EFFECTS OF SELECTIVE LOGGING ON THE REGENERATION OF TWO COMMERCIAL TREE SPECIES IN THE KABAUNG RESERVED FOREST, BAGO MOUNTAINS, MYANMAR

R Ne Win[1], *, R Suzuki[2] & S Takeda[1]

[1]*Graduate School of Asian and African Area Studies, Kyoto University 606-8501, 46 Shimoadachi-cho, Yoshida, Sakyo-ku, Kyoto, Japan*
[2]*Institute of Sustainability Science & Center for Southeast Asian Studies, Kyoto University 606-8501, 46 Shimoadachi-cho, Yoshida, Sakyo-ku, Kyoto, Japan*

NE WIN R, SUZUKI R & TAKEDA S. 2012. Effects of selective logging on the regeneration of two commercial tree species in the Kabaung Reserved Forest, Bago Mountains, Myanmar. The density and growth of two commercial tree species from shoot recruitment after selective logging were studied for 13 months in the Kabaung Reserved Forest, Myanmar. The highest density and greatest initial height growth of *Tectona grandis* (teak) were observed in log landing and logging road sites. These were areas with disturbed soils and increased light intensity. Despite the higher light availability in felling gaps compared with areas unaffected by logging, the density and height of recruited teak shoots at both sites were not significantly different. Among disturbance types, log landing created the highest canopy openness and caused the greatest recruitment and growth of new teak shoots. These findings suggest that the level of disturbance in felling gaps caused by current selective logging practices may be inadequate to promote satisfactory teak regeneration. Activities that increase light and control interference from competing vegetation in felling gaps may be necessary. *Xylia xylocarpa* did not resprout because of the damage to both stems and roots of shoots caused by the construction of logging roads and log landing sites. This resulted in a much lower post-logging recruitment than mortality of pre-existing shoots.

Keywords:　*Tectona grandis, Xylia xylocarpa*, canopy openness, logging road, log landing, felling gap

NE WIN R, SUZUKI R & TAKEDA S. 2012. Kesan tebangan memilih terhadap pemulihan dua spesies pokok komersial di Hutan Simpan Kabaung, Gunung Bago, Myanmar. Kajian dijalankan selama 13 bulan di Hutan Simpan Kabaung, Myanmar untuk menyelidiki kepadatan dan pertumbuhan dua spesies pokok komersial daripada pertambahan anak pokok selepas tebangan memilih. Kepadatan dan ketinggian awal *Tectona grandis* (pokok jati) yang maksimum terdapat di matau dan jalan pembalakan. Kawasan ini mengalami gangguan tanah dan pertambahan keamatan cahaya. Kepadatan dan ketinggian anak pokok jati di kedua-dua tapak tidak berbeza dengan signifikan walaupun keamatan cahaya adalah lebih tinggi di ruang tebangan berbanding dengan kawasan yang tidak dibalak. Antara jenis gangguan, matau mengakibatkan pembukaan kanopi yang paling besar, justeru pertambahan dan pertumbuhan anak pokok jati yang paling besar. Kajian menunjukkan bahawa paras gangguan di ruang tebangan yang diakibatkan oleh amalan tebangan semasa mungkin tidak mencukupi untuk menggalakkan pemulihan pokok jati yang memuaskan. Aktiviti yang meningkatkan keamatan cahaya dan aktiviti yang mengawal gangguan daripada vegetasi saingan di ruang tebangan mungkin diperlukan. *Xylia xylocarpa* tidak bertunas semula disebabkan kerosakan pada batang dan akar anak pokok akibat pembinaan jalan pembalakan dan matau. Akibatnya selepas pembalakan, kadar kematian anak pokok sedia ada adalah lebih daripada pertambahan anak pokok.

INTRODUCTION

The Bago mountain range is a forested region possessing some of the best growth and highest density teak species in Myanmar. This area represents 11.3% of all teak-bearing forests in the country (Zin 2000). Natural teak-bearing forests are the country's primary source of forest products. Teak and other commercial hardwood species are a major source of foreign exchange that enhances the country's economy.

