RELATIONSHIPS BETWEEN FOREST REGENERATION AND GROUND FLORA DIVERSITY IN DEFORESTED GAPS IN DOI SUTHEP-PUI NATIONAL PARK , NORTHERN THAILAND

BHIM PRASAD ADHIKARI

MASTER OF SCIENCE IN
ENVIRONMENTAL RISK ASSESSMENT FOR
TROPICAL ECOSYSTEMS

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19 MARCH 1996

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Thesis Title Relationships Between Forest Regeneration and Ground Flora Diversity in Deforested Gaps in Doi Suthep-Pui National Park, northern Thailand

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M. S. Environmental Risk Assessment for Tropical Ecosystems (ERA)

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ABSTRACT

Interactions between tree seedlings and herbaceous vegetation are widely assumed to be important factors affecting the growth and performance of seedlings. However, few experimental studies have been conducted to investigate the importance of such phenomena. This study was carried out to determine if the herbaceous ground flora in deforested areas can be used to indicate the suitability of sites for the natural establishment or planting of various tree seedling species. It examined recruitment (density, relative growth rate, mortality), species composition, diversity and richness of the natural tree seedling community and their association with the herbaceous ground flora vegetation communities on deforested sites. Three major types of dominant ground flora communities were selected for the quantitative investigation (*Eupatorium adenophorum* Spreng. (Compositae); *Imperata cylindrica* (L.) P. Beauv. var. *major* (Nees) C.E. Hubb. ex Hubb. & Vaugh. (Gramineae); *Pteridium aqilinum* (L.) Kuhn ssp. *aquilinum* var. *wightianum* (Ag.) Try.(Dennstaedtiaceae) and two additional sites were selected for qualitative study i.e. *Imperata cylindrica* dominated site, and mixed ground flora species (*Pennisetum pedicellatum* Schumach.(Gramineae); *Setaria parviflora* (Poir.) Kerg., *Microstegium vaganas* (Nees ex Steud.) *A. camus* (both

Gramineae), and *Eupatorium adenophorum*. A total of 48 quadrats of 2 X 2 m were laid down in 50 X 50 m. permanent plots. The quadrats were inspected every 2 months over 10 months.

Tree seedling diversity (N1) was highest in the *Eupatorium*-dominated site (10.23) followed by the *Imperata*-dominated site (7.52) and the *Pteridium*-dominated site (5.59). Moreover, the *Eupatorium* site had the lowest seedling mortality (21.7 % over 10 months) followed by the *Pteridium* site (25.7 %) and the *Imperata* site (30 %). For most tree seedlings species, growth rates were highest in the *Eupatorium* site and lowest in the *Pteridium* site. There were no significant associations between any of the tree seedling species found in the *Imperata* and *Pteridium*-dominated sites with the dominant herbaceous ground flora species and in the *Eupatorium*-dominated site, only three tree seedling species [*Castanopsis diversifolia* King ex Hk. f. (Fagaceae), *Leea indica* (Burm. f.) Merr. (Leeaceae) and *Phoebe lanceolata* (Nees) Nees (Lauraceae)] showed significant association. There were no significant differences among sites in soil parameters. Out of the four vegetation types, *Eupatorium adenophorum* seems to provide the best conditions for tree seedling establishment and growth and provides a reliable indicator for success of *C. diversiflolia*, *L. indica* and *P. lanceolata* seedlings. In general, however, dominant ground flora did not provide a reliable indication of the tree seedling community or the soil conditions, since few positive associations were found and the soil conditions were very similar at all three sites.

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CHAPTER 1
INTRODUCTION

Thailand has experienced rapid deforestation over the past three decades. Like other developing nations, Thailand has high rates of population growth and economic growth, resulting in severe degradation of natural resources. These trends are reflected in the decline of nearly one half the country's entire forest, from 54 % to less than 28 % cover today (Poffenberger and McGean,1993). But in reality, remaining natural forest may be as low as 20 % or even less. Primary forest has been almost been completely destroyed due to heavy logging, encroachment and development. Forests in northern Thailand, the most deforested region, decreased from 7.4 million hectares in 1961 to 3.2 million hectares in 1978 and to 2.88 million hectares by 1988 (Leungarameri and Rajesh, 1992). Furthermore, between 1976 and 1980 Thailand's annual deforestation was 333,000 ha., almost twice the rate in 1980. According to the Lanely's data (1982) the rate of deforestation was 4.33 % per year. The continued deforestation in northern Thailand has been a result of the expansion of farming area for export cash crop like jute, corn and cassava.

Illegal logging remains one of the major causes of forest destruction in Thailand. The history of logging in northern Thailand began with teak concessions and the subsequent growth of the timber business. Thailand's forests were viewed as an economic resource to be exploited, particularly the teak forests in northern region which was under the control of autonomous local chiefs (Leungarameri and Rajesh, 1992). During the late 19th century, the economic value given to forest resources was clearly reflected in the increasing conflicts over the control of teak between the local regimes in the north and the central administration. Over the century, the country's forests have been systematized for commercial exploitation under the jurisdiction of the Royal Forestry Department. By 1969, about 516 concessions were granted to state enterprises and private agencies covering 150 million rai of the country with a total land area of 321 million rai. The state enterprises and private agencies were allowed to exploit the forest through the concession system under a 30 year contract. It was a very unfortunate period when intensive logging caused large scale destruction of the forests of Northern Thailand. In one concession area alone in Sumoeng District of Chiang Mai Province, the rate of logging almost tripled in only one year, increasing from 789 logs extracted in 1986 to 2316 logs in 1987 (Leungarameri and Malapetch, 1992). Large scale deforestation during that period led to widespread protests from people in various provinces throughout the country. These protests were especially strong from rural villagers in the mountain watersheds of the northern region where logging was responsible for the destruction of catchment areas and traditional agroecology that were crucial for the subsistence of rural people. Rapid deforestation caused by logging concessions has become a major environmental issue in the country. Many local conservation organizations and institutions organized protests calling on the government to take immediate action to protect the remaining forest area which had dwindled to less than 29 % of the total land area.

Northern Thailand is a region with the highest proportion of forest area and has consequently been the region with the highest rate of illegal logging. Logging companies were drawn to the north because of the abundant forests, the low costs, and lack of pressure involved in illegal logging. The booming tourism industry in the north has also created conditions for the growth of furniture and crafts. All of the tourism oriented provinces in the north, including Chiang Mai, are centers for forest resource based industries. About 32 million ha. were reforested in 1950, but by 1985 natural forest had been reduced to 14.4 million ha with the rate of deforestation at about 1.44 % per year (Flaherty and Filipchuk, 1993). Intensive logging has also destroyed the protected areas in the northern region. For example, Doi Suthep-Pui National Park has lost about a third of its forest cover and Doi Inthanon nearly half (Elliott *et al.*, 1993).

After a long history of forest degradation and responding to concerted pressure from people all over the country, the Thai Government promulgated an emergency decree that revoked all timber concessions and declared a total logging ban throughout the country. The national forestry policy of Thailand was prepared after the logging ban with a target area of 40 % forest cover in Thailand. Basically, the policy was divided into two parts: forests for conservation and others for commercial production. The policy emphasizes the role of business and the private sector in helping the government program aimed at reforestation of areas classified as production forests, more than half of which is "degraded forest land". Between 1964 and 1966, 30.21 million baht or 24 % of the Royal Forestry Department's budget was specially allocated for reforestation projects (Koohacharoen,1992). Nevertheless, the rate of deforestation was much higher than the attempted reforestation. During the period of 1961-1969, 63 million rai of forest land was deforested (4.8 million rai annually), but only a little more than two million rai in total was replanted from 1960 to 1986.

In the fifth national economic development plan (1982- 1986) , the government targeted an annual planting area of 300,000 rai of "economic forest". The large target area of the plan encouraged the private sector to participate in reforestation activities. Furthermore, in March 1984, the government passed a resolution to promote private sector reforestation with the hope of increasing support and participation from the private sector. Government promotion of private sector participation in reforestation was ostensibly aimed at meeting the domestic wood demand for housing and fuelwood. However, the private sector, consisting of Thai and multinational companies, introduced plantations of the fast -growing species like *Eucalyptus* spp. (Myrtaceae) to provide raw materials for the pulpwood and paper industries. The reforestation program, characterized by large eucalyptus plantations, grew into a major controversy in Thailand and was strongly opposed by villagers and NGOs. The villagers opposed the reforestation program because eucalyptus trees were responsible for adverse social and environmental impacts. In many areas, the eucalyptus plantations have been found to deplete the ground water supply, threatening irrigation and agriculture. *Eucalyptus* monocultures provide meager benefits to local people in terms of fuel and fodder needs.

With the accelerating destruction of natural forests and huge losses of biological diversity, the government and the private sector are gradually becoming aware of the need to conserve Thailand's remaining forests. Forest restoration and watershed protection are becoming priorities for further research and education. The Thai government is implementing a large scale tree planting program on the occasion of His Majesty's the King's golden jubilee in Thailand in 1996. Various private sector companies as well as non- governmental organizations have been invited to participate in a forest conservation and reforestation programmes. Consequently, there has been enthusiastic support for several forest restoration projects.

However, a lack of knowledge of the habitat requirements of individual tree species is a major constraint to restoring natural forest ecosystems. Although there is a growing awareness of the need to accelerate natural forest regeneration, there is a lack of knowledge of which tree species can successfully be planted on each site. Furthermore, the best criteria by which to select tree species for rapid and cost-effective afforestation programs are not yet known. There is very little knowledge of the suitability of native tree species for forest restoration programs and the full potential of many species has not yet been investigated. This is partly due to insufficient research on species site requirements (Srivastava, 1992). It is essential to determine which species perform best in any particular locality. The quality of a site must be known in order to avoid planting species that have no chance of thriving there (Toumey and Korstian, 1948). The life cycles, ecological requirements, competitive ability, and proper sites for each species must be determined in order to improve forest restoration programmes. We know almost nothing of the autecology of most of the world's valuable tropical tree species (Gomez-pompa and Burley, 1991).

In Europe, extensive research has enabled ground flora to be used to assess site condition and site quality. Effective systems have been developed and are working well there (Whitmore, 1995: pers. comm.). It is suggested that under natural conditions some indicator pioneer species, comprising the herbaceous ground flora, may be associated with site conditions. Indicator species are those sensitive to physical conditions. Their presence and relative abundance indicate the quality of particular sites and the suitability of sites for different tree species. Thus, a better and more comprehensive understanding of these relationships would be particularly important for assessing suitable species for forest restoration programmes. To date, the use of ground flora to indicate the site condition and their possible association with tree seedling in humid tropics has not been investigated. The growing interest in large scale afforestation and restoration programs demands suitable criteria for the selection of appropriate tree species. Simple observations of dominant ground flora species could provide a rapid and simple method to assess the niches available to individual species and provide better understanding of species suitability.

THEORY / HYPOTHESIS

Ground flora species can indicate which tree species can be successful on each site because there are stable relationships between the ground flora species composition and soil conditions and suitability of the site for certain tree species. Plants respond to the combined effects of many different environmental factors including nutrients, moisture, light, temperature, etc. The presence/ absence or abundance of ground flora species, therefore, indicate the integral of all these factors, i.e. the overall site condition. Recording the presence/ absence or abundance of plant species is much easier than measuring each environmental factor individually and then determining their combined effects on the growth of various tree seedling species.

However, the use of ground flora species to indicate site quality presupposes that stable relationships exist between the plants and the environmental factors determining plant growth. Thus, carrying out rapid surveys of the ground flora could provide guidance as to which tree species to plant on which site. This project attempts to determine whether such stable relationships exists.

Various authors have described the ecological processes and interspecific associations that may result in positive and negative association among species. Schluter (1984) and Ludwig and Reynolds (1988) described the four different interactions among species, i.e. no interaction, mutualism, competition, and predation. Table 1 summarizes these interactions.

Table 1. 1 Ecological processes and interspecific interactions that may result in positive and negative association among species

Negative Association	Positive Association
1. Species have different resource requirements	Species have same response to supply of unlimited resources
2. Interference between species and exclusion	Species fluctuate in unison in response to limited resources
3. Resource competition and exclusively by species	Species enhance each others existence
4. High predator densities produce a local depression of prey	Predator population fluctuate positively in response to variation in prey population

After: Schluter (1984) and Ludwig and Reynolds (1988)

In spite of the high ground flora diversity of Doi Suthep-Pui National Park (Chiang Mai Province, Thailand), research regarding the various aspects of ground flora diversity and its possible linkage to forest regeneration is quite limited. A few studies concerning forest regeneration have been carried out there. Although Elliott *et al.*, (1989) carried out a study of species composition and diversity of tree species, there is considerable scope for further research regarding the association among herbaceous vegetation and tree seedling species. Karimuna (1995) compared the ground flora diversity among types of tree plantations and primary forest and found the highest diversity in natural forest . However, his study did not explore the possibilities that dominant ground flora vegetation could be a good indicator of the suitability of the sites for certain tree seedling species. Thus, research on forest regeneration and ground flora dynamics is urgently needed for Doi Suthep-Pui National Park, to accelerate conservation activities and the forest restoration programmes. It is essential to explore the possibilities that dominant ground flora species could indicate the site conditions and ultimately the suitability of tree seedlings in a particular site which will help foresters, ecologists, and land managers in the selection of appropriate tree species for large scale reforestation projects. Moreover, such information will help avoid planting of the wrong species which have a minimum chance of survival in any particular site. This project, addresses the problem regarding the selection of appropriate tree species, by observing the dominant ground flora and their association patterns with tree seedling species.

CHAPTER 2
LITERATURE REVIEW

A proper understanding of natural succession processes can play an important role in analyzing basic biological problems. As claimed by Richard (1952) and noted by Riswan and Kartawinata (1988) the study of secondary succession is an essential requirements for determining a rational system of land-use in the tropics. To date, secondary succession studies in the tropics have been limited to a few areas.

Forests can be considered as a dynamic mosaic of vegetation patches of different ages produced by disturbances and influenced by different abiotic and biotic conditions (Martinez-Rames *et al.,* 1989). As stated by Watt (1947) and noted by Rames (1989), three main phases, viz. gap, building and maturity have been recognized in the forest regeneration cycle. Whitmore (1989) and Swine and Whitmore (1988) have placed tropical trees in either of two categories defined by their light requirements for germination and establishment. Light demanding pioneer species germinate and grow to maturity in gaps, while non -pioneer species can germinate and establish primarily in shade.

Connell (1989) claimed that there is incomplete knowledge of the origin of colonists of gaps, or of how recruitment, growth, and survival of colonists in these gaps vary as functions of density or frequency. Also there is no knowledge of how herbaceous vegetation interacts with other natural tree seedlings that determine the potentiality of a site for certain species. There is need to study the mechanisms affecting the population dynamics of individuals both inside and outside gaps to achieve a fuller understanding of forest ecology.

Concentrations of annual plants amongst shrubs, or in the openings of semi arid communities have often been observed (Shreve, 1931; Went, 1942; Muller, 1953; Adams *et al.,* 1970). Such patterns of annual plants are an integral expression of the effects of some plant populations on others (Muller and Muller 1956; Muller *et al.*, 1964; Rice, 1974) as instances of mosaic like structure in communities (Wiens, 1976; Whittaker and Levin, 1977) and for their bearing on species diversity. Characteristic patterns of association between some kinds of plants and dissociation between others are widely known (Muller and Muller, 1956). Some of these phenomena have been investigated critically while others have not. Data collected in the field by Cooper and Stoesz (1931) indicated a "fairy ring" effect of *Helianthus scaberrimus* (Compositae). There were very few plants in the central area but a large number of closely spaced plants formed another ring (4-5 m diameter). They also noted that the outermost individuals in the ring were taller and more floriferous than those inward from the outer margin. Curtis and Cottam (1950) investigated this phenomenon and demonstrated that an antibiotic action of a chemical nature was involved.

These data and observations might well suggest that biochemical control is widespread and that the complexity of plant communities is frequently the result of degrees of toxin production by some plants and of toxin tolerance by others. Indeed, it is in one sense true, for all plants come in contact with the metabolic byproducts of their neighbors. These products may be harmful, helpful, or of no effect, depending upon the tolerances of the associated species (Muller and Muller, 1956).

The plants of a community may be interpreted as occupying a mosaic of microsites (Whittaker, 1975). Once established, a plant excludes others from its microsite. The microsites are not bordered, they overlap with one another, expand with growth of plants, and differ in scale with species. Herb microsites are within those of canopy plants. Some other microsites potentially suitable for seedlings are normally unoccupied. Under certain conditions, two or more species populations can coexist in a stable flow of their reproduction through a mosaic of microsites that are not differentiated (Skellam, 1951). For annual plants, Herb's produce a strong and relatively stable pattern of microsite differentiation, in which different fractions of species seed pools germinate and mature in different parts of the pattern and in different years.

Further study is needed to determine the degree to which observed species population responses are consistent in different communities on different soils and in the climatic conditions of different years (Shmida, 1981).

Gleason (1926) revealed that a community of plants and animals was formed by the chance dispersal of propogules into an area and their subsequent differential mortality because of environmental factors. Moreover, the dispersion and commonness of each species is, in general, different from the distribution and abundance of any other species. Poole (1974) stated that not all species populations are independently distributed in a community. There are significant associations, both positive and negative, between many species of plants due to interactions between the species or to similar responses of species to the same environmental variables. For example, if two plant species both need selenium- bearing soils, they will be positively associated . Furthermore, in some cases one species will create conditions necessary for the survival of another. Common examples are many herbaceous plants found in forests, which are dependent on the trees for their existence (Poole, 1974). In some cases a herb may be dependent on a single species of tree.

Watt (1973) discussed that the particular association of plant species found at any point is fundamentally determined by only three factors: temperature, precipitation, and moisture, the last being dependent on the other two. Groups of plant species associations can be defined on the basis of the three named climatic variables, and these groups are called life zones. These zones refer to certain type of plants and also to the ranges of moisture and precipitation which produce them. Thus, one can determine the range of weather conditions operating in a certain site on the basis of field inspection of the plant associations there. Moreover, it implies that one ought to be able to go anywhere in the field and, having sufficient information about the association pattern, predict what type of plant community will be growing naturally on a particular site and, especially, what type of plants should be attempted to grow there.

Toumy and Korstian (1948) mentioned that the particular character of herbage and shrubs present is indicative of both atmospheric and soil conditions. Thus, a luxuriant growth of sagebrush denotes a fertile soil, but one which is generally deficient in moisture and certain species are indicative of alkaline soils. Ericaceous shrubs indicate acid soils, and cacti and other succulents indicate arid soil. Thus, the lesser forms of vegetation enable us to interpret site factors and judge the particular species of tree that are most likely to succeed.

Information on the productivity of ecosystems is an essential tool for sustained yield forest management. Forest productivity is correlated to site conditions and, without deep knowledge of site quality, sustained yield management cannot be performed. Direct measurement of site quality can only be obtained from accurate, long term records of establishment and long term growth pattern of stand growth. Generally, site quality is estimated using indirect methods. The most common of a wide range of methods use tree, environmental, or understorey vegetation information (Spurr and Barnes, 1980, Green *et al.,* 1989).

As defined by the Society of American Foresters (1971), site refers to "an area considered in terms of its environment, particularly as this determines the type and quality of the vegetation the area can carry". Sites may be classified qualitatively into site types, by their climate, soil and vegetation; or quantitatively into classes, by their potential to produce primary wood products. The presence or absence of certain groups or their association according to dominance can be used to classify the site.

The assessment of site quality in terms of productive capacity for certain species can be predicted by tree height. The height of a specified sample of trees in a stand at a reference age is used to determine site index - an empirical gauge of a site's capacity to support forest growth (Green *et al.,* 1989). However, there is a direct relationship between stand density and tree height. The assessment of site quality from tree height cannot be a universal approach, because the value of the site index, as an estimate of productivity, depends on several factors (Green *et al.,* 1989):

- the stand should be dominated by the species for which productivity is being assessed,
- the stand should be even-aged and have a closed canopy, and
- the trees measured must be free of visible damage

If these criteria are not met, height and age measurements of site trees may produce inaccurate results and alternative methods of estimating site quality are required. Understorey species with relatively narrow ecological amplitudes can be good indicators of site quality and therefore, may serve as useful indices of forest productivity (Green *et al.,* 1989). Plants act as "phytometers" of site quality by integrating many growth-related factors which are difficult to measure directly (Major, 1951; Daubenmire, 1976 and Green *et al.,* 1989). The use of lesser vegetation to indicate site quality was developed in Canada, North America (Minore, 1972; Pfister and Arno, 1980; Corns and Pluth, 1984; Green *et al.,* 1989) and in Europe (Cajander, 1926; Arnborg, 1964; Ellenberg, 1976; Jahn, 1982). However, vegetation alone does have limits due to its response to understorey light conditions, disturbance, and chance (Spurr and Branes, 1980; Green *et al.,* 1989). Thus, multifactor, ecological classification approaches which integrate relatively stable plant communities with the basic elements of site quality climate, soil moisture, and soil nutrients offer the most promising basis for estimating productivity (Green *et al.,* 1989).

