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Pattern and rate of succession after selective logging in evergreen forests of Kerala

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ABSTRACT OF PROJECT PROPOSAL

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CONTENTS

ABSTRACT

In a humid evergreen forest of the Western Ghats of India, density and basal area of primary, late and early secondary tree species, both in seedling and tree phases in the undisturbed plot were compared with those in a) selectively logged plots representing post-logging period ranging from 14 years to 23 years, and b) area around the logged tree and area covering coupe roads and adjacent to them within each selectively logged plot. Although, the basal area of primary species in tree phase in selectively logged sites can become equal to that in un-logged forest when the post-logging period is around 20-25 years, seedling and tree density and seedling basal area remained less in selectively logged plots. The study also demonstrated that the primary species showed less fluctuation in population size due to post-logging period differences. When compared with the un-logged primary forest, selectively logged plots still retained the structural characteristics typical of secondary forests such as significantly more density and basal area of secondary species. The study also indicated that the secondary species are sensitive to post-logging period. However, time required for the selectively logged forests to have value of a given parameter comparable to that in un-logged primary forests can differ with less time for the density to reduce than for the decline of basal area of trees of secondary species. When compared with the un-logged primary forests, the recruitment of late secondary species in logged forests continues to be more up to 32 to 36 years after logging. Similarly, the estimated time for the secondary forests to resemble primary forest in terms of seedling and tree density of early secondary species ranged from 48 to 69 years. At this slow rate of decline in density, it is expected that more than 80 to 90 years since logging will be required for the secondary forests to simulate the primary forests in terms of secondary species composition and basal area. Thus it is concluded that the degree of disturbance caused by selective logging in this evergreen forest is severe and that the felling cycle of prescribed 40-45 years is too short for the forest to recover from the selective logging impacts.

1. INTRODUCTION

Natural forests in the tropics generally represent mixed forest in terms of species, growth and age-class distribution of trees. Here, canopy openings created by natural means such as tree fall and crown fall trigger the growth of younger generation of trees (Richards, 1952; Whitmore, 1984). Parallel to this pattern of forest growth cycle, selective logging system has been followed in the forests of South East Asian, African, South American and Central American tropical regions (Wyatt-Smith, 1963; Crow, 1980; Balasubramanyan, 1987; Chandrashekara, 1991; Chapman and Chapman, 1997; Webb, 1997; Whitman et al., 1997; Pinfil and Gullison, 1998; Finegon and Camacho, 1999). In this silvicultural system, since fellings and regeneration distributed over the whole area of a patch of forest, the resultant crop would be un-even aged and mixed together over every part of the area. In its ideal or typical form prescribed, the selection system is a nature's system as it follows nature, but the objects with which nature produces vegetation are not identical with those of a forest (Ram Prakash and Khanna, 1979). A comparative study on the vegetation structure, composition and nutrient cycling patterns in natural canopy gap area and in gaps created by selective logging operations indicated that the disturbances caused by selective logging are much more than that by the natural gap formation (Chandrashekara and Ramakrishnan, 1994a). In addition to this, the felling cycle of 30-40 years is expected to be inadequate time for the forest to recover from disturbance caused by selective logging. In fact, the estimated time taken for clearfelled forest patches to undergo progressive succession and thus resemble primary forest ranged from 50-500 years (Knight, 1975; Riswan et al., 1985; Brown and Lugo, 1990; Kartawinata, 1994; Hughes et al., 1999; Brearley et al., 2004). Similarly, Okuda et al. (2003), demonstrated that the structure of lowland dipterocarp forests in peninsular Malaysia had not completely recovered from the changes or begun to resemble the primary forest even after 41 years of selective logging. However, such information to several other tropical forests is not available.

Based on life history patterns, tropical evergreen forest species can be categorized into primary species and secondary species. While the seedlings of primary species establish in closed canopy area, need small canopy gaps for grow up; secondary species establish medium to large size gaps for both establishment and growth (Whitmore, 1989). Several studies indicated that in relatively undisturbed evergreen forest patches both the number and density (individuals ha^{-1}) of primary tree species are comparatively more than those of secondary species (Brokaw, 1985; Bazzaz, 1990; Chandrashekara and Ramakrishnan, 1994b). However, when the forest is disturbed, number and density of secondary species would increase and the increase would depend on intensity and frequency of disturbance (Whitmore, 1984; 1989; Pascal, 1988; Chandrashekara and Ramakrishnan, 1994a). As the forest recovers from the disturbance, contribution by secondary species to the total species number, density and basal area is expected to decline and the rate of decline may be influenced by the extent and scale of the disturbance. Thus a comparative analysis of stand structure and tree species composition in primary forest patches and selectively logged forests would help to determine the patterns and rate of succession in the selectively logged forests. In this study, the effects of time since selective logging on the seedling and tree density and basal area of primary and secondary species were analysed and also it was tested whether the stand characteristics around the felled trees and in coupe road area were similar at different post-logging periods. An attempt was also made to estimate the logging recovery time for forest stand structure in the wet evergreen forests in the Western Ghats of India.