Clear knowledge of the dynamics of stand structure and regeneration is, therefore, important for sustainable timber production. A critical step in sustainable forestry is ensuring the establishment and regeneration of seedlings

*E-mail: rosynewin@gmail.com

and sapling of commercial tree species following harvesting (Fredericksen & Mostacedo 2000). Due to their importance in forest management, the dynamics of regeneration have received a lot of attention (Wang et al. 2005, Felton et al. 2006). If tree regeneration increases in response to selective logging, then sustained use is at least possible. However, if the removal of woody vegetation results in insignificant regeneration or a change to a different forest structure and composition, then heavy exploitation of timber resources may have adverse effects on species composition of both fauna and flora (Schwartz & Caro 2003). Several studies on regeneration following selective- and conventionally-executed logging have been conducted (Dekker & de Graaf 2003, Lobo et al. 2007).

The Bago Mountain area is located in the southern part of the central basin of Myanmar. Natural teak-bearing forests in the Bago Mountains have been managed under the Myanmar Selection System (MSS) since 1856 (Gyi & Tint 1995) and the MSS remains the main regime used for managing natural teak-bearing forests in Myanmar. Under the MSS, the felling cycle is 30 years. The minimum limit for exploitable diameter at breast height (dbh) is 73 cm in moist teak forests and 63 cm in dry teak forests (Zin 2000). Various tending operations are conducted to help restore forests prior to the start of the next harvest cycle. The essential idea behind this system is to sustainably harvest teak-bearing forests every 30 years. Trees, that meet exploitable dbh limits, are felled, creating single- or multiple-tree felling gaps depending on the density and proximity of selected individual trees. Harvested trees are cut into logs and dragged by elephants to log landing sites, where they are piled. Piled logs are transported by truck along logging roads to timber depots. These activities and processes create various types of disturbance regimes in the forests, affecting canopy cover, understorey vegetation and soil.

Teak (*Tectona grandis*) is the most important tree species in Myanmar in terms of timber production and plantation development programmes. It is recognised as a light-demanding species (Troup 1921). Light has been shown to be the primary factor that affects the establishment of teak seedlings; 75–95% of full daylight appears to be the most suitable regime for growth and development (White 1991). Teak is sensitive to drought but has remarkable abilities to resist

effects of fire compared with most of its associates and competitors (Kyaw 2003). Teak seeds exhibit some degree of dormancy and delayed germination due to the thick pericarp (Kadambi 1972). Temperature is the main factor which triggers the germination of teak seeds. Heat may come from either the sun or generated by fire (Troup 1921).

Pyinkado (*Xylia xylocarpa*), the Myanmar ironwood, is a shade-tolerant species, particularly during the young stages. It is a natural associate of teak. It is not fire resistant. It is a popular commercial species because of its strength, durability and relative abundance (Shin 2006). It is one of the most desirable species for building houses, bridges and railway sleepers in Myanmar.

Both teak and pyinkado have the ability to resprout. If the aboveground part of a seedling/shoot dies, leaving a small stump with an undamaged root still in the ground, a new shoot can emerge from the undamaged stump (personal observation). Thus, these species have two regeneration sources, namely, seed and stump of dead shoot.

Since selective logging is one of the main silvicultural practices in Myanmar, a detailed understanding of regeneration following selective logging is vital. Understanding the requirements for the establishment and regeneration of commercially important tree species is essential for designing more effective management systems. There is, however, lack of empirical studies delineating logging effects on tree regeneration in the teak-bearing forests of Myanmar. This poses a problem in the understanding of the dynamics of these forests. This study was an attempt to bridge this gap. The objective was to determine whether current logging practices enhanced the recruitment of commercially important tree species by comparing shoot densities in areas disturbed by logging.

MATERIALS AND METHODS

The study area, Kabaung Reserved Forest, is a forest reserve in the Bago Mountains (Figure 1). It is located at approximately 18°50'–19°09' N, 95°50'–96°12' E in the Taungoo and Oktwin townships of Taungoo district.

