CHAPTER 1
INTRODUCTION

1.1 Background

In Thailand destruction of primary tropical forests is considered to be one of the most serious environmental problems, causing degradation of watersheds, loss of biodiversity and exacerbating rural poverty. However, positive steps have been taken to stop the destruction and repair the damage. This project was inspired by pioneering efforts by government, non-governmental and private sector organisations in Thailand to restore damaged forest ecosystems. These efforts have given cause for optimism that the restoration of damaged forest ecosystems is an attainable goal.

In November 1988, in southern Thailand, a severe rainstorm caused flooding over a wide area. Thousands of tonnes of logs, soil and water descended through a hillside logging camp, destroying two villages and killing over 300 people (Leungaramsri and Rajesh, 1992). Public pressure for a logging ban became overwhelming and, despite the fact that many government ministers were financially involved in the industry, a nation-wide ban was passed by cabinet in January 1989 (Leungaramsri and Rajesh, 1992). Eleven years later the ban is still in force. Although the logging companies mostly moved their activities to neighbouring Myanmar (Burma) and Laos, forest destruction continues in Thailand through illegal logging, infrastructure projects, encroaching lowland settlers and highland agriculture (Hirsch, 1990).

In 1995 the remaining forest area in Thailand was officially 131,485 km^2 or 26% of the total land area (Royal Thai Forest Department, 1996), although even in 1992 it had been considered to be closer to 18% in reality (Leungaramsri and Rajesh, 1992). The Fourth National Economic and Social Development Plan (NESDP) (1977-1981) states that the government aims to restore forest cover to 40% of total land area and in the Seventh NESDP (1992-1996) it was stated that this should comprise 15% for production forest and 25% for conservation (Chatwiroon, 1997). At first, reforestation of both types of area was largely along the lines laid out in the commercially orientated Thai Forestry Master Plan, drawn up in 1988 with the help of Finnish forestry consultants (Leungaramsri and Rajesh, 1992). The Thai Royal Forest Department (RFD) or a private company would take control of the land and establish a monoculture plantation, usually of a fast growing species. In commercial forests this tended to be eucalyptus species, except in the north where teak (*Tectona grandis*) has long been grown. Conservation areas were mostly re-planted with pine (*Pinus merkusii*). However, public opinion moved against monocultures due to their perceived adverse affects on the local economy and society, their failure to provide villagers with non-timber forest products and their low value to wildlife (Lohmann, 1990).

In 1994, reforestation in Thailand dramatically changed course. On the anniversary of the King's coronation day, 5th May, the first tree was planted in what was claimed to be the biggest non-plantation reforestation project in the world (Nah Ayuthaya, 1994). The project aimed to reforest five million rai of degraded land in the conservation zone (8,000 km^2, or about 1.6% of total land area) and 447 km^2 on community and public land in honour of the 50th Anniversary of HM the King's reign in 1996 (Chatwiroon, 1997). Officially titled "The Reforestation Campaign in Commemoration of the Royal Golden Jubilee", it was widely referred to as the Five Million Rai Project. The duration of the project was originally intended to be three years, from 1994 to 1996, but this has now been extended to 1999 (Chatwiroon, 1997). Government officials estimated that the cost of the project would be 17 billion baht, then about 49 million pounds sterling, to be contributed by members of the public and businesses (Chatwiroon, 1997).

HM King Bhumibol stipulated that only uninhabited areas were to be planted, using a mixture of mainly indigenous tree species and that natural regeneration, where possible, was to be encouraged. He is quoted as saying, "Do not bully the trees, let them grow naturally" (Bangkok Post, 1993a). Afterwards, the restored forests were to be conserved and protected from commercial exploitation, (Bangkok Post, 1994a). In practice, rather than promoting natural forest regeneration, the traditional methods of plantation forestry were continued, although mixtures of native species were planted instead of single species (pers.obs.). Typically, one metre wide lines were cut through the vegetation and seedlings raised in nurseries were planted along them at intervals.