2. METHODS

2.1. Study area and climate

The study area at Nelliampathy, under Nenmara Forest Division of the Western Ghats in Kerala State (10^o 30'N and 76^o 40'E) is located at an altitude of 950 m. The soil is red, sandy loam, porous and lateritic origin (oxysol) and acidic in nature (pH 5). The underlying rocks are composed of schist with quartz and felspar. The climate is typically monsoonal with an annual rainfall of 283 cm. The retreating monsoon fall during October-December is about 7% of the total. January to March is relatively dry. The pre-monsoon fall during April-May may be about 14% of the total. The mean monthly maximum temperature during the monsoon season is 23.8 ^{0} C and the mean monthly is 20.5 ^{0}C. During the dry season, the mean maximum is 25.2 ^{0}C and minimum is 20.4 ^{0}C. The forest is a typical example for a Southern wet evergreen forest of medium elevation dominated by trees like *Palaquium ellipticum* (Dalz.) Baill., *Cullenia exarillata* Robyns and *Mesua nagassarium* (Burm.f.) Kostermans (Pascal, 1988).

2.2. Sampling

In the wet evergreen forest tract of Nelliampathy, both un-logged and selectively logged forest patches are seen. During the year 2000, an un-logged patch as a benchmark forest and also the selectively logged forest patches, each one to represent a patch logged in 1986, 1982, and 1979 were selected. Thus the post-logging period of these plots was 14, 18, and 21 years respectively. These selectively logged plots were studied again after two years and thus their post-logging period was 16, 20 and 23 years respectively.

In the un-logged forest, which had no past history of logging or other human intervention, three plots each of 1 ha in size were marked. The mean distance between plots was 500 m. Twenty-five quadrats each of 10 m x 10 m in size were randomly established in each plot. In each selectively logged forest, three sub plots each of 4-5 ha in size were marked following two areas were identified

a. Canopy gap area around the stump of the logged tree (hereafter, Tree Logged Stand),
b. Road which was constructed for the transportation of logged wood and later abandoned and area adjacent to road (hereafter, Coupe Road Stand).

In each of the above mentioned two habitats in a given replicate plot, 25 quadrats each of 10 m x 10 m were established. However, the quadrats established in a selectively logged plot in the year 2000 and in the year 2002 were different.

2.3. Density and basal area estimation

A rope was tied along the border of each quadrat and all trees (individuals with gbh above 10.1 cm; gbh was measured with tape at 1.37 m from the ground) located in the quadrats were marked, identified and their gbh recorded. For the trees with large buttresses, girth was measured just above the level of buttress. In each quadrat, one sub quadrat of the size 2 m x 2 m was marked and used to study the tree seedlings (individuals with girth < 10.0 cm and height < 1 m).

The total number of stems on a hectare basis was estimated separately for tree seedlings and trees in the un-logged plot as well as in each habitat in selectively logged forests of different post-logging period. Similarly, basal area of all stems of a species was also calculated.

Based on the available literature (Chandrasekharan, 1960; Rai, 1979; Rai and Proctor, 1986; Pascal, 1988; Chandrashekara and Ramakrishnan, 1993, 1994a), species encountered in the study area were categorised into primary species and secondary species (Appendix 1). Species-wise data obtained for density and basal area were used to estimate the total stem density and basal area in seedling and tree phases in each successional category.

2.4. Statistical analysis

To compare the undisturbed sites and sites representing different post-logging periods, and tree logged stands and coupe road stands in a given selectively logged site, Student's t-test was used for comparing the values of the parameters studied. The influence of post-logging age on the parameters studied was tested using ANOVA and means compared using Fisher's least significant difference (LSD) test. Consequently, each parameter was regressed to post-logging period using curvilinear regression. Wherever the R^2 value of regression equations was statistically significant, equations were used to estimate the time required for a given parameter to reach the mean value similar to that in undisturbed forest plots.