In November 2008 (prior to logging), a permanent plot (60 m × 100 m) was established and divided into 20 m × 20 m subplots. In each
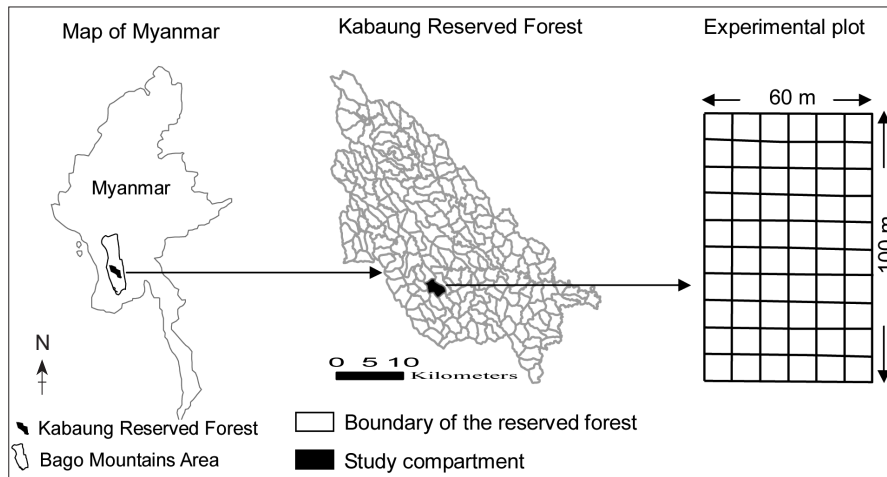
Figure 1   Location of the study area and sample plot design

subplot, all trees species with heights ≥ 1.3 m were measured. A bamboo census was conducted in order to know the basal area of bamboos. The regeneration of teak and pyinkado was monitored. Trees with heights ≥ 1.3 m were identified, tagged and the stem dbh measured. The bamboo census involved measuring the maximum and minimum culm diameter and recording the number of culms per clump. The basal area of a bamboo clump was calculated as $n \times d_{max} \times d_{min} \times \pi/4$ (Thein et al. 2007), where n is the number of culms per clump, d_{max} is the maximum culm diameter and d_{min} is the minimum culm diameter. Shoots (< 1.3 m height) of teak and pyinkado were counted and tagged. Their diameter and height were measured. The direction and distance of each tree, bamboo plant, teak and pyinkado shoots were measured from the centre point of each subplot using an Ushikata Tracon surveying compass and a Vertex compass. Four canopy photos were taken with a fisheye lens at 1 m height in the four interior places of each subplot (20 m × 20 m). The mean canopy openness of these four canopy photos was calculated and used in the analysis as the canopy openness of each subplot.

Logging was conducted in March 2009 by timber companies. In December 2009, nine months after logging, the plot was revisited and resurveyed. Damaged trees, bamboo plants, dead shoots and surviving shoots were counted. New shoots that had sprouted since the November 2008 survey were counted, tagged, and their height and diameter determined. The exact location of each recruited shoot was measured using the same method used in 2008. In each subplot, canopy photos were taken at the same locations as in 2008. The images were analysed using Gap Light Analyser. The locations of logging roads (LR), log landing (LL) and stumps were recorded by global positioning system. Using the direction and distance, a map showing the location of each tree, bamboo plant, stump, and old and new shoots was prepared using ArcGIS and overlaid with locations of the LR and LL. The map and field observation were used to study effects of selective logging.