The population responded enthusiastically to the project: millions of baht were donated from the private sector and all over the country community groups planted trees (Elliott *et al.*, 1995). The depth of public support for forest protection and restoration generated by this project is reflected in this quote from the Thailand Times (Nah Ayuthaya, 1994):

> "As for selfish capitalists who have kept on sneakily cutting the forest, it is hoped that from now on they will give up this evil activity. For if they carry on, they will not only be traitors to the country of their birth but traitors to their monarch, who is universally loved and respected."

1.2 Problems with mixed species plantations

The technical problems faced by Thailand are typical of those faced by any tropical country attempting to reforest degraded lands using mixed species plantations and the following points have been noted by authors throughout the tropics.

Labour and capital intensive. — The cost is relatively high (see section 1.3.2) because an input of labour is required at every stage of the regeneration process, from collecting the seed or seedlings, to raising the seedlings in nurseries, preparing sites, planting seedlings and maintaining them afterwards. Thus plantation forestry is not always an "appropriate" technology in cash-poor communities (Jensen and Pfeifer, 1989). In fire prone areas, a high capital investment may be considered too great a risk. Furthermore, the high cost may deter investment in forests for watershed protection and conservation, which are not expected to produce a financial return. If the level of human input could be reduced, costs could correspondingly be lowered.

Impractical in inaccessible areas. — The transport of large quantities of seedlings, tools and labourers can be impractical and expensive, especially in steep, inaccessible areas (Perera, 1995; Reddell, 1996).

Site disturbance. — Damage caused in site preparation for intensive planting can be counterproductive. An extreme example of this is a report of a bulldozer clearing away a thicket containing trees whose trunks were "about the size of a boy's hand" in preparation for forest restoration (Bangkok Post, 1995). Possible damage could include the damage or destruction of existing seedlings, erosion and compaction of access paths, the re-exposure of primary forest margins and the facilitation of weed invasion into the forest and land to be reforested (Reddell, 1996).

Lack of knowledge. — For every species to be planted, information is required on when to collect the seed, optimal storage and germination conditions, how to grow and where to plant the seedling (Elliott *et al.*, 1995), site preparation and after care. When hundreds of species are planted, this involves lengthy research. Lack of such knowledge could lead to the failure of a plantation. In Thailand local people rarely possess this knowledge, as growing montane forest trees is not a traditional activity. In northern Thailand this is particularly evident among immigrant hill tribes such as the Hmong (Elliot, pers. comm.,1998,), who are most likely to inhabit montane forest areas and most of whom have lived in Thailand for less than a generation (Kunstadter *et al.*, 1978).

1.3 Accelerated Natural Regeneration

1.3.1 What is ANR?

An alternative to mixed species plantations is "accelerated natural regeneration" or ANR. There is some confusion over whether this acronym stands for "accelerated" or "assisted" natural regeneration. In an informal survey of (mostly Indonesian) foresters, officials and academics (Drilling, 1989), eight out of ten people who expressed a preference said they preferred "accelerated", so that term will be adopted for this thesis. It should be noted that in this context "regeneration" signifies the colonization of cleared areas by woody species, not the gap dynamics through which primary forests replace individual trees (Bazzaz, 1991).

ANR is already practised by governmental organisations in the Philippines (Dalmacio, 1987; Jensen and Pfeifer, 1989) and Indonesia (Drilling , 1989) and on a small scale by non-governmental and community organisations in Thailand (Bangkok Post, 1994b). Jensen and Pfeifer (1989) define ANR as an approach to reforestation in which human intervention accelerates natural secondary succession. The growth of naturally established shrub and tree species is promoted and any missing but desired species are added later. ANR as explained here differs from "natural regeneration" as defined by Fox (1976) which allows some human intervention but precludes tree planting.

