FIELD NOTE

Regeneration of natural-forest species in plantations of fast-growing species in northeast Thailand

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ABSTRACT We examined the ‘catalyzing effect’, by which the establishment of indigenous species and secondary succession are facilitated in plantations. A tree census was conducted at two 24-year-old plantations (agroforestry and eucalyptus plots), and a grassland in northeast Thailand. Three natural forests adjacent to the two plantation plots and the grassland plot were also investigated to evaluate their possible influence on the catalyzing effect based on the differences in species diversity and the intensity of disturbance among the natural forests. The catalyzing effect seemed to be observed at the study site; the two plantations had more individuals and species of indigenous trees than the grassland, indicating faster natural regeneration of the formers than the latter. Although our results found the tendency of the catalyzing effect, further studies using sufficient plot replication are required to verify the generality of the effect.

Key words: Exotic plantation, forest succession, reforestation, secondary growth, species richness

INTRODUCTION

In South and Southeast Asia, about 0.7 million ha of forest has been lost every year since 2000, and forest area is still rapidly decreasing in most countries (FAO 2010). Instead, grasslands dominated by Imperata cylindrica have spread with increasing human populations and the expansion of agricultural lands in Southeast Asia (Jussi et al. 1995). Reforestation has been conducted to increase forest cover and rehabilitate degraded forests. In a pilot project of land rehabilitation conducted in Sakaerat, northeast Thailand, plantations of exotic and native species were established in grasslands in 1982 as a trial for reafforestation (Kamo et al. 2002; Kamo et al. 2008).

Reforestation in grasslands is, however, usually difficult because grasses are strong competitors of tree seedlings for water, light, and nutrients and thus suppress tree growth (Jussi et al. 1995). Furthermore, frequent fires retard succession. It is, therefore, urgent to develop methods for effectively changing grasslands to forest.

Recently, many studies have reported that indigenous species regenerate in plantations near natural forests. This phenomenon is called the ‘catalyzing effect’, meaning that plantations facilitate the regeneration of indigenous species and forest succession in their understories in the tropics (Kamo et al. 2002; Parrotta 1992, 1999; Parrotta et al. 1997). Parrotta et al. (1997) reported that compared to conifers, broadleaf species, especially fast-growing species such as Acacia mangium, are more suitable for facilitating natural regeneration in plantations, and that natural forests are necessary for seed sources.

The catalyzing effect has been reported in the following tropical and subtropical areas: Puerto Rico (Parrotta 1992, 1999), southern Ethiopia (Senbeta et al. 2002), and Thailand (Kamo et al. 2002; Oberhauser 1997). Thus, the catalyzing effect seems to be useful for the reforestation of degraded lands which are difficult to rehabilitate. To apply this effect to reforestation, however, an understanding of the mechanism is indispensable.

The following factors have been reported to affect the catalyzing effect: overstory tree species (Jones et al. 2004), stand age (Loumeto and Huttel 1997; Parrotta 1999), mixed planting (Carnevale and Montagnini 2002), planting density and distance from natural forests (Loumeto and Huttel...
1997). According to these reports, the mechanism is closely related to regional environmental and socio-economic conditions. Application of the catalyzing effect to reforestation should therefore be considered based on regional characteristics. In this context, knowledge on the mechanism remains insufficient.

As in other Southeast Asian countries, forest area in Thailand has decreased since early in the last century. Sakaerat in northeast Thailand is one of the forest reserves that still comprises less-disturbed natural forests. Kamo et al. (2002) found that seedlings originating from natural forests naturally regenerate in the plantations in Sakaerat. This is an important finding, indicating the potential for applying the catalyzing effect to reforestation.

While reporting natural regeneration in plantations, however, Kamo et al. (2002) also observed many tree seedlings in the grassland in Sakaerat. This means that natural regeneration of indigenous tree species may proceed without any management practices in the area. On the contrary, Jussi et al. (1995) reported that natural regeneration of tree species in grasslands in Indonesia is restricted or impossible since grasses suppress the growth of the tree species. Thus, it remains unclear whether the catalyzing effect really exists in Sakaerat. Further research on regeneration both in grasslands and in plantations is necessary to examine the catalyzing effect and to advance techniques for the rehabilitation of degraded lands. The factors reported to affect the catalyzing effect are also important research subjects. These factors include the frequency of fires, and the proximity to a natural forest in Sakaerat (Kamo et al. 2002).

This study deals with the catalyzing effect and related factors in Sakaerat. The purpose is to obtain fundamental knowledge to effectively and rapidly convert plantations into natural forests with high species diversity. Regeneration was surveyed in two plantations and in a grassland, and the sites’ species richness and diversity were compared.

**MATERIALS AND METHODS**

The study site was located at the Sakaerat Silvicultural Research Station (14°12’ N, 101°50’ E), which is inside the Sakaerat Biosphere Reserve (SBR), Nakhon Ratchasima Province, northeast Thailand. The average annual temperature and average annual precipitation during the period from 1969 to 2005 were 26.3°C and 1101 mm (SERS Website), respectively. The study site is in a tropical monsoon climate with a distinct wet season from April to October and a dry season from November to March.