As we could not determine the exact regeneration source of each individual, we used the term 'shoot' in this study to refer to new aboveground plant growth that either developed from a seed or as a young coppice that sprouted from an undamaged stump after stem dieback. Shoot recruitment was compared between the four types of disturbances: LR, LL, felling gap (FG), and areas with no logging disturbance (NLD). Six 10 m × 10 m plots with roads accounting for > 50% of the total plot area were selected as LR sites. Four 10 m × 10 m plots which accounted for > 50% of the total plot area were chosen as LL sites. Twelve 10 m × 10 m plots that were positioned within a 10 m radius (estimated crown area) of a stump and with crown areas > 50% were selected as FG sites. Sixteen 10 m × 10 m plots with no logging effects and which were at least 10 m away from the boundary of LR and LL sites and had no felling damage from logged trees were chosen as NLD sites (Figure 2). Plots that were a combination of LR and LL, within 10 m of LR and LL, with felling damage by logged trees, and with < 50% of their area affected by logging were classified as 'Others'.
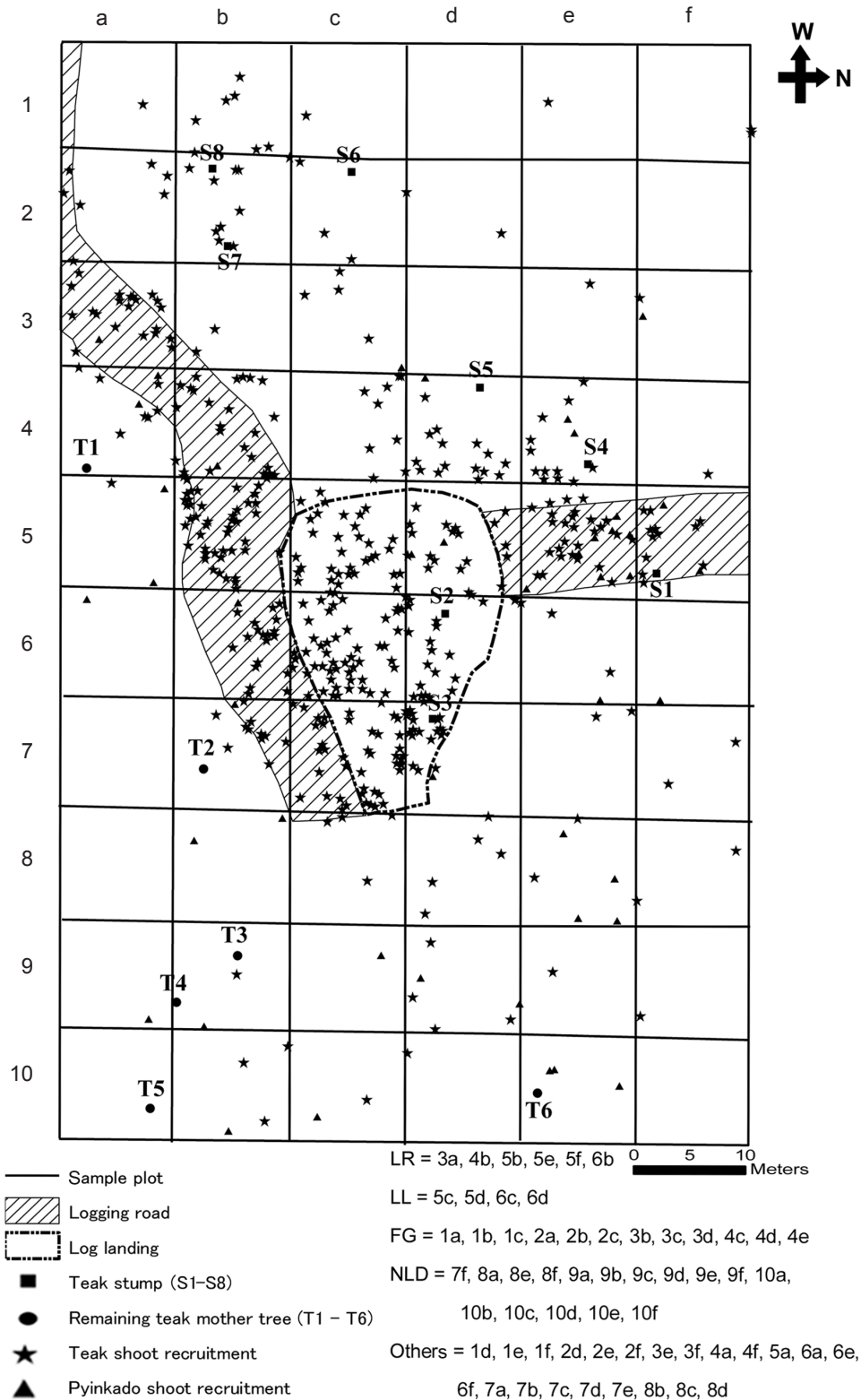
Figure 2   Map showing the study plot with logging road (LR), log landing (LL), teak stumps, trees and new shoots

Among the four types of disturbances (LR, LL, FG and NLD sites), LR and LL included soil disturbance from logging machines, while FG sites had no soil disturbance due to elephant skidding. Shoot density and height between plots that experienced different disturbance types were examined with Mann–Whitney test. Statistical analyses were carried out with SPSS 16.0.

RESULTS

Average canopy openness in each disturbance category

Figure 3 shows the average canopy openness after logging in each disturbance category. LL sites had the highest canopy openness, followed by LR sites. Canopy openness values for LL and LR sites were significantly higher than those for FG and NLD sites (p < 0.01).

