imperata cylindrica*, burned in 1999
40	*Pinus kesiya* (5)	45	1225	6	100	10	3	open, degraded, deforested area, in FORRU planting area, not burned in recent years, dominated by *Imperata cylindrica*
41	*Pinus kesiya* (6)	49	1225	7	83	11	3.5	open, degraded, deforested area, bordering cabbage field, not burned in recent years, dominated by *Imperata cylindrica*
42	*Pinus kesiya* (7)	50	1225	7	89	12	3.5	open, degraded, deforested area, bordering cabbage field, not burned in recent years, dominated by *Imperata cylindrica*
43	*Pinus kesiya* (8)	51	1225	6	85	12	3	open, degraded, deforested area, bordering cabbage field, not burned in recent years, dominated by *Imperata cylindrica*
44	*Schima wallichii* (1)	1	1325	9	205	18	4.5	open, degraded, deforested area, not burned in recent years, dominated by *Pteridium aquilinum, Imperata cylindrica, Eupatorium adenophorum*
45	*Schima wallichii* (2)	2	1250	6	188	12	3	open, degraded, deforested area, scattered trees nearby
46	*Schima wallichii* (3)	6	1275	10.5	350	35	5.25	open, degraded, deforested area, road side, dominated by *Pteridium aquilinum*, not burned in recent years

Appendix A (continued)

No.	Remnant trees	Plot code	Elevation (m)	Diameter of plot (m)	GBH (cm)	Hight (m)	Radius of control plot	Habitat
47	*Schima wallichii* (4)	10	1225	7	125	14	3.5	open, degraded, deforested area, bordering FORRU planting area, dominated by *Pteridium aquilinum* , not burned in recent years
48	*Schima wallichii* (5)	18	1225	15	335	30	7.5	open, degraded, deforested area, bordering FORRU planting area, dominated by *Imperata cylindrica* , burned in 2001
49	*Schima wallichii* (6)	29	1325	8	155	20	4	open, degraded, deforested area, not burned in recent years, dominated by *Microstegium vagans*
50	*Schima wallichii* (7)	30	1325	9	180	18	4.5	open, degraded, deforested area, not burned in recent years, dominated by *Dioscorea bulbifera*
51	*Schima wallichii* (8)	31	1325	6	135	20	3	open, degraded, deforested area, not burned in recent years, dominated by *Imperata cylindrica*

Appendix B

List of naturally established tree seedling species in the study plots

No.	Botanical name	Family name	Dispersal means
1	*Alangium kurzii* Craib	Alangiaceae	birds, small mammals
2	*Albizia chinensis* (Osb.) Merr.	Leguminosae, Mimosoideae	wind
3	*Albizia odoratissima* (L. f.) Bth.	Leguminosae, Mimosoideae	wind
4	*Alseodaphne andersonii* (King *ex* Hk. f.) Kosterm.	Lauraceae	small mammals
5	*Anneslea fragrans* Wall.	Theaceae	birds
6	*Antidesma acidum* Retz.	Euphorbiaceae	birds
7	*Antidesma bunius* (L.) Spreng. var. *bunius*	Euphorbiaceae	birds
8	*Aporusa villosa* (Wall. *ex* Lindl.) Baill.	Euphorbiaceae	birds
9	*Archidendron clypearia* (Jack) Niels. ssp. *clypearia* var. *clypearia*	Leguminosae, Mimosoideae	wind
10	*Artocarpus lakoocha* Roxb.	Moraceae	birds, small mammals
11	*Artocarpus lanceolata* Trec.	Moraceae	birds, small mammals
12	*Baccaurea ramiflora* Lour.	Euphorbiaceae	small mammals
13	*Bauhinia variegata* L.	Leguminosae, Caesalpinioideae	wind
14	*Beilschmiedia* aff. *intermedia* Allen	Lauraceae	small mammals
15	*Callicarpa arborea* Roxb. var. *arborea*	Verbenaceae	birds
16	*Canarium subulatum* Guill.	Burseraceae	small mammals
17	*Canthium parvifolium* Roxb.	Rubiaceae	small mammals
18	*Castanopsis acuminatissima* (Bl.) A. DC.	Fagaceae	small mammals
19	*Castanopsis argyrophylla* King *ex* Hk. f.	Fagaceae	small mammals

Appendix B (continued)

No.	Botanical name	Family name	Dispersal means
20	*Castanopsis diversifolia* (Kurz) King *ex* Hk. f.	Fagaceae	small mammals
21	*Cinnamomum longipetiolatum* H.W. Li	Lauraceae	small mammals
22	*Cratoxylum cochinchinense* (Lour.) Bl.	Guttiferae, Hypericaceae	wind
23	*Dalbergia cultrata* Grah. *ex* Bth.	Leguminosae, Papilionoideae	wind
24	*Dalbergia ovata* Grah. *ex* Bth.	Leguminosae, Papilionoideae	wind
25	*Dillenia parviflora* Griff. var. *kerrii* (Craib) Hoogl.	Dilleniaceae	birds, small mammals
26	*Dimocarpus longan* Lour. ssp. *longan* var. *longan*	Sapindaceae	small mammals
27	*Diospyros glandulosa* Lace	Ebenaceae	small mammals
28	*Elaeocarpus lanceifolius* Roxb.	Elaeocarpaceae	small mammals
29	*Engelhardia spicata* Lechen. *ex* Bl. var. *spicata*	Juglandaceae	wind
30	*Erythrina stricta* Roxb.	Leguminosae, Papilionoideae	wind
31	*Eugenia claviflora* Roxb.	Myrtaceae	birds, small mammals
32	*Eugenia fruticosa* (DC.) Roxb.	Myrtaceae	birds, small mammals
33	*Eurya acumminata* DC. var. *wallichiana* Dyer	Theaceae	birds, small mammals
34	*Ficus fistulosa* Reinw. *ex* Bl. var. *fistulosa*	Moraceae	birds, small mammals
35	*Ficus hispida* L. f. var. *hispida*	Moraceae	birds, small mammals
36	*Ficus semicordata* B.-H. *ex* J.E. Sm. var. *semicordata*	Moraceae	birds, small mammals
37	*Ficus subulata* Bl. var. *subulata*	Moraceae	birds, small mammals
38	*Firmiana colorata* (Roxb.) R. Br.	Sterculiaceae	wind
39	*Fluggea virosa* (Roxb. *ex* Willd.) Voigt	Euphorbiaceae	birds, small mammals
40	*Garuga pinnata* Roxb.	Burseraceae	small mammals
41	*Glochidion acuminatum* M.-A. var. *siamense* A.S.	Euphorbiaceae	birds, wind
42	*Glochidion kerrii* Craib	Euphorbiaceae	birds, wind
43	*Glochidion sphaerogynum* (M.-A.) Kurz	Euphorbiaceae	birds, wind
44	*Gluta obovata* Craib	Anacardiaceae	small mammals