Site is a complex of physical and biological factors of an area that determines what forest or other vegetation it may carry (Avery, 1986). It is also a measure of the relative productive capacity of a site for a particular species. As stated by Chaturvedi and Khanna (1985), every site gives a different growth response to different species. Knowledge of this inter-relationship can help a forester in utilizing the growth potential of a site to its optimum level. Site quality can be evaluated by measurement of either site factors or vegetative characteristics (Chaturvedi and Khanna, 1985).

The biogeoclimatic ecosystem classification (BEC) system is a good approach to assess site quality. In the BEC system, indirect synoptic measures of climate, soil moisture, and soil nutrients are used to characterize site quality. In other words, soil moisture and nutrient regimes would be the most desirable situation for the study of relationships between site index and ecological site quality. The system, originally developed by V. J. Krajina and his students (Karjina, 1972 and Green *et al.,* 1989), has been adopted and enhanced by the British Columbia Forest Service. In British Columbia, the BEC system is widely used by forest researchers and managers to recognize different types of forest sites and to characterize their quality (Krajina, 1972, Pojar *et al.,* 1987; Klinka and Carter, 1990). To assist forest managers in selecting the most suitable crop species and silvicultural regimes, recent research efforts have focused on (a) determining potential productivity of different tree species on different sites and (b) examining the usefulness of the classification for studies addressing relationships between site quality and potential productivity (e.g., Carter and Klinka, 1990a and b; Green *et al.*, 1989; Klinka *et al.*, 1989a).

Site quality has been defined as the sum of all environmental factors affecting the biotic components of an ecosystem. The study of single factors cannot evaluate and predict their integrated effect on plants. Different combinations of factors can have similar effects on plants because of compensating effects. These numerous factors can be reduced to three synoptic ones: climate, soil moisture, and soil nutrients (Cajander, 1926; Pogrebnyak, 1930; Hills, 1952; Major, 1951; Bakuzis, 1969; Krajina, 1969; Damman, 1979; Klinka and Carter, 1990). These factors have direct and major influence on plant establishment, survival and growth, and are used by the biogeoclimatic ecosystem system classification to define site quality. This approach helps us to understand plant-site relationships. Sites with the same quality rating are considered to be biologically equivalent (Cajander, 1926) or ecologically equivalent , and have the same vegetation and productivity potentials (Klinka and Carter, 1990).

According to Smith (1986), species composition can also be used to assess potential productivity, limitations set by environmental factors, and species suitability. The best known method, originally developed in Finland, involves use of the lesser vegetation that grows beneath tree stands. The principle behind this appears to be that some of the small plants are much more sensitive to variations in site factors than large trees. Some such plants have high indicator significance while others, presumably highly adaptable, have little. However, a limitation is that this mode of classification seems to be most successful where climatic conditions are restrictive (Smith, 1986).

As stated by Daubenmire and Daubenmire (1968); Steele *et al.*, (1981) and Smith (1986), there has been some success with what is termed habitat classification in which late successional plant communities are used as the basis of what amounts to site classification. Understorey shrubs and other lesser vegetation are of high diagnostic importance. There are, for example, large areas covered with Douglas-fir but much information can be obtained about the site, without measuring trees or digging soil pits, by noting whether the understorey has sword ferns or rhododendrons.

Tree species that are closely restricted to good or poor site conditions also make good indicators (Leak, 1980 and 1982). This mode of site analysis works best where species composition is mostly the result of natural processes. For example, in northwestern Pennsylvania, black cherry seedlings occurring in low-density stands, are characterized by a dense ground cover of grass and forbs (nongraminoid perennial herbaceous plants), grow slowly and soon die (Horsely, 1977).

Sharma (1994) mentioned that plants species and communities serve as a indicators of the environment. If plants serve as indicators, they are called plant indicators. Every plant is a product of the conditions under which it grows and is, therefore, a measurement of the environment. Moreover, the dominant species in a particular area are the most important indicators as they receive the full impact of the habitat for over longer periods. Consequently plant communities are more reliable indicators than individual plants. Luxuriant growth of some taller and deeply rooted grasses like *Psoralea* indicates a sandy loam type of soil, whereas the presence of grasses such as *Andropogan* indicates sandy soil. *Rumex acetosella* indicates an acid grassland soil, whereas *Spermacoce stricata* thrives in iron-rich soil. Plants like *Chrozophora rottleri*, *Heliotropium supinum* and *Polygonum plebejum* grow better in low-lying lands. Grasses like *Saccharum spontaneum* prefer to grow in poorly-drained soils. Plants such as *Artemisia tridentata*, *Kochia vesrita*, *Salicornia utahensis* and *S. rubra* indicate saline soils. *Capparis spinosa* and *Carissa spinarum* indicate intense soil erosion. Thus the lesser types of vegetation can be a good indicator of soil type and other soil characteristics (Sharma, 1994). Individual species acting as indicators as well as some plant and animal communities can be indicators of certain conditions. The characteristic flora of serpentine soils, which are low in calcium and high in magnesium, is a good example of a plant indicator community (Spellerberg, 1992).

As stated by Spurr and Branes (1980), the presence, relative abundance, and relative size of the various plants in the forest reflect the nature of the forest ecosystem of which they are a part of and thus may serve as indication of site quality. As stated by Schlenker (1964), Seblad (1964) and noted by Spurr and Branes (1988), each site unit is characterized by a local overstorey type and in addition is floristically delineated through the use of ecological species groups. Each group is composed of several plant species which, because of similar environmental requirements or tolerance, indicate certain site-factor complexes, for example soil moisture or soil acidity gradients. However, a site index is not an appropriate guide for determining silvicultural practices for regeneration and care of stands. Therefore, site quality study and site classification using vegetation and physical site factors have attracted universal attention (Spurr and Burton ,1980).

Site quality, generally, is measured by the maximum biomass the land can produce in a given time. Measurement of maximum biomass, however, is not possible for most forest areas. Therefore, indirect methods are applied, most commonly the site index method or methods employing environmental factors, as indices of site quality (Klinka and Carter,1990). Relationships between environmental factors and site index have been examined in many studies. The approaches and results of these studies were reviewed by Jones (1969), Carmean (1975), Baker and Broadfoot (1977) , Fries (1978), Spurr and Barnes (1980), Hagglund (1981), and Monserud (1984,1987).

The quality of a particular site is determined by more than one factor. While it is fairly easy to work with individual environmental factors, it is very difficult to determine their integrated effects on plants. Because of compensating effects, sites with different combinations of individual environmental factors can have similar ecological qualities (Bakuzis, 1969; Damman, 1979). To circumvent this problem, ecologists and physiologists have identified four primary factors that directly influence plant establishment, survival, and growth: climate (light and temperature), soil moisture, soil nutrients, and soil aeration (Cajander, 1926; Pogrebnyak, 1930; Major,1951; Hills, 1952 ; Krajina, 1969; Tilman, 1988; Grier *et al.*, 1989; Kozlowski *et al.,* 1991; Wang *et al.*, 1993).

The use of site factors to devise a lodgepole pine and interior spruce site index in the sub-boreal Spruce zone in British Columbia was attempted by various researchers. To establish links between ecological site quality and forest productivity, Wang *et al.* (1993) analyzed site index and site data from 93 lodgepole pine and 77 interior spruce stand areas . Strong and meaningful relationships were obtained when categorical measures of ecological site quality were used as independent variables to describe lodgepole pine and interior spruce site index in the SBSdk and SBSmc subzones. The most useful variables were the soil moisture regime and soil nutrient regime. Biogeoclimatic subzones did not improve performance of the edatope models.

The ability to express quantitatively the extent to which two species do or do not co-occur (in a series of quadrats, samples etc.) is a useful tool for ecologists. Several coefficients have been proposed to measure the degree to which the observed member of joint occurrence expected on the basis of chance alone (Hurlbert 1969). Coel (1949) proposed a coefficient of interspecific association (C7) which later was found biased in that it is influenced by species frequencies. Goodall (1953) and Willams and Lambert (1959) have employed chi-square as a measure of association in their attempts. Again it seems a poor measurement of association ; being dependent on the species frequencies and on the total number of quadrats. Therefore a measure of association will be of greatest value when it is calculated at each of several quadrat sizes (Kershaw, 1960; 1961; 1963; Greig-Smith, 1952). Since the use of several quadrat sizes is also recommended for the study of single-species distribution patterns (Greig-Smith, 1952; 1964; Kershaw,1963) and for the study of competition, it will be efficient and valuable for association, distribution and competition to be studied simultaneously.

Ecological communities are composed of different coexisting species. Ludwig and Reynolds (1988) mentioned that coexisting species utilize common resources and species having similar patterns of resource usage may be thought as having a high degree of overlap and species with dissimilar usage patterns have low overlap. Various studies have been attempted by community ecologists to understand how coexisting species utilize common resources. This type of coexistence can be measured in terms of the degrees to which species utilize common resources. Association analysis is concerned only with measuring how often two species are found together in the same locations. This affinity (or lack of it) for coexistence is tested by examining if the occurrence of the species in a series of sampling units is greater than or less than what could be expected if they were independent. If either positive or negative association is detected, it is possible to measure the strength of this association with indices (Ludwig and Reynolds, 1988). Association analysis is based relied on presence/ absence data from sampling units. If a sample contains quantitative measures of species abundance, the covariation in abundance between species can be determined. For example, if the abundance of one species always decreases when the other species increases, there might be some type of causal negative interaction (Ludwig and Reynolds, 1988).

Species interactions are an area of central importance in the understanding of the ecology of a species. Hubalek (1982) proposed that an association between two species exists because (1) both species select or avoid the same habitat or habitat factors; (2) they have the same general abiotic and biotic environmental requirements; (3) one or both of the species have an affinity for the other, either attraction or repulsion. The interspecific association analysis method is based solely on the presence or absence of species in a collection of sampling units which utilizes binary data where presence of species is indicated by 1 and absence zero. This involves two distinct components, first is a statistical test of the hypothesis that two species are associated or not, under some predetermined probability level and the second is a measure of the degree or strength of the association. These should be regarded as separate characteristics of an association (Ludwig and Reynolds, 1988).

The size and shape of sampling units influence the outcome of association analysis. According to Ludwig and Reynolds (1988) this dependency can be minimized if the selection of sampling unit is made relative to the size, shape, and spatial distribution of species under study. The sampling unit must be large enough to potentially include at least one individual of each species and yet not so large that one of those species is included in every sampling unit (Greig-Smith, 1983). There are different kinds of sampling units like plots, quadrats and lines. Southwood (1992), Ludwig and Reynolds (1988), and Goldsmith *et. al.*, (1986) indicated that quadrats are the most commonly used sampling unit to survey tree seedlings and ground flora communities.

The properties of various indices are another important consideration in the measure of the degree of association between pairs of species. Hubalek (1982) reviewed the properties of 43 indices that have been used to measure the degree of association. Hubalek identified five "admission conditions" to select the best indices and the indices that were unable to satisfy any of these conditions were excluded for further consideration. The remaining admissible indices were then compared against eight optional criteria in order to select the best association indices. Janson and Vegelius (1981) conducted a similar type of study in which the characteristics of 20 association indices were examined over six "admission" criteria. Ludwig and Reynolds (1988) mention five important conditions of association indices: 1) each association index should reach its minimum value at a = 0, when the two species are never found together, 2) the maximum value of index should be when both species always occur together, that is, b = c = 0, 3) the association index should be symmetric, that is, the value of index should be the same regardless of which species is designated "A" or "B", 4) the index should be able to discriminate between positive and negative associations, 5) the index should be independent of d, that is, the number of joint species.

Hubalek (1982) found six association measures to satisfy these admission conditions and Janson and Vegelius (1981) found three that generally performed well. Three association indices- the Ochiai, Dice and Jaccard are the best indices to perform association analysis. These indices are equal to 0 at " no association" and 1 at "maximum association". The Ochiai index is based on the geometric mean whereas the Dice index is based on the harmonic mean. The Jaccard index is the number of sampling units where both the species occur as a proportion of the total number of sampling units where at least one of the species is found. Goodall (1973) took repeated samples from a population with known species in order to determine the sampling properties of a number of association measures and computed the mean and variance of each index. Jaccard's index was found to be generally unbiased even at small sample sizes (N

= 10). The Dice index tended to underestimate the true population values at small samples, but it performed better at larger sample sizes (Ludwig and Reynolds 1988).

Fager (1957) demonstrated that if two species are rare and therefore both are absent from most of the samples, a high level of association will be found. Conversely, if two species occur in most of the samples and so are nearly always found together, no association will be shown with these methods. The interspecific association should be based either on presence or absence data or on abundance (Southwood 1966). However, Hurbert (1971) pointed out that, presence- absence data is preferable if it is desired to measure the extent to which two species requirements are similar and interspecific association may lead to a "misleading" lack of association if the measure is based on abundance.

Cluster analysis can also be used in the field of vegetation analysis. It is a classification technique for placing similar entities or objects. The cluster analysis model used to place samples into cluster, which are arranged into hierarchical treelike structure called a dendogram (Ludwig and Reynolds 1988). Moreover, this method is computationally efficient once the distance matrix (D) is calculated, since it contains all the information needed to cluster the sampling units. The various clustering processes operate on the D matrix of all possible pairwise combinations of distance between sampling units. Cluster analysis has been widely applied by various researchers for the study of plant communities e.g. Lance and Williams (1967) Ludwig and Reynolds (1988), Elliott *et. al* (1989) Suwannaratana (1994) and Karimuna (1995). Extensive reviews of various cluster analysis methods are described in Anderberg (1973), Gauch (1982), Goodall (1978a), Orloci (1978), Pielou (1977, 1984), Romesburg (1984), Sneath and Sokal (1973), Whittaker (1978b), and Ludwig and Reynolds (1988).

Objectives

The main objectives of this study were;

1. To determine the diversity, abundance, and species composition of tree seedlings in different regenerating gaps dominated by different ground flora and their possible relationships or associations with ground flora.

2. To determine if ground flora species composition can be used as an indicator of site quality and thus facilitate appropriate tree species selection for forest restoration programs.

3. To assess the existing site quality in relation to dominant ground flora and finally to develop a site quality index based on indicator species.

CHAPTER 3
STUDY SITE DESCRIPTION

3.1 Introduction

The study area was located in Doi Suthep- Pui National Park few km west of Chiang Mai City at approximately 18^0 50' N latitude, 99^0 0' E longitude. The area was designated a national park in 1981 and covers an area of 261 km^2. The highest point is the summit of Doi-Pui which is about 1685 m above the mean sea level.

There is a remarkable variation of rainfall and temperature from the base (350 m) to the summit of the mountain. At the base of the mountain, temperatures are relatively high and rainfall is low so the soil holds little moisture. The higher slopes of the mountain (above 900 m) receive higher rainfall and experience lower temperatures. Annual rainfall varies from 1000 mm/year on the lower slopes to approximately 2000 mm/ year near the summit (Elliott *et al.*, 1989). Peak rainfall occurs in August during the rainy season. There is also a marked dry season from December to March with little or no rainfall. The cool dry season starts from November and ends in March, when mean temperatures at the base of the mountain are 20 - 24^0 Celsius. Mean temperatures rise sharply and reach a peak in April at about 30^0 Celsius. Temperatures at higher elevations are relatively cooler than at base of the mountain. Granite bedrock is found in most areas, while shale occurs in a few lowland areas. The forests are not influenced by the bedrock. However, the soils are a major factor influencing the kind and distribution of the vegetation on the mountain (Maxwell, 1988). Soils are deep and highly weathered.

Maxwell (1988) described two basic kinds of forest in the national park, viz. deciduous forest which extends from base of the mountain at 350 m elevation to between 850- 950 m elevation and evergreen forests which are confined above 950 m to the summit of the mountain. Furthermore, he described two different associations of deciduous forest i.e. the deciduous-dipterocarp- oak association and mixed deciduous + evergreen association.

The primary evergreen forest of Doi Suthep extends from 950 m elevation to the summit of Doi Pui. Higher amounts of rainfall, higher primary productivity and consequently high organic matter content in the soil favors the growth of large trees as such *Sapium baccatum* Roxb. (Euphorbiaceae) which reaches up to 30 m in height. Some common understorey species are: *Lasianthus lucidus* Bl. (Rubiaceae), *Psychotria ophioxyloides* Wall. (Rubiaceae), *Euodia triphylla* DC. and *Glycosmis puberula* Lindl. ex Oliv. var. craib. (Tana.) Stone (both Rutaceae). There is a maximum diversity of herbaceous ground flora in the primary evergreen forest. Common species of herbs are *Phrynium capitatum* Willd. (Marantaceae), *Amomum siamense* Craib (Zingiberaceae) and *Curculigo capitulata* (Lour.) O. K. (Hypoxidaceae). In disturbed areas with less shade, several species of ground herbs are present. *Eupatorium adenophorum* Spreng. (Composiateae) is the dominant plant in more open and disturbed places. Areas disturbed for a long time and which have suffered from periodic burning are occupied by dense thickets of *Pteridium aquilinum* (L.) Kuhn ssp. *aquilinum* var. *wightianum* (Ag.) Try. (Dennstaedtiaceae). In secondary growth areas the dominant herbaceous species are *Eupatorium odoratum* L. (Compositae) *Euphorbia heterophylla* L. (Euphorbiaceae) and grasses like *Imperata cylindrica* (L.) P. Beauv. var. *major* (Nees) C. E. Hubb. ex Hubb. & Vaugh. (Gramineae). Some common secondary growth trees are *Trema orientalis* (L.) Bl. (Ulmaceae) , *Ficus hispida* L. f. var. *hispida* (Moraceae), *Rhus chinensis* Mill. (Anacardiaceae) *Callicarpa arborea* Roxb. var. *arborea* (Verbenaceae) and others.

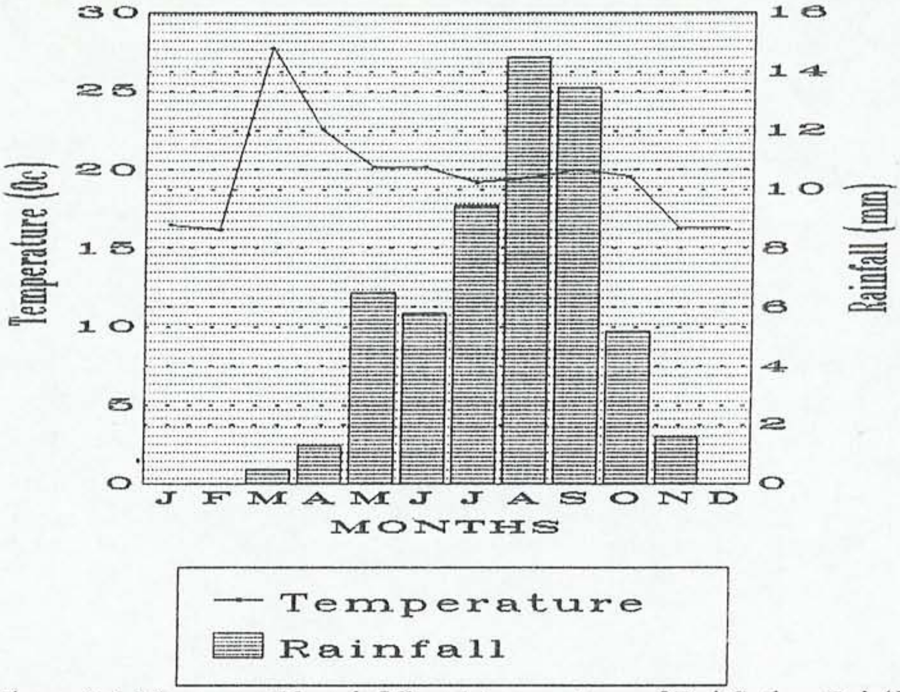

Figure 3.1 Mean monthly rainfall and temperature of Doi Suthep-Pui (Source: Meterological Research Unit, Kasetsart University, Doi Suthep-Pui)

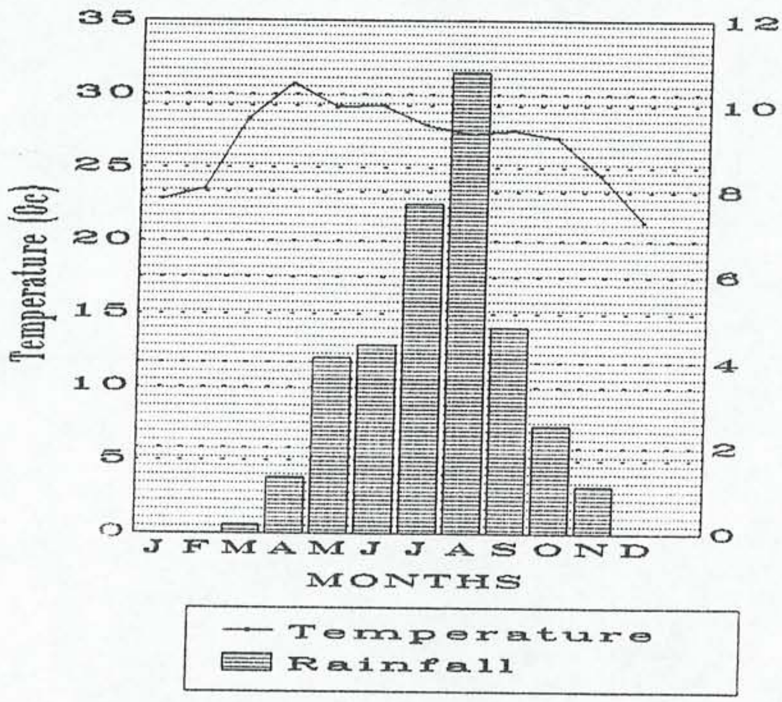

Figure 3.2 Mean monthly rainfall and temperature of Chiang Mai and base of Doi Suthep-Pui National Park (Source: Chiang Mai Materological Station, Airport, Chiang Mai)

A sketch map showing Doi Suthep-Pui Headquarters, Chiang Kian Village, roads and locations of study sites is shown in Figure 3.3.