Survival, mortality and recruitment in each disturbance category

Figure 4a presents the mortality and survivors of teak shoots before logging, while Figure 4b presents those of pyinkado shoots before logging. Figure 4c presents the survivors and recruitment of teak shoots after logging, while Figure 4d presents those of pyinkado shoots after logging. The number of pyinkado surviving shoots was much higher in FG than in LR and LL sites (Figure 4b or 4d). Shoot survival was 65% in FG sites but 12 and 0% for LR and LL sites respectively.

Teak shoot mortality was highest in LL sites, followed by LR and FG sites (Figure 4a). The highest recruitment was found in LL sites (Figure 4c). In LR sites, 333 teak shoots/ha died. However, 2450 new teak shoots/ha (seven times the mortality rate) were recruited in LR sites after selective logging. In LL sites, 375 teak shoots/ha were lost, but 3825 new teak shoots/ha (10 times the mortality rate) were recruited after logging. In FG sites, teak shoot recruitment was about five times higher than

the mortality of pre-existing shoots. At FG and NLD sites, some shoots were lost due to herbivory by insects, wild boars and forest fires (personal observation).

Pyinkado shoot mortality was highest in LR sites, followed by LL and FG sites (867 shoots per ha in LR, 400 shoots per ha in LL, 308 shoots per ha in FG, Figure 4b). However, density of recruitment after logging was much lower than that of mortality in each disturbance category (250 shoots per ha in LR, 75 shoots per ha in LL, 100 shoots per ha in FG).

Teak and pyinkado shoot recruitment after selective logging

Teak recruitment was greatest in LL sites, followed by LR sites, and significantly higher in these locations than in FG sites (Mann–Whitney test, p < 0.01) (Figure 4c). In FG sites, recruitment of new teak shoots was slightly higher than in NLD sites, but the difference was not significant (Mann–Whiney test, p = 0.418). Pyinkado recruitment was greatest in LR sites, followed by FG, NLD and LL sites (Figure 4d). However, recruitment was not significantly different with disturbance types.
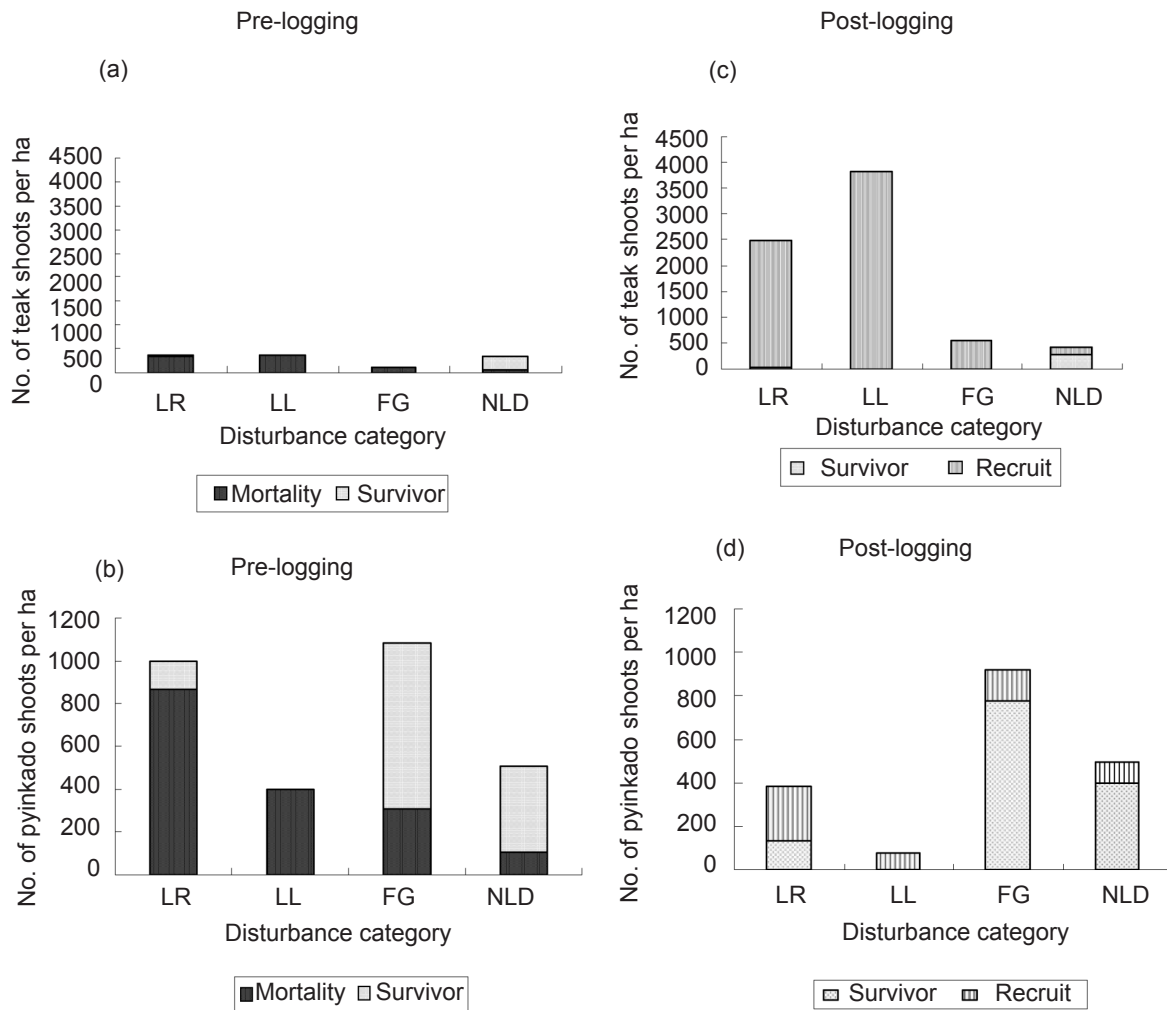
Relationship between basal area of bamboo and light intensity in felling gaps