Appendix B (continued)

No.	Botanical name	Family name	Dispersal means
45	*Gmelina arborea* Roxb.	Verbenaceae	small mammals
46	*Grewia eriocarpa* Juss.	Tiliaceae	birds, small mammals
47	*Helicia nilagirica* Bedd.	Proteaceae	small mammals
48	*Horsfieldia thorelii* Lec.	Myristicaceae	small mammals
49	*Ilex umbellulata* (Wall.) Loesn.	Aquifoliaceae	wind
50	*Kydia calycina* Roxb.	Malvaceae	wind
51	*Lithocarpus fenestratus* (Roxb.) Rehd.	Fagaceae	small mammals
52	*Litsea cubeba* (Lour.) Pers. var. *cubeba*	Lauraceae	birds, small mammals
53	*Litsea glutinosa* (Lour.) C.B. Rob. var. *glutinosa*	Lauraceae	birds, small mammals
54	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	birds, small mammals
55	*Litsea salicifolia* Nees *ex* Roxb.	Lauraceae	birds, small mammals
56	*Machilus bombycina* King *ex* Hk. f.	Lauraceae	birds, small mammals
57	*Maesa ramentacea* (Roxb.) A. DC.	Myrsinaceae	birds, small mammals
58	*Mallotus philippensis* (Lmk.) M.-A.	Euphorbiaceae	wind
59	*Markhamia stipulata* (Wall.) Seem. *ex* K. Sch. var. *kerrii* Sprague	Bignoniaceae	wind
60	*Melochia umbellata* (Houtt.) Stapf	Sterculiaceae	wind
61	*Michelia baillonii* Pierre	Magnoliaceae	birds, small mammals
62	*Oroxylum indicum* (L.) Kurz	Bignoniaceae	wind
63	*Phoebe lanceolata* (Wall. *ex* Nees) Nees	Lauraceae	birds, small mammals
64	*Phyllanthus emblica* L.	Euphorbiaceae	birds, small mammals
65	*Planchonella punctata* Flet.	Sapotaceae	small mammals
66	*Protium serratum* (Wall. *ex* Colebr.) Engl.	Burseraceae	small mammals
67	*Rhus chinensis* Mill.	Anacardiaceae	birds, small mammals
68	*Sapindus rarak* DC.	Sapindaceae	small mammals
69	*Saurauia roxburghii* Wall.	Saurauiaceae	birds, small mammals

Appendix B (continued)

No.	Botanical name	Family name	Dispersal means
70	*Schima wallichii* (DC.) Korth.	Theaceae	wind
71	*Sterculia villosa* Roxb.	Sterculiaceae	small mammals
72	*Stereospermum colais* (B.-H. *ex* Dillw.) Mabb.	Bignoniaceae	wind
73	*Styrax benzoides* Craib	Styracaceae	birds, small mammals
74	*Toona ciliata* M. Roem.	Meliaceae	wind
75	*Trema orientalis* (L.) Bl.	Ulmaceae	birds
76	*Turpinia pomifera* (Roxb.) Wall. *ex* DC.	Staphyleaceae	small mammals
77	*Vernonia volkameriifolia* DC. var. *volkameriifolia*	Compositae	wind
78	*Wendlandia tinctoria* (Roxb.) DC. ssp. *floribunda* (Craib) Cowan	Rubiaceae	wind

Appendix C

Quantity of naturally tree seedlings in the study plots

Appendix C1 Quantity of seedlings found beneath remnant trees

No.	Botanical name	Albizia chinensis						Calliocarpa arborea var. arborea							Castanopsis diversifolia								Erythrina stricta						Eucalyptus camaldulensis								Pinus kesiya								Schima wallichii								total
		1	2	3	4	5	6	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	1	2	3	4	5	6	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
1	*Alangium kurzii* Craib																	1																													1						2
2	*Albizia chinensis* (Osb.) Merr.							1	1												1																							1			1		5				10
3	*Albizia odoratissima* (L. f.) Bth.																1	1										1														1											4
4	*Alseodaphne andersonii* (King ex Hk. f.) Kosterm.				1																																																1
5	*Anneslea fragrans* Wall.														1						8																																9
6	*Antidesma acidum* Retz.				1	1									1	3		2			2		1	3				1									4				1						1		1		2		24
7	*Antidesma bunius* (L.) Spreng. var. *bunius*		2				1						1																									2					1					1					8
8	*Aporusa villosa* (Wall. ex Lindl.) Baill.				1						1											1	2	2		1										2									5		4		1	3	8		31
9	*Archidendron clypearia* (Jack) Niels. ssp. *clypearia* var. *clypearia*						1													1																																	2
10	*Artocarpus lakoocha* Roxb.			1										1																			1			1		2															6
11	*Artocarpus lanceolata* Treo.										1	1																									1																3
12	*Baccaurea ramiflora* Lour.													1																																							1
13	*Bauhinia variegata* L.														1								3	2				2				1			9											2							20
14	*Beilschmiedia* aff. *intermedia* Allen																																																		1		1
15	*Callicarpa arborea* Roxb. var. *arborea*																																															1					1
16	*Canarium subulatum* Guill.																																																	1			1