The following procedure has been used in the Philippines to reforest *Imperata* spp. dominated grasslands. These methods (described by Jensen and Pfeifer, 1991 and Dalmacio, 1987) are not necessarily universally applicable, because, as Drilling (1989) points out, success depends on tailoring the techniques to local site conditions.

1. **Clarify objectives for reforestation.**

   ANR can be used for watershed protection and conservation, agroforestry or timber production. The choice of enrichment species (if any) will be influenced by the objectives.

2. **Decide if ANR is appropriate technique for site.**

   According to Jensen and Pfeiffer two considerations are of key importance here: proximity to forest remnants which will act as a seed source and local community interest. The presence of five or more mature forest trees per hectare is desirable since a source of propagules is critical for ANR (Sajise *et al.*, 1989). Also, it is important to recognise the successional stage of the site: Sajise *et al.* (1989) suggest that ANR should only be used on shrub communities with 15-150 cm high seedlings of woody species at a density of 200 to 800 ha^{-1}. Jensen and Pfeiffer recommend a density of 700 woody plants per hectare to achieve canopy closure within three years, although this would clearly depend on mortality rate. This is to ensure that there is a sufficient number of seedlings to be assisted so that ANR will be less expensive than conventional reforestation. Sajise *et al.* consider that the process would be ineffective in grasslands although Jensen and Pfeiffer argue that woody plants are often present within the grass layer although they are continually suppressed by periodic burning. The successional stage will also affect the micro-environment, which affects the establishment of enrichment seedlings (Sajise *et al.*, 1989). The likelihood of future disturbance, such as fire or grazing should also be taken into account.

3. **Protect site from fire.**

   It is recommended that 10m- wide firebreaks are cut or "green firebreaks" of economic crops such as bananas are planted.

4. **Identify and mark existing woody plants.**

   Existing seedlings should be located and marked for protection, monitoring and predicting the need for enrichment planting, with 1 x 1 m clumps being counted as a single seedling.

5. **Inhibit grass layer.**

   Grass should be flattened by walking over the stems with a light plank suspended from rope handles. The stems should not be broken as this stimulates tillering (Sajise, 1972, cited in Jensen and Pfeiffer, 1989). This treatment can be combined with oversowing with a cover crop. Drilling (1989) suggests various crops, such as *Cajanus cajan* (pigeon peas) and *Pueraria triloba*, which will grow over and shade out the flattened grass. A fruiting cover crop would have the advantage of attracting seed dispersing birds and mammals into the area.

6. **Facilitate the growth of woody plants.**

   Common methods are ring-weeding within a 1 m radius around seedlings; thinning and transplanting dense clumps of seedlings and fertilising seedlings once the grass layer has been inhibited.

7. **Plant more trees.**

   Extra trees may be needed to attain the target of 700 trees ha^{-1} but these should not be planted until a year after beginning ANR, when grass competition is reduced. Pfeifer and Jensen suggest that fast growing pioneer trees be planted first, followed by shade tolerant species about three years later.

1.3.2. The pros and cons of ANR

ANR is a low technology, low cost, environmentally sound approach to reforestation, which maximises biodiversity and ecological services (Jensen and Pfeiffer, 1989). Drilling (1989) compared six projects to rehabilitate *Imperata* infested land and showed that ANR had the lowest establishment costs. Non-ANR projects cost from 457.5 to 1192.5 Indonesian rupias per ha, while ANR cost 337.5, a decrease of 26 - 72%. In the Philippines the cost of ANR per ha was 28% cheaper than conventional reforestation (Sajise *et al.*, 1989). Two reasons for the reductions in cost are low land clearing costs (involving only the establishment of fire breaks) and low nursery establishment costs (Drilling, 1989).

A drawback of ANR is that both the final species composition of the forest and the amount of time needed to achieve forest cover are uncertain. Another possible problem is that ANR may not be effective in areas very far from a tree seed source, although it is not known exactly how close source areas should be. Furthermore, ANR would be difficult in areas where there was a lack of labour or a very high risk of fire, although both these problems could be overcome, especially with community participation - one of the key elements for success (Drilling, 1989).