An assessment in 1985 reported that 63% of Sakaerat Biosphere Reserve (total area: 81 km$^2$) was forest, in which most dominant forest types was dry evergreen forest (Trisurat 2010), having three-layer canopy, top of which consists of Hopea ferrea, Shorea henryana, Irvingia oliveri and Lagerstoemia dappureana (Lamotte et al. 1998). Dry dipterocarp forest is also dominant forest type (Trisurat 2010), having two layers, with the dominant species being Shorea talura, Shorea obtusa and Dipterocarpus intricatus (Lamotte et al. 1998). Agricultural land sheared 36% at that time, but all settlements in SBR were relocated in 1983 with the start of the reforestation program (Trisurat 2010).

Dry evergreen forests had covered this site until the 1950s, but they were converted into grasslands of Imperata cylindrica or Saccharum spontaneum through shifting cultivation (Kamo et al. 2008). The grasslands were afforested with exotic (Acacia spp., Eucalyptus spp., and Leucaena spp.) and indigenous species (Xyliya xylocarpa, Dalbergia cochinchinensis, and Pterocarpus macrocarpus) during the Research and Training for the Re-afforestation Project of the Japan International Cooperation Agency (JICA) from 1982 to 1990 (Kamo et al. 2002, 2008). Many stands were over 20 years old at the time of our survey. Fires have not occurred frequently in the area since the Sakaerat Silvicultural Research Station started to control them from 1982.

A field survey was conducted at six plots: Acacia auriculiformis and Azizia xylocarpa stand (agroforestry plot, AP), Eucalyptus camaldulensis stand (eucalyptus plot, EP), grassland (grassland plot, GP), and three natural forest plots NAP, NEP and NGP, each of which is adjacent to AP, EP, and GP, respectively (Fig. 1, Table 1).

In the agroforestry stand, soybean was cultivated in 1986 and no other agricultural practices were conducted. This stand was completely weeded once or twice in the year of establishment. The eucalyptus stand was weeded once a year from 1986 to 2000 and twice for nine years from 2001 to 2010. The grassland was not under the control of the station and had been burned almost every year in February or March by local people until the beginning of this study. The natural forests we surveyed were dry evergreen. The representative species in the NAP and NEP was S. henryana, and Dipterocarpus turbinatus in NGP.

To assess the tree species composition, one plot (10 m × 100 m) was established in each of AP, EP, and GP (Table 1). For the plots in plantations (AP and EP), we measured individuals with a DBH of ≥1.0 cm and a tree height of ≥1.3 m. For GP, individuals ≥1.0 m height were measured. The tree individuals were mapped and identified at the species level at all plots. All the individuals were measured.
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In order to determine the species composition of forests that were inferred to be the seed sources, conventional quadrats (50 m × 50 m) were established in NAP, NEP, and NGP. We measured individuals ≥5.0 cm DBH and identified the species. Distance between each plantation plot (AP, EP and GP) and its nearest natural forest plot (NAP, NEP and NGP, respectively) is about 20 m: The distance between EP and NEP is the largest (ca 5 km) in those between any two plots (Fig. 1).

The density of overstory trees, the mean DBH, the mean height, the planting spacing and the survival rate of planted trees were respectively different between the AP and EP (Table 1). The tree density in NEP was 1464 ha⁻¹, which was greater than those of other two natural forest plots, 1168 and 1056 ha⁻¹, for NAP and NGP, respectively (see Table 1).

Analytical procedures

The species diversity of tree community at each plot was evaluated using Fisher’s α (Fisher et al. 1943), which is defined as:

\[ S = \alpha \ln (1 + N/\alpha) \]

where \( S \) is the number of species and \( N \) is the total number of individuals. The larger value indicates that the species composition of the community is more complex.

Similarity was evaluated using Morisita’s \( C_2 \) (Morisita 1959). This is defined as:

\[ C_2 = \frac{2 \sum n_{ij} n_{3ij} / (N_i + N_j)}{N_i N_j} \]

\[ \lambda_1 = \sum n_{ij} (a_{ij} - 1) / N_i (N_j - 1) \]

\[ \lambda_2 = \sum n_{3ij} (a_{3ij} - 1) / N_j (N_2 - 1) \]

where \( n_{ij} \) and \( n_{3ij} \) are the numbers of individuals of species \( i \) in study plots 1 and 2, respectively, and \( N_i \) and \( N_j \) are the total number of individuals in study plots 1 and 2, respectively.

RESULTS

Understory species richness

The number of indigenous tree species was greater in AP and EP than in GP. The total number of species recorded in AP, EP and GP were 74, 61, and 23, respectively (Fig. 2).
The species diversity of tree and climber species in AP and EP was greater than that in GP (Table 2).