Appendix C1 (continued)

No.	Botanical name	Albizia chinensis						Callicarpa arborea var. arborea							Castanopsis diversifolia								Erythrina stricta						Eucalyptus camaldulensis								Pinus kesiya								Schima wallichii								total
		1	2	3	4	5	6	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	1	2	3	4	5	6	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
17	*Canthium parvifolium* Roxb.																				1			1																									5	2	1		10
18	*Castanopsis acuminatissima* (Bl.) A. DC.																																																4	2		2	8
19	*Castanopsis argyrophylla* King *ex* Hk. f.										1																																						1	1		1	4
20	*Castanopsis diversifolia* (Kurz) King *ex* Hk. f.		1		2																																	1											2		6		12
21	*Cinnamomum longipetiolatum* H.W. Li																															1	1		1																		3
22	*Cratoxylum cochinchinense* (Lour.) Bl.																																																				
23	*Dalbergia cultrata* Grah. *ex* Bth.			2																								2																			2						6
24	*Dalbergia ovata* Grah. *ex* Bth.		1		3			1							4	8					2		3	4	1				1																35		2		1	9	3	2	80
25	*Dillenia parviflora* Griff. var. *kerrii* (Craib) Hoogl.		1											1					2																																		4
26	*Dimocarpus longan* Lour. ssp. *longan* var. *longan*																																										2										2
27	*Diospyros glandulosa* Lace							1	1											1		2													1			2										1					9
28	*Elaeocarpus lanceifolius* Roxb.																1																2																				3
29	*Engelhardia spicata* Lechen. *ex* Bl. var. *spicata*														1	1																																1					3
30	*Erythrina stricta* Roxb.																											8																									8
31	*Eugenia claviflora* Roxb.														1					1				1		3	1																		2	1						1	11
32	*Eugenia fruticosa* (DC.) Roxb.											1						1	2		1																1								2								8
33	*Eurya acumminata* DC. var. *wallichiana* Dyer	1																1																														1					3
34	*Ficus fistulosa* Reinw. *ex* Bl. var. *fistulosa*																																																				
35	*Ficus hispida* L. f. var. *hispida*																																								1												1
36	*Ficus semicordata* B.-H. *ex* J.E. Sm. var. *semicordata*																																	1																			1
37	*Ficus subulata* Bl. var. *subulata*																																															1					1

Appendix C1 (continued)

		Albizia chinensis						Callicarpa arborea var. arborea							Castanopsis diversifolia								Erythrina stricta						Eucalyptus camaldulensis								Pinus kesiya								Schima wallichii								total
No.	Botanical name	1	2	3	4	5	6	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	1	2	3	4	5	6	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
38	*Firmiana colorata* (Roxb.) R. Br.																											2																									2
39	*Fluggea virosa* (Roxb. *ex* Willd.) Voigt													1																																							1
40	*Garuga pinnata* Roxb.															1																					1																2
41	*Glochidion acuminatum* M.-A. var. *siamense* A.S.																2				1																																3
42	*Glochidion kerrii* Craib																																											1									1
43	*Glochidion sphaerogynum* (M.-A.) Kurz									1					2	2	2		2	1	1			1			1	1								1		1									2						18
44	*Gluta obovata* Craib																																																		1		1
45	*Gmelina arborea* Roxb.						1										1				1																																3
46	*Grewia eriocarpa* Juss.																																																				
47	*Helicia nilagirica* Bedd.							1									1	1			1																	1							1								6
48	*Horsfieldia thorelii* Lec.																			1																																	1
49	*Ilex umbellulata* (Wall.) Loesn.																																																				
50	*Kydia calycina* Roxb.													1		1							1		1																												4
51	*Lithocarpus fenestratus* (Roxb.) Rehd.															1																																					1
52	*Litsea cubeba* (Lour.) Pers. var. *cubeba*	1			3			1			1	1		1	2						1					1			4			6	1	3	1	4			1								2		4	3	2		43
53	*Litsea glutinosa* (Lour.) C.B. Rob. var. *glutinosa*																		1																																		1
54	*Litsea monopetala* (Roxb.) Pers.		1		4					2	2		4											2		1				9	13	1			1	1	1																42
55	*Litsea salicifolia* Nees *ex* Roxb.																									1																											1
56	*Machilus bombycina* King *ex* Hk. f.														1						2		1			1												1	1						2				2			1	12
57	*Maesa ramentacea* (Roxb.) A. DC.																																																				
58	*Mallotus philippensis* (Lmk.) M.-A.								1																																												1
59	*Markhamia stipulata* (Wall.) Seem. *ex* K. Sch. var. *kerrii* Sprague											3		1			1																															1	1				7

Appendix C1 (continued)