3. RESULTS

3.1. Primary species

In the relatively undisturbed forest, total density of primary species in seedling and tree phases was 5973 ± 271 individuals ha^{-1} and 1405 ± 5 individual ha^{-1} respectively. Both in tree logged stands and coupe road stands in each selectively logged site, the values were significantly lower ($P < 0.05$) than those in the undisturbed forest sites (Fig. 1A and 1B). When the plots of different post-logging periods were considered, no clear pattern in the difference between the tree logged stands and the coupe road stands for the primary seedlings density was noticed. However, the tree density in coupe road stands was significantly lower than that in tree logged stands of plots representing post-logging period 14 to 18 years. In the regression equations of parameters like seedling density in coupe road stand and tree density in logged stand on post-logging period (Table 1) the regression coefficients were statistically significant ($P < 0.05$).

Total basal area of seedlings and trees of primary species in the relatively undisturbed forest plots was 23265 ± 726 cm^2 ha^{-1} and 549867 ± 6671cm^2 ha^{-1} respectively. Compared to the seedling basal area in the undisturbed forests, that in the selectively logged forests was significantly low ($P < 0.05$). On the other hand, basal area of tree community in plots felled more than 21 years earlier was significantly more than that in the undisturbed plots. Except in post-logging period of 14 years, no significant difference between tree logged stands and coupe road stands was recorded for the seedlings basal area (Fig. 1C). However, generally tree basal area was less in the coupe road stands (Fig. 1D). Comparison of plots of different post-logging period indicated that, in tree logged stands the seedling and tree basal area increased as the post-logging period increased ($P<0.05$), exception being seedling basal area in coupe road stands where no such trend was recorded (Table 1).