The number of tree species and tree individuals and the species composition of trees differed among the three plots. In AP, 74 species and 478 individuals were found (See Appendix). Seedlings of *C. wallichii* and *S. henryana* were most abundant. In EP, 61 species and 295 individuals were found (See Appendix). There were fewer species and individuals than in AP, and *D. angustifolia* and *M. ovatum* were not found. In GP, the numbers of species and individuals were small compared with AP and EP. Twenty-three species and 61 individuals were found (See Appendix). *Dipterocarpus turbinatus* was not found, although many mother trees of this species were found around the plot.

The number of tree species and tree individuals, and the species composition of trees differed among the natural forests. In NAP, 89 species and 292 individuals were found (See Appendix). In NEP, 88 species and 366 individuals were found, and 69 species and 264 individuals were found in NGP.

Relative dominance of tree species was different among six plots, and no common species was found in the top five dominants, except *S. henryana* (Fig. 3). Most dominant species in each plot was as follows; AP: *Clausena wallichii* (0.15), EP: *Nephelium hypoleucum* (0.08), GP: *B Accea javanica* (0.20), NAP: *Hydnocarpus ilicifolius* (0.13), NEP: *S. henryana* (0.22), and NGP: *Mallotus paniculatus* (0.44). *S. henryana*, a dominant canopy species (Lamotte et al 1998), was found in five plots except GP (see Appendix), and seems to have seed dispersal ability to long distance by wind.

Value of similarity index varied among plantation and forest plots, and was small as a whole (Table 3). While the value between AP and EP was 0.591, those between GP and other two plantation plots were much smaller than 0.1. Similarly, while the value between NAP and NEP was 0.209, those between NGP and other two natural forests were quite smaller than 0.1. Species composition of EP was similar to that of NEP to some extent (C = 0.445), whereas similarity between AP and NAP was small (C = 0.140). Species composition of GP and NGP showed actually no similarity (C = 0.007). Similarity between AP and NEP (C = 0.472) was greater than that between AP and NAP (C = 0.140).

**DISCUSSION**

Catalyzing effect of two plantations

A catalyzing effect seemed to be observed in this study site; more individuals of indigenous species regenerated in the plantations than in the grassland (Fig. 2, Table 3). This
observation agrees with those reported by others (Carnevale and Montagnini 2002; Kamo et al. 2002; Parrotta 1992, 1999; Parrotta et al. 1997). Since the plot size and tree size were not same among six plots, care should be taken in interpreting the results. For example, in comparisons of natural forest vs. plantation or natural forest vs. grassland, the area and tree size surveyed were greater in the former (2500 m$^2$ and DBH $\geq 5$ cm) than in the latter (1000 m$^2$ and DBH $\geq 1$ cm). The difference may affect the results, but still it is informative.

The species diversity of understory species was slightly different from that of Kamo and Tiyanon (2006). For AP, the Fisher’s $\alpha$ was 18.8 for trees and climbers, 14.3 for trees, and 4.5 for climbers, and for EP, the values were 19.2, 15.1, and 4.1, respectively (Table 2). On the other hand, Kamo and Tiyanon (2006) reported a Fisher’s $\alpha$ of 12–21 for all plant species, 4.6–9.7 for trees, and 4.4–8.3 for climbers in plantations in the same study site.

This difference was likely to be caused by disturbance condition of natural forests adjacent to plantations (Kamo and Tiyanon 2006), planted tree species, and stand age.

Table 3. Similarity (Morisita’s C.) for tree species composition between the research plots. Abbreviations of the plots (AP, EP, GP, NAP, NEP, NGP) are as in Fig. 1. The data on unknown species were omitted from the analysis.

| Plot* | EP   | GP   | NAP  | NEP  | NGP  |
|-------|------|------|------|------|------|
| AP    | 0.591| 0.011| 0.140| 0.472| 0.077|
| EP    | 0.023| 0.009| 0.445| 0.169|       |
| GP    | 0.009| 0.038| 0.007|      |       |
| NAP   | 0.209| 0.038|      |       |       |
| NEP   | 0.085|      |       |       |       |

* Refer to Table 1 for the abbreviations.
Relative dominance of species was different among six plots (Fig. 3), and some early and late successional species were found among six plots (See Appendix). The type of successional species was defined by references (Lamotte et al. 1998, Prachaiyo 2000, Useful Tropical Plants Website) and the frequency of plant species. In case of *M. paniculatus*, an early-successional species, many young trees were found in NGP. This species was not recorded in GP, but it was found outside the plot, indicating that some adult individuals providing seeds were distributed in the area. Repeated fire seemed to hamper the seedlings of *M. paniculatus* to grow in grassland.

**Factors promoting regeneration in plantations**

In this study, site conditions did not allow us to set sufficient replication for robust statistical analyses, but the results still provide information on several factors affecting the establishment of seedlings originated from natural forests in plantations. These factors are classified into two categories, external and internal. The former includes factors outside the plantations, and the latter includes factors within the plantations.