No.	Botanical name	Albizia chinensis						Callicarpa arborea var. arborea							Castanopsis diversifolia								Erythrina stricta						Eucalyptus camaldulensis								Pinus kesiya								Schima wallichii								total
		1	2	3	4	5	6	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	1	2	3	4	5	6	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
60	*Melochia umbellata* (Houtt.) Stapf																							1																											1		2
61	*Michelia baillonii* Pierre				1																																																1
62	*Oroxylum indicum* (L.) Kurz													4									1																														5
63	*Phoebe lanceolata* (Wall. *ex* Nees) Nees															1										1																		1						1			4
64	*Phyllanthus emblica* L.					1					2						5	2			1							1	1		1														3		1		1		1		20
65	*Planchonella punctata* Flet.																							1																													1
66	*Protium serratum* (Wall. *ex* Colebr.) Engl.						1																																														1
67	*Rhus chinensis* Mill.						2	4			1	1			1		11			6			1																						1		5	2	2				37
68	*Sapindus rarak* DC.		1																																																		1
69	*Saurauia roxburghii* Wall.				1				1																														1					2									5
70	*Schima wallichii* (DC.) Korth.		1	1			1			1	1									2	2					2			2			2	1			9																	25
71	*Sterculia villosa* Roxb.														2	1			4	2	1		1	1	1			1	1			1				1		3					1		2	1	1		2				27
72	*Stereospermum colais* (B.-H. *ex* Dillw.) Mabb.			4			1							1		2			1	1			1					1											1					1			1						15
73	*Styrax benzoides* Craib		1																	1	1			1																									2			3	9
74	*Toona ciliata* M. Roem.		3									1																																									4
75	*Trema orientalis* (L.) Bl.																																																				
76	*Turpinia pomifera* (Roxb.) Wall. *ex* DC.		1		2										5	1							1	4	1													2			1		2			2					1		23
77	*Vernonia volkameriifolia* DC. var. *volkameriifolia*	1	1															2																		1																	5
78	*Wendlandia tinctoria* (Roxb.) DC. ssp. *floribunda* (Craib) Cowan						2														1	1					4											1			1						1				1		12
	Total	3	14	8	19	2	10	9	4	4	10	8	5	12	22	22	25	11	12	17	28	4	16	24	4	11	6	20	9	9	14	12	6	4	13	20	8	17	3	0	4	1	8	4	53	6	24	9	34	22	28	10	648

Appendix C2 Quantity of seedlings found in control plots of the remnant trees

		Albizia chinensis						Callicarpa arborea var. arborea							Castanopsis diversifolia								Erythrina stricta						Eucalyptus camaldulensis								Pinus kesiya								Schima wallichii								total
No.	Botanical name	1	2	3	4	5	6	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	1	2	3	4	5	6	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
1	*Alangium kurzii* Craib																																																				
2	*Albizia chinensis* (Osb.) Merr.		1					1							1	1																				1																	5
3	*Albizia odoratissima* (L. f.) Bth.						1									1		1										1																					1				5
4	*Alseodaphne andersonii* (King ex Hk. f.) Kosterm.								1																																												1
5	*Anneslea fragrans* Wall.																		1																															1			2
6	*Antidesma acidum* Retz.				2	1									1	6		1	2		1				7											4															2		27
7	*Antidesma bunius* (L.) Spreng. var. *bunius*							2			1																																					2					5
8	*Aporusa villosa* (Wall. ex Lindl.) Baill.																				1	1		2	3		1								1			1							6				2				18
9	*Archidendron clypearia* (Jack) Niels. ssp. *clypearia* var. *clypearia*										1									1		1																															3
10	*Artocarpus lakoocha* Roxb.																					2	1		1								2				2			1						1							10
11	*Artocarpus lanceolata* Trec.										1															1								1																			3
12	*Baccaurea ramiflora* Lour.							1																																													1
13	*Bauhinia variegata* L.															2									1					1					14											1							19
14	*Beilschmiedia* aff. *intermedia* Allen																																																				
15	*Callicarpa arborea* Roxb. var. *arborea*																																																				
16	*Canarium subulatum* Guill.																																																				
17	*Canthium parvifolium* Roxb.			3												2				2		1																3							2							1	14
18	*Castanopsis acuminatissima* (Bl.) A. DC.																																																	1			1
19	*Castanopsis argyrophylla* King ex Hk. f.																																																				
20	*Castanopsis diversifolia* (Kurz) King ex Hk. f.															2	1				2				1													2														1	9
21	*Cinnamomum longipetiolatum* H.W. Li																															2																					2

Appendix C2 (continued)

No.	Botanical name	Albizia chinensis						Callicarpa arborea var. arborea							Castanopsis diversifolia								Erythrina stricta						Eucalyptus camaldulensis								Pinus kesiya								Schima wallichii								total
		1	2	3	4	5	6	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	1	2	3	4	5	6	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
22	*Cratoxylum cochinchinense* (Lour.) Bl.										2																																										2
23	*Dalbergia cultrata* Grah. *ex* Bth.		1	2																								2																			1		2				8
24	*Dalbergia ovata* Grah. *ex* Bth.													1	2	12						4		8	1								1					4							8		2			4			47
25	*Dillenia parviflora* Griff. var. *kerrii* (Craib) Hoogl.																	1																														1					2
26	*Dimocarpus longan* Lour. ssp. *longan* var. *longan*																																																				
27	*Diospyros glandulosa* Lace						1				1				1		1					1																1									1						7
28	*Elaeocarpus lanceifolius* Roxb.									1															1																												2
29	*Engelhardia spicata* Lechen. *ex* Bl. var. *spicata*															1																																	1				2
30	*Erythrina stricta* Roxb.																																													1							1
31	*Eugenia claviflora* Roxb.				1											1				3			2	4	2	1												2							1							1	18
32	*Eugenia fruticosa* (DC.) Roxb.																															1					3								1			1			1		7
33	*Eurya acumminata* DC. var. *wallichiana* Dyer								1																																							1					2
34	*Ficus fistulosa* Reinw. *ex* Bl. var. *fistulosa*							1																																													1
35	*Ficus hispida* L. f. var. *hispida*																																															1					1
36	*Ficus semicordata* B.-H. *ex* J.E. Sm. var. *semicordata*																																																				
37	*Ficus subulata* Bl. var. *subulata*																																																				
38	*Firmiana colorata* (Roxb.) R. Br.																																																				
39	*Fluggea virosa* (Roxb. *ex* Willd.) Voigt																																																				
40	*Garuga pinnata* Roxb.													2																																							2
41	*Glochidion acuminatum* M.-A. var. *siamense* A.S.																	2																																			2
42	*Glochidion kerrii* Craib																																																				
43	*Glochidion sphaerogynum* (M.-A.) Kurz													1	1			1	1	2	1																										1						8