Canopy openness was lower in FG sites than in LR and LL sites due to the presence of bamboo plants. The basal area of bamboo was negatively correlated with canopy openness in FG sites (r = -0.604, p < 0.05, Figure 5).


LR = logging road
LL = log landing
FG = felling gap
NLD = no logging disturbance
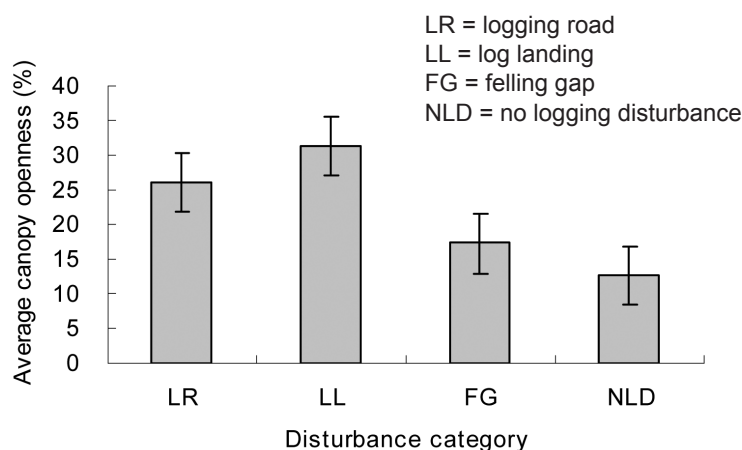
Figure 3   Average canopy openness in each disturbance category

Pre-logging

(a)

Post-logging

(c)

Figure 4   Pre-logging mortality and survivors for (a) teak and (b) pyinkado; post-logging survivors and recruits for (c) teak and (d) pyinkado; LR = logging road, LL = log landing, FG = felling gap, NLD = no logging disturbance
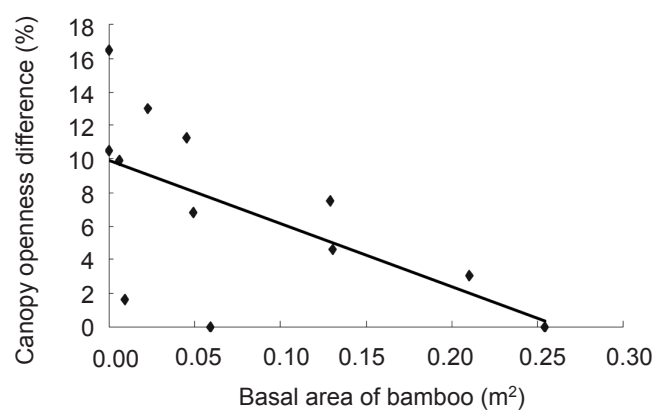
Figure 5   Relationship between basal area of bamboo and canopy openness in felling gaps

Height distribution pattern of shoots in each disturbance category

Teak shoots were more common in LR and LL sites than in FG and NLD sites, whereas pyinkado shoots were more common in FG and NLD sites than in LR and LL sites (Table 1).