The most important external factor is the condition of the natural forests providing seeds to the plantations. Although there was not much difference in the number of individuals and species in NAP and NEP (Table 2), species composition of the two plots showed some differences. Twenty-one tree species was common in NAP (71 species) and NEP (75 species) (Table 2 and Appendix). While *Hydnocarpus ilicifolius* and *Walsura trichostemon*, typical elements of DEF (Lamotte et al. 1998) were plenty in NAP, *Aporosa planchoniana*, typical in secondary and disturbed evergreen or deciduous forest (Welzen and Chayamarit Website), was abundant in NEP (Fig. 3). In addition, tree density was slightly greater in NEP than in NAP, but mean DBH was smaller in NEP than in NAP (Table 1). The above difference suggests that NEP is more affected by disturbance than NAP.

As indicated by the low similarity index, NGP does not function well as a seed provider to GP. As long as we examine the species richness and diversity of NGP, the forest seems to have enough potential as a seed source. The main reason why the seedlings derived from the natural forest cannot grow in GP is attributable to frequent fire. Actually, number of individual in GP was much less than those in AP and EP (see Appendix), indicating that even though a seed-source natural forest is located close to a reforestation site, seedlings cannot grow in the plots without fire protection.

The internal factors are the establishing conditions of plantations and the management practice after establishment. The tree form of planted species and planting spacing may affect the light conditions of the forest floor. For the fast-growing species such as *Acacia mangium*, growth and canopy closure are fast, which may affect the light condition and suppress the grass invasion.

Another important internal factor is the demographic traits of the planted species. The survival rate of the overstory species in AP and EP was 73.6% and 35.3%, respectively. The short-aged stand of EP may be effective for promoting a catalyzing effect by creating gaps that allow much light to reach the forest floor.

In the present study, we observed the natural regeneration of seedlings originating from natural forests (the catalyzing effect) in two plantations in northeast Thailand. The regeneration seemed to be more enhanced in plantations of fast growing species. However, in order to obtain more robust and detailed conclusions, more intensive survey with sufficient plot replication would be required.

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Appendix. List of the identified plant species and the frequency. Abbreviations of the plots (AP, EP, GP, NAP, NEP, NGP) are as in Fig. 1: E: Early-successional species, L: Late-successional species, –: Not confirmed. C: Climber, T: Tree.