Appendix C2 (continued)

No.	Botanical name	Albizia chinensis						Callicarpa arborea var. arborea							Castanopsis diversifolia								Erythrina stricta						Eucalyptus camaldulensis								Pinus kesiya								Schima wallichii								total
		1	2	3	4	5	6	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	1	2	3	4	5	6	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
44	*Gluta obovata* Craib																																															1		1			2
45	*Gmelina arborea* Roxb.													1							1																	3									1						6
46	*Grewia eriocarpa* Juss.													1																																							1
47	*Helicia nilagirica* Bedd.							1											1		1																																3
48	*Horsfieldia thorelii* Lec.																																																				
49	*Ilex umbellulata* (Wall.) Loesn.										1																																										1
50	*Kydia calycina* Roxb.													2		2																																					4
51	*Lithocarpus fenestratus* (Roxb.) Rehd.																																																				
52	*Litsea cubeba* (Lour.) Pers. var. *cubeba*	1			2		1			1						1		1				1				1	2		4				8		1	5							2							1		1	33
53	*Litsea glutinosa* (Lour.) C.B. Rob. var. *glutinosa*																											1																									1
54	*Litsea monopetala* (Roxb.) Pers.		2										5		1										1								2						2														13
55	*Litsea salicifolia* Nees ex Roxb.																																																				
56	*Machilus bombycina* King ex Hk. f.						1													1	1	2				1	1									1	1								1						1		11
57	*Maesa ramentacea* (Roxb.) A. DC.						1													1													1																				3
58	*Mallotus philippensis* (Lmk.) M.-A.									4											1																1							1									7
59	*Markhamia stipulata* (Wall.) Seem. ex K. Sch. var. *kerrii* Sprague											1																										1			1							1					4
60	*Melochia umbellata* (Houtt.) Stapf																																																				
61	*Michelia baillonii* Pierre																					1																															1
62	*Oroxylum indicum* (L.) Kurz													2					1																							1											4
63	*Phoebe lanceolata* (Wall. ex Nees) Nees	1								1	1											2																						1									6
64	*Phyllanthus emblica* L.						1								1			2							1													1									2	1	1		1		11
65	*Planchonella punctata* Flet.																																																				

Appendix C2 (continued)

		Albizia chinensis						Callicarpa arborea var. arborea							Castanopsis diversifolia								Erythrina stricta						Eucalyptus camaldulensis								Pinus kesiya								Schima wallichii								total
No.	Botanical name	1	2	3	4	5	6	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	1	2	3	4	5	6	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	
66	*Protium serratum* (Wall. *ex* Colebr.) Engl.																																																				
67	*Rhus chinensis* Mill.						2	1									22								1																						1						27
68	*Sapindus rarak* DC.																																																				
69	*Saurauia roxburghii* Wall.																1																																				1
70	*Schima wallichii* (DC.) Korth.			1	29									1						1		1				2			1				13			5				1					1		2						58
71	*Sterculia villosa* Roxb.						2				3				1	2	4						1	1	1		3	3										1	1						1		2						26
72	*Stereospermum colais* (B.-H. ex Dillw.) Mabb.														1			3																				1															5
73	*Styrax benzoides* Craib							2								1						1																														1	5
74	*Toona ciliata* M. Roem.		3																				1																														4
75	*Trema orientalis* (L.) Bl.																																				1																1
76	*Turpinia pomifera* (Roxb.) Wall. *ex* DC.									1				1		1							4	1	1																					1		2					12
77	*Vernonia volkameriifolia* DC. var. *volkameriifolia*						1												1																								1										3
78	*Wendlandia tinctoria* (Roxb.) DC. ssp. *floribunda* (Craib) Cowan						2	1	1										1								1														1						4	5			1	1	18
Total		2	7	6	34	1	13	10	3	8	11	1	5	12	10	35	29	12	8	11	9	18	9	16	22	6	8	7	5	1	0	3	27	1	16	16	8	20	3	2	2	1	3	2	21	4	17	16	7	8	6	6	508

Appendix D

R squares of linear regressions between three parameters of remnant tree size and the density of natural seedlings, established beneath their crowns