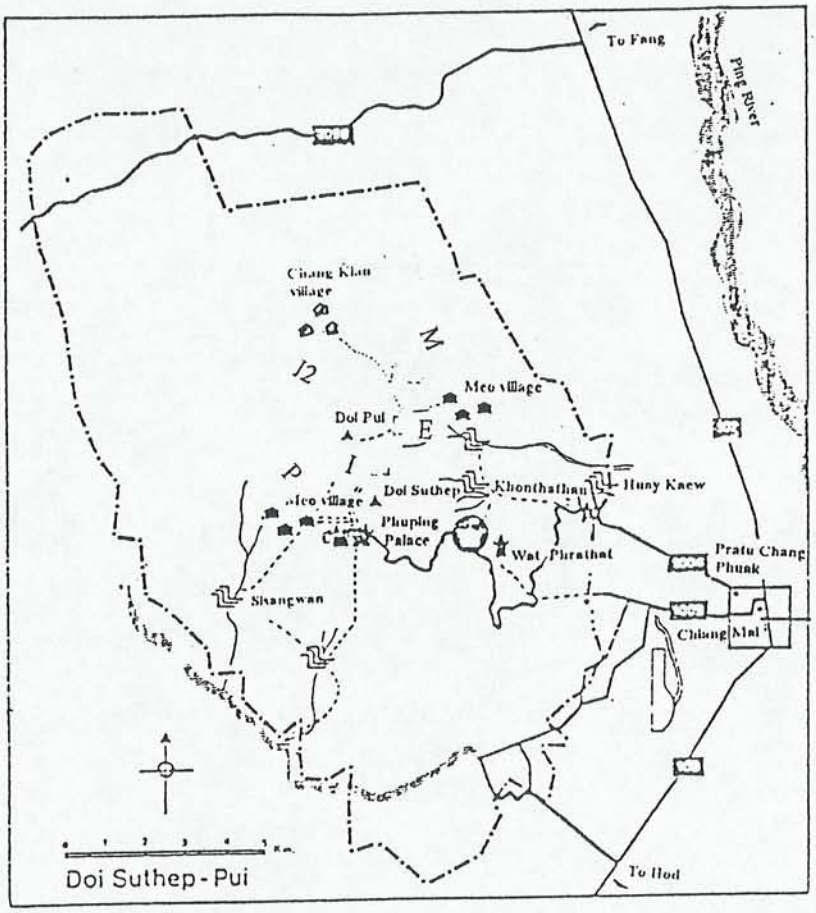

Figure 3.3 Map showing Doi Suthep-Pui National Park, Chiang Kian Meo village and Puping Palace and location of five sites

P = The *Pteridium*-dominated site

I = The *Imperata*-dominated site

E = The *Eupatorium*-dominated site

I2 = The *Imperata*-dominated site 2

M = Mixed ground flora dominated site

Table 3.1 The altitude, slope and aspect of five study sites

Sites	Altitude (m)	Slope (0)	Aspect
The *Pteridium*-dominated site	1375	18	SE
The *Imperata*-dominated site	1460	20	SW
The *Eupatorium*-dominated site	1500	5	SE
The *Imperata*-dominated site 2	1220	17	NW
The Mixed ground flora dominated site	1100	10	SW

3.2 Study Site Description: Initially, three sites were chosen for quantitative study, viz. a *Pteridium* dominated site (1375 m), an *Imperata*-dominated site (1400 m.) and an *Eupatorium*-dominated (1500 m.)

3.2.1. The *Pteridium* -dominated Site

This site was located about 7 km southeast of Doi Suthep-Pui National Park headquarters. It was adjacent to disturbed primary evergreen forest. It was an open deforested area with some secondary growth treelets, shrubs, and plenty of herbs. There was a gentle slope with granite bedrock. The top soil was shallow with a moderate amount of organic matter and low water holding capacity. Tree seedling species here included *Castanopsis diversifloia* King ex Hk. f. (Fagaceae), *Ficus hispida* L.f. var. *hispida* (Moraceae), *Litsea monopetela* (Roxb.) Pers.(Lauraceae), *Mallotus philippensis* (Lmk.) M.-A. var. *philippensis* (Euphorbiaceae), *Prunus cerasoides* D. Don (Rosaceae), *Phoebe sp.*(Lauraceae), and *Pterospermum acerifolium* Willd. (Sterculiaceae) *Pteridium aquilinum* (L.) Kuhn ssp. *aquilinum* var. *wightianum* (Ag) Try. (Dennstaedtiaceae) was the dominant herb, but other ground flora like *Eupatoriun odoratum* L.(Compositae), *Imperata cylindrica* (L.) P. Beauv. var. *major* (Nees) C. E. Hubb. ex Hubb & Vaugh.(Gramineae), *Shuteria involucrata* Wall. Wight. & Arn., *Clitoria mariana* L., *Desmodium multiflorum* Dc., *Millettia pachycarpa* Bth. (all

Leguminosae, Papilionoideae) *Commelina diffusa* Burm. f (Commelinaceae) and *Melastoma normale* D. Don var. *normale* (Melastomataceae) were also common (Figure 3.4).

Figure 3.4 Ground flora in the *Pteridium* dominated site

3.2.2 The *Imperata*-dominated Site

This site was located (1500 m above sea level) about 6.5 km along the road, northwest of the park headquarters opposite an old *Eucalyptus camadulensis* (Myrtaceae) plantation site. The soil texture was a sandy- loam, red in color, with low organic matter content. The area was completely surrounded by primary evergreen forest. Dominant grasses were *Imperata cylindrica* (L.) P. Beauv. var. *major* (Nees) C. E. Hubb. ex Hubb & Vaugh. and *Phragmites vallatoria* (Pluk. ex L.) Veldk. (both Gramineae) with higher percent cover of *Imperata*. Other common species were *Apluda mutica* L.(Gramineae), *Commelina diffusa* Burm. f. (Commelinaceae) *Eupatorium odoratum* L. (Compositae) *Desmodium multiflorum* DC. (Leguminosae, Papilionoideae) and *Pteridium aquilinum* (L.) Kuhn ssp. *aquilinum* var. *wightianum* (Ag.) Try. (Dennstaedtiaceae). The common tree species growing at this site were *Engelhardia spicata* Bl. (Juglandaceae), *Helicia nilagirica* Bedd. (Proteaceae), *Litsea cubeba* (Lour.) Pers. (Lauraceae) and *Castinopsis diversifolia* King ex Hk. f. and *Castanopsis tribuloides* (Sm.) A. DC. (both Fagaceae).

Figure 3.5 The *Imperata*-dominated site

3.2.3 The *Eupatorium*-dominated Site

This site (1500 m) was located immediately adjacent to primary evergreen forest. The soil was black in color with considerable amounts of ash, and is basically sandy loam with high organic matter content. Common secondary growth plants included; *Trema orientalis* (L.) Bl. (Ulmaceae), *Debregeasia longifolia* (Burm. f.) Mett. ex Kuhn (Urticaceae) and some planted fruit trees like *Prunus persica* (L) (Rosaceae) and *Artocarpus heterophyllus* Lmk. (Moraceae). The dominant herb was *Eupatorium adenophorum* Spreng. (Compositae). Other common herbaceous species were *Shuteria involucrata* (Wall.) Wight. & Arn., *Clitoria mariana* L. (both Leguminosae, Papilionoideae), *Pteridium aquilinum* (L.) Kuhn ssp. *aquilinum* var. *wightianum* (Ag.) Try. (Dennstaedtiaceae) and *Imperata cylindrica* (L.) P. Beauv. var. *major* (Nees) C. E. Hubb. ex. & Vaugh. (Gramineae), and *Shuteria involucrata* Wall. Wight. & Arn. (Leguminosae, Papilionoideae).

Figure 3.6 The *Eupatorium*-dominated site

3.2.4. The *Imperata*- dominated Site 2

This site (1300) was located about 12 km along the dirt road, north of Doi Suthep National Park near to the Chang Kian village. The area was totally dominated by *Imperata* grass with low percent cover of *Pteridium*. The general soil characteristics were a shallow top and sandy loam, very little organic matter and low water- holding capacity. The area was extensively burnt by forest fire a year previous to this study. The site was gentle slope. There were very few other ground flora and tree seedling species. Very common treelet seedlings were *Rhus chinensis* Mill. (Anacardiaceae) and *Ficus hispida* L. f. var. *hispida* (Moraceae).

Figure 3.7 The *Imperata*-dominated site 2

3.2.5. The Mixed Ground Flora Grass-Dominated Site

This site was nearly 15 km from park headquarters near the Mahidol Waterfall. There was clear evidence of slash-and-burn agriculture in this site recently. It was situated on a south-west facing slope. The soil was a sandy loam with little organic matter and has a higher amount of soil moisture than *Imperata* site 2. Some common ground flora species were *Setaria parviflora* (Poir.) Kerg., *Pennisetum pedicellatum* Trin., *Imperata cylindrica* (L.) P. Beauv.var. *major* (Nees) C. E. Hubb. ex. Hubb & Vaugh., *Microstegium vagans* (Nees ex Steud.) *A.* *Camus*, *Eleusine indica* (L.) Gaertn. and *Sccharum arundinaceum* Retz. (all Gramineae), *Desmodium multiflorum* DC. (Leguminosae, Papilionoideae), *Conzya sumatrensis* (Retz.) Walk, *Eupatorium odoratum* L. (both Composiateae). Common treelet seedlings were *Ficus hispida* L. f. var. *hispida* (Moraceae) *Morinda angustifolia* Roxb. var. *scabridula* Craib (Rubiaceae), *Aporusa dioca* (Roxb.) M.-A. (Euphorbiaceae), and *Ixora cibdela* Craib var. *cibdela* (Rubiaceae).

Figure 3.8 The mixed ground flora grasses dominated site

CHAPTER 4
METHODOLOGY

4.1 Materials and Equipment

Map of Doi Suthep-Pui National Park

Plastic bags and rubber bands

Paper bags

Bamboo poles

Measuring Tape (1.5 m and 50 m)

Altimeter and Recta Compass

Strong knife and scissors

Iron wire and metal labels

Trowel and hammer

Nylon string and plant press

Red spray and electric balance

4.2 Site Selection

Initially three sites (regenerating gaps) were chosen for a quantitative study and later an additional two sites were selected for a qualitative study in order to determine the association patterns between tree seedling and ground flora species.

4.3 Data Collection Method

4.3.1 Species collection and identification

Two data collection methods were employed to determine the abundance, and species composition of the ground flora and tree seedling species and association between them. An extensive qualitative survey was carried out from March to April to record the dominant ground flora, tree seedlings and other common species. It was performed by surveying all sites during a two month period. During the qualitative survey, all woody and herbaceous found in study site were collected, and natural tree seedlings (without coppices) were recorded. Specimens of ground flora and tree seedlings were collected and identified at the Herbarium, Department of Biology, Chiang Mai University. A rough indication of the abundance of each species was recorded using an abundance scale as follows.

1 = very few individuals with minimum chance of occurrence
2 = rare
3 = moderately abundant
4 = common but not dominant, and
5 = dominant

For the quantitative study, study sites dominated by *Pteridium*, *Imperata* and *Eupatorium* were chosen. Seasonal changes in tree seedling and ground flora populations were monitored in a total of 48 2 x 2 m^2 quadrats distributed in a regular pattern within 50 x 50 m permanent plots at each site. All herbs and natural tree seedlings more than 5 cm and not taller than 3 m in height in each quadrats were recorded and quantified using the domain scale and percent cover. The percent cover and domain scores (see table 1) of each species were recorded every two months from April to December.

Table 4.1 The percent cover and domain score system

Class	Description
+	Isolated, cover small
1	Scares, cover small
2	Very scattered, cover small
3	Scattered, cover small
4	Abundant, cover about 5 %
5	Abundant, cover about 20 %
6	Cover 25-33 %
7	Cover 35- 50 %
8	Cover 50-75 %
9	Cover 75- below 100 %
10	Cover about 100 %

4.3.2 Soil Sample Collection and Analysis

To assess the relationship between the dominant ground flora and soil conditions, 10 soil samples from each study site were collected randomly from the quadrats. All soil samples were analyzed for pH, organic matter, nutrients (N, P, K) and % moisture at field capacity at the Faculty of Agriculture, Chiang Mai University using standard methods. Every month 1 kg of soil sample from deforested gap floors (0-30 cm) was collected from various places and mixed together to make one sample for each site. Approximately 100 g soil samples were air dried to constant mass in an electric oven at 80^0 Celsius for 24 hours to determine soil moisture. Percentage of moisture content was calculated by using following formula.

Soil moisture content = B- C / C - A (g water/ g dry soil)

where,

A = Weight of paper bag (container)

B = Weight of paper bag + Wet soil sample

C = Weight of paper bag + Dry Soil (final weight)

The significant difference of different soil parameters between and within sites were assessed with one way ANOVA.

4.3.3 Study of Tree Seedling Communities

All seedlings present in each quadrat earlier were measured, their mortality noted with new recruits identified, measured, mapped and tagged. At the end of the study, seedling heights were recorded to determine the relative growth rate of tree seedlings in the different dominant ground flora communities. The equation employed to calculate relative growth rate (RGR) was as follows:

RGR = Ln H2 - Ln H1 / T2 - T1 X 365 days

Where,

RGR = Relative growth rate

H1 = Height of the Seedling at the beginning of study

H2 = Height at the end of study

T2 - T1 = Number of days between T1 and T2

Ln = Natural log

Mortality = (ND / TN) X 100 %

where,

ND = Number of dead species

TN = Total number of species

4.3.4 Qualitative survey of tree seedling

A rapid survey was carried out in five different study sites in order to explore the potential tree seedling species that are associated with dominant ground flora. Four transects were established in each site and the number of tree seedling and percent cover of dominant ground flora were noted. During this rapid survey all tree seedlings at 3 meters interval (roughly) in transects were recorded and the ground flora species associated with 2 meters radius was also recorded. During this extensive survey all these seedling were observed by walking along the transect line and counting the tree seedling and associated ground flora at every three meters interval.

4.4 Data Analysis

Potential associations between the dominant ground flora and tree seedling species were determined using the basic computer program SPASSOC. BAS (Ludwig and Reynolds 1988). Chi- square and the interspecific association indices Ochiai, Dice and Jaccard were computed for all pairwise combinations of species as well as the variance ratio test (VR) for multiple species association. This method of detecting interspecific association is based on the presence or the absence of species in a collection of sample units with presence indicated by 1 and absence with 0. Since the chi-square method of testing the significance of association of many pairwise comparisons is impractical (Pielou 1972), the new approach proposed by Schluter (1984) was used. According to this approach if the objective is to assess the presence or absence of association in a large group of species simultaneously, the variance ratio (VR) is the most reliable method. The association analysis table also revealed the biased chi-square value as well as chi-square continuity correction. If an expected frequency < 1 or if more than two of the table cells have expected frequencies < 5 in any cell in the 2 X 2 contingency table, then the resulting chi-square test statistic will be biased. Therefore, a corrected chi-square value was used to avoid biased values resulting from low cell expectations. For this correction, continuity correction is applied to ensure a closer approximation to the theoretical, continuous chi-square distribution. This continuity correction was performed by using Yate's correction formula. The null hypothesis that " there is no association among the S species" was carried out following test statistics.

4.4.1 Interspecific Association Analysis

4.4.1.2. Test Statistic $\sigma^2_T = \sum_{i=1}^{S} p_i\ (1 - P_i)$

Where,

$P_i = n_i / N$

b) $S^2_T = 1/N \sum_{i=1}^{S} (T_j - t)^2$

Where,

t = the mean number of species per sample

$VR = S^2_T / \sigma^2_T$

$W = (N)(VR)$

Where,

VR = variance ratio

W = Test Statistics

N = total number of sampling units (N = a + b + c + d)

To measure the strength of association the following indices were used.

4.4.1.3. Chi-square Test $\chi^2_t = \sum (\text{observed} - \text{expected})^2 / \text{expected}$

Which is a summation over the four cells of the 2 X 2 table. The expected value for cell a is given by,

$E(a) = (a + b)(a + c)/N = rm/N$

$E(b) = ms/N$

$E(c) = rn/N$

$E(d) = sn/N$, Thus chi-square test statistic is given as,

$\chi 2_t = [a - E(a)]^2 / E(a) + \ldots\ldots + [d - E(d)]^2 / E(d)$

4.4.1.4 Ochiai Index $(OI) = a / \sqrt{(a + b)}\sqrt{(a + c)}$

4.4.1.5 Dice index $(DI) = 2a / 2a + b + c$

4.4.1.5 Jaccard Index (JI) $= a / a + b + c$

Where,

a = the number of sampling units where both species occur

b = the number of sampling units where species A occurs but not B

c = the number of sampling units where species B occur, but not A

d = the number of sampling units where neither A nor B are found

4.4.2 Species Diversity Indices:

Species diversity and evenness of tree seedlings were calculated for each site using Simpson's diversity index and modified Hill's ratio E5 respectively. Sorenson's similarity index was used to quantify the difference between plant communities dominated by different ground flora species (Ludwig and Reynolds, 1988).

4.4.2.1 Species Diversity : (Hill's number)

Number 1: $N1 = e^{H'}$

Number 2 : $N2 = 1 / \lambda$

Where H' is the Shannon's index and λ is the Simpson's index

4.4.2.2 Shannon's Index : $H' = \sum_{i=1}^{S} p_i \ln p_i$

Where,

$p_i = n_i / N$

4.4.2.3 Simpson's index, $\lambda = \sum p_i^2$

Where,

H' = average uncertainty per species in an infinite community

S' = total number of species in the community

p_i = proportional abundance of the ith species

n_i = number of individuals (abundance) of the ith

N = total number of individuals (abundance)

4.4.2.4 Species Richness:

N0 = total number of species

4.4.2.5 Evenness : (Modified Hill's Index)

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

$$\text{Where, } \lambda = \sum_{I=1}^{S} p_i^2$$

4.4.2.6 Similarities coefficient

(Sorenson's Index) = 2a / b + c

Where,

a = Number of species that present in both sites

b = Number of species that present only in site 1

c = Number of species that present only in site 2

4.4.2.7 Difference coefficients

CRDjk = ✓2 (1-ccosjk)

Where, CRDjk = chord distance between SU j and SU k which range from 0 to ✓2

ccos = chord cosine is computed from following formula

$$Ccosjk = \sum_{I=1}^{S} (X_{ij} . X_{ik}) / \checkmark \sum_{1=1}^{S} X_{ij}^2 . \sum_{I=1}^{S} X_{ik}^2$$

Where:

X_{ij} = relative abundance of ith species in SUj
X_{ik} = relative abundance of ith species in SU k

4.4.3 Cluster analysis and Ordination

Cluster analysis was carried out for placing the similar sampling units into groups or clusters as described by Ludwig and Reynolds (1988). The result of the cluster analysis is summarized in a hierarchical treelike structure called a dendrogram. The dendrogram was prepared using the average percent cover in all five observation for 48 quadrats. Likewise, the polar ordination coordinates for the sampling units were determined using Polar Ordination Method (Bray and Curtis, 1957; Ludwig and Reynolds, 1988). The polar ordination was also plotted using same data as that of cluster analysis, but it was performed by computing the percent dissimilarity between sampling units.