1.3.3. Development of ANR strategies

The underlying principle of ANR is that human intervention is targeted to remove or manage the key factors limiting natural succession. In the Philippines, these factors were judged to be grass competition and fire. However, limiting factors differ from climate to climate and even from site to site. In order to develop appropriate ANR strategies elsewhere, such as in northern Thailand, the barriers to tree colonization must be fully understood. Certain factors, such as moisture and shade, will have different effects on different species, so any research should include a wide range of species.

1.4 Review of literature on factors affecting tree colonization of large clearings in the seasonal tropics

Three possible mechanisms are thought to operate during secondary succession (Connell and Slatyer, (1977). *Facilitation* occurs when early colonizing species modify the clearing environment creating conditions which "facilitate" the establishment of later species that cannot occur in their absence. Some later colonizing species may be able to establish and grow through *tolerance* of the competitive environment growing up around them or but some may be unable to establish due to *inhibition* by the early-arriving species. These mechanisms are by no means mutually exclusive, and probably all play a role in maintaining species diversity. It is helpful to distinguish between mere inhibition, where the colonization is slowed down by the influence of an early-successional species and *exclusion*, where colonization is made impossible (Grubb, 1987). Similarly, one can distinguish between facilitation, where the rate of colonization is increased and *enablement*, where one species makes it possible for another to colonize (Grubb, 1987). These terms were devised to describe the effect of one plant on another, but can equally well be applied to the effect of other environmental factors on colonization by a particular tree species. The term *limiting factor* is used in this thesis in a broader sense to represent a factor which has a negative effect, when the severity of that effect may not be known or may differ according to species.

The problem for those who wish to practically apply these models is that each mechanism may only be applicable in certain habitats, for a certain period of an organism's life cycle, or may even work interdependently during the same period (Finegan, 1984). For example, in a highly seasonal climate such as northern Thailand, the appropriate model may vary according to season. Finegan (1984) advocates "theoretical agnosticism" and the induction of theory from observational and experimental fieldwork, rather than the deduction of observed phenomena from possibly inappropriate general models.

While the regeneration of small, natural gaps in tropical forests have received detailed attention over the last 20 years (e.g. Hartshorn, 1978; Denslow, 1980; Popma *et al.*, 1988; Fisher at al., 1991; Osunkoya *et al.*, 1993), there have been surprisingly few experimental studies of forest regeneration on abandoned agricultural land. The regeneration processes observed in natural treefall gaps cannot be assumed to operate on a larger scale in man-made clearings. The latter tend to be highly degraded and much larger (usually 1 to >1000 ha compared with less than 1 ha for tree-fall gaps, Uhl *et al.*, 1990); as a result the limiting factors tend to be more extreme (Bazzaz and Sipe, 1987).

The limiting factors described in the literature can be classed as "historical" or "active" (Fig.1.1). Historical factors are characteristics of previous land use (e.g. length of cultivation, De Rouw, 1993) which affect subsequent regeneration. Although important, these are beyond the scope of this study. Active factors are those which exert their influence during tree colonization. They fall into two groups: resources (the building blocks of ecological processes, e.g. irradiation, soil moisture, on-site propagules) and regulators (the site variables which affect the resources, e.g. weed competition, predators, fire), (see Bazzaz and Sipe, 1987). Both groups may be either biotic or abiotic in nature (Fig.1.1). It is important that the type of factor is recognised - Bazzaz and Sipe warn of the dangers of making incorrect assumptions about low level processes from higher level observations.