Species	Dispersal type	Individual			Specie richness		
		Height	GBH	Canopy width	Height	GBH	Canopy width
Albizia chinensis	w	0.0326 (-)	0.0056	0.0107 (-)	0.0621 (-)	0.0127 (-)	0.0182 (-)
	a	0.6392	0.6077	0.7290 *	0.5757	0.2359	0.5227
	w+a	0.2034	0.4921	0.3301	0.1209	0.0717	0.1857
Callicarpa arborea var. *arborea*	w	0.0478	0.1647	0.0839 (-)	0.0954	0.0461	0.4297 (-)
	a	0.0232	0.0379 (-)	0.3889 (-)	0.1642	0.0054 (-)	0.3790 (-)
	w+a	0.0456	0.0015 (-)	0.3922 (-)	0.1954	0.0014	0.4707 (-)
Castanopsis diversifolia	w	0.0688	0.2829	0.4403 (-)	0.2359	0.1712	0.6590 (-) *
	a	0.1889	0.1718	0.7989 (-) *	0.1924	0.1696	0.7628 (-) *
	w+a	0.1812	0.2228	0.7421 (-) *	0.2087	0.1804	0.7245 (-) *
Erythrina stricta	w	0.1812	0.1401	0.0078	0.2671	0.2395	0.0059
	a	0.2380 (-)	0.0304	0.2148	0.4287 (-)	8.9E-05 (-)	0.0555
	w+a	0.0001 (-)	0.2215	0.2067	0.0639 (-)	0.0848	0.0751

Appendix D (continued)

Species	Dispersal type	Individual			Specie richness		
		Height	GBH	Canopy width	Height	GBH	Canopy width
Eucalyptus camaldulensis	w	0.0248	0.0017	0.1590	0.4748	0.0001	0.1884
	a	0.1580 (-)	0.4277 (-)	0.2767 (-)	5.9E-05 (-)	0.0656 (-)	0.0204
	w+a	0.1296 (-)	0.5368 (-) *	0.1238 (-)	0.0995	0.0392 (-)	0.0518
Pinus kesiya	w	0.0895	0.1885 (-)	0.3693 (-)	0.0895	0.1885 (-)	0.3693 (-)
	a	0.3980	0.1311	0.0378 (-)	0.3497	0.1074	0.1038 (-)
	w+a	0.4279	0.0744	0.0990 (-)	0.3587	0.0287	0.2492 (-)
Schima wallichii	w	0.0162 (-)	0.0031 (-)	0.0008 (-)	0.0506	0.0204	0.0371 (-)
	a	0.0253 (-)	0.1519 (-)	0.0452 (-)	0.3424 (-)	0.7884 (-) *	0.5961 (-) *
	w+a	0.0359 (-)	0.0452 (-)	0.0119 (-)	0.2161 (-)	0.5645 (-) *	0.5833 (-) *
Total	w	0.0096	0.0160	0.0084 (-)	0.0009	0.0003	0.0723 (-)
	a	0.0511	0.0282	0.0352 (-)	0.0176	0.0012	0.0984 (-) *
	w+a	0.0427	0.0310	0.0388 (-)	0.0093	0.0001	0.1291 (-) *

Remark

w wind
a animal
w+a both wind and animal
(-) negative relation
* significant difference (P<0.05)

Appendix E

Average relative growth rate (% per year) of naturally established tree seedlings (h>10 cm) in each remnant tree species plot

No.	Botanical Name	Family	*Albizia chinensis* - plots		*Callicarpa arborea* -plots		*Castanopsis diversifolia* - plots		*Erythrina stricta* -plots		*Eucalyptus camaldulensis* -plots		*Pinus kesiya* - plots		*Schima wallichii* - plots		Total		Total
			Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	
1	*Alseodaphne andersonii* (King *ex* Hk. f.) Kosterm.	Lauraceae	54.69														54.69		54.69
2	*Anneslea fragrans* Wall.	Theaceae														26.83		26.83	26.83
3	*Antidesma acidum* Retz.	Euphorbiaceae	52.63										69.58		54.70	39.60	60.49	39.60	57.88
4	*Antidesma bunius* (L.) Spreng. var. *bunius*	Euphorbiaceae	67.29			11.86							99.89		51.07	40.50	72.75	30.96	51.85
5	*Aporusa villosa* (Wall. *ex* Lindl.) Baill.	Euphorbiaceae													38.21	28.09	38.21	28.09	35.83
6	*Archidendron clypearia* (Jack) Niels. ssp. *clypearia* var. *clypearia*	Leguminosae, Mimosoideae						90.43										90.43	90.43
7	*Artocarpus lakoocha* Roxb.	Moraceae	37.55					25.15			8.98	24.28		36.84			18.50	28.75	25.34
8	*Artocarpus lanceolata* Trec.	Moraceae			52.02	32.66							26.32				43.45	32.66	40.75

Appendix E (continued)

No.	Botanical Name	Family	*Albizia chinensis* - plots		*Callicarpa arborea* -plots		*Castanopsis diversifolia* - plots		*Erythrina stricta* -plots		*Eucalyptus camaldulensis* -plots		*Pinus kesiya* - plots		*Schima wallichii* - plots		Total		Total
			Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	
9	*Baccaurea ramiflora* Lour.	Euphorbiaceae				32.63												32.63	32.63
10	*Bauhinia variegata* L.	Leguminosae, Caesalpinioideae							7.30		82.93						45.11		45.11
11	*Beilschmiedia* aff. *intermedia* Allen	Lauraceae													39.60		39.60		39.60
12	*Callicarpa arborea* Roxb. var. *arborea*	Verbenaceae													114.83		114.83		114.83
13	*Canarium subulatum* Guill.	Burseraceae													17.20		17.20		17.20
14	*Canthium parvifolium* Roxb.	Rubiaceae						31.73							41.77	25.22	41.77	27.39	34.58
15	*Castanopsis acuminatissima* (Bl.) A. DC.	Fagaceae														31.54		31.54	31.54
16	*Castanopsis argyrophylla* King *ex* Hk. f.	Fagaceae			82.25										42.19		55.54		55.54
17	*Castanopsis diversifolia* (Kurz) King *ex* Hk. f.	Fagaceae														65.37		65.37	65.37
18	*Cinnamomum longipetiolatum* H.W. Li	Lauraceae									58.12	54.09					58.12	54.09	56.78
19	*Dalbergia cultrata* Grah. *ex* Bth.	Leguminosae, Papilionoideae		25.37						2.83								14.10	14.10