Some teak and pyinkado shoots reached heights of > 80 cm in LR and LL sites, but no shoots exceeded 80 cm in height in FG and NLD sites.

Table 1   Height distribution of shoots in each disturbance area for (a) teak and (b) pyinkado

(a)

Category	Height (cm)					
	0–20	20–40	40–60	60–80	80–100	> 100
	Total no. of teak shoots per ha					
LR	1700 (1683)	617 (600)	117 (100)	50 (33)	33 (33)	0
LL	2225 (2225)	1200 (1200)	200 (200)	100 (100)	25 (25)	75 (75)
FG	375 (375)	125 (117)	25 (25)	0	0	0
NLD	319 (131)	63 (6)	25 (19)	0	0	0

(b)

Category	Height (cm)					
	0–20	20–40	40–60	60–80	80–100	> 100
	Total no. of pyinkado shoots per ha					
LR	17 (0)	167 (117)	83 (67)	83 (50)	0	33 (17)
LL	25 (25)	25 (25)	25 (25)	0	0	0
FG	200 (0)	358 (125)	192 (8)	67 (8)	0	0
NLD	263 (31)	163 (38)	63 (13)	13 (13)	0	0

Number of new shoots in parentheses; LR = logging road, LL = log landing, FG = felling gap, NLD = no logging disturbance

DISCUSSION

Shoot recruitment in logging road and log landing sites

The lower survival percentage of shoots in LR and LL sites compared with FG and NLD sites clearly showed that both teak and pyinkado were greatly affected by the construction of LR and LL.

Shoot recruitment during the 13 months was substantially higher in LL and LR sites than in FG and NLD sites. This improved recruitment was reflected in the number of tree shoots significantly exceeding the losses of pre-existing shoots due to the construction of LR and LL. Improved recruitment of commercial trees in LR and LL sites was accounted for largely by teak, a light-demanding species that performed better as a result of increased light due to partial removal of crown cover.

The availability of teak seeds at the time of the disturbance was an important factor in the successful regeneration of teak. Figure 2 shows that one teak stump (S1, 60.5 cm dbh) was located in a future LR site, two teak stumps (S2, 63.7 cm and S3, 76.4 cm dbh) were found in LL sites and some teak trees were located near future roads. Teak trees usually fruit every year (Kermode 1964). These trees could be the main

source of seeds for seed banks in the LR and LL sites. After logging, dormant seeds in the seed banks of LR and LL sites were then able to geminate under favourable conditions created by LR and LL construction. This may explain the enhancement of teak recruitment in LR and LL sites after selective logging. Although teak stumps and trees were present in FG and NLD sites, recruitment was low due to the absence of favourable conditions.

Some studies have shown that soil compaction can delay the establishment of seedlings (Whitman et al. 1997, Pinard et al. 2000), while other studies have reported that greater canopy openness and soil disturbance favour tree regeneration (Denslow 1995, Dickinson & Whigham 1999). In this study, the recruitment of teak shoots was enhanced in LR and LL sites (Figure 4) where light availability increased due to logging and disturbance of soils by logging machines. These findings concurred with those of other studies in which improved seedling and sapling recruitments were observed in areas where soil had been disturbed by logging equipment (Fredericksen & Mostacedo 2000, Fredericksen & Pariona 2002). The regeneration of free-standing fig tree species harvested for timber was found to increase in areas with logging-induced soil disturbance (Fredericksen et al. 1999).

The compaction of wet soil by logging machines can impede regeneration on skid trails (Pinard et al. 1996). However, if the soils are dry during logging, commercial tree species can regenerate abundantly on skid trails (Dickinson & Whigham 1999, Dickinson et al. 2000). The soils at the present study site were sandy loams and forest road construction began at the end of the rainy season, around November, when forest soils hardened (Zaw 2004). Dry soils are much more resistant to compaction than moist or wet soil. Therefore, soil compaction from logging machines should be limited during logging.