Historical factors:	Type of previous land use Frequency of previous land use Intensity of previous land use		
affect ↓			
	(Secondary)	*affect*	(Primary)
Active factors:	Regulators	→	Resources
- Abiotic	Fire Season Topography Aspect Geology		Solar radiation Temperature Humidity Soil moisture Soil nutrients Soil structure
- Biotic	Distance to seed source Dispersal types of seeds @ source Regularity of seed production @ source Seed dispersers Weed competition Predators Pathogens		On-site propagules Seed rain

Fig. 1.1. Potential limiting factors in abandoned agricultural clearings

Factors limiting tree regeneration can operate at any stage of the life cycle, e.g. seed production and dispersal (if there are no on-site propagules), germination or seedling establishment and growth. For practicality, most authors isolate one or two stages of the life cycle for particular study. For literature reviews of work on seed production and dispersal see Chapter 3, on germination, see Chapter 4 and on seedling establishment and growth see Chapter 5. Although this approach permits a thorough analysis of the topic in question, it provides a narrow view of the regeneration process and it is not always easy to extrapolate results to make general predictions in the field. Also, in reality, unforeseen limiting factors may nullify the results obtained under experimental conditions. For example, a seed may germinate and grow well in clearings, but if the animal dispersal agents are absent, then that species is unlikely to be a coloniser (Janzen, 1985). A further problem is that a limiting factor may operate at one stage of the life cycle but not at another. For example, the shade tolerance of some species changes with maturity (Oldeman and van Dijk, 1991).

These drawbacks can be avoided by taking a more holistic approach. Alvarez-Buylla and Martinez-Ramos (1992) measured the fecundity, seed rain and seed and seedling mortality of a single pioneer tree species, discovering that establishment in gaps was limited at the seedling stage. By concentrating on this stage they were able to deduce the key limiting factors (including reduced light, falling debris and soil dryness). Turner (1990) compared the germination and establishment of three *Shorea* species in canopy gaps and the understorey and was able to deduce the most significant factors limiting these stages. Although these studies were about small gaps, the methodology would be suitable for use in large clearings.

Boman and Panton (1993) took a similar approach in a very different environment in north-western Australia. Their research aimed to determine the factors that prevented forest seedlings from establishing in eucalyptus savanna, concentrating on two common species representing the two major seed dispersal syndromes. Field observations and experiments on germination and seedling survival showed that mycorrhizas, soil fertility and soil moisture were significant limiting factors, especially at the seedling stage. Seed dispersal was not included in the study.

Two studies in the Amazon basin applied similar methods to explore regeneration of the whole tree community. Uhl (1987) studied slashed and burnt sites, combining observation and experiment in a study that covered all stages of the life cycle. The three main elements for recovery were found to be a source of regeneration material, suitable microhabitats and sufficient nutrients. Nepstad *et al.* (1990) worked with a diverse range of species in their study on barriers to forest regeneration in abandoned pastures. Their research showed that lack of seed dispersal, seed and seedling predation and seasonal drought were the main limiting factors. They went on to consider the traits that a tree species would need to overcome these factors.

The preceding studies demonstrate the versatility of the holistic approach, which can be applied to a single species, representatives of significant functional groups or the whole community. The systematic analysis of all stages of regeneration enabled the researchers to focus their attention on the blocked stage(s). In each study, several limiting factors were found to be significant. This demonstrates the inherent complexity of the regeneration process and supports Uhl's conclusion (1987) that no simple, unifying process is at work. Rather, forest regeneration is controlled by a "myriad" of factors, which are often site specific. More research is required to enable us to predict accurately what those factors will be.

1.5 Objectives

The following study was conceived to determine factors limiting forest regeneration in abandoned agricultural clearings in northern Thailand, so that appropriate ANR techniques could be developed. A holistic approach was taken to study tree colonization in abandoned agricultural clearings in seasonal tropical montane forest. The results will also be relevant to other countries that share a similar seasonal tropical climate. Specific questions were:

- Can species be divided into functional groups based on their critical and inhibiting stages in the colonisation of abandoned agricultural clearings?
- If so, what traits characterise these groups?
- What environmental factors block or inhibit colonisation at each stage?
- What further research is needed to develop ANR strategies to remove or overcome these limiting factors?