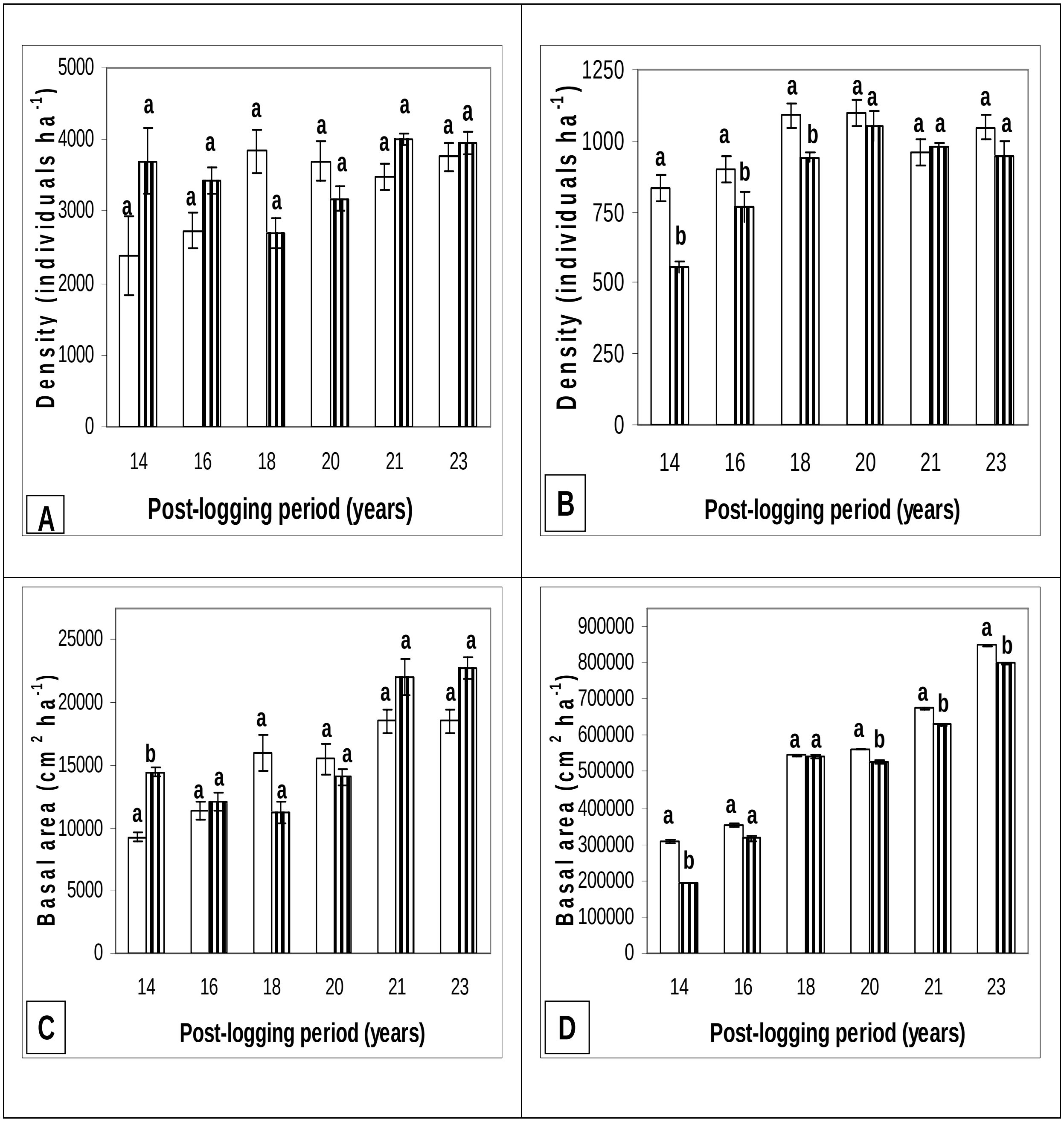

Fig. 1. Density and basal area of seedlings and trees of primary species in tree logged stand (∀) and coupe road stand (||) in selectively logged wet evergreen forest plots at Nelliampathy: Kerala, India. Means with different letters in a given post-logging period are significantly different at P < 0.05. A: Density of tree seedlings, B: density of Trees, C: Basal area of tree seedlings; D: Basal area of trees.

Table 1. Curvilinear regression equations derived for density and basal area of primary species on post-selective logging period in the wet evergreen forest of Nelliampathy, Kerala, India.

Primary species	
Tree seedling community	
	Regression equation
Tree logged stands	Density (individuals ha^{-1}) = $1283.6e^{0.05 \times \text{Post-logging period(years)}}$ $R^2 = 0.7002^*$
	Basal area (cm^2 ha^{-1}) = $3278.1e^{0.0793 \times \text{Post-logging period (years)}}$ $R^2 = 0.8893^*$
Coupe road stands	Density (individuals ha^{-1}) = $2757.3e^{0.0122 \times \text{Post-logging period (years)}}$ $R^2 = 0.0736^{ns}$
	Basal area (cm^2 ha^{-1}) = $4667.7e^{0.0643x \text{ Post-logging period (years)}}$ $R^2 = 0.5063^{ns}$
Tree community	
Tree logged stands	Density (individuals ha^{-1}) = $634.52e^{0.0234 \times \text{Post-logging period (years)}}$ $R^2 = 0.4867^{ns}$
	Basal area (cm^2 ha^{-1}) = $62619e^{0.1131x \text{ Post-logging period (years)}}$ $R^2 = 0.9619^*$
Coupe road stands	Density (individuals ha^{-1}) = $281.02e^{0.0596 \times \text{Post-logging period (years)}}$ $R^2 = 0.6994^*$
	Basal area (cm^2 ha^{-1}) = $28461e^{0.1485x \text{ Post-logging period (years)}}$ $R^2 = 0.9167^*$

3.2. Late secondary species

In the relatively undisturbed forest plots, the late secondary species were sparse with total seedling density of 19 ± 4 individuals ha^{-1} and total tree density of 54 ± 6 individuals ha^{-1}. In each post-logging period, both in tree logged stands and coupe road stands, seedling and tree densities were more than that of the undisturbed forest plots (Fig. 2A and 2B). In a given post-logging period, when the seedling density was more in the coupe road stands than that in tree logged stands ($P < 0.05$), no difference between two stands was noted for the tree density ($P > 0.05$). In the regression equations of seedling and tree density on post-logging period (Table 2), the regression coefficients were statistically significant (P < 0.05).