| Species                      | Family       | Type | Form | AP | EP | GP | NAP | NEP | NGP |
|------------------------------|--------------|------|------|----|----|----|-----|-----|-----|
| *Acacia comosa*              | Fabaceae     | –    | C    | 0  | 0  | 0  | 3   | 4   | 0   |
| *Acacia concinna*            | Fabaceae     | –    | C    | 1  | 1  | 0  | 0   | 0   | 0   |
| *Acronychia pedunculata*     | Rutaceae     | L    | T    | 0  | 0  | 0  | 1   | 0   | 0   |
| *Adenanthera pavoninay*      | Fabaceae     | L    | T    | 1  | 0  | 0  | 1   | 0   | 0   |
| *Aglaia odoratissima*        | Meliaceae    | L    | T    | 0  | 0  | 0  | 6   | 0   | 0   |
| *Aglaia piriifera*           | Meliaceae    | L    | T    | 7  | 1  | 0  | 13  | 0   | 1   |
| *Alangium chinensis*         | Fabaceae     | –    | T    | 0  | 0  | 0  | 0   | 1   | 0   |
| *Albizia odoratissima*       | Meliaceae    | L    | T    | 1  | 0  | 0  | 1   | 0   | 0   |
| *Amoora pllystachya*         | Meliaceae    | –    | T    | 0  | 1  | 0  | 0   | 0   | 0   |
| *Ancistrocladus tectorius*   | Fabaceae     | C    | 0    | 6  | 3  | 0  | 0   | 0   | 0   |
| *Antiaris toxicaria*         | Moraceae     | E    | T    | 0  | 2  | 0  | 0   | 0   | 0   |
| *Antidesma puncticulatum*    | Phyllanthaceae| –    | T    | 0  | 0  | 0  | 4   | 0   | 0   |
| *Aphananthe cuspidata*       | Ulmaceae     | L    | T    | 0  | 0  | 0  | 0   | 0   | 2   |
| *Aporosa octandra*           | Phyllanthaceae| –    | T    | 3  | 2  | 0  | 0   | 0   | 0   |
| *Aporosa planchoniana*       | Phyllanthaceae| L    | T    | 3  | 4  | 0  | 6   | 31  | 1   |
| *Aquilaria crassna*          | Thymelaeaceae| L    | T    | 0  | 0  | 0  | 0   | 0   | 1   |
| *Ardisia collinsae*          | Myrsinaceae  | –    | T    | 0  | 0  | 0  | 1   | 0   | 0   |
| *Ardizia helferiana*         | Myrsinaceae  | –    | T    | 0  | 1  | 0  | 0   | 0   | 0   |
| *Ardisia sp.*                | Myrsinaceae  | –    | T    | 0  | 0  | 0  | 0   | 0   | 3   |
| *Areytera litoralis*         | Sapindaceae  | –    | T    | 1  | 0  | 0  | 0   | 7   | 0   |
| *Baccaurea ramiflora*        | Phyllanthaceae| L    | T    | 0  | 1  | 0  | 3   | 7   | 1   |
| *Beilschmiedia brevipes*     | Lauraceae    | –    | T    | 0  | 0  | 0  | 0   | 0   | 1   |
| *Bhesa robusta*              | Cetropalaceae| –    | T    | 0  | 0  | 1  | 0   | 1   | 1   |
| *Bombax anceps*              | Malvaceae    | –    | T    | 0  | 0  | 1  | 0   | 0   | 0   |
| *Brenynia glauca*            | Phyllanthaceae| –    | T    | 1  | 0  | 0  | 0   | 0   | 0   |
| *Bridelia insulana*          | Phyllanthaceae| L    | T    | 2  | 0  | 0  | 0   | 0   | 0   |
| *Brueca javanica*            | Simaroubaceae| E    | T    | 0  | 0  | 12 | 0   | 0   | 0   |
| *Buchanania sessifolia*      | Anacardiaceae| –    | T    | 3  | 1  | 0  | 0   | 0   | 0   |
| *Byttneria aspera*           | Sterculiaceae| –    | C    | 0  | 0  | 0  | 0   | 0   | 3   |
| *Calamus sp.*                | Arecaceae    | –    | C    | 1  | 0  | 0  | 0   | 0   | 0   |
| *Canarium coffeoides*        | Rubiaceae    | –    | T    | 0  | 1  | 0  | 0   | 0   | 0   |
| *Carallia brachiata*         | Rhiophoraceae| L    | T    | 1  | 1  | 0  | 5   | 2   | 0   |
| *Castanopsis sp.*            | Fagaceae     | –    | T    | 3  | 5  | 0  | 0   | 3   | 0   |
| *Celtis timorenensis*        | Cannabaceae  | L    | T    | 0  | 0  | 0  | 1   | 0   | 0   |
| *Chaetocarpus castanocarpus* | Euphorbiaceae| L    | T    | 0  | 0  | 0  | 1   | 0   | 0   |
| *Chasalia chartacea*         | Meliaceae    | –    | T    | 12 | 10 | 0  | 0   | 0   | 0   |
| *Chrysophyllum roxburghii*   | Sapotaceae   | L    | T    | 0  | 0  | 0  | 2   | 0   | 0   |
| *Chukrasia velutina*         | Meliaceae    | –    | T    | 1  | 0  | 0  | 0   | 0   | 0   |
| *Cinnamomum iners*           | Lauraceae    | L    | T    | 3  | 0  | 0  | 3   | 0   | 0   |
| *Cissus repanda*             | Vitaceae     | –    | C    | 8  | 17 | 0  | 0   | 0   | 0   |
| *Claoxylon indicum*          | Euphorbiaceae| –    | T    | 1  | 0  | 0  | 0   | 0   | 0   |
| *Clausena wallichii*         | Rutaceae     | E    | T    | 72 | 11 | 0  | 0   | 0   | 0   |
| *Combretum acuminatum*       | Combretaceae | –    | C    | 0  | 0  | 0  | 1   | 5   | 0   |
| *Combretum sp.*              | Combretaceae | –    | C    | 19 | 2  | 0  | 2   | 0   | 4   |
| *Croton roxburghii*          | Euphorbiaceae| –    | T    | 0  | 0  | 0  | 17  | 0   | 0   |
| *Cyathostemma micranthum*    | Anonaceae    | –    | C    | 3  | 0  | 0  | 0   | 0   | 0   |
| Species                     | Family      | Type | Form | AP | EP | GP | NAP | NEP | NGP |
|-----------------------------|-------------|------|------|----|----|----|-----|-----|-----|
| Dalbergia cultrata         | Fabaceae    | E    | T    | 0  | 0  | 0  | 6   | 0   | 0   |
| Dalbergia sp.              | Fabaceae    | –    | C    | 0  | 1  | 0  | 0   | 6   | 0   |