Appendix E (continued)

No.	Botanical Name	Family	*Albizia chinensis* -plots		*Callicarpa arborea* -plots		*Castanopsis diversifolia* -plots		*Erythrina stricta* -plots		*Eucalyptus camaldulensis* -plots		*Pinus kesiya* -plots		*Schima wallichii* -plots		Total		Total
			Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	
20	*Dalbergia ovata* Grah. *ex* Bth.	Leguminosae, Papilionoideae	68.07					37.12			45.44	17.33			56.56	67.55	57.20	58.11	57.46
21	*Dillenia parviflora* Griff. var. *kerrii* (Craib) Hoogl.	Dilleniaceae	11.43														11.43		11.43
22	*Dimocarpus longan* Lour. ssp. *longan* var. *longan*	Sapindaceae											24.00				24.00		24.00
23	*Diospyros glandulosa* Lace	Ebenaceae			87.32	31.89	40.63				6.17				45.52		44.91	31.89	42.31
24	*Elaeocarpus lanceifolius* Roxb.	Elaeocarpaceae					32.55				150.30						91.42		91.42
25	*Eugenia claviflora* Roxb.	Myrtaceae													43.84	50.45	43.84	50.45	46.05
26	*Eugenia fruticosa* (DC.) Roxb.	Myrtaceae			28.79							46.50	82.03	58.02	61.12	61.73	57.31	57.33	57.33
27	*Eurya acumminata* DC. var. *wallichiana* Dyer	Theaceae	11.43			119.50									54.69	55.02	33.06	87.26	60.16
28	*Ficus fistulosa* Reinw. *ex* Bl. var. *fistulosa*	Moraceae				5.23												5.23	5.23
29	*Ficus hispida* L. f. var. *hispida*	Moraceae														19.08		19.08	19.08
30	*Ficus semicordata* B.-H. *ex* J.E. Sm. var. *semicordata*	Moraceae									67.81						67.81		67.81
31	*Ficus subulata* Bl. var. *subulata*	Moraceae													54.69		54.69		54.69

Appendix E (continued)

No.	Botanical Name	Family	*Albizia chinensis* - plots		*Callicarpa arborea* -plots		*Castanopsis diversifolia* - plots		*Erythrina stricta* -plots		*Eucalyptus camaldulensis* -plots		*Pinus kesiya* - plots		*Schima wallichii* - plots		Total		Total
			Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	
32	*Firmiana colorata* (Roxb.) R. Br.	Sterculiaceae							28.10								28.10		28.10
33	*Glochidion acuminatum* M.-A. var. *siamense* A.S.	Euphorbiaceae					18.50										18.50		18.50
34	*Glochidion sphaerogynum* (M.-A.) Kurz	Euphorbiaceae			43.32		34.57				45.58						39.51		39.51
35	*Gluta obovata* Craib	Anacardiaceae													26.44	55.70	26.44	55.70	45.95
36	*Gmelina arborea* Roxb.	Verbenaceae					26.25										26.25		26.25
37	*Helicia nilagirica* Bedd.	Proteaceae					32.55								32.61		32.58		32.58
38	*Ilex umbellulata* (Wall.) Loesn.	Aquifoliaceae				45.96												45.96	45.96
39	*Litsea cubeba* (Lour.) Pers. var. *cubeba*	Lauraceae	85.28	43.80	62.50	153.05		36.73			39.78	69.99			50.30	21.05	51.03	61.36	54.13
40	*Litsea glutinosa* (Lour.) C.B. Rob. var. *glutinosa*	Lauraceae								18.07								18.07	18.07
41	*Litsea monopetala* (Roxb.) Pers.	Lauraceae		99.03	123.33						39.58	65.89					50.75	87.98	56.95
42	*Machilus bombycina* King *ex* Hk. f.	Lauraceae						30.91				12.51		17.27	73.60	43.40	73.60	29.73	40.70
43	*Mallotus philippensis* (Lmk.) M.-A.	Euphorbiaceae			39.36	15.54								71.04			39.36	26.64	28.76

Appendix E (continued)

No.	Botanical Name	Family	*Albizia chinensis* -plots		*Callicarpa arborea* -plots		*Castanopsis diversifolia* -plots		*Erythrina stricta* -plots		*Eucalyptus camaldulensis* -plots		*Pinus kesiya* -plots		*Schima wallichii* -plots		Total		Total
			Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	
44	*Markhamia stipulata* (Wall.) Seem. *ex* K. Sch. var. *kerrii* Sprague	Bignoniaceae			17.07	38.87	13.89								51.96	6.17	25.00	22.52	24.17
45	*Phoebe lanceolata* (Wall. *ex* Nees) Nees	Lauraceae				49.59		90.38							47.06		47.06	69.98	62.34
46	*Phyllanthus emblica* L.	Euphorbiaceae					53.98		79.73		39.63				49.65	16.68	53.78	16.68	49.66
47	*Rhus chinensis* Mill.	Anacardiaceae			73.45	4.69	33.27								6.31		34.37	4.69	32.09
48	*Sapindus rarak* DC.	Sapindaceae	17.70														17.70		17.70
49	*Saurauia roxburghii* Wall.	Saurauiaceae	85.25		21.66												53.46		53.46
50	*Schima wallichii* (DC.) Korth.	Theaceae	78.67	80.95	19.00			68.11			61.83	31.96					60.81	66.31	65.07
51	*Sterculia villosa* Roxb.	Sterculiaceae				12.96				36.70	25.95				17.55	33.03	23.15	27.56	25.36
52	*Stereospermum colais* (B.-H. *ex* Dillw.) Mabb.	Bignoniaceae	96.98						38.44					125.83			89.56		89.56
53	*Styrax benzoides* Craib	Styracaceae	17.70			9.59		74.27							62.28	43.58	39.99	34.26	36.17
54	*Toona ciliata* M. Roem.	Meliaceae	33.64	39.86													33.64	39.86	37.38
55	*Trema orientalis* (L.) Bl.	Ulmaceae												228.24				228.24	228.24
56	*Turpinia pomifera* (Roxb.) Wall. *ex* DC.	Staphyleaceae	21.05			31.04									69.22	73.58	45.14	52.31	48.72
57	*Vernonia volkameriifolia* DC. var. *volkameriifolia*	Compositae	112.36								54.95						83.65		83.65