4.3.1 Percent Dissimilarity

$$PD = 1 - [2W / (A + B)]$$

Where,

$$W = \sum_{i=1}^{S} [\min(X_{ij}, X_{ik})]$$

$$A = \sum_{i=1}^{S} X_{ij} \quad \text{and } B = \sum_{i=1}^{S} X_{ik}$$

Where,

X_{ij} = relative abundance of ith species at SUj

X_{ik} = relative abundance of ith species at SUk

CHAPTER 5

RESULTS

5.1 Species composition, richness, diversity and evenness

Over the period of observation, 127 species were recorded belonging to 109 genera, 49 families and 3 sub families including 58 species belonging to 49 genera and 31 families and 3 subfamilies recorded in the quantitative survey. Table 5.1 shows the species composition of three sites. A total of 32 herb species, 4 shrubs, 10 woody climber, 14 vines, and 67 tree species were recorded. Herb species were very abundant in all sites. As the rainy season approached, the number of species of herbs as well as some species of shrubs increased, but there was no remarkable variation of tree seedlings observed. Lists of total species found are presented in Appendix 2, 3 and 4 respectively. A total 37 species was recorded in the *Pteridium*-dominated site and 29 and 28 in the *Imperata* and *Eupatorium*-dominated sites respectively. Species richness was higher in the *Pteridium*-dominated site. Unlike species richness, species diversity (both N1 and N2) was higher in the *Eupatorium*-dominated site (Table 5.2).

The most common tree seedling species recorded in the extensive qualitative survey at the *Eupatorium* site were *Engelhardia specter* Lecher. ex. B/L. var. *colebrookena* (Ldl. ex Wall.) O. K., *Engelhardia serrata* Bl. (both Juglandaceae) and *Phoebe* sp. (Lauraceae). Similarly, treelet seedlings *Rhus chinensis* Mill. (Anacardiaceae), and *Ficus hispida* L. f. var. *hispida* (Moraceae) were abundant in the *Imperata* site with very few seedlings of *Litsea cubeba* (Lour.) Pers. (Lauraceae) and *Castanopsis diversifolia* King ex Hk. f. (Fagaceae) while very few seedlings like *Eugenia albiflora* Duth. ex Kurz (Myrtaceae) and *Phyllanthus embelica* L. (Euphorbiaceae) were present in the *Pteridium*-dominated site. Herb species were almost similar in the *Peteridium* and the *Imperata*-dominated sites while being slightly different in the *Eupatorium*-dominated site. The common herbs were *Polygonum chinensis* L. (Polygonaceae) , *Zingiber kerri* Craib (Zingiberaceae), *Commelina diffusa* Burm. f., *Commelina paludosa* Bl. (both Commelinaceae) and *Conyza sumatrensis* (Retz.) Walk.

Compositae). Other common plants were *Shuteria involucrata (*Wall.) Wight. & Arn., *Millettia pachycarpa* Bth. and *Pureria stricata* Kurz. (all Leguminosae, Papilionoideae).

Table 5.1 Species composition in five different sites

Species Composition	*Pteridium* Site	*Imperata* Site	*Eupatorium* Site	Mixed Ground Flora Site
Herbs	20	22	18	8
Vines (ev/dev)	6	6	5	-
Woody . Climbers (ewc/dwc)	7	5	4	-
Shrubs (es/des)	4	5	7	4
Trees (et/etlt/dt/detlt)	17	23	39	11

Note: ev/ dv = evergreen vine/ deciduous vine
ewc/dwc = evergreen woody climber/ deciduous woody climber
es/ ds = evergreen shrub/ deciduous shrub
et/ etlt = evergreen tree/ evergreen treelet
dt/ detlt = deciduous tree/ deciduous treelet

The number of tree species (et/ etlt/ dt/ detlt) was highest (39) followed by herb, shrub and vine species.

Table 5.2 Total species richness, diversity (Hill's number) and evenness (Modified Hill's ratio) for three sites

Sites	Species richness	Species diversity N1	N2	Evenness
Pteridium-dominated site	37	8.77	4.32	0.427
Imperata-dominated site	29	7.46	4.12	0.486
Eupatorium-dominated site	28	15.25	8.59	0.53

5.2 Tree Seedling Diversity and Recruitment

Species diversity indices (both N1 and N2) were higher for the *Eupatorium* site compared with the *Imperata* and the *Pteridium* sites. The lowest diversity was found in the *Pteridium*-dominanted site (Table 5.3).

Table 5.3 Species diversity (Hill's number), richness (N0) and evenness (modified Hill's ratio) of tree seedlings at three different sites

Sites	Species richness	Diversity		Evenness
		N1	N2	
Pteridium-dominated site	8	5.59	8.5	1.34
Imperata-dominated site	8	7.52	9.37	1.28
Eupatorium-dominated site	12	10.23	11.2	1.11

The mortality and density of tree seedlings is shown in Table 5.4. The highest density was found in the *Eupatorium*-dominated *site* followed by the *Imperara* and the *Pteridium*-dominated site while the highest mortality was observed in the *Imperata* site. During the qualitative survey, very few tree seedlings were recorded in quadrats. The observed tree seedling density is lower than the tree seedling density reported by Karimuna 1995. The remarkable difference of tree seedling density in these two studies may be due to the patchy dispersion of seeds in particularly quadrat or difference in seed rain in two different years in the study sites.

Table 5.4 Mortality (%) and density (m^{-2}) of tree seedlings at three different sites

	Pteridium site	*Imperata* site	*Eupatorium* site
Mortality (%)	25.71	30.00	21.73
Density (m^{-2})	0.16	0.23	0.35

The relative growth rates (RGR) of different species are presented in Tables 5.5. The relative growth rate of all recorded tree seedling is not included due to the loss of some species during the period of observation. The table shows a much higher relative growth rate for seedlings, in general, in the *Eupatoriun*-dominated site than in the other sites. The relative growth rate of *Saurauia roxburghii* Wall. seems to be higher in the *Pteridium*-dominated site while RGR of *Ficus hispida* and *Rhus chinensis* was found relatively higher in the *Imperata*-dominated site. Like wise, RGR of *Ficus hispida* was higher in the mixed ground flora dominated site.

Table 5.5 Average Relative Growth Rate (cm growth/cm of original height/year) of tree seedlings in four different sites

Species	*Pteridium* Site	Mixed ground flora site	*Imperara* site	*Eupatorium* site
Adinandra integerrima T. And. ex Miq.	-		-	1.09
Albizia odoratissima (L. f.) Bth.	0.51		-	-
Aporusa dioica (Roxb.) M. - A.		0.40		
Artocarpus lanceolata Trec.	-		0.26	
Castanopsis diversifolia King ex Hk. f.	0.45		0.41	1.8
Cinnamomun caudatum Nees	-		-	1.36
Croton oblongifolius Roxb.		0.42		
Dalbergia sp.		0.88		
Dillenia aurea Sm. var. *aurea*	0.49		-	-
Engelhardia spicata Lechen. ex. Bl. var. *colebrookena* (Ldl. ex. Wall.) O. K.	-		0.57	1.8
Engelhardia serrata Bl.	-		-	1.52
Eugenia albiflora Duth. ex Kurz	-		-	1.29
Ficus hispida L. f. var. *hispida*	0.54	0.77	0.85	-
Helicia nilagirica Bedd.			0.62	-
Ixora cibdela Craib var. *cibdela*		0.99		
Lithocarpus elegans (Bl.) Hatus. ex Soep.	-		-	0.57
Litsea cubeba (Lour.) Pers.	-		0.38	-
Morinda angustifolia Roxb. var. *scabridula* Craib		1.07		
Litsea monopetala (Roxb.) Pers.	0.45		0.24	-
Phoebe lanceolata (Nees) Nees	-		-	1.18
Phoebe sp.	-		-	0.95
Phoebe aff. cathia (D. Don) Kosterm.	-		-	1.32
Prunus cerasoides D. Don	-		0.45	-
Rhus chinensis Mill.	-		-	-
Saurauia roxburghii Wall.	0.66		-	-
Schima wallichii (DC.) Korth.	0.33		-	0.61
Trema orientalis (L.) Bl.	-	0.34	-	1.28

5.3 Qualitative survey of tree seedlings

A total of 304 tree seedlings were recorded belonging to 43 species, 36 genera and 22 families. The highest number of tree seedlings was found in the *Eupatorium*-dominated site where *Rhus chienesis* was the most common species. The total number of tree seedlings and their associated ground flora is presented (Table 5.6).

Table 5.6 Tree seedlings in qualitative survey and their associated ground flora

Species	N	*Pteridium* site		*Imperata* site		*Eupatorium* site	
		F	M. C.	F	M. C.	F	M. C.
Adinandra integerrima T. And. ex Miq.	5	2	20	5	60	1	15
Acronychia pedunculata (L.) Miq.	3	1	10	1	15	3	40
Albizzia odoratissima (L. f.) Bth.	3	1	10	3	30	2	20
Anneslea fragrans Wall.	2	2	5	0	0	2	50
Artocarpus lanceolata Trec.	2	0	0	0	0	2	50
Bischofia javanica Bl.	6	0	0	0	0	6	50
Boehmeria thilandica Yaha.	3	3	50	1	25	0	0
Castanopsis diversifolia King ex Hk. f.	12	4	22	6	30	2	15
Cinnamomum caudatum Nees	5	0	0	0	0	5	42
Dillenia parviflora Griff. var. *Kerrii* (Craib) Hoogl.	3	2	5	1	5	3	10
Diospyros glandulosa Lace	4	0	0	0	0	4	0
Engelhardia spicata Lechen. ex. Bl. var. *colebrookena* (Ldl. ex. Wall.) O. K.	20	5	10	6	30	20	40
Engelhardia serrata Bl.	7	0	0	2	7	7	30
Erythrina suberosa Roxb.	1	0	0	0	0	1	30
Eugenia albiflora Duth. ex Kurz	2	2	50	1	24	1	15
Eurya acumminata DC. var. *wallichina* Dyer	2	1	5	2	20	0	0
Eurya nitida Korth. var. *siamensis* (Craib) H. Keng	1	0	0	1	40	0	0
Ficus auriculata Lour.	1	0	0	1	15	1	5
Ficus hispida L. f. var. *hispida*	29	2	15	29	69	0	0
Garcinia cowa Roxb.	2	1	7	0	0	2	25
Gordonia dalglieshiana Craib	1	1	8	0	0	1	50
Helicia nilagirica Bedd.	11	2	9	5	20	11	45
Litsea cubeba (Lour.) Pers.	5	2	8	5	20	1	9
Litsea sp.	2	2	40	0	0	1	15
Litsea monopetala (Roxb.) Pers.	2	2	40	2	18	0	0
Lithocarpus elegans (Bl.) Hatus. ex Soep.	2	1	16	0	0	2	35
Markhamia stipulata (Wall.) Seem ex Sch var. *stipulata*	3	3	40	1	6	3	35
Macropanax concinnus Miq.	1	1	14	0	0	1	30
Phyllanthus emblica L.	3	3	35	1	15	2	5
Phoebe aff. cathia (D. Don) Kosterm	1	0	0	0	0	1	35
Phoebe lanceolata (Nees) Nees	19	5	13	0	0	19	39
Phoebe sp.	6	2	15	3	18	6	20
Pyrenaria garrettiana Craib	2	1	10	2	30	0	0
Pterospermum acerifolium Willd.	1	1	30	1	5	1	6
Rhus chinensis Mill.	120	0	0	120	50	0	0
Saurauia roxburghii Wall.	1	1	20	1	12	1	9
Schima wallichii (DC.) Korth.	6	2	15	1	12	6	40

Semecarpus cochinchinensis Engl.	1	1	14	0	0	1	30
Tarennoidea wallichii (Hk. f.) Tirv. Sastre	1	1	13	1	40	1	7
Trema orientalis (L.) Bl.	2	1	10	0	0	2	35
Turpinia pomifera (Roxb) Wall. ex Dc.	1	0	0	0	0	1	35
Vernonia volkamerrifolia DC. var *volkameriifolia*	1	1	18	1	15	1	0
Wendlandia paniculata (Roxb.) DC. ssp. *scabra* (Kurz) Cowan	1	1	45	1	20	1	15

Note:
N = Total number of tree seedlings
F = Frequency of seedlings
M.C. = Mean % cover

In order to determine the associated tree seedlings and dominanted herbaceous vegetation from qualitative data , a criteria was developed to rank the associated species in a logical order. The criteria assinged here is fully based on the percent cover of dominant vegetation around the tree seedling species. Moreover, when frequency of tree seedlings is greater than 5 or more and mean % cover is more than 50 % a possible association expected and these associations should be further investigated by rigorous methods.

% cover	Association criteria
< 20	Very weak
20-40	Weak
40-60	Strong
60-80	Very strong

Based on these association criteria, it is revealed that there is lack of very strong association between *Eupatorium adenophorum* and tree seedlings but some tree seedlings like *Bischofia javanica*, *Cinnamomum caudatum*, *Engelhardia spicata*, *Helicia nilagirica* and *Schima wallichii* were strongly associated. Likewise, *Adinandra integerrima* and *Ficus hispida* seems to be very strongly associated with *Imperata cylindrica* whereas *Rhus chinensis* was strongly associated.

5.4 Soil Water Determination

One way ANOVA ($p < 0.05$) was done but no significant difference was observed between the three different sites. Moisture content of three different sites presented in Figure 5.1.

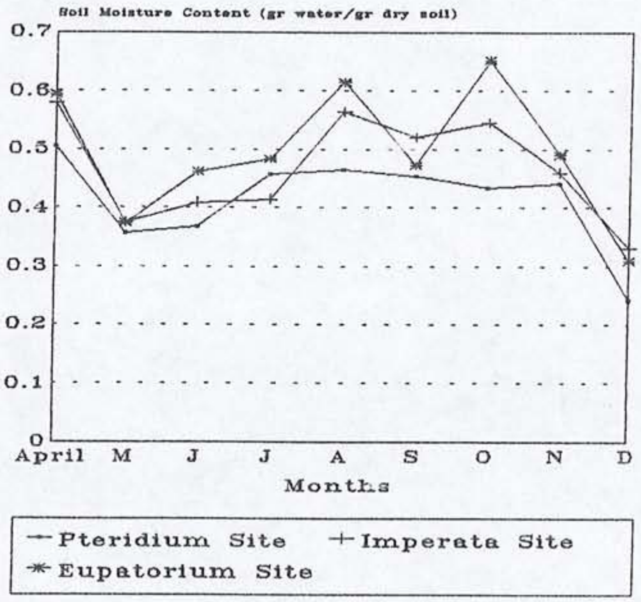

Figure 5.1 The moisture content of three different sites (gr water/gr dry soil)

5.5 Soil Properties

One way ANOVA with LSD test ($p= 0.05$) showed that the *Eupatorium* site had a significantly higher field capacity than *Pteridium*-dominated site. Other soil parameters were not significantly different among sites. Nutrient content in the *Eupatorium*-dominated site was highest followed by the *Pteridium*-dominated site. Regression analysis using bivariate analysis suggested that the field capacity of sites was influenced by percent organic matter content ($p = 0.031$). Moreover, the nitrogen content was strongly correlated ($p= 0.000$) with percent organic matter.

Cluster analysis of soil parameters using the SPSS program demonstrated highest similarity between the *Pteridium* and the *Eupatorium*-dominated sites whilst highest was *Imperata* dominated site. The outcome of cluster analysis of soil parameter is presented in Figure 5.2.

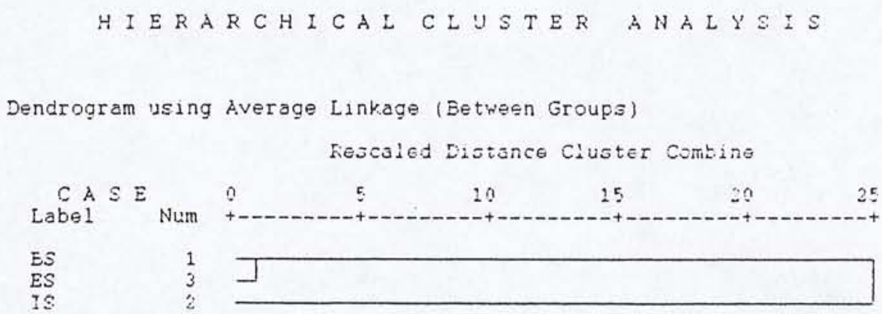

Figure 5.2 Dendrogram showing the clustering of sites using soil parameters

Table 5.7 Mean value of soil properties in all sites from ten replications

Soil Properties	*Pteridium* Site	*Imperata* Site	*Eupatorium* Site	Level of Significance
% Nitrogen	.4212	.4128	0.4458	NS
Phosphorus (ppm)	17.75	22.7	21.6	NS
Potassium (ppm)	173.1	143.5	174.5	NS
pH	5.56	5.7010	5.6680	NS
Organic Matter (%)	9.23	8.8760	9.8130	NS
% Moisture at Field Capacity	33.76	36.37	38.027	*

Note:

NS: Non significant (ANOVA with homogeneity test, $p < 0.05$)

* : Significant difference between 93 % confidence level

5.6 Cluster analysis

The basic computer program CLUSTER.BAS was employed to compute the clustering pattern among tree seedling and ground flora species in order to assess the degree of similarity between sites. The outcome of cluster analysis showed the largest difference between the *Imperata* and the *Pteridium*-dominated sites while the lowest between the *Eupatorium* and the *Imperata* site. This result is different as obtained previously with the soil parameters.

Table 5.8 Cluster analysis a) chord distance between 3 sites b) clustering of the sites

a. Chord distance (CRD)

Sites	*Pteridium* Site	*Imperata* Site	*Eupatorium* Site
Pteridium Site		1.09	1.08
Imperata Site			0.70
Eupatorium Site			

b. Table 5.9 Clustering by the flexible strategy with $\beta = -0.25$

Clustering Cycle	No. of Groups	Clustering level	Reference Sus	Sus in the Groups
1	2	0.70	2	3
2	1	0.91	1	2 3
2	1	0.91	1	all Sus from one Groups

Note:
Sampling unit 1 = *Pteridium*-dominated site
Sampling unit 2 = *Imperata*-dominated site
sampling unit 3 = *Eupatorium* dominated site

Hierarchical Cluster Analysis : The cluster analysis showed quite clear differences between the three different sites. This revealed that the three sites are significantly different with reference to species composition and abundant of each species.

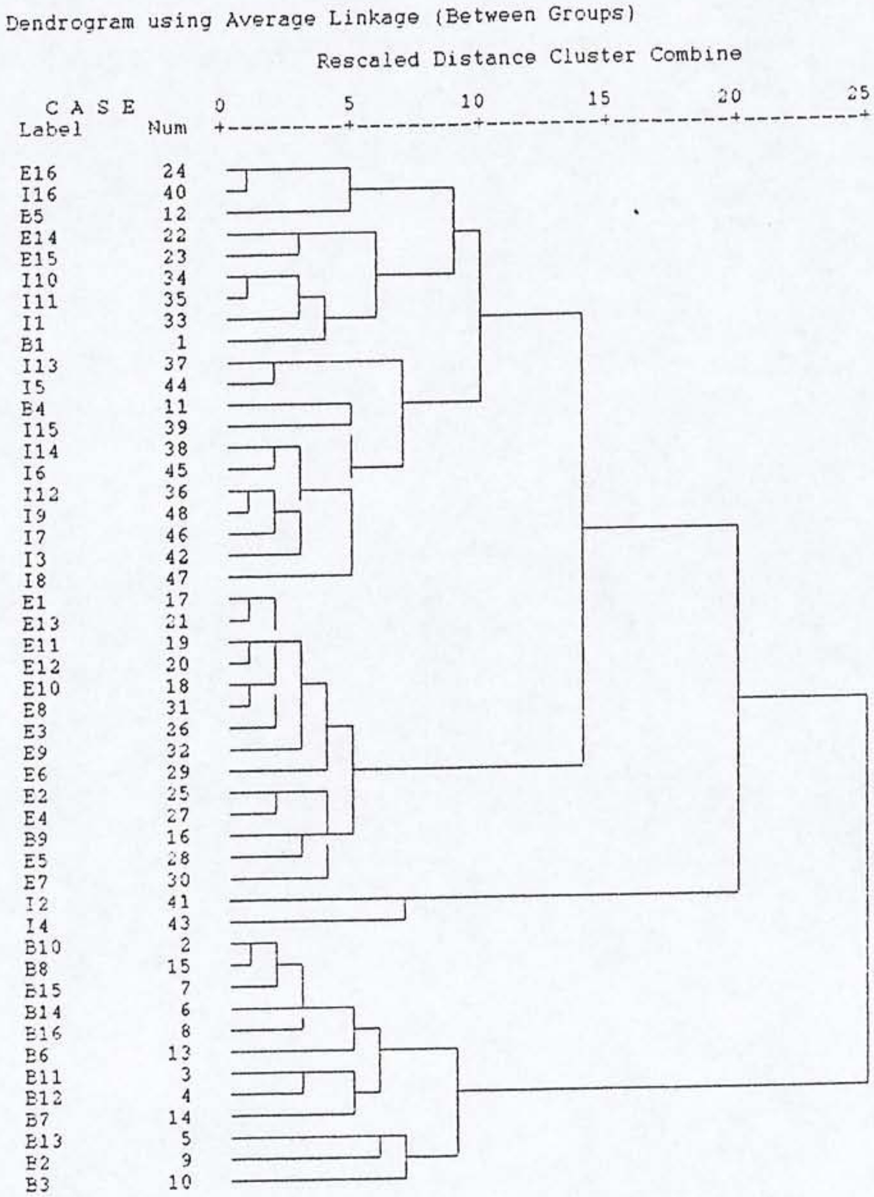

Figure 5.3 Hierarchical cluster analysis using average percent cover of 48 quadrats over 5 observation

5.7 Interspecific Association Analysis

The Basic computer program SPASSOC. BAS was used to determine the potential association between the dominant ground flora and tree seedling (Table 5.12, 5.13, and 5.14). The chi-square test was performed to test for the presence of association between tree seedling species and the dominant ground flora species using all 48 quadrats from all three sites in the quantitative survey.