| Derris elliptica           | Fabaceae    | –    | C    | 5  | 0  | 0  | 0   | 0   | 0   |
| Dialium cochin chinense    | Fabaceae    | –    | T    | 0  | 0  | 0  | 1   | 2   | 0   |
| Diospyros apiculata        | Ebenaceae   | –    | T    | 0  | 0  | 0  | 0   | 2   | 0   |
| Diospyros areolata         | Ebenaceae   | L    | T    | 0  | 0  | 0  | 0   | 1   | 0   |
| Diospyros malabarica       | Ebenaceae   | L    | T    | 0  | 0  | 0  | 1   | 1   | 0   |
| Dipterocarpus costatus     | Dipterocarpaceae | L  | T  | 0  | 0  | 0  | 0   | 3   |     |
| Dipterocarpus turbinatus   | Dipterocarpaceae | L  | T  | 0  | 0  | 0  | 0   | 4   |     |
| Dracaena angustifolia      | Agavaceae   | L    | T    | 33 | 0  | 0  | 3   | 0   | 1   |
| Drypetes hoaensis          | Euphorbiaceae | –  | T    | 0  | 0  | 0  | 1   | 0   | 0   |
| Elaeocarpus stipularis     | Elaeocarpaceae | L  | T  | 0  | 1  | 0  | 0   | 0   | 0   |
| Erythrina stricta          | Fabaceae    | E    | T    | 0  | 0  | 0  | 0   | 0   | 0   |
| Ficus heterostyla          | Moraceae    | –    | T    | 0  | 0  | 0  | 0   | 2   |     |
| Ficus hirta                | Moraceae    | –    | T    | 0  | 2  | 0  | 0   | 0   | 0   |
| Ficus hispida              | Moraceae    | E    | T    | 1  | 0  | 1  | 0   | 0   | 0   |
| Ficus lampsonga            | Moraceae    | –    | T    | 0  | 0  | 0  | 1   | 0   | 0   |
| Ficus pubigera             | Moraceae    | –    | T    | 0  | 0  | 0  | 0   | 1   | 0   |
| Ficus sp.                  | Moraceae    | –    | T    | 0  | 0  | 0  | 0   | 1   | 0   |
| Ficus variegata            | Moraceae    | –    | T    | 1  | 2  | 0  | 0   | 0   | 0   |
| Garcinia cowa              | Clusiaceae  | L    | T    | 0  | 0  | 0  | 0   | 0   | 1   |
| Garcinia rostrata          | Clusiaceae  | –    | T    | 0  | 0  | 0  | 2   | 1   | 0   |
| Garcinia speciosa          | Clusiaceae  | –    | T    | 5  | 0  | 0  | 4   | 5   | 4   |
| Gironniera subaequalis     | Ulmaceae    | L    | T    | 0  | 0  | 0  | 0   | 0   | 4   |
| Glycosmis pentaphylla      | Rutaceae    | E    | T    | 2  | 0  | 0  | 0   | 0   | 0   |
| Glycosmis pierrei          | Rutaceae    | –    | T    | 1  | 0  | 0  | 0   | 0   | 0   |
| Gnetum macrostachyum       | Gnetaceae   | L    | C    | 2  | 0  | 0  | 0   | 0   | 0   |
| Gnetum montanum            | Gnetaceae   | L    | C    | 0  | 0  | 0  | 0   | 0   | 1   |
| Gonocaryum lobbianum       | Icacinaceae | L    | T    | 3  | 8  | 0  | 5   | 16  | 2   |
| Helicia excelsa            | Proteaceae  | L    | T    | 2  | 0  | 0  | 0   | 2   | 0   |
| Helicia formosana var.oblanceolata | Proteaceae  | –    | T    | 0  | 0  | 0  | 1   | 0   | 0   |
| Hopea ferrea               | Dipterocarpaceae | L  | T  | 0  | 0  | 0  | 1   | 0   | 0   |
| Horsfieldia glabra         | Myristicaceae | L  | T  | 0  | 0  | 0  | 0   | 0   | 5   |
| Hydnocarpus ilicifolius    | Flacourtiaeae | L  | T  | 0  | 0  | 0  | 38  | 3   | 0   |
| Hymenodictyon oritense     | Rubiaceae   | –    | T    | 0  | 0  | 1  | 0   | 0   | 0   |
| Ilex umbellulata           | Aquifoliaceae | L  | T  | 0  | 1  | 0  | 0   | 0   | 1   |
| Irvingia malayana          | Irvingiaceae | L    | T    | 0  | 3  | 0  | 0   | 0   | 0   |
| Jasminum anodontum         | Oleaceae    | E    | C    | 6  | 7  | 0  | 0   | 0   | 0   |
| Knema globularia           | Myristicaceae | L  | T  | 0  | 0  | 0  | 0   | 0   | 5   |
| Lithocarpus thomsonii      | Fagaceae    | L    | T    | 0  | 0  | 0  | 4   | 1   | 0   |
| Litsea myristicaefolia     | Lauraceae   | –    | T    | 6  | 7  | 0  | 0   | 4   | 0   |
| Litsea umbellata           | Lauraceae   | –    | T    | 0  | 0  | 0  | 0   | 4   | 1   |
| Litsea verticillata        | Lauraceae   | L    | T    | 0  | 0  | 0  | 1   | 0   | 1   |
| Lophophotnum disperranean  | Celastraceae | –    | T    | 0  | 0  | 0  | 0   | 0   | 2   |
| Macaranga denticulata      | Euphorbiaceae | E  | T  | 0  | 0  | 0  | 0   | 0   | 7   |
| Mallotus paniculatus       | Euphorbiaceae | E  | T  | 4  | 10 | 0  | 0   | 0   | 115  |
| Mangifera cochin chinensis | Anacardiaceae | L  | T  | 0  | 0  | 0  | 10  | 0   | 2   |
| Markhamia stipula          | Bignoniaceae | E    | T    | 0  | 1  | 0  | 0   | 0   | 0   |
| Meladorum fruticosum       | Annonaceae  | L    | T    | 1  | 3  | 0  | 2   | 4   | 0   |
| Memecylon caeruleum        | Memecylaceae | L  | T  | 0  | 0  | 0  | 6   | 0   | 5   |
| Memecylon geddesianum      | Memecylaceae | L    | T    | 6  | 0  | 0  | 0   | 0   | 0   |
| Species                  | Family               | Type | Form | AP | EP | GP | NAP | NEP | NGP |
|-------------------------|----------------------|------|------|----|----|----|-----|-----|-----|
| Memecylon ovatum        | Memecylaceae         | L    | T    | 27 | 0  | 0  | 0   | 0   | 0   |
| Metadina trichotoma     | Rubiaceae            | –    | T    | 0  | 0  | 0  | 0   | 0   | 1   |