Appendix E (continued)

No.	Botanical Name	Family	*Albizia chinensis* -plots		*Callicarpa arborea* -plots		*Castanopsis diversifolia* -plots		*Erythrina stricta* -plots		*Eucalyptus camaldulensis* -plots		*Pinus kesiya* -plots		*Schima wallichii* -plots		Total		Total
			Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	Under crown	Control	
58	*Wendlandia tinctoria* (Roxb.) DC. ssp. *floribunda* (Craib) Cowan	Rubiaceae				37.00	36.37								40.63	69.64	38.50	61.48	56.89
Total			60.22	72.48	56.17	34.54	34.04	47.32	38.39	19.20	45.25	39.08	70.85	70.53	50.12	50.19	49.47	51.36	50.24

Appendix F

List of birds observed in this study

No.	Scientific Name	Common Name	Diet	Abundance Rating*	Seasonality*	Habitat Type*	Observed in remnant trees in deforested site	Observed in fruinting trees in intact forest
1	*Aegithina tiphia*	Common Iora	insectivore	U	N	D,S,plains to 750 m	y	y
2	*Aethopyga saturata*	Black-throated Sunbird	nectar/insectivore	C	N	E, 1000-1685 m		y
3	*Chloropsis aurifrons*	Golden-fronted Leafbird	omnivore	U	N	D, plains to 750 m		y
4	*Chloropsis hardwickii*	Orange-bellied Leafbird	omnivore	U	N	E, 900-1685 m		y
5	*Chrysococcyx maculatus*	Asian Emerald Cuckoo	insectivore	U	NM	E, 700-1685 m	y	
6	*Criniger pallidus*	Puff-throated Bulbul	omnivore	C	N	E, 700-1150 m		y
7	*Hypsipetes flavala*	Ashy Bulbul	omnivore	C	N	E, 800-1200 m		y
8	*Hypsipetes mcclellandii*	Mountain Bulbul	omnivore	C	N	E, 800-1685 m		y
9	*Lanius collurioides*	Burmese Shrike	carnivore	C	N	E, 800-1685 m	y	y
10	*Lanius schach*	Long-tailed Shrike	carnivore	U	N	S, plains to 1000 m	y	
11	*Megalaima asiatica*	Blue-throated Barbet	omnivore	C	N	E, 800-1400 m		y
12	*Myiophoneus caeruleus*	Blue Whistling Thrush	carnivore	xU	NM	D, E, plains to 1685 m		y
13	*Pericrocotus cinnamomeus*	Small Minivet	insectivore	U	N	D, plains to 850 m	y	
14	*Phaenicophaeus tristis*	Green-billed Malkoha	omnivore	C	N	D,E, plains to 1500 m	y	
15	*Phylloscopus inornatus*	Inornate Warbler	insectivore	C	M	D,E,S, plains to 1685 m	y	y

Appendix F (continued)

No.	Scientific Name	Common Name	Diet	Abundance Rating*	Seasonality*	Habitat Type*	Observed in remnant trees in deforested site	Observed in fruinting trees in intact forest
16	*Pteruthius melanotis*	White-browed Shrike-Babbler	insectivore	C	N	E, 1000-1685 m	y	
17	*Pycnonotus atriceps*	Black-headed Bulbul	omnivore	C	N	D,E, 800-900 m	y	
18	*Pycnonotus aurigaster*	Sooty-headed Bulbul	omnivore	C	N	S, plains to 1685 m	y	y
19	*Pycnonotus flavescens*	Flavescent Bulbul	omnivore	C	N	S, plains to 1685 m	y	y
20	*Pycnonotus jocosus*	Red-whiskered Bulbul	omnivore	C	N	D,E, plains to 1685 m	y	y
21	*Pycnonotus melanicterus*	Black-crested Bulbul	omnivore	C	N	D,E, plains to 1685 m		y
22	*Sitta frontalis*	Velvet-fronted Nuthatch	insectivore	C	N	D,E, plains to 1685 m	y	
23	*Treron sphenura*	Wedge-tailed Pigeon	frugivore	U	N	E, 900-1500 m		y
24	*Zosterops palpebrosus*	Oriental White-eye	omnivore	C	N	E,S, plains to 1685 m		y

Remark:

* = reference source: Round, 1984

Abundance Rating
- x = abundance estimated
- C = common to abundant
- U = uncommon to fairly common

Seasonality
- N = non-migrant resident
- M = migrant or winter visitor

Habitat Type
- D = deciduous forest
- E = evergreen forest
- S = secondary growth, scrub, or grassland

CURRICULUM VITAE

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