Competing vegetation at ground level can result in tree regeneration failure (Kermode 1964). In the study area, LL and LR sites had high light availability and low competing plant volume due to their frequent use by logging trucks. The initial removal of vegetation from LR and LL by logging machines may be one of the causes of successful early recruitment of teak shoots.

Shoot recruitment in felling gaps

Some studies have shown that logging gaps in the tropics are quickly filled with a dense cover of competing plants (Buschbacher 1990, Webb 1997). In this study, there was no soil disturbance in FG sites due to elephant skidding. Thus, competing vegetation was not minimised and canopy openness was much lower in FG than in LR and LL sites (Figure 3). Therefore, teak shoot recruitment was not as high in FG as in LR and LL sites because of insufficient levels of canopy openness and minimal control of competing vegetation.

In mixed deciduous forests of Thailand, canopy gaps have been shown to have little effect on tree recruitment because of the bamboo undergrowth (Marod et al. 1999). In Myanmar, natural tree regeneration is also hampered by the heavy undergrowth of bamboo (Tewari 1992). As shown in Figure 5, the basal area of bamboo in FG sites was significantly correlated with canopy openness (r = -0.604, p < 0.05). The shade created by the bamboo cover may have affected teak regeneration at these sites.

Shoot mortality in the shade-tolerant pyinkado exceeded recruitment in all disturbance categories, indicating that disturbances from selective logging negatively affected this species. According to the Marod et al. (2002), resprouting is the only means through which pyinkado can

survive under the disturbance regimes of water and fire. The ability of pyinkado to resprout following disturbances in the LR, LL and FG sites is, however, made difficult due to damage by construction of LR and LL and by animals (personal observation) which tend to destroy both stem and root. This explains the lower recruitment of post-logging pyinkado shoots.

Effects of canopy openness on shoot height

Figure 3 shows that LR and LL create higher canopy openness (> 20%). This resulted in rapid growth that produced the greatest height of shoots among the disturbances types (Table 1). This finding was in accordance with that of Thein et al. (2007) who found that a combination of logging and bamboo flowering which created canopy openness level of > 20% could stimulate the recruitment of saplings into pole-sized trees. Sist and Nguyen-The' (2002) found that canopy opening from logging stimulated tree growth during the four years after logging.

Factors affecting future survival and growth of recruited shoots

Forest fires and bamboo flowering are the two most important factors affecting natural regeneration of teak-bearing forests (Gyi & Tint 1995). In Myanmar, ground fires are normal dry season occurrences in natural teak forests. These fires reduce the number of teak and pyinkado seedlings and consequently reduce the number of saplings and pole-sized trees (Keh 2004). Teak seedlings are, however, able to survive because of their resistance to fire, enabling rapid recovery after a fire (Troup 1921). The estimated height of teak shoots that could escape from forest fires was about 100 cm. Taller teak shoots as listed in Table 1a (> 100 cm height) were, therefore, highly likely to survive the next fire event. Surface fires may destroy smaller teak shoots (< 100 cm height) but these have the ability to resprout from their roots. In contrast, fires kill most pyinkado shoots as they are not fire resistant.

Another important factor that promotes natural regeneration in teak-bearing forests is the timing of bamboo flowering (Gyi & Tint 1995). Bamboo is the main undergrowth species in natural teak-bearing forests. The middle layer of the study site was dominated by bamboo (personal observation). Figure 5 shows that the

presence of bamboo causes reduced canopy openness in felling gaps. The death of bamboo plants created large openings with improved light conditions in felling gaps. This facilitated regeneration of teak.

CONCLUSIONS

Teak exhibited higher rates of regeneration in areas where the soil was disturbed and light intensity increased following the removal of canopy cover (LL and LR sites). With regard to teak recruitment, FG sites were not significantly different from the NLD sites. This can be explained by the limited canopy openness and the presence of competing vegetation at FG sites. Activities that are specifically designed to increase light and control competing vegetation are necessary in FG sites to promote teak recruitment. Of the disturbance types, LL created the highest canopy openness, resulting in the creation of more open spaces and increased light intensity. This produced the greatest recruitment and growth of teak shoots.

ACKNOWLEDGEMENTS

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