| Michelia champaca       | Magnoliaceae         | –    | T    | 0  | 0  | 0  | 0   | 1   | 0   |
| Microcos tomentosa      | Malvaceae            | L    | T    | 17 | 16 | 0  | 3   | 5   | 0   |
| Microdesmis casearifolia| Pandaceae            | L    | T    | 9  | 14 | 0  | 0   | 6   | 0   | 2   |
| Micromelum minutum      | Rutaceae             | L    | T    | 0  | 0  | 0  | 0   | 0   | 2   | 0   |
| Murraya paniculata      | Rutaceae             | –    | T    | 0  | 0  | 0  | 0   | 1   | 0   | 0   |
| Mussaenda sp.           | Rubiaceae            | –    | C    | 2  | 0  | 0  | 0   | 0   | 0   | 0   |
| Myoporymum smilacifolium| Oleaceae             | –    | T    | 0  | 0  | 0  | 1   | 1   | 0   | 0   |
| Nephelium hypoleucum    | Sapindaceae          | L    | T    | 21 | 24 | 1  | 1   | 40  | 3   |
| Parameria barbata       | Apocynaceae          | C    | T    | 13 | 4  | 0  | 0   | 2   | 0   |
| Parkia sumatrana        | Mimosaceae           | L    | T    | 0  | 0  | 0  | 1   | 0   | 0   | 0   |
| Pheobe lanceolata       | Lauraceae            | E    | T    | 1  | 1  | 0  | 3   | 4   | 2   | 0   |
| Prismatomeris tetrandra | Rubiaceae            | –    | T    | 3  | 2  | 0  | 0   | 0   | 0   | 0   |
| Prunus arboea           | Rosaceae             | L    | T    | 1  | 0  | 0  | 0   | 0   | 0   | 0   |
| Prunus javanica         | Rosaceae             | L    | T    | 2  | 4  | 0  | 0   | 0   | 0   | 0   | 0   |
| Psydrea cochinchinensis | Rubiaceae            | –    | T    | 4  | 8  | 0  | 0   | 0   | 0   | 0   | 0   |
| Psydrea divoca var.divoca| Rubiaceae           | L    | T    | 0  | 0  | 0  | 0   | 3   | 5   | 0   |
| Pterocarpus macrocarpus | Fabaceae             | L    | T    | 0  | 0  | 0  | 0   | 0   | 0   | 1   | 0   |
| Pterocymbium tinctorium | Malvaceae            | L    | T    | 0  | 0  | 0  | 0   | 0   | 0   | 1   |
| Pterospermum cinnamomeum| Malvaceae            | –    | T    | 0  | 0  | 9  | 0   | 2   | 1   | 0   |
| Pterospermum lanceolatum| Malvaceae            | –    | T    | 3  | 1  | 0  | 0   | 0   | 0   | 0   | 0   |
| Quercus angustii        | Fagaceae             | –    | T    | 0  | 0  | 0  | 0   | 0   | 0   | 2   | 0   |
| Quercus sp.             | Fagaceae             | –    | T    | 0  | 0  | 0  | 3   | 1   | 0   |
| Rothmannia sootepensis  | Rubiaceae            | –    | T    | 6  | 6  | 0  | 5   | 0   | 11  |
| Salacia grandiflora     | Celastraceae         | –    | C    | 6  | 4  | 0  | 0   | 0   | 0   | 0   | 0   |
| Sandoricum koetjape     | Meliaceae            | L    | T    | 0  | 0  | 0  | 0   | 0   | 8   |
| Shorea henryana         | Dipterocarpaceae     | L    | T    | 53 | 12 | 0  | 7   | 82  | 10  |
| Sladenia celastifolia   | Sladeniaceae         | –    | T    | 0  | 0  | 0  | 0   | 0   | 1   | 0   |
| Sterculia balanghas     | Malvaceae            | –    | T    | 0  | 0  | 0  | 0   | 0   | 0   | 1   |
| Streblus ilicifolius    | Moraceae             | –    | T    | 7  | 0  | 0  | 6   | 0   | 2   |
| Symlocos cochinchinensis| Symlocaceae          | –    | T    | 0  | 0  | 0  | 0   | 0   | 1   | 0   |
| Syzygium cuminii        | Myrtaceae            | L    | T    | 0  | 0  | 0  | 0   | 0   | 2   | 0   | 0   |
| Syzygium gracile        | Myrtaceae            | –    | T    | 0  | 0  | 0  | 6   | 0   | 0   | 0   |
| Syzygium gratum         | Myrtaceae            | –    | T    | 0  | 0  | 0  | 0   | 0   | 1   | 0   | 0   |
| Syzygium megacarpum     | Myrtaceae            | L    | T    | 1  | 8  | 0  | 0   | 3   | 1   | 0   |
| Syzygium syzygioides    | Myrtaceae            | –    | T    | 0  | 0  | 0  | 0   | 1   | 0   |
| Terminalia calamansanai | Combretaceae         | L    | T    | 0  | 3  | 0  | 0   | 0   | 0   | 0   |
| Terminalia sp.          | Combretaceae         | –    | T    | 0  | 1  | 0  | 0   | 0   | 0   |
| Tetracera laurei        | Acanthaceae          | –    | T    | 0  | 0  | 2  | 4   | 1   | 0   |
| Tetradium glabrifolium  | Rutaceae             | –    | T    | 1  | 4  | 0  | 0   | 0   | 0   |
| Todalia asiatica       | Rutaceae             | L    | C    | 0  | 0  | 0  | 5   | 7   | 0   |
| Trema orientalis        | Cannabaceae          | E    | T    | 0  | 0  | 0  | 0   | 0   | 5   |
| Turpinia pomifera       | Staphyleaceae        | L    | T    | 0  | 0  | 0  | 0   | 2   | 2   |
| Uroborya siamensis      | Opilaceae            | L    | C    | 3  | 0  | 0  | 0   | 0   | 0   |
| Uvaria dac              | Annonaceae           | –    | C    | 0  | 0  | 0  | 0   | 7   | 0   |
| Uvaria hahnii           | Annonaceae           | –    | C    | 44 | 12 | 0  | 0   | 0   | 1   |
| Vatica harmandiana      | Dipterocarpaceae     | –    | T    | 0  | 0  | 0  | 0   | 1   | 0   |
| Ventilago denticulate   | Rhamnaceae           | –    | C    | 0  | 0  | 0  | 10  | 1   |
| Vitex canescens         | Lamiaceae            | –    | T    | 0  | 0  | 2  | 0   | 0   | 0   | 0   |