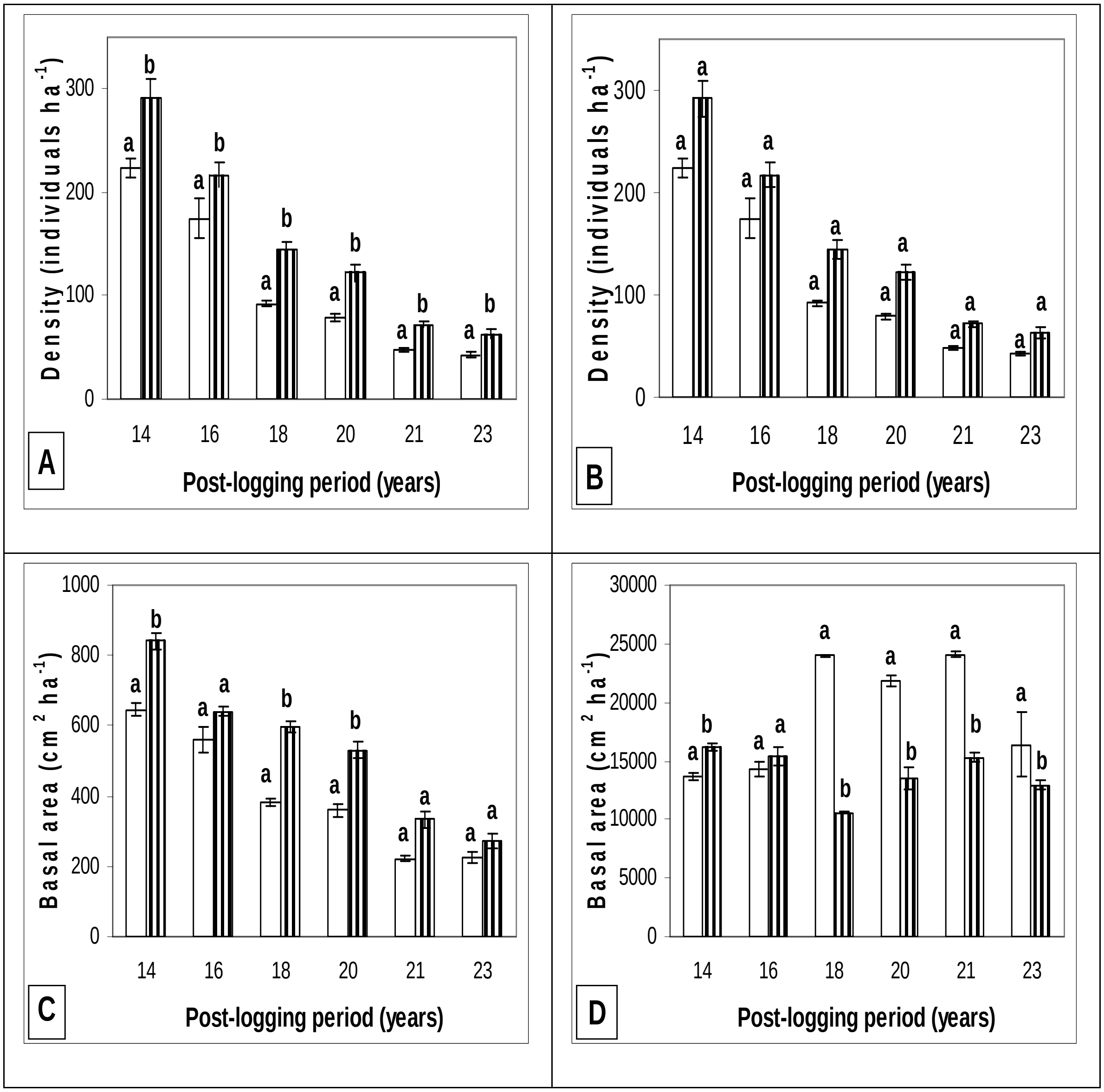

Fig. 2. Density and basal area of seedlings and trees of late secondary species in tree logged stand (∀) and coupe road stand (||) in selectively logged wet evergreen forest plots at Nelliampathy: Kerala, India. Means with different letters in a given post-logging period are significantly different at P<0.05. A: Density of tree seedlings, B: density of Trees, C: Basal area of tree seedlings; D: Basal area of trees.

Table 2. Curvilinear regression equations derived for density and basal area of late secondary species on post-selective logging period in the wet evergreen forest of Nelliampathy, Kerala, India.

Late secondary species	
Tree seedling community	
	Regression equation
Tree logged stands	Density (individuals ha^{-1}) = $3599.4e^{-0.1967x \text{ Post-logging period (years)}}$ $R^2 = 0.9601^*$
	Basal area (cm^2 ha^{-1}) = $3995.6e^{-0.1278x \text{ Post-logging period (years)}}$ $R^2 = 0.9202^*$
Coupe road stands	Density (individuals ha^{-1}) = $3588.7e^{-0.1773x \text{ Post-logging period (years)}}$ $R^2 = 0.964^*$
	Basal area (cm^2 ha^{-1}) = $4797e^{-0.1212x \text{ Post-logging period (years)}}$ $R^2 = 0.902^*$
Tree community	
Tree logged stands	Density (individuals ha^{-1}) = $627.15e^{-0.0675x \text{ Post-logging periood (years)}}$ $R^2 = 0.8811^*$
	Basal area (cm^2 ha^{-1}) = $8601.6e^{0.041x \text{ Post-logging period (years)}}$ $R^2 = 0.2721^{ns}$
Coupe road stands	Density (individuals ha^{-1}) = $988.07e^{-0.0914x \text{ x Post-logging period (years)}}$ $R^2 = 0.9665^*$
	Basal area (cm^2 ha^{-1}) = $18888e^{-0.0167x \text{ Post-logging period (years)}}$ $R^2 = 0.1255^{ns}$