If the chi-square method indicated association between species the Ochiai, Dice and Jaccard indices (OI, DI, and JI) were calculated to indicate strength of association. The indices are equal to 0 at " no association" and 1 at "maximum association".

5.7.1 Associated tree seedlings with *Pteridium aquilinum*

Not even a single pair had the chi-square test statistic greater than 3.84, so the null hypothesis was accepted and no tree seedling species were associated with *Pteridium aquilinum*. However, if we had looked for species affinities using the association indices, it might have been tempted to conclude that all species which has positive association type are associated. This is due to the fact that the indices measure the degree of association and do not provide a test for association as chi-square does.

Table 5.10 Interspecific association indices and test statistics between *Pteridium aquilinum* and associated tree seedlings

Associated Species	Association + or -	Chi-square Correction	O I	D I	J I
Beilschmiedia sp.	-	0.010	0.178	0.174	0.095
Castanopsis diversifolia	+	0.039	0.252	0.250	0.143
Debregeasia longifolia	+	2.051 *	0.385	0.333	0.200
Engelhardia spicata	+	0.039	0.252	0.250	0.143
Eugenia albiflora	-	0.112	0.000	0.000	0.000
Gordonia dalglieshiana	-	0.655 *	0.333	0.200	0.111
Leea indica	+	0.281 *	0.149	0.143	0.007
Litsea cubeba	-	0.009 *	0.000	0.000	0.000
Litsea monopetala	-	0.054 *	0.000	0.000	0.000
Melastoma normale	+	0.117	0.211	0.211	0.118
Markhamia stipulata	+	0.009 *	0.192	0.167	0.091
Mallotus philippensis	-	0.655 *	0.000	0.000	0.000
Phoebe lanceolata	-	0.176 *	0.136	0.133	0.071
Phoebe sp.	-	0.054 *	0.000	0.000	0.000
Prunus cerasoides	+	0.985	0.354	0.353	0.214
Pyrenaria garrettiana	+	0.009 *	0.192	0.167	0.091
Pterospermum acerifolium	-	0.655 *	0.000	0.000	0.000
Rhus chinensis	+	0.054 *	0.236	0.182	0.100
Schima wallichii	+	0.655 *	0.333	0.200	0.111

5.8.2 Associated tree seedlings with *Imperata cylindrica*

Table 5.11 Interspecific association indices and test statistics between *Imperata cylindrica* and associated tree seedlings

Associated Species	Association + or -	Chi-square Correction	O I	D I	J I
Beilschmiedia sp.	-	2.151	0.077	0.077	0.077
Castanopsis diversifolia	+	1.423	0.464	0.452	0.292
Debregeasia longifolia	+	0.119 *	0.167	0.133	0.071
Engelhardia spicata	-	1.394	0.000	0.000	0.000
Eugenia albiflora	-	0.364	0.000	0.000	0.000
Gordonia dalglieshiana	-	0.340 *	0.000	0.000	0.000
Leea indica	-	0.670 *	0.000	0.000	0.000
Litsea cubeba	-	0.119 *	0.000	0.000	0.000
Litsea monopetala	+	0.340 *	0.289	0.154	0.083
Melastoma normale	+	0.000	0.274	0.273	0.158
Markhamia stipulata	+	0.119 *	0.167	0.133	0.071
Mallotus philippensis	+	0.340 *	0.289	0.154	0.083
Phoebe lanceolata	+	0.000 *	0.236	0.222	0.125
Phoebe sp.	-	0.000 *	0.000	0.000	0.000
Prunus cerasoides	-	1.180	0.000	0.000	0.000
Pyrenaria garrettiana	-	0.119 *	0.000	0.000	0.000
Pterospermum acerifolium	+	0.340 *	0.289	0.154	0.083
Rhus chinensis	-	0.000 *	0.000	0.000	0.000
Schima wallichii	+	0.340 *	0.289	0.154	0.083

Since all corrected chi-square test is less than table value (3.48), there is no association between tree seedling species and *Imperata cylindrica.*

5.7.3 Associated tree seedlings with *Eupatorium adenophorum*

Table 5.12 Interspecific association indices and test statistics between *Eupatorium adenophorum* and associated tree seedlings

Associated Species	Association + or -	Chi-square Correction	O I	D I	J I
Beilschmiedia sp.	-	0.538	0.154	0.154	0.083
Castanopsis diversifolia	+	15.361 +	0.728	0.710	0.550
Debregeasia longifolia	+	1.007 *	0.333	0.267	0.154
Engelhardia spicata	+	0.502	0.327	0.316	0.188
Eugenia albiflora	+	0.364	0.144	0.125	0.067
Gordonia dalglieshiana	-	0.340 *	0.000	0.000	0.000
Leea indica	+	6.028 * +	0.516	0.471	0.308
Litsea cubeba	+	0.119 *	0.167	0.133	0.071
Litsea monopetala	-	0.340 *	0.000	0.000	0.000
Melastoma normale	-	2.695	0.000	0.000	0.000
Markhamia stipulata	+	1.067 *	0.333	0.267	0.154
Mallotus philippensis	-	0.340 *	0.000	0.000	0.000
Phoebe lanceolata	+	4.063 * +	0.471	0.444	0.286
Phoebe sp.	-	0.000 *	0.000	0.000	0.000
Prunus cerasoides	-	0.200	0.102	0.100	0.053
Pyrenaria garrettiana	-	0.119 *	0.000	0.000	0.000
Pterospermum acerifolium	-	0.340 *	0.000	0.000	0.000
Rhus chinensis	+	2.783 *	0.408	0.286	0.167
Schima wallichii	+	0.340 *	0.289	0.154	0.083

Note:
* Chi-square biased with correction
\+ Significantly associated

Based on the association analysis the following table is developed for that species which had significant association between the dominant herbaceous vegetation.

Table 5.13 Interspecific association indices and test statistics of significantly associated species

Associated Species	Associated Ground flora	Association + or -	Chi-square Corrected	OI	DI	JI
Castanopsis diversifolia	*Eupatorium adenophorum*	+	15.361	0.728	0.710	0.550
Leea indica	*Eupatorium adenophorum*	+	6.028	0.516	0.471	0.308
Phoebe lanceolata	*Eupatorium adenophorum*	+	4.063	0.471	0.444	0.286

Note:
OI- Ochiai Index
DI - Dice Index
JI - Jaccard Index

Since the corrected chi-square value of these species is greater than the table value 3.84 (at 1 degree of freedom), an overall positive association is suggested. *Castanopsis diversifolia, Leea indica* and *Phoebe lanceolata* seems to be strongly associated with *Eupatorium adenophorum.*

CHAPTER 6
DISCUSSION

Total species richness was higher for the qualitative survey since it also covers all species found in the quantitative survey. The total species diversity (N1) was highest in the*Eupatorium*-dominated site followed by the *Pteridium* and *Imperata*-dominated site. The evenness index of the *Eupatorium*-dominated site suggests that all the individuals of different species were evenly distributed among the species. The *Eupatorium*-dominated site seems to be equally favorable for all species and there were few rare species. The loss of individuals and species during the observation period were found to be lower in this site. Besides the herbaceous vegetation, there were plenty of perennial weeds and shrubs each represented by many established seedlings with lower chance of dying at the same site.

Unlike the species diversity, total species richness was higher in the *Imperata* and *Pteridium*-dominated site than that of the *Eupatorium*-dominated site (Table5.2). The higher species richness of the *Imperata* and the *Pteridium*-dominated site could be explained if these sites were at an earlier stage of succession than the *Eupatorium*-dominated site. The observed changes in species richness and diversity are better described by the early stage of the model by Bormann and Likens (1979) in which diversity increases rapidly in the earliest stage of succession and then drops gradually after a few years. Connel and Slatyer (1977) discussed the facilitation model of early succession, in which species modify the environment so that is more suitable for later successional species to invade and grow to maturity.

RGR for almost all species was higher in the *Eupatorium* site (Table 5.5). Sheltered microhabitats may be crucial for the establishment of seedlings. The lower temperature in such microhabitats may lead to a greater retention of soil moisture and hence an extension of the growing period. This possible effect on soil moisture together with the reduction in temperature might enhance the growth of tree seedlings in this site. RGR was relatively lower in the

Pteridium site. The dense canopy of the *Pteridium* may be associated with lower seedling growth rate by reducing the amount of sun light. Since the species growing in gaps are pioneer in nature, they would not grow in the shady conditions which reduce the rate of photosynthesis. Whitmore (1992) and Grime (1979) discussed that early successional species are shade-intolerant and are photosynthetically efficient under sufficient light conditions. *Pteridium* fronds seem to be the reason for the low light availability for tree seedlings together with some chemical effects. Lodhi and Rice (1971) reported that growth of tree seedlings was considerably better under the tree canopy rather than herbaceous cover. The reduced growth was due to the alleolopathic effects of some herbaceous plants. Such chemicals released from *Pteridium* litter can inhibit nitrogen-fixing and nitrifying bacteria (Rice 1964, 1965, 1972) which cause a microbial shift in soil micro-organisms and can induce a deficiency of available nitrogen, which in turn has a negative effects on tree seedling growth.

Tree seedling mortality was highest in the *Imperata*-dominated site (Table 5.4) followed by the *Pteridium*-dominated site. Likewise, species loss was also higher in this site because most of the tree seedlings recorded were represented by one or two individuals with a high probability of dying within the short period from suppression under the *Imperata* shade. Smith (1986) revealed that low shrubs and grasses or other herbaceous growth of "open" lands do not cast as much shade as a closed tree canopy but can cause even more root competition as far as seedlings are concerned. Consequently, some lesser forms of vegetation are most likely to have to be controlled in order to get higher seedling survival (Stewart *et al.*, 1984). The higher mortality and lower relative growth rate of tree seedlings at this site could be due to the competitive ability of *Imperata* grasses on low soil nutrient condition. Larson and Schubert (1969) observed that grasses and grass-like vegetation hamper the growth of tree seedlings more than might be inferred from their comparatively short stature. Tall, dense grass often competes with tree seedlings enough to reduce survival. Moreover, grass competition is almost always detrimental if there are serious seasonal moisture deficiencies. Rice (1984) revealed that not all of the effects of grass or other inhibiting vegetation are from competition for light, water and nutrients. There is a growing body of evidence that allelopathic effects (chemical antagonisms between different species) enable one species to poison the progeny of others. Evidence from previous research and this study demonstrate that there might be some chemical substances which cause the higher mortality of tree seedlings in the *Imperata*-dominated site. In community types, in which a seedling takes longer to escape the competitive effects of surrounding vegetation, the cumulative risk of mortality will be higher because of the compounding of annual mortality rates (Hill *et al.* 1994).

Cluster analysis grouped SU's within sites closely together but revealed large differences between sites (Table 5.8 & 5.9). All quardats among the sites were clustered clearly. This revealed that the three sites had a different characteristics in reference to species composition and percent cover. Moreover, the clustering among sites also suggests that the three sites could be at different stage of succession, so that species composition was different. The outcome of cluster analysis simply revealed that the particular dominant herbaceous vegetation may support different species composition and richness as they are at different successional stage.

Like total species diversity, tree seedling diversity was also higher for the *Eupatorium* site. (Table 5.3). Most species found on the study site were light demanding herbs and grasses. The percentage of herbaceous vegetation and grass cover increased with increasing amounts of light. Tree seedlings tended to become established in the open herbaceous cover, particularly near the margins of the forest, with few in the gap centers. Advancing shrubs in the central part of gaps could be lowering the number of seedlings. Mcquilkin (1940) also found dense stands of little bluestem a deterrent to establishment of pine seedlings as compared to bare or under canopy condition.

In a separate assessment of the species diversity of tree seedlings, computed as the reciprocal of Simpson's (1949) index, it was found to be higher in the *Eupatorium* site compared to other sites. Seedling mortality was lowest in this site, whilst it was pronounced in the *Pteridium* and the *Imperata* sites. The high diversity, high density, and low mortality of tree seedlings supports the fact that *Eupatorium adenophorum* may have some positive effects on seedling growth and survival. More generally, the establishment of forest trees is often assisted by the temporary protective effects of other vegetation. Such cover may be essential in preventing damage by heat when tree seedlings are very young and tender. Muick (1991) also found that artificial shade enhanced the survival of planted seedlings. The most interesting results of this study were the relatively higher growth, higher survival and low mortality rate of tree seedling beneath *Eupatorium adenophorum* stands. In this site, the growth of some tree seedling species like *Engelhardia spicata, Engelhardia serrata* and *Phoebe lanceolata* were found to be facilitated by *Eupatorium* shade. The effect of neighboring biomass of herbaceous vegetation could be associated with better tree seedling performance in this site. Moreover, due to the abundance of decayed organic matter in the *Eupatorium* site, soil nutrient levels would be higher there than in other sites. However, one way ANOVA failed to produce even one case in which nutrient levels were higher in this site. Although other influencing factors were unknown, gap location may also have a strong effect on species composition and seedling growth.

Even though establishment and survival of tree seedlings seems to be facilitated by *Eupatorium* cover, the study of association and effects of lesser vegetation on tree seedling growth and performance between four different site was handicapped by the absence of true replication for all sites. Since the study is confined in the sites with no replication, further investigation is needed with sufficient true replication. The natural variability within sites can only be assessed with more than two replications. Moreover, the small samples were not sufficient to understand the potential interaction between tree seedlings and ground vegetation. However, the close proximity of mother trees at all study sites and similarity in species composition and soil nutrients concentration (Table 5.7) throughout the study area, leads us to believe that *Eupatorium* cover could have positive effect on tree seedling performance. Orians

(1983) also postulated that germination and survival of seeds and seedlings should vary with gap microhabitat and gap size. Nonetheless, the higher growth rates of tree seedlings reported for the *Eupatorium* site could result from site differences created by its stand rather than gap size.

The three sites were remarkably different in respect to performance of tree seedlings while soil water moisture were not statistically significant (Figure 5.1). The *Eupatorium*-dominated site had the greater number of species per unit area than did the *Imperata* and the *Pteridium* sites. In spite of lower species richness (for total species, which is not included here), the distribution of individuals among the species was more even in the *Eupatorium* site. Very few tree seedling were observed in both the *Imperata* and the *Pteridium*-dominated sites. As described by Bhumibhamon *et al.,* (1980), *Imperata cylindrica* is allelopathic to some crops and tree species. The characteristics of *Imperata* and the difficulties associated with it are relatively well documented. The grass is strong competitor in acid infertile soils (Saxena and Ramakrishana 1983), but it is susceptible to shading (Aken' Ova and Atta-Krah, 1986), and becomes less competitive when pH and nutrient levels increase (Chou and Lee 1988). The completely open area might favor for growth of this grass and prevent the growth and survival of tree seedlings. Furthermore, this grass is considered a primary colonizer in slash-and-burn agricultural fields, so that it can be considered an earlier stage of succession compared to *Pteridium* and *Imperata.* Intense competition from this grass for space, light and nutrients may have suppressed the entry of more individuals of tree seedlings in this site. The survival of tree seedling species also depends on the shade tolerance of the target species. All of these different results suggest that the effect of lesser vegetation on the survival and growth of tree seedlings cannot be reliably judged by one year's results.

In contrast to other species, *Rhus chinensis* Mill. (Anacardiaceae) and *Ficus hispida* L. f. var. *hispida* (Moraceae) had high relative growth rates and relatively low percent of mortality. Both *Rhus chinensis* and *Ficus hispida* are secondary growth treelets and seem to be tolerant to the possible allelopathic influence of *Imperata.* Like the *Imperata* site, few tree seedlings were recorded in the quantitative survey in the *Pteridium*-dominated site. Tree seedling density, growth rate, diversity were lower in this site. There may be a variety of factors which limit seedling recruitment there. The relativeness importance of individual factors and microsite variables, and how they interact to produce observed spatial and temporal variation in seedling recruitment are still poorly understood and also far from the scope of this study. However, a number of authors have argued that *Pteridium aquilinum* has strong alleopathy effects which inhibits the emergence and survival of seedlings. For example, Amo (1991) reported that *Pteridium aquilinum* markedly inhibited germination and radicle growth of some tree seedlings by its macerated fronds. The higher mortality and lower density of naturally established tree seedlings in the *Pteridium* site may be due to the allelopathic product from *Pteridium aquilinum*. Moreover, *Pteridium* inhibits cover production of other species near itself, making their cover relatively higher elsewhere. Thick layers of *Pteridium* may have contributed to the inhibition of growth of tree seedlings under its shade and prevent air borne seeds from reaching the soil. So the negative effect of litter on seedling growth and survival was as expected, given the negative effects of *Pteridium* litter to shade the soil as well as allelopathy. Most small-seeded species can germinate only on dense media such as exposed mineral soil. This is mainly because there must be close contact between the seed and the moisture-supplying medium. Moreover, thick layers of dead fronds can cause seedling death if the seeds germinate in the litter above the ground (Fowler 1986b), or by shading them, because *Pteridium* litter observed in this study site was considerably thick.

Although the performance of tree seedlings seems to be favored by *Eupatorium* nurse cover, some differences were observed between the performance of each species. For example, the relative growth rates of *Engelhardia spicata* Lechen. ex. Bl. var. *colebrookena* (Ldl. ex Wall.) O. K. (Juglandaceae), *Phoebe lanceolata* (Nees) Nees and *Phoebe aff. cathia* (D. Don) Kosterm. (both Lauraceae) were comparatively higher in this site than for other species. This may have been due to the effects of slightly different microclimate in the quadrats rather than variable effects of *Eupatorium* nurse cover. However, soil moisture near the surface was monitored near each quadrat upto 30 cm below the surface. No relationship between seedling performance and either seedling density or moisture level were evident. It was suspected that soil moisture is an important factor, but that it was inadequately measured by the methods used in this study. As mentioned by the Fowler (1988) many other explanations exist, including fluctuations in soil nutrient levels between quadrats and date, and differences between the genotypes of the seedlings from different germination cohorts, years and quadrats. Vegetative cover of *Eupatorium* could facilitated the germination of most of these seedlings, providing wetter microsite for germination, and reducing the susceptability of predation.

Seed production, predation and dispersal are important processes that determine subsequent recruitment of tree seedlings. Seed dispersion or seed rain could be one important factor affecting the different distribution of tree seedlings in these deforested gaps. Dispersal of seeds may occur over a short or long time period, and this depends in part on the establishment adaptations of the seedlings. Seeds of some species are dispersed over a short period of time whereas it takes long time period for some species. Seedling emergence and growth is highly dependent on dispersal patterns and systems which ultimately determine recruitment attempts. The appearance of tree seedlings at a site is dependent upon the dispersal of propagules from the source population outside gaps. Further, individuals that had higher survival probabilities, grow faster than individuals with lower survival probabilities. The higher tree seedling density on *Eupatorium*-dominated site may be due to a different seed rain type. The seeds that arrived at safe site by chance dispersal could largely contribute to their regeneration. In addition, some species could have a seed bank strategy with longer seed survival and delayed germination. The regenerative strategies of these species to some extent could explain the relative abundance of tree seedlings in the three different sites. A seedling bank strategy is common for climax (or shade tolerant) species (Swine and Whitmore, 1988). Moreover, there is also a chance of selective removal of seed of particular species. Washitani and Takenaka 1987 discussed that typical long-lived seeds sometimes have mechanisms to detect gap climate and thus it enables an effective regeneration in safe sites. Another possible explanation of different tree seedling density in three different sites may be large annual fluctuations of seed production. The morphology and weight of wind dispersed fruits and seeds can greatly affect their rate of descent and hence the distance they may be carried by wind. Small seeds can more easily fall into soil or be buried by shifting soil, and thus obtain a safe site for germination. Timing of seed dispersal and subsequent germination will determine . whether emerging seedlings experience favorable seasonal conditions for establishment. Furthermore, both the site and surroundings influence dispersal distance. Age of gap is also other consideration. Seed and seedlings may have the best chances of success in newly formed treefall gaps with lower densities of competing vegetation than in existing gaps that have received seed input each year since they formed. At this extreme, the history and age of gaps of these three different sites may be different and thus influential for seedling establishment. Soil seed bank is another factor that determines the distribution and abundance of the species. The intensity of forest fire influence the soil seed bank. So that the fire history of a particular site is essential to evaluate the regeneration process. Although, fire was not evident for the difference in tree seedling performance in recent years, the past fire history could effect seed biology and consequently regeneration process. If seeds were not present in the soil when a disturbance occurs, or when fields was abandoned, then the limited spatial dispersal abilities of species is expected. That's why the reduction in seed input in gaps will reduce the recruitment process and subsequently result in the eventual poor distribution of tree seedlings.