Appendix (continued)
Regeneration of natural-forest species in plantations of fast-growing species

Appendix (continued)

| Species                  | Family    | Type | Form | AP | EP | GP | NAP | NEP | NGP |
|--------------------------|-----------|------|------|----|----|----|-----|-----|-----|
| *Vitex peduncularis*     | Lamiaceae | L    | T    | 3  | 5  | 0  | 1   | 8   | 2   |
| *Walsura pinnata*        | Meliaceae | –    | T    | 0  | 0  | 0  | 0   | 0   | 8   |
| *Walsura robusta*        | Meliaceae | L    | T    | 0  | 0  | 0  | 1   | 0   | 0   |
| *Walsura trichostemon*   | Meliaceae | L    | T    | 1  | 0  | 0  | 26  | 0   | 4   |
| *Willughbeia edulis*     | Apocynaceae | L  | C    | 0  | 1  | 0  | 0   | 0   | 0   |
| *Wrightia arborea*       | Apocynaceae | –  | T    | 0  | 7  | 0  | 0   | 0   | 0   |
| *Wrightia tomentosa*     | Apocynaceae | –  | T    | 0  | 0  | 1  | 0   | 0   | 0   |
| *Xanthophyllum flavescens* | Polygalaceae | E  | T    | 0  | 0  | 0  | 3   | 0   | 0   |
| *Zizyphus oenoplia*      | Rhamnaceae | –   | C    | 2  | 4  | 0  | 0   | 2   | 0   |
| *Zollingeria dongnaiensis* | Sapindaceae | –  | T    | 0  | 0  | 0  | 0   | 0   | 1   |
| Unknown                  | –         | –    | –    | 15 | 26 | 22 | 46  | 47  | 21  |
| Total                    |           |      |      | 478| 295| 61 | 292 | 366 | 264 |