Basal area of late secondary species in the seedling and tree phases in the relatively undisturbed forest was 4.8 ± 0.1 cm^2 ha^{-1} and 2977 ± 521 cm^2 ha^{-1} respectively; and these values were significantly lower than those recorded in logged over forests (Fig. 2C and 2D). In general, the seedling basal area in plots logged about 14 to 20 years earlier was more in coupe road stands than in tree logged stands ($P<0.05$). However, in plots felled more than 20 years earlier, tree basal area was more in tree logged stands than in coupe road stands. A significant negative correlation between post-logging period and seedling basal area was observed ($P < 0.05$).

However, correlation between post-logging period and tree basal area was not statistically significant (P > 0.05) (Table 2).

3.3. Early secondary species

The seedling and tree density in undisturbed forest plots was 12 ± 5 individuals ha^{-1} and 7 ± 1 individuals ha^{-1} respectively. In each post-logging period, both in tree logged stands and coupe road stands, seedling and tree density was significantly more than those recorded in undisturbed forest plots (Fig. 3A and 3B). In general no significant difference between tree logged stands and coupe road stands was observed for the value of these two parameters in each post-logging period. Statistically significant decrease in the seedling density (in both coupe road and tree logged stands) and the tree density (in coupe road stands) as the post-logging period increased was noticed (P<0.05) (Table 3).

Table 3. Curvilinear regression equations derived for density and basal area of early secondary species on post-selective logging period in the wet evergreen forest of Nelliampathy, Kerala, India.

Early secondary species	
Tree seedling community	
	Regression equation
Tree logged stands	Density (individuals ha^{-1}) = $1338.8e^{-0.0805x \text{ Post-logging period (years)}}$ $R^2 = 0.9328^{*}$
	Basal area (cm^2 ha^{-1}) = $2802.8e^{-0.0311x \text{ Post-logging period (years)}}$ $R^2 = 0.3046^{ns}$
Coupe road stands	Density (individuals ha^{-1}) = $2882.1e^{-0.1136x \text{ Post-logging period (years)}}$ $R^2 = 0.7023^{*}$
	Basal area (cm^2 ha^{-1}) = $4355e^{-0.0463x \text{ Post-logging period (years)}}$ $R^2 = 0.1927^{ns}$

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Table 3 (cont'd). Curvilinear regression equations derived for density and basal area of early secondary species on post-selective logging period in the wet evergreen forest of Nelliampathy, Kerala, India.

Early secondary species	
Tree community	
Tree logged stands	Density (individuals ha^{-1}) = $638.94e^{-0.0775x \text{ Post-logging period (years)}}$ $R^2 = 0.277^{ns}$
	Basal area (cm^2 ha^{-1}) = $8071.4e^{0.0324x \text{ Post-logging period (years)}}$ $R^2 = 0.122^{ns}$
Coupe road stands	Density (individuals ha^{-1}) = $875.51e^{-0.0703x \text{ x Post-logging period (years)}}$ $R^2 = 0.757^{*}$
	Basal area (cm^2 ha^{-1}) = $15385e^{0.0098x \text{ Post-logging period (years)}}$ $R^2 = 0.0059^{ns}$

Basal area of early secondary species in the seedling and tree phases in the relatively undisturbed forest was 56 ± 10 cm^2 ha^{-1} and 333 ± 126 cm^2 ha^{-1} respectively. Both these values were significantly lower than those recorded in logged over forests (Fig. 3C and 3D). In general, the seedling and tree basal area in plots logged about 18 to 20 years earlier was more in coupe road stands than in tree logged stands ($P < 0.05$). In the regression equations of seedling and tree basal area on post-logging period (Table 3), the regression coefficients were not statistically significant ($P>0.05$).

3.4. Logging recovery time for the forest stand structure

As already given in the Tables 1 to 3, in some regression equations derived for parameters like density and basal area on post-logging period regressive coefficients are statistically significant. Such equations were used to estimate the expected time required for the secondary forest to have value for a given parameter comparable to that in the relatively undisturbed forest plot (Table 4). The value ranged from 12 years to 69 years.