As described earlier, the morphology of an emerging seedling may also limit its ability to establish in various types of ground cover. The size, shape, and orientation of the cotyledons will affect the young plant's ability to emerge and to survive in various types of ground cover. The large seeds are capable of establishing in a wide variety of habitat but also susceptible to intense predation. Further, small seed size are likely to avoid the post dispersal seed predators. So the difference in tree seedling performance in three different site seems to be affected by seedling safe sites, together with differences in their dispersal abilities which determined the seedling colonization in these gaps. Further work is required to determine which characteristics of the regenerative stage (e. g., seed size, seedling morphology, seed bank etc.) determine the performance of seedling establishment and survival in these gaps. However, this study has shown the possibility that distribution, abundance, and species composition of tree seedling species could be explained to some extent by the different seed rain strategy of different species.

Individual-and species-specific seed production patterns vary within the individual, population, year, season and habit (Janzen and Vazquez-Yanes, 1991). The different cyclic nature of seed production of different species could also affect the establishment of tree seedlings. In general, fast growing, shade-intolerant species tend to produce seed within few years interval than slower growing shade-tolerant species. Little information is available of the most important traits of the life history of trees in Doi Suthep-Pui National Park, which hindered the evaluation of different establishment and distribution of tree seedlings on these deforested gaps. If flowering and seed production are studied over a long time, this overcome might be avoided as seed production of individual tree species could evident.

An indicator plant spectrum with the group of indicator ground flora species and associated tree seedlings is suggested (Table 5.15). Since the ground flora species in humid tropical forests are highly dynamic and sensitive in respect to various disturbing factors, a site quality index could not be developed from a single lesser vegetation. Furthermore, the approach trying to demonstrate correlation's between site quality and different ground flora species also proved invalid . Moreover, the key indicator ground vegetation may or may not be present in a given locality because of chance, past forest destruction and competition (Spurr and Branes, 1980). However, the indicator plant spectrum were proposed instead of an ecological site quality index which is a simple list of group of indicator plants. During the fieldwork, the relative abundance of indicator species were recorded as present, common or abundant with, associated tree seedlings. The data obtained from the qualitative analysis (e.g. percent cover and frequency of species) were combined with the outcome of interspecific association analyses and the indicator plant spectrum was developed. Three main indicator plant species groups (groups of indicator species) or site associations are apparent. The proposed site quality was characterized by the group· of indicator species. A synthesis of indicator species groups for the index is described through indicator plant spectrum (Table 5.15). Furthermore, the associated tree species with corresponding ground flora species group were also mentioned in the same Table. These were determined using the mean percent cover of associated ground flora both from the extensive qualitative as well as quantitative survey, and their relative abundance. Moreover, the outcome of association analysis was also considered to develop site quality index based on lesser vegetation.

Table 6.1 Indicator plant spectrum and associated tree species

Ground Flora	Present	Common	Abundant	Associated Tree Species
Pteridium aquilinum			X	*Beilschmiedia sp.*
Commelina diffusa		X		*Boegmeria thailandica*
Desmodium multiflorum	X			*Eugenia albiflora*
Eupatorium odoratum	X			*Markamia stipulata*
Imperata cylindrica	X			
Imperata cylindrica			X	*Adinandra integerrima*
Apluda mutica		X		*Beilschmiedia sp*
Commelina paludosa	X			*Ficus hispida*
Eupatorium odoratum		X		*Rhus chinensis*
Melastoma normale	X			
Eupatorium adenophorum			X	*Bischofia javanica*
Eupatorium adoratum		X		*Castanopsis diversifolia*
Imperata cylindrica	X			*Cinnamomum caudatum*
Shuteria incolucrata		X		*Engelhardia spicata*
Pteridium aquilinum	X			*Engelhardia serrata*
				Helicia nilagirica
				Leea indica
				Phoebe lanceolata

Based on this spectrum, it can proposed that *Engelhardia spicata*, *E. serrata* and *Phoebe lanceolata*, *Leea indica*, *Castanopsis diversifolia* and *Helicia nilagirica* grow better in the *Eupatorium*-dominated site whilst *Beilschmiedia sp.*, *Ficus hispida* and *Rhus chinensis* and seems to do better in the *Imperata* sites. Likewise, the *Pteridium*-dominated site was suitable for *Boehmeria thailandica*, *Debregeasia longifolia*, *Eugenia albiflora*.

Tables 5.10, 5.11, and 5.12 revealed the interspecfic association analysis and association indices. The outcome of this analysis suggested three significant positive associations between ground flora and tree seedling species. In the *Eupatorium*-dominated site, tree seedlings like *Castanopsis diversifolia*, *Leea Indica* and *Phoebe lanceolata* were strongly associated with this herb. The statistically insignificant soil nutrient and soil moisture regime force to believe that the positive and negative associations result largely from a heterogeneity in biological forest floor environment provided by ground flora communities. However, the observed pattern of associations and tree seedling density could also controlled by other abiotic environmental factors, the interaction mechanism between tree seedling and ground vegetation overrides these abiotic factors.

Association between species observed within the sampling units could be due to a number of obvious reasons. As they have germinated together in similar habitats in the past, adaptations have occurred which permit close physical placement without excessive competition. Species with different root depths or species with photosynthesize at different times of the year may be positively associated (Smith and Cottam, 1967). Species which require the same type of soil or moisture conditions may be found together if they have evolved mechanisms by which they do not directly compete for these needs within the same microhabitat at the same time. The presence of neighboring vegetation (i.e. *Eupatorium adenophorum*) itself may be a good indication of productivity. In this point I am fully agreed with Fowler (1992) in which he mentioned that the probable explanation for most of the apparent positive effects of neighbors on seedling performance could be the presence of a surviving neighbor which indicates that a spot had been favorable , or at least suitable, for seedlings; the neighbor could not have survived had the spot not been sufficiently favorable for it in the past. Thus the presence of surviving neighbor was an indication that the spot had been favorable for the neighboring plant in the past. If the neighbor and the seedling had had similar response to the microenvironment of the spot, then the spot would have been favorable for the seedlings. There is no doubt that the lesser vegetation cover has both positive and negative effects on tree seedling growth and survival, but there have been many hypotheses presented in the literature such as the following: vegetative reproduction, heavy seeds that remains near the parent plant, competition, exudation of toxic chemicals, preconditioning of an area by a species previously occupying the site, drainage pattern, moisture, humidity, light, soil texture, soil depth, soil chemistry, life history of the species, microrelief, windfall pits and burning (Greig-Smith 1964; Smith and Cottom 1967). So that the environmental and autoecological information related to this study is not sufficient to give the reasonable answers about the observed pattern of distribution and survival of tree seedlings in different ground flora vegetation. However, the fundamental niche differentiation caused by ground flora vegetation seems to strongly influence tree seedling growth and performance.

In summary, the study revealed that the multiple mechanisms of differential seed rain, plant competition, allelopathy, herbivory and abiotic environmental factors interact in complex ways which influence the tree seedling growth and performance at three different sites. Since all soil factors (pH, soil nutrient, and % moisture at field capacity etc.) were not significantly different between sites, the cover of lesser vegetation could be accounted for the remarkable variation in tree seedling density, growth and performance. Furthermore, variation in the seed rain could account for it, including all species interactions, which could explain the amount of variability of total tree seedling density. The most striking finding of the study is the facilitative effect of *Eupatorium* nurse cover for tree seedling recruitment. The survival and growth performance of some species were seems to be enhanced by neighboring cover of *Eupatorium*. Naturally established tree seedlings were higher at this site with high tree seedling diversity. The growth of *Engelhardia spicata, Phoebe lanceolata* and *Phoebe* sp. was facilitated by *Eupatorium* cover. These seedlings naturally established under herbs may eventually outcompete the nurse cover for light and moisture. Biogenic safe sites (Callway 1992) provided by *Eupatorium* shade may positively effect the seedling recruitment and spatial distribution of these seedlings.

Seedlings of *Rhus chinensis* were found only in the *Imperata*-dominated site, almost all of them under the canopy of this grass. Relative growth rate of this species was quite satisfactory and very few seedlings died during the observation period. It seems that survival of newly established treelet seedlings of *Rhus* in some cases was facilitated by intact cover of *Imperata*. The very abundance of this species implies relatively broad tolerance or dense seed rain. Likewise, there is also an evidence of facilitation of growth and survival of *Ficus hispida* seedling both in *Imperata* and mixed ground flora species. In contrast, other tree seedling found in the *Pteridium* and the *Imperata*-dominated sites tend to be more susceptible to competitive inhibition. Likewise, there were very few other individuals were recorded and growth rate of these species were relatively very low with higher percent of mortality. The results suggest that only these two species benefited from the presence of *Imperata* grass in the experimental sites. Further studies employing a variety of sampling and analysis procedures could help determine the positive interactions between this grass and different tree seedling species.

CHAPTER 7
CONCLUSION AND RECOMMENDATION

Tree seedlings in the *Pteridium*-dominated site seemed to be not positively affected by its shade. While growth of the seedling species was uniformly poor over the quadrats, the distribution of seedlings was also found very sparse during the qualitative survey. The thick layer of *Pteridium* fronds seems to be strongly correlated with lower seedling density in this site. The thick *Pteridium* layer might have created unfavorable microsites for seed germination. It is known that *Pteridium* has relatively strong allelopathic effects on soil which has negative effects on tree seedling growth and performance (Amo, 1991). However, seed dispersal or seed rain, germination and survival also need to be studied before coming to a definite explanation of the poor performance of tree seedlings in the *Pteridium* and the *Imperata* dominated sites. Continued monitoring of naturally established tree seedlings in study sites over a long period of time would provide valuable information as to the overall regeneration pattern, as well as performance of individual species.

Microsite differentiation created by nurse cover could affect the floristic composition and density of individual tree seedling species. In general, regeneration seems to be unsatisfactory. However, regeneration in the *Eupatorium* gap was relatively high but in the *Pteridium* and *Imperata* gaps it was unsatisfactory except for two species in the *Imperata*-dominated site (*Rhus chinensis* and *Ficus hispida*). Even though , the seedlings were present, unfavorable soil conditions by possible allelopathy adversely affected their establishment and growth.

The interspecific association analysis provides some positive association between *Eupatorium adenophorum* and indicate that this ground flora can be used to assess the site suitability for few native tree species for forest restoration and natural regeneration facilitating program. Some tree seedling species like *Castanopsis diversifolia, Leea indica* and *Phoebe lanceolata* seems to be better in the *Eupatorium*-dominated sites. However, both the *Pteridium* and *Imperata* could not indicate the associated tree seedling in the study site according to interspecific association analysis. Likewise, the result of qualitative survey indicated that *Rhus chinensis* and *Ficus hispida* will be suitable for *Imperata*-dominated sites while *Beilschmiedia sp.*, *Boehmeria thailandica* and *Eugenia albiflora* seems to be better in *Pteridium*-dominated site.

Abiotic environmental factors are generally accepted as a primary factors affecting tree seedling distribution, but biotic factors (including interaction between neighboring species) also play an important role in forest regeneration. The study re-affirmed that the dynamic models of forest growth, species diversity, and composition must take into consideration the lesser vegetation and its distribution. Since the study was a natural experiment, it began after the "treatment" i. e. the different ground flora, were already existed and the initial conditions of three different gaps were unknown. Therefore, it is hard to confirm whether facilitation or the performance of some tree seedlings was actually was due to the lesser vegetation. However, the affect of herbaceous vegetation cover remains as the major possible determinants for the different distribution and performance of tree seedlings in three different sites.

The devising ecological site quality indices based on the presence/ absence of indicator species in tropics is difficult and their reliability seems to be suspect since most of the ground vegetation changes over time as it responds to various disturbing factors like fire, grazing and human interference. Moreover, a single indicator species may or may not be present in a particular site due to chance, predation, dispersion and competition. Nonetheless, rapid investigation at the community level and their relative abundance might be useful to select the appropriate tree species in afforeatation program. However, the validity of such approach needs further testing. Moreover, the planting experiments should be carried out to test validity of proposed plant spectrum.

In order to achieve a full understanding of mechanism of tree seedling-lesser vegetation interactions, further experiment's are required. The relevant data are still very scarce or absent over large areas. Research related to the net effect of early successional communities, mainly dominated by shrub or herb species should be carried out. These experiment can be done sites with different successional community types. At each site, nursery raised tree seedlings of the main species should be transplanted into quadrats with relatively undisturbed ground vegetation, and into adjacent quadrats from which the lesser vegetation has been experimentally removed. The net effect of lesser vegetation should be assessed by comparing growth and survival of tree seedlings in clearing vs. those beneath ground vegetation. The seed rain and predation are other major factors affecting regeneration attempts in tree fall gaps. Moreover, the effect of gap size and location should be one research priority. Another important but little-studied aspect is the possible allelopathic effects of *Pteridium* fronds. A simple bioassay test of the liquid extract from *Pteridium* fronds should be done both in laboratory as well as under field conditions. A small project could be designed to see the effects of such liquid on the germination of seeds of different tree species. In general, the following research projects are recommended to confirm the effects of the lesser vegetation on tree seedling growth and performance.

1.Ecology of seed dispersal and predation in gaps

2. Study of seed germination in natural conditions beneath the shade of different types of lesser vegetation

3. Seed germination tests in nurseries with application of *Pteridium* green fronds extract and extract from *Imperata* and *Eupatorium*.

4. Study of the effects of the microclimatic variables (e.g. light, temperature, evaporation, shade, humidity etc.) under different ground vegetation types,

5. Transplantation of nursery raised tree seedlings into quadrats containing different lesser vegetation and quadrats in which lesser vegetation has been experimentally removed

The dynamics of lesser vegetation in deforested gaps is an integral part of understanding of forest ecosystems. The negative as well as the positive effects of herbaceous vegetation are important in the dynamics of tree seedling recruitment. Proper understanding of the herb stratum dynamics and their ecological significance is an inseparable part of tropical forest ecosystems. Herb and shrub cover seem to provide favorable regeneration niches for some species. Grubb (1977) stressed the importance of such regeneration niches in the maintenance of species richness. Various authors also mentioned the dynamics of herb and their potential role in tree seedling recruitment. In this regard, I agree with Whittaker (1969), Whittaker and Levin (1977) and Maquire and Forman (1983) when they considered the biological complexity of the microsite mosaic as one way of augmenting species diversity. Thus neighboring coverage of some herb and shrubs contributes the positive influence on growth and performance of some species differentially, assuming the existence of herb-seedling interactions.

In general, however, herb and shrubs cover seem to be a major factor affecting forest regeneration. Heterogeneity in the forest floor environment created by the lesser vegetation seems to contribute to the growth and survival of tree seedlings whilst some herb species inhibit tree seedling growth possibly by allelopathy. Herb and shrub cover in the gap floor should be treated as a integral component of the forest ecosystem. The proper understanding of their ecological significance and dynamics should be inseparable part of tropical forest regeneration and restoration.

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APPENDIX

APPENDIX 1 Cluster Analysis

The basic computor program SPSS (Statistical Pacakge for Social Science) was used for all statistical analysis. Cosine of vectors of variables were used as a index of cluster. The subunit was projected onto a circle of unit radius through the use of direction cosine. The most similar subunit were determined and grouped together to form a artificial sub unit. The similarity between all units were further calculated and most similar unit were combined. This process continues unless all sub unit be graphed together. The index was calculated with following formula.

$$\text{Cosine} = \sum_{n=1}^{S} (Xi\ Yi) \,/\, \sum_{n=1}^{S} Xi^{2} \ \sum_{n=1}^{S} Yi^{2}$$

APPENDIX 2 Total species found in extensive qualitative survey

Botanical name	Family/ Sub Family	Habit
Acacia megaladena Desv. var. *megaladena*	Leguminosae, Mimosoideae	dwc
Acronychia pendunculata (L.) Miq.	Rutaceae	et
Adinandra integerrima T. And. ex Miq.	Theaceae	et
Alpinia belpharocalyx K. Sch.	Zingiberaceae	eh
Alpinia malaccensis (Burm.f.) Rosc.	Zingiberaceae	eh
Albizia odoratissima (L.f.) Bth.	Leguminosae, Mimosoideae	dt
Amomum siamense Craib	Zingiberaceae	eh
Anneslea fragrans Wall.	Theaceae	dt
Apluda mutica L.	Gramineae	eh
Aporusa dioica (Roxb.) M.-A.	Euphorbiaceae	dtlt
Argyreia capitiformis (Poir.) Oost.	Convolvulaceae	ev
Archidendron clypearia (Jack) Niels. ssp. *clypearia* var. *clypearia*	Leguminosae, Mimosoideae	et
Artocarpus heterophyllus Lmk.	Moraceae	et
Artocarpus lanceolata Trec.	Moraceae	et
Aspidistra longifolia Hk.f.	Liliaceae	eh
Bauhinia ornata Kurz var. *kerrii* (Gagnep.) K.& S.S. Lar.	Leguminosae, Caesalpinioideae	ewc
Beilschmiedia sp.	Lauraceae	et
Bischofia javanica Bl.	Euphorbiaceae	dt
Boehmeria thailandica Yaha.	Urticaceae	etlt
Bridelia pubescens Kurz	Euphorbiaceae	et
Castanopsis diversifolia King ex Hk.f.	Fagaceae	et
Castanopsis tribuloides (Sm.) A. DC.	Fagaceae	et
Cinnamomum caudatum Nees	Lauraceae	et
Cissus discolor Bl. var. *discolor*	Vitaceae	ev
Clerodendrum glandulosum Colebr. ex Ldl.	Verbenaceae	etlt
Clitoria mariana L.	Leguminosae, Papilionoideae	ev
Commelina diffusa Burm.f.	Commelinaceae	eh
Commelina paludosa Bl.	Commelinaceae	eh
Conyza sumatrensis (Retz.) Walk.	Compositae	ah
Crotalaria alata D.Don.	Leguminosae	ah
Croton oblongifolius Roxb.	Euphorbiaceae	dt
Cruddasia insignis Prain	Leguminosae, Papilionoideae	ev
Cupressus torulosa D.Don	Cupressaceae	et
Curculigo capitulata (Lour.) O.K.	Hypoxidaceae	eh
Cyclea polypetala Dunn	Menispermaceae	ev
Cyperus brevifolius (Rottb.) Hassk. var. *brevifolius*	Cyperaceae	eh
Cyrtococcum oxyphyllum (Steud.) Stapf	Gramineae	eh
Dalbergia rimosa Roxb.	Leguminosae, Papilionoideae	dt

Debregeasia longifolia (Burm.f.) Mett. ex Kuhn	Urticaceae	etlt
Desmodium repandum (Vahl) DC.	Leguminosae, Papilionoideae	eh
Desmodium multiflorum DC.	Leguminosae, Papilionoideae	eh
Dillenia parviflora Griff. var. Kerrii (Craib) Hoogl.	Dilleniaceae	dt
Dioscorea bulbifera L.	Dioscoreaceae	dpv
Dichroa febrifuga Lour.	Saxifragaceae	es
Diospyros glandulosa Lace	Ebnaceae	et
Diosporum calcaratum Wall. ex D. Don var. *rubiflorum* Gagnep.	Liliaceae	dh
Dillenia aurea Sm. var. *aurea*	Dilleniaceae	dt
Dianella ensifolia (L.) DC.	Liliaceae	eh
Embelia stricta Craib	Myrsinaceae	dwc
Engelhardia spicata Lechen. ex. Bl. var. *colebrookena* (Lindl. ex Wall.) O. K.	Juglandaceae	dt
Engelhardia serrata Bl.	Juglandaceae	dt
Eleusine indica (L.) Gaertn.	Gramineae	eh
Erythrina suberosa Roxb.	Leguminosae, Papilionoideae	dt
Eugenia albiflora Duth. ex Kurz	Myrtaceae	et
Eugenia tetragona Wight	Myrtaceae	et
Eupatorium adenophorum Spreng.	Compositae	eh
Eupatorium odoratum L.	Compositae	aeh
Eurya acumminata DC. var. *wallichina* Dyer	Theaceae	et
Eurya nitida Korth. var. *siamensis* (Craib) H. Keng	Theaceae	et
Fagerlindia sp.	Rubiaceae	es
Ficus hispida L. f. var. *hispida*	Moraceae	detlt
Flemingia sootepensis Craib	Leguminosae, Papilionoideae	detlt
Garcinia cowa Roxb.	Guttifereae	dt
Goldfussia anfractuosa (Cl. ex Hoss.) Brem.	Acanthaceae	dh
Gomphostemma lucidum Wall. ex. Bth.	Labiatae	dh
Gordonia dalglieshiana Craib	Theaceae	et
Helicia nilagirica Bedd.	Proteaceae	et
Imperata cylindrica (L.) P. Beauv. var. *major* (Nees) C. E.Hubb. ex Hubb. & Vaugh.	Gramineae	eh
Ixora cibdela Craib var. *cibdela*	Rubiaceae	etlt
Jasminum nervosum Lour.	Oleaceae	ev
Leea indica (Burm.f.) Merr.	Leeaceae	detlt
Mallotus philippensis (Lmk.) M.-A. var. *philippensis*	Euphorbiaceae	et
Mangifera indica L.	Anarcardiaceae	et
Markhamia stipulata (Wall.) ex Seem. ex Sch. var. *stipulata*	Bignoniaceae	dt

Melastoma normale D. Don var. *normale*	Melastomataceae	etlt
Mesua ferrea L.	Guttifereae	et
Micromelum minutum (Forst.f.) Wight & Arn.	Rutaceae	detlt
Microstegium vagans (Nees ex Steud.) *A. Camus*	Gramineae	dph
Millettia pachycarpa Bth.	Leguminosae, Papilionoideae	dwc
Millettia pubinervis Kurz	Leguminosae, Papilionoideae	dwc
Morinda angustifolia Roxb. var. *scabridula* Craib	Rubiaceae	etlt
Mucuna brevipes Craib	Leguminosae, Papilionoideae	ev
Mucuna macrocarpa Wall.	Leguminosae, Papilionoideae	ewc
Mussaenda kerrii Craib	Rubiaceae	ewc
Mussaenda sanderiana Ridl.	Rubiaceae	es
Mussaenda parva Wall. ex G. Don	Rubiaceae	ewc
Pennisetum purpureum Schumach.	Gramineae	ah
Phoebe aff. cathia (D.Don) Kosterm.	Lauraceae	et
Phoebe lanceolata (Nees) Nees	Lauraceae	et
Phoebe sp.	Lauraceae	et
Pinus kesiya Roy. ex. Gord.	Pinaceae	et
Phyllanthus emblica L.	Euphorbiaceae	dt
Plectranthus striatus Bth.	Labiate	ah
Polygonum chinense L.	Polygonaceae	ah
Prunus cerasoides D.Don	Rosaceae	dt
Prunus persica	Rosaceae	dt
Pueraria stricta Kurz	Leguminosae, Papilionoideae	ev
Protium serratum (Wall. ex Colebr.) Engl.	Burseraceae	dt
Pteridium aquilinum (L.) Kuhn ssp. aquilinum var. wightianum (Ag.) Try.	Dennstaedtiaceae	eh
Pterospermum acerifolium Willd.	Sterculiaceae	et
Pyrenaria garrettiana Craib	Theaceae	et
Rhus chinensis Mill.	Anacardiaceae	detlt
Rourea minor (Gaertn.) Leenh. ssp. *minor*	Connaraceae	ewc
Rubus blepharoneurus Card.	Rosaceae	ev
Rauvolfia ophiorrhizoides (Kurz) Kerr	Apocynaceae	etlt
Quercus kingiana Craib	Fagaceae	dt
Saurauia nepaulensis DC.	Saurauiaceae	et
Saurauia roxburghii Wall.	Saurauiaceae	et
Schima wallichii (DC.) Korth.	Theaceae	dt
Semecarpus cochinchinensis Engl.	Anacardiaceae	et
Shuteria involucrata (Wall.) Wight. & Arn.	Leguminosae, Papilionoideae	ev
Smilax perfoliata Lour.	Smilacaceae	ev
Smilax zeylanica L. ssp. *hemsleyana* (Craib) T. Koy.	Smilacaceae	ev

Spatholobus floribundus Craib	Leguminosae, Papilionoideae	ewc
Setaria parviflora (Poir.) Kerg.	Gramineae	ah
Styrax benzoides Craib	Styracaceae	et
Tarennoidea wallichii (Hk.f.) Tirv. & Sastre	Rubiaceae	et
Trema orientalis (L.) Bl.	Ulmaceae	etlt
Themeda triandra Forssk.	Gramineae	dph
Turpinia pomifera (Roxb.) Wall. ex DC.	Staphyleaceae	et
Urena lobata L. ssp. *lobata* var. *lobata*	Malvaceae	aph
Vernonia volkameriifolia DC. var *volkameriifolia*	Compositae	etlt
Vigna radiata (L.) Wilcz. var. *sublobata* (Roxb.) Verdc.	Leguminosae, Papilinoideae	av
Wendlandia paniculata (Roxb.) DC.ssp. *scabra* (Kurz) Cowan	Rubiaceae	et
Zingiber kerrii Craib	Zingiberaceae	dph
Zingiber smilesianum Craib	Zingiberaceae	dph
Zanthoxyum acanthopodium DC.	Rutaceae	es

Note

et = evergreen tree
etlt = evergreen treelet
dt = deciduous tree
detlt = deciduous treelet
ewc = evergreen woody climber
dwc = deciduous woody climber
es = evergreen shrub
ds = deciduous shrub

dph = deciduous perrenial herb
aph = annual perennial herb
dpv = deciduous perennial vine
ev = evergreen vine
dh = deciduous herb
av = annual vine
ah = annual herb
dh = deciduous herb

APPENDIX 2 List of Tree Seedling Found in Extensive Qualitative and Quantitative Survey

Botanical Name	Family	Habit
Acronychia pedunculata (L.) Miq.	Rutaceae	et
Adinandra integerrima T. And. ex Miq.	Theaceae	et
Albizia odoratissima (L. f.) Bth.	Leguminosae, Mimosoideae	dt
Aporusa dioica (Roxb.) M.-A.	Euphorbiaceae	dtlt
Archidendron clypearia (Jack) Neils. ssp. *clypearia* var. *clypearia*	Legumonisae, Mimosoideae	et
Artocarpus heterophyllus Lmk.	Moraceae	et
Artocarpus lanceolata Trec.	Moraceae	et
Beilschmiedia sp.	Lauraceae	et
Bischofia javanica Bl.	Euphorbiaceae	dt
Boehmeria thailandica Yaha.	Urticaceae	etlt
Castanopsis diversifolia King ex Hk. f.	Fagaceae	et
Castanopsis tribuloides (Sm.) A.DC.	Fagaceae	et
Cinnamomum caudatum Nees	Lauraceae	et
Clerodendrum glandulosum Colebr. ex Lindl.	Verbenaceae	etlt
Croton oblongifolius Roxb.	Euphorbiaceae	dt
Cupressus torulosa D.Don	Cupressaceae	et
Dalbergia rimosa Roxb.	Leguminosae, Papilionoideae	dt
Debregeasia longifolia (Burm.f.) Wedd.	Urticaceae	etlt
Dillenia parviflora Griff.var. *kerrii* (Craib) Hoogl.	Dilleniaceae	dt
Dillenia aurea Sm. var. *aurea*	Dilleniaceae	dt
Englehardia spicata Lechen. ex. Bl. var. *colebrookena* (Ldl. ex. Wall.) O. K.	Juglandaceae	dt
Engelhardia serrata Bl.	Juglandaceae	dt
Erythrina suberosa Roxb.	Leguminosae, Papilionoideae	dt
Eugenia albiflora Duth. ex Kurz	Myrtaceae	et
Eugenia tetragona Wight	Myrtaceae	et
Eurya acumminata DC. var. *wallichina* Dyer	Theaceae	et
Eurya nitida Korth. var. *siamensis* (Craib) H.Keng	Theaceae	et
Ficus auriculata Lour.	Moraceae	et
Ficus hispida L. f. var. *hispida*	Moraceae	detlt
Flemingia sootepensis Craib	Leguminosae, Papiloinoideae	detlt
Garcinia cowa Roxb.	Guttifereae	dt
Gordonia dalglieshiana Craib	Theaceae	et
Helicia nilagirica Bedd.	Proteaceae	et
Ixora cibdela Craib var. *cibdela*	Rubiaceae	etlt
Leea indica (Burm.f.) Merr.	Leeaceae	dtlt
Litsea monopetala (Roxb.) Pers.	Lauraceae	etlt
Lithocarpus elegans (Bl.) Hatus. ex Soep.	Fagaceae	et

Macaranga denticulata (Bl.) M.-A.	Euphorbiaceae	etlt
Macropanax concinnus Miq.	Araltaceae	etlt
Mallotus philippensis (Lmk.) M.-A. var. *philippensis*	Euphorbiaceae	et
Mangifera indica L.	Anacardiaceae	et
Markhamia stipulata (Wall.) Seem ex Sch. var. *stipulata*	Bignoniaceae	dt
Melastoma normale D.Don var. *normale*	Melastomataceae	etlt
Mesua ferrea L.	Guttifereae	et
Morinda angustifolia Roxb. var. *scabridula* Craib	Rubiaceae	etlt
Phoebe aff. cathia (D.Don) Kosterm.	Lauraceae	et
Phoebe lanceolata (Nees) Nees	Lauraceae	et
Phoebe sp.	Lauraceae	et
Pinus kesiya Roy. ex. Gord.	Pinaceae	et
Phyllanthus emblica L.	Euphorbiaceae	dt
Prunus persica	Rosaceae	dt
Prunus cerasoides D.Don	Rosaceae	dt
Protium serratum (Wall. ex Colebr.) Engl.	Burseraceae	dt
Pterospermum acerifolium Willd.	Sterculiaceae	et
Pyrenaria garrettiana Craib.	Theaceae	et
Quercus kingiana King Craib	Fagaceae	dt
Rauvolfia ophiorrhizoides (Kurz) Kerr	Apocynaceae	dtlt
Rhus chinensis Mill.	Anacardiaceae	dtlt
Saurauia roxburghii Wall.	Saurauiaceae	et
Schima wallichii (DC.) Korth.	Theaceae	dt
Semecarpus cochinchinensis Engl.	Anacardiaceae	et
Styrax benzoides Craib	Styracaceae	et
Tarennoidea wallichii (Hk. f.) Tirv. & Sastre	Rubiaceae	et
Trema orientalis (L.) Bl.	Ulmaceae	etlt
Turpinia pomifera (Roxb.) Wall. ex DC.	Sraphyceaceae	et
Urena lobata L. ssp. *lobata* var. *lobata*	Malvaceae	etlt
Wendlandia paniculata (Roxb.) DC. ssp. *scabra* (Kurz) Cowan	Rubiaceae	et

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av = annual vine
ah = annual herb
dh = deciduous herb

APPENDIX 4 List of Tree Seedlings and Ground Flora Recorded in Quantitative Survey

Botanical Name	Family	Habit
Albizzia odoratissima (L.f.) Bth.	Leguminosae, Mimosoideae	dt
Alpinia blepharocalyx K. Sch.	Zingiberaceae	eh
Alpinia malaccensis (Burm.f.) Rosc.	Zingiberaceae	dh
Apluda mutica L.	Gramineae	eh
Bauhinia ornata Kurz. var. *krrrii* (Gagnep.) K. & S. S. Lar.	Leguminosae, Caesalpinioideae	ewc
Beilschmiedia sp.	Lauraceae	et
Boehmeria thailandica Yaha.	Urticaceae	etlt
Castanopsis diversifolia King ex Hk. f.	Fagaceae	et
Clitoria mariana L.	Leguminoase, Papilionoideae	ev
Commelina diffusa Burm.f.	Commelinaceae	eh
Commelina paludosa Bl.	Commelinaceae	eh
Conyza sumatrensis (Retz.) Walk.	Composiateae	ah
Crotalaria alata D. Don	Leguminosae	ah
Cruddasia insignis Prain	Leguminosae, Papilionoideae	ev
Curculigo capitulata (Lour.) O.K.	Hypoxiadeae	eh
Cyperus brevifolius (Rottb.) Hassk. var. *brevifolius*	Cyperaceae	eh
Debregeasia longifolia (Burm.f.) Wedd.	Urticaceae	etlt
Desmodium multiflorum DC.	Leguminosae, Papilionoideae	eh
Dioscorea bulbifera L.	Dioscoreaceae	dpv
Dichroa febrifuga Lour.	Saxifragaceae	es
Dianella ensifolia (L.) DC.	Liliaceae	eh
Engelhardia spicata Lechen. ex Bl. var. *colebrookena* (Lindl. ex Wall.) O. K.	Juglandaceae	dt
Eugenia albiflora Duth. ex Kurz	Myrtaceae	et
Eupatorium odoratum L.	Compositae	aeh
Eupatorium adenophorum Spreng.	Compositae	eh
Eurya acumminata DC. var. *wallichina* Dyer	Theaceae	et
Fagerlindia sp.	Rubiaceae	es
Flemingia sootepensis Craib	Leguminosae, Papilionoideae	detlt
Phragmitus vallatoria (Pluk. ex L.) Veldk	Gramineae	eh
Gordonia dalglieshiana Craib	Theaceae	et
Imperata cylindrica (L.) P. Beauv. var. *major* (Nees) C. E. Hubb. ex Hubb. & Vaugh	Gramineae	eh
Jasminum nervosum Lour.	Oleaceae	ev
Leea indica (Burm.f.) Merr.	Leeaceae	dtlt
Litsea monopetala (Roxb.) Pers.	Lauraceae	etlt

Mallotus philippensis (Lmk.) M.-A. var. *philippensis*	Euphorbiaceae	dt
Markhamia stipulata (Wall.) ex Seem. ex. Sch. var. *stipulata*	Bignoniaceae	det
Melastoma normale D.Don var. *normale*	Melastomataceae	etlt
Millettia pachycarpa Bth.	Leguminosae, Papilionoideae	dwc
Millettia pubinervis Kurz	Leguminosae, Papilionoideae	dwc
Phoebe lanceolata (Nees) Nees	Lauraceae	et
Phoebe sp.	Lauraceae	et
Polygonum chinense L.	Polygonaceae	ah
Prunus cerasoides D.Don	Rosaceae	det
Pueraria stricta Kurz	Leguminosae, Papilionoideae	ev
Pteridium aquilinum (L.) Kuhn ssp. *aquilinum* var. *wightianum* (Ag.) Try.	Dennstaedtiaceae	eh
Pterospermum acerifolium Willd.	Sterculiaceae	et
Pyrenaria garrettiana Craib	Theaceae	et
Rhus chinensis Mill.	Anacardiaceae	dtlt
Rubus belpharoneurus Card.	Rosaceae	ev
Rourea minor (Gaertn.) Leenh. ssp. *minor*	Connaraceae	ewc
Rauvolfia ophiorrhizoides (Kurz) Kerr	Apocynaceae	etlt
Schima wallichii (DC.) Korth	Theaceae	dt
Shuteria involucrata (Wall.) Wight. & Arn.	Leguminosae, Papilionoideae	ev
Smilax zeylanica L. ssp. *hemsleyana* (Craib) T. Koy.	Smilacaceae	ev
Urena lobata L. ssp. *lobata* var. *lobata*	Malvaceae	etlt
Vigna radiata (L.) Wielz. var. *sublobota* (Roxb.) Verdc.	Leguminosae, Papilionoideae	ev
Zingiber kerrii Craib	Zingiberaceae	dph
Zingiber smilesianum Craib	Zingiberaceae	dph

Note

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Appendix 5 Hierarchical Cluster Analysis (using Cosine Index)

Agglomeration Schedule using Average Linkage (Between Groups)

	Clusters Combined			Stage Cluster 1st Appears		Next
Stage	Cluster 1	Cluster 2	Coefficient	Cluster 1	Cluster 2	Stage
1	24	40	.000000	0	0	46
2	17	21	.807482	0	0	11
3	19	20	1.360729	0	0	5
4	25	26	1.425510	0	0	17
5	18	19	1.554136	0	3	8
6	2	15	1.716956	0	0	13
7	43	44	1.752432	0	0	12
8	18	31	1.826849	5	0	11
9	3	7	2.400195	0	0	16
10	36	48	2.421704	0	0	15
11	17	18	2.826453	2	8	17
12	37	43	3.014540	0	7	21
13	2	14	3.161323	6	0	16
14	27	32	3.339774	0	0	19
15	36	41	3.687788	10	0	23
16	2	3	4.146763	13	9	22
17	17	25	4.214418	11	4	19
18	28	29	4.568449	0	0	20
19	17	27	4.898804	17	14	20
20	17	28	5.942071	19	18	25
21	37	38	6.722408	12	0	33
22	2	8	7.038680	16	0	24
23	36	42	7.535419	15	0	26
24	2	6	8.313212	22	0	32
25	17	22	8.446578	20	0	30
26	36	45	9.156117	23	0	28
27	34	35	9.290587	0	0	34
28	36	46	10.715208	26	0	35
29	4	5	10.989946	0	0	37
30	16	17	13.120874	0	25	31
31	16	30	13.833662	30	0	34
32	2	13	14.266456	24	0	37
33	1	37	15.067272	0	21	39
34	16	34	15.217965	31	27	36
35	36	47	15.238316	28	0	41
36	16	33	16.078110	34	0	39
37	2	4	17.466528	32	29	43
38	9	10	20.002733	0	0	40
39	1	16	21.367731	33	36	42
40	9	11	25.349903	38	0	44
41	36	39	29.059155	35	0	45
42	1	23	29.679140	39	0	45
43	2	12	31.082336	37	0	44
44	2	9	34.454231	43	40	47
45	1	36	50.136524	42	41	46

Appendix 6 Hierarchical Cluster Analysis Using Soil Parameters

Agglomeration Schedule using Average Linkage (Between Groups)

Stage	Clusters Combined		Coefficient	Stage Cluster 1st Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	2	3	5.889493	0	0	3
2	4	6	30.186707	0	0	4
3	1	2	33.061722	0	1	4
4	1	4	47.696350	3	2	5
5	1	5	64.494064	4	0	0

APPENDIX 7 Monthly records of soil moisture content (g water/g dry soil)

Month	Bracken site	Imperata Site	Eupatorium Site
April	0.5045	0.5786	0.5937
May	0.3559	0.3745	0.3731
June	0.3678	0.4083	0.4612
July	0.4578	0.4138	0.4829
August	0.4638	0.5632	0.6145
September	0.4530	0.5196	0.4716
October	0.4333	0.5452	0.5620
November	0.4401	0.4598	0.4898
December	0.2413	0.3308	0.3089

Appendix 8 Soil Sample Analysis Result (Faculty of Agriculture/ Soil Science Laboratory)

Lab No.	Sample	PH	% OM	% Nitrogen	Phosphorous (ppm)	Potasium (ppm)	% Moisture at F.C.
389	1.1	5.51	7.91	0.338	23.00	147.50	31.88
396	1.2	5.54	10.07	0.482	24.00	170.00	35.05
390	1.3	5.62	8.60	0.411	25.00	225.00	35.89
391	1.4	5.64	9.39	0.432	24.00	122.50	22.22
418	1.5	5.91	10.07	0.428	13.00	242.00	34.55
392	1.6	5.79	10.45	0.449	13.00	162.50	36.64
393	1.7	5.59	7.89	0.352	11.00	207.50	31.61
394	1.8	5.55	10.0	0.449	9.50	222.50	37.91
406	1.9	5.41	8.44	0.419	13.00	122.50	36.84
395	1.10	5.02	9.46	0.452	22.00	110.00	35.02
397	2.1	5.56	5.38	0.311	5.00	80.00	38.12
398	2.2	6.20	7.45	0.353	11.00	222.50	32.42
399	2.3	5.27	7.79	0.362	54.00	85.00	34.36
400	2.4	5.95	9.70	0.472	11.00	127.50	37.51
401	2.5	5.99	9.58	0.461	24.00	182.50	36.33
402	2.6	5.87	7.79	0.352	11.00	245.00	37.12
403	2.7	5.50	12.16	0.494	36.00	125.000	39.20
404	2.8	5.55	9.88	0.448	18.00	120.00	36.52
405	2.9	5.68	9.95	0.452	19.00	117.50	37.00
407	2.10	5.44	9.08	0.423	38.00	130.00	35.12
408	3.1	5.51	8.16	0.408	31.00	177.50	32.73
409	3.2	5.02	9.27	0.413	17.50	205.00	42.02
410	3.3	5.97	9.15	0.432	11.00	205.00	40.16
416	3.4	6.16	10.26	0.488	20.00	202.50	41.52
412	3.5	5.49	9.21	0.433	13.00	107.50	37.73
413	3.6	5.88	12.78	0.583	33.50	107.50	42.48
414	3.7	6.23	11.92	0.492	14.00	297.50	44.94
415	3.8	5.60	9.15	0.424	21.00	210.00	35.36
417	3.9	5.80	10.07	0.382	28.00	107.50	30.11
411	3.10	5.22	8.16	0.403	27.00	125.00	33.22

Note:

Sample 1.1- 1.10 (The *Pteridium* dominated site)
Sample 2.1-2.10 (The *Imperata* dominanted site)
Sample 3.1-3.10 (The *Eupatorium* dominanted site

Appendix 7 Total mean percent cover in 16 quadrat over 5 observation on three different sites

The *Pteridium*-dominated site

Botanical Name	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	114	Q15	Q16
Alpinia malaccensis (Burm. f.) Rosc.	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0
Apluda mutica L.	0	0	0	0	0	0	0	0	0	0	0	0	10.2	0	0	5.2
Bauhinia ornata Kurz var. *kerrii* (Gagnep.) K. & S. S. Lar.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Beilschmiedia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boehmeria thailandica Yaha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Castanopsis diversifolia King ex Hk. f.	3.6	7.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clitoria mariana L.	9.6	14	0	0	0	0	0	0	0	0	0	0	6.8	0	0	0
Commelina diffusa Burm. f.	0	0	6.2	0	0	11.2	8	8	5.1	5.2	0	6.2	7.4	1	5.8	0
Commelina paludosa Bl.	0	0	0	0	0	5.4	4.2	4.2	0	4	0	0	0	0	0	0
Conyza sumatrensis (Retz.) Walk.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Crotalaria alata D. Don	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cruddasia insignis Prain	0	0	0	0	0	0	1.2	0	0	0	1.4	1.4	0	0	0	0
Curculigo capitulata (Lour.) O. K.	3.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperus brevifolius (Rottb.) Hassk. var. *brevifolius*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	4.2
Debregeasia longifolia (Burm. f.) Wedd.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmodium multiflorum DC.	5.6	8.2	7.4	0	10	0	5	3.4	0	6	0	0	0	0	0	0
Dioscorea bulbifera L.	0	0	0	0	5.6	0	0	0	0	0	0	0	0	0	0	0
Dichroa febrifuga Lour.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dianella ensifolia (L.) DC.	0	0	0	0	3.6	0	0	0	0	0	0	0	0	0	0	0
Engelhardia spicata Lechen. ex Bl. var. *colebrookena* (Ldl. ex Wall) O. K.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eugenia albiflora Duth. ex Kurz	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
Eupatorium odoratum L.	28	15	11.8	18	12.8	17	23	22	40	16	13	0	0	26	14	19
Eupatorium adenophorum Spreng.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eurya acumminata DC. var. *wallichina* Dyer	0	0	0	0	0	0	7.2	0	0	0	0	0	0	0	0	0
Fagerlindia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.2
Flemingia sootepensis Craib	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.2
Phragmitus vallatoria (Pluk. ex L.) Veldk.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gordonia dalglieshiana Craib	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.8

Appendix 7 Total mean percent cover in 16 quadrat over 5 observation on three different sites

The *Pteridium*-dominated site

Botanical Name	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	114	Q15	Q16
Alpinia malaccensis (Burm. f.) Rosc.	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0
Apluda mutica L.	0	0	0	0	0	0	0	0	0	0	0	0	10.2	0	0	5.2
Bauhinia ornata Kurz. var. *kerrii* (Gagnep.) K. & S. S. Lar.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Beilschmiedia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boehmeria thailandica Yaha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Castanopsis diversifolia King ex Hk. f.	3.6	7.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clitoria mariana L.	9.6	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Commelina diffusa Burm. f.	0	0	6.2	0	0	11.2	8	8	5.1	5.2	0	0	6.8	0	0	0
Commelina paludosa Bl.	0	0	0	0	0	5.4	4.2	4.2	0	4	0	6.2	7.4	1	5.8	0
Conyza sumatrensis (Retz.) Walk.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crotalaria alata D. Don	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Cruddasia insignis Prain	0	0	0	0	0	0	1.2	0	0	0	1.4	1.4	0	0	0	0
Curculigo capitulata (Lour.) O. K.	3.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperus brevifolius (Rottb.) Hassk. var. *brevifolius*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	4.2
Debregeasia longifolia (Burm. f.) Wedd.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmodium multiflorum DC.	5.6	8.2	7.4	0	10	0	5	3.4	0	6	0	0	0	0	0	0
Dioscorea bulbifera L.	0	0	0	0	5.6	0	0	0	0	0	0	0	0	0	0	0
Dichroa febrifuga Lour.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dianella ensifolia (L.) DC.	0	0	0	0	3.6	0	0	0	0	0	0	0	0	0	0	0
Engelhardia spicata Lechen. ex Bl. var. *colebrookena* (Ldl. ex Wall) O. K.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eugenia albiflora Duth. ex Kurz	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
Eupatorium odoratum L.	28	15	11.8	18	12.8	17	23	22	40	16	13	0	0	26	14	19
Eupatorium adenophorum Spreng.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eurya acumminata DC. var. *wallichina* Dyer	0	0	0	0	0	0	7.2	0	0	0	0	0	0	0	0	0
Fagerlindia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.2
Flemingia sootepensis Craib	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.2
Phragnitus vallatoria (Pluk. ex L.) Veldk.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gordonia dalglieshiana Craib	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.8

Imperata cylindrica (L.) P. Beauv. var. *major* (Nees) C. E. Hubb. ex Hubb. & Vaugh.	10.8	19.6	19.8	21	0	7.8	0	0	6.2	0	0	0	11.8	0	0	0
Jasminum nervosum Lour.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leea indica (Burm.f.) Merr.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Litsea monopetala (Roxb.) Pers.	0	0	0	8.2	0	9	9	9.5	0	0	0	0	0	0	0	0
Mallotus philippensis (Lmk.) M.-A. var. *philippensis*	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Markhamia stipulata (Wall.) Seem. ex Sch. var. *stipulata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melastoma normale D. Don var. *normale*	5.8	4.4	0	4.2	5.6	0	0	0	0	0	0	0	0	0	0	0
Millettia pachycarpa Bth.	0	0	0	0	5.6	0	9	0	0	0	6.8	0	0	0	0	0
Millettia pubinervis Kurz	0	0	0	0	0	0	5.4	0	0	0	0	0	0	0	0	0
Phoebe lanceolata (Nees) Nees	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phoebe sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonum chinense L.	0	0	0	0	0	0	0	0	0	0	0	0	0	6.2	0	0
Prunus cerasoides D.Don	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.4
Pureria stricta Kurz	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pteridium aquilinum (L.) Kuhn ssp. *aquilinum* var. *wightianum* (Ag.) Try.	0	40	26.7	16.6	15.7	33.3	60.3	46.7	23.3	43.3	63.3	53.3	36.7	36.7	45	45
Pterospermum acerifolium Willd.	0	0	14.2	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrenaria garrettiana Craib	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhus chinensis Mill.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubus belpharoneurus Card.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rourea minor (Gaertn.) Leenh. ssp. *minor*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Rauvolfia ophiorrhizoides (Kurz) Kerr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Schima wallichii (DC.) Korth	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shuteria involucrata (Wall.) Wight. & Arn.	0	0	6.2	7.4	0	9.4	0	0	0	0	0	0	0	0	0	0
Smilax zeylanica L. ssp. *hemsleyana* (Craib) T. Koy.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urena lobata L. ssp. *lobata* var. *lobata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vigna radiata (L.) Wilcz. var. *sublobata* (Roxb.) Verdc.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zingiber kerrii Craib	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zingiber smilesianum Craib	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The *Imperata*-dominated site

Botanical Name	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	14	Q15	Q16
Alpinia malaccensis (Burm.f.) Rosc.	0	0	0	0	0	0	10.2	0	0	0	1.6	2.4	0		3.4	10
Apluda mutica L.	2	0	0	0	0	0	0	0	0	0	0	0	10.2	0	0	5.2
Bauhinia ornata Kurz. var. *kerrii* (Gagnep.) K. & S. S. Lar.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beilschmiedia sp.	0	2.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boehmeria thailandica Yaha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Castanopsis diversifolia King ex Hk. f.	11	10.4	11.6	0	0	0	0	0	0	0	0	0	0	0	0	0
Clitoria mariana L.	0	0	5.2	5	0	0	0	0	0	0	0	0	0	0	0	0
Commelina diffusa Burm.f.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Commelina paludosa Bl.	5	7	7.6	7	7.4	5.2	3	4.2	6.8	5.4	11	3	0	0	0	0
Conyza sumatrensis (Retz.) Walk.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crotalaria alata D. Don	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cruddasia insignis Prain	0	0	0	0	0	0	1.2	0	0	0	0	0	0	0	0	0
Curculigo capitulata (Lour.) O.K.	0	0	0	0	3	3.6	0	0	0	0	0	0	0	0	0	0
Cyperus brevifolius (Rottb.) Hassk. var. *brevifolius*	0	0	0	0	0	0	0	0	0	0	4.8	0	7.2	0	0	0
Debregeasia longifolia (Burm. f.) Wedd.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmodium multiflorum DC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dioscorea bulbifera L.	0	4.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dichroa febrifuga Lour.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dianella ensifolia (L.) DC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Engelhardia spicata Lechen. ex Bl. var. *colebrookena* (Ldl. ex Wall.) O. K.	6.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eugenia albiflora Duth. ex Kurz	0	0	0	0	4.4	2.6	0	0	0	0	0	0	0	0	0	0
Eupatorium odoratum L.	27	39	25	60	42.4	21.2	18.6	11.6	22	19.8	23	22	39.8	25.4	10.2	0
Eupatorium adenophorum Spreng.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eurya acumminata DC. var. *wallichina* Dyer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fagerlindia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flemingia sootepensis Craib	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phragmitus vallatoria (Pluk. ex L.) Veldk.	0	0	0	1.7	1.7	5	1.7	0	0	0	6.7	0	0	0	0	10 0
Gordonia dalglieshiana Craib	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Imperata cylindrica (L.) P. Beauv. var. *major* (Nees) C. E. Hubb. ex Hubb. & Vaugh.	0	50	30	40	23	20	30	40	30	0	0	30	19	15	17	0

Jasminum nervosum Lour.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leea indica (Burm.f.) Merr.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Litsea cubeba (Lour.) Pers.	0	0	0	0	0	4.4	0	0	0	0	0	0	0	0	0	0
Mallotus philippensis (Lmk.) M.-A. var. *philippensis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Markhamia stipulata (Wall.) Seem. ex. Sch. var. *stipulata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melastoma normale D. Don var. *normale*	0	0	1.2	1	0.6	0	0	0	0	0	0	0	0	0	0	0
Millettia pachycarpa Bth.	0	0	0	3	3.2	0	0	0	0	0	0	0	2.8	0	0	0
Millettia pubinervis Kurz	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phoebe lanceolata (Nees) Nees	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phoebe sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	6.2	0	0
Polygonum chinense L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prunus cerasoides D.Don	0	0	0	2.8	3.6	0	2.8	5	5.8	9.6	0	0	0	0	0	0
Pureria stricta Kurz	0	0	0	0	0	0	0	0	0	0	2.8	2	3.4	0	0	0
Pteridium aquilinum (L.) Kuhn ssp. *aquilinum* var. *wightianum* (Ag.) Try.	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pterospermum acerifolium Willd.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrenaria garrettiana Craib	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhus chinensis Mill.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubus belpharoneurus Card.	0	0	6.6	0	0	0	0	0	0	0	0	0	0	0	0	0
Rourea minor (Gaertn.) Leenh. ssp. *minor*	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rauvolfia ophiorrhizoides (Kurz) Kerr	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Schima wallichii (DC.) Korth	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shuteria involucrata (Wall.) Wight. & Am.	0	0	0	0	0	0	1	6	0	0	1.8	0	3.6	5.4	14.8	5
Smilax zeylanica L. ssp. *hemsleyana* (Craib) T. Koy.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urena lobata L. ssp. *lobata* var. *lobata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vigna radiata (L.) Wilcz. var. *sublobata* (Roxb.) Verdc.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zingiber kerrii Craib	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zingiber smilesianum Craib	0	0	0	0	0	0	0	0.8	3	4.2	0	0	0	0	0	0

The *Eupatorium*-dominated site

Botanical Name	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	14	Q15	Q16
Alpinia malaccensis (Burm.f.) Rosc.	3.2	8	0	0	0	3.8	5	0	0	0	0	0	0	0	0	0
Apluda mutica L.	0	0	0	0	0	0	5.6	0	0	0	0	0	0	12.4	32	0
Bauhinia ornata Kurz. var. *kerrii* (Gagnep.) K. & S. S. Lar.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beilschmiedia sp.	0	2.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boehmeria thailandica Yaha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Castanopsis diversifolia King ex Hk. f.	11	10.4	11.6	0	0	0	0	0	0	0	0	0	0	0	0	0
Clitoria mariana L.	0	0	5.2	5	0	0	0	0	0	0	0	0	0	0	0	0
Commelina diffusa Burm.f.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Commelina paludosa Bl.	0	0	4.6	0	0	0	4.2	3.8	0	0	5	0	2.4	0	0	0
Conyza sumatrensis (Retz.) Walk.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crotalaria alata D. Don	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cruddasia insignis Prain	0	0	0	0	4	10.6	0	5.4	0	0	0	0	0	0	0	0
Curculigo capitulata (Lour.) O.K.	3	0	0	0	0	3	4	0	0	0	0	0	0	0	0	0
Cyperus brevifolius (Rottb.) Hassk. var. *brevifolius*	2.8	0	0	0	0	0	0	4.4	0	0	0	2.8	0	0	0	0
Debregeasia longifolia (Burm. f.) Mett. ex Kuhn	11.8	0	0	0	0	0	0	0	0	0	0	0	8.2	0	0	0
Desmodium multiflorum DC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dioscorea bulbifera L.	0	4.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dichroa febrifuga Lour.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dianella ensifolia (L.) DC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Engelhardia spicata Lechen. ex Bl. var. *colebrookena* (Ldl. ex Wall.) O. K.	0	0	6	4	1	1..5	1.8	1..5	1..3	1.2	0	0	0	0	0	0
Eugenia albiflora Duth. ex Kurz	0	0	0	0	4.4	2.6	0	0	0	0	0	0	0	0	0	0
Eupatorium adenophorum Spreng.	18	22	12	20	10	10	12	11	12	15	13	10	10	15	10	0
Eupatorium odoratum L.	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
Eurya acumminata DC. var. *wallichina* Dyer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fagerlindia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flemingia sootepensis Craib	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Phragmitus vallatoria (Pluk. ex L.) Veldk.	0	0	0	1.7	1.7	5	1.7	0	0	0	6.7	0	0	0	0	0

Gordonia dalglieshiana Craib	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Imperata cylindrica (L.) P. Beauv. var. *major* (Nees) C. E. Hubb. ex Hubb. & Vaugh	0	0	0	0	0	0	0	0	0	0	0	30	19	15	17	0
Jasminum nervosum Lour.	0	0	0	0	0	0	3.6	11.4	0	0	0	0	0	0	0	0
Leea indica (Burm.f.) Merr.	0	0	0	0	0	2.4	0	3	6	0	3.6	0	0	0	0	0
Litsea cubeba (Lour.) Pers.	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
Mallotus philippensis (Lmk.) M.-A. var. *philippensis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Markhamia stipulata (Wall.) Seem. ex Sch. var. *stipulata*	0	0	4	0	0	0	0	0	0	0	2.4	3.6	0	0	0	0
Melastoma normale D. Don var. *normale*	0	0	0	4		0	6	0	0	0	0	0	0	0	0	0
Millettia pachycarpa Bth.	0	0	0	9.2	0	0	0	0	0	5.8	0	0	0	0	0	0
Millettia pubinervis Kurz	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phoebe lanceolata (Nees) Nees	0	0	0	3	0	0	0	0	10	0	0	0	0	0	0	0
Phoebe sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonum chinense L.	0	0	0	0	0	9.2	0	0	0	0	0	0	0	0	0	0
Prunus cerasoides D.Don	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pueraria stricta Kurz	0	0	0	6	0	4	0	0	0	0	0	0	0	0	0	0
Pteridium aquilinum (L.) Kuhn ssp. *aquilinum* var. *wightianum* (Ag.) Try.	6.4	5.8	8.8	0	11	8	9	6	6	7	7.8	10	5.6	8.6	0	0
Pterospermum acerifolium Willd.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrenaria garrettiana Craib	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhus chinensis Mill.	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rubus belpharoneurus Card.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rourea minor (Gaertn.) Leenh. ssp. *minor*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rauvolfia ophiorrhizoides (Kurz) Kerr	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
Schima wallichii (DC.) Korth	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
Shuteria involucrata (Wall.) Wight. & Arn.	5	0	0	0	6	0	6	4.6	7.6	0	6	5.8	1.8	3	2.6	1.6
Smilax zeylanica L. ssp. *hemsleyana* (Craib) T. Koy.	0	0	0	0	0	0	0	0	0	0	6.5	3.5	0	0	0	0
Urena lobata L. ssp. *lobata* var. *lobata*	0	0	0	0	10	0	5	0	0	0	0	0	0	0	0	0
Vigna radiata (L.) Wilcz. var. *sublobata* (Roxb.) Verdc.	0	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0
Zingiber kerrii Craib	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zingiber smilesianum Craib	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CURRICULUM VITAE

Personal

Name	:	Bhim Prasad Adhikari
Date of Birth	:	13/01/ 1964
Birth Place	:	Nuwakot, Nepal
Marital Status	:	Married
Permanent Address	:	PO Box 5832, Maharajgung, Kathmandu, Nepal Tel # 423099, Fax # 225184
Profession	:	Environment Specialist

Key Qualification

- 6 Years extensive experience in natural resource and environmental management including community forestry, sustainable agriculture and agroforestry, forest management, forest research methodology, ecosystem dynamics and rehabilitation and watershed management
- Experience in environmental impact assessment /env. risk assessment, considerable experience and knowledge on environmental problems and mitigation measures relating hydropower development.
- Familiar with WP, Microsoft Windows, SPSS, ECOSTAT, Harvard Graphics

Academic Qualification

Master's degree in Environmental Science (major : environmental risk assessment). Joint International Post-graduate Program Between University of Saarland, Germany and Chiang Mai University, Chiang Mai, Thailand.

Major Course Studied

Basic and Applied Ecology, Wildlife Conservation, Environmental Monitoring and Risk Assessment, Environmental Monitoring and Ecosystem Management (both terrestrial and fresh water ecosystem), Environmental Law, Environmental Impact Assessment, Environmental Health and Sanitation, Environmental Chemistry

Bachelor's degree of Science in Forestry (B.Sc. F.), Tribhuvan University, Nepal

Certificate in Forestry (Forest Ranger Course), Institute of Forestry, Hetauda, Nepal

Diploma in Permaculture, Permaculture Institute, Tyalgum, NSW, Australia

Employment /Experience Record

1996, September-To date:

Employer : **UNDP, Kathmandu (REDP/NEP/95/016)**
Post : **Environment Advisor**

May 1996- August 1996

Employer : **Khimti Hydropower Project (60 MW), Dolakha (Funded by WB and ADB**
Tittle : **Environment Specialist**

July 1994-Aug. 1995 :

Employer : **Forest Restoration Research Unit, Chiang Mai University Thailand.**
Title : **Research Assistant**

Feb. 1993-May 1994 :

Employer : **Department of Forest, District Forest Office, Surkhet**
Title : **Assistant Forest Officer**

Jan 1986-March 1989 :

Employer: **Department of Forest, District Forest Office (Pyuthan and Syangja).**
Title : **Community Forestry Assistant/Forest Ranger**

Award/Scholarship :

1983-1985 : Tribhuvan University Merit Scholarship

1989-1991 : Tribhuvan University Merit Scholarship

1994-1996 : German Government through GTZ Scholarship

Research Paper/Publications :

- Common Property Resource Management by User Groups: A Experience from Middle Hill of Nepal. Paper Presented on International Seminar on "Geology and Environment", 31 Jan.-2 Feb. 1996, Chiang Mai, Thailand.

- Effect of Herbaceous Vegetation on Tree Seedling Growth and Performance. Paper Presented on International Symposium on "Forest and Environment" Nanjing Forestry University, 4-6 Nov., 1996 Nanjing, PR China.

- Various articles relating on environmennal matters on local news paper i.e The Rising Nepal and The Kathmandu Post.

Thesis/Project Paper :

- Relationship Between Forest Regeneration and Ground Flora Diversity in Deforested Gaps in Doi Suthep National Park, northern Thailand. Master's degree thesis, Chiang Mai University, Thailand.

- Effectiveness of Community Forestry through User Groups in Middle Hill of Nepal. A research paper submitted to Institute of Forestry for the partial fulfillment of B.Sc. Forestry Degree, Institute of Forestry, Pokhara.

Language Ability

Nepali: Mother Tongue

English: Excellent

Thai: Understandable

Affiliation :

Member: Nepal Foresters Association, Kathmandu
Member: Institute for Sustainable Agriculture Nepal (INSAN)
Member: Nepal Permaculture Group, Kathmandu
Member: Nepal Agroforestry Foundation, Kathmandu
Member: International Society of Tropical Foresters, USA
Member: International River Network, USA