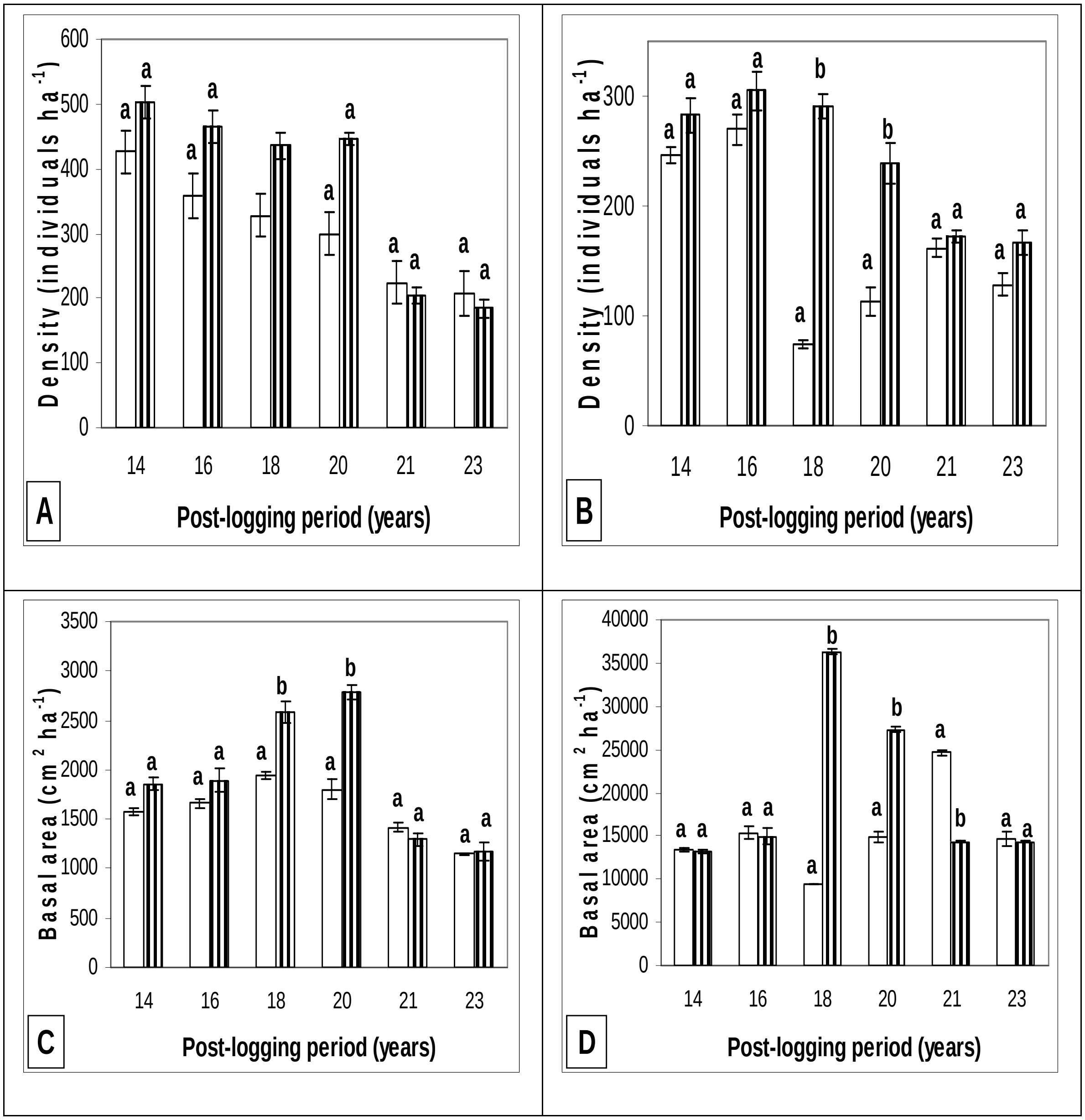

Fig. 3. Density and basal area of seedlings and trees of early secondary species in tree logged stand (∀) and coupe road stand (||) in selectively logged wet evergreen forest plots at Nelliampathy: Kerala, India. Means with different letters in a given post-logging period are significantly different at $P < 0.05$. A: Density of tree seedlings, B: density of Trees, C: Basal area of tree seedlings; D: Basal area of trees.

Table 4. Estimated period (based on equations given in Tables 1 to 3) for the selectively logged forest patches to simulate a relatively undisturbed forest patch in terms of different parameters in the wet evergreen forest of Nelliampathy, Kerala

	Estimated period (years)	
	Density	Basal area
Primary species		
Tree seedling community		
Tree logged stands	30.8	24.7
Coupe road stands	-ne-	-ne-
Tree community		
Tree logged stands	-ne-	12.2
Coupe road stands	27.3	19.9
Late secondary species		
Tree seedling community		
Tree logged stands	26.7	52.6
Coupe road stands	29.6	57.0
Tree community		
Tree logged stands	36.3	-ne-
Coupe road stands	31.8	-ne-
Early secondary species		
Tree seedling community		
Tree logged stands	58.6	-ne-
Coupe road stands	48.2	-ne-
Tree community		
Tree logged stands	-ne-	-ne-
Coupe road stands	68.7	-ne-

-ne-, not estimated wherever R^2 value is not significant at 95% confidence limit.

4. DISCUSSION

Subsequent to the extensive damage done by selective logging, both canopy and the ground layer undergo changes. The microclimatic conditions changed in the gaps created by selective operations include very high light levels which may lead to increase in temperature and vapour pressure deficits in the soil (Brown, 1993) followed by soil desiccation. Under such conditions, particularly in the coupe road stand, low survivability of young seedlings of primary species can be expected. Another impact of selective logging is the soil compaction due to dragging of harvested timber from the site of felling to the coupe road and the movement of trucks for transporting the timber. The seeds of primary species generally fall during pre-monsoon season (May-June) and begin to germinate immediately (Chandrashekara, 1991). When such seedlings are lying on the compacted soil, their roots fail to penetrate into the soil and thus mass seedling mortality can be seen, particularly in the coupe road stand. In addition, felling and damage to many primary trees also reduce the seed source in the logged forests. Thus the combined effect of mortality of seedlings during felling operations, reduction in the seed source from the neighboring trees in logged stand, inability of young seedlings to establish due to the compactness of soil could be attributed for significantly low density of primary seedlings and trees in selectively logged forests than in un-logged forests. The study also revealed that when compared with the primary forests, selectively logged forests with post-logging period ranging from 14 to 23 years are still retaining the structural characteristics typical of secondary forests, such as significantly more density and basal area of secondary species both in seedling and tree phases. The impacts of selective logging were more pronounced soon after felling (Chandrashekara and Ramakrishnan, 1994b) and however, are expected to be attenuated as time passes and the gaps and cleared areas such as roads close. The present study also revealed the fact that both late and early secondary species are sensitive to post-logging period as their density is comparatively less in older plots than in younger plots, and that the progressive succession is taking place in selectively logged forests.

It seems that the scale of difference in micro-climatic and micro-edaphic factors in tree logged stands and coupe road stands is sufficient to induce the difference between these two stands in terms of seedling density and basal area of late secondary species and seedling basal area of early secondary species in the initial stage of succession. Thus more seedling density and basal area of late secondary species were observed in coupe road stands than in tree logged stands. However, the differences in the impacts of logging and road construction appear to be diminished as the succession progresses. Thus, generally no significant difference between two stands (coupe road stands and tree logged stands) for majority of the parameters studied was observed.

According to Okuda et al. (2003), 40 years after logging using the Malayan Uniform System, the basal area of dipterocarps in the regenerating forest in peninsular Malaysia was similar to that in primary forests. Similarly, Pelissier et al.(1998) reported that a selectively logged moist evergreen forest in Karnataka part of the Western Ghats gradually recovered and in 10-15 years after logging became similar to primary forest in terms of growing stock (density and basal area). However, the time required for the selectively logged forests to have growing stock of trees belonging to different successional species comparable to that in un-logged primary forests can differ. For instance, density of late secondary species when compared with basal area in seedling phase declines at a relatively faster rate. Thus secondary forests are expected to resemble in terms of late secondary seedling density when the post-logging period is around 27-30 years. Similarly, it is expected that the tree density of late secondary species in selectively logged forests may become equal to that in primary forests of when the post-logging period is around 32 to 36 years (Table 4). The study also revealed that the basal area of late secondary species is not showing a clear trend of decline in the values when increase in post-logging period was considered (14 to 23 years). As already indicated, the recruitment of secondary species continues to be more than that in un-logged plots up to 32 to 36 years after logging. Since the late secondary species are long-lived ones (more than 50 years), it can be expected that more than 80-90 years since logging may be required for the secondary forests to simulate relatively undisturbed forest in terms of secondary species composition and growing stock. The estimated time required for the secondary forests to resemble in terms of seedling and tree density of early secondary species ranged from 48 to 69 years. Since these species are shot-lived species, their basal area reduction could also coincide with the reduction of basal area of late secondary species. However, further studies in secondary forests are required to calculate the time required for the complete recovery of these forests from the impacts of selective logging.

6. CONCLUSIONS

The present study revealed that in the selectively logged forests the basal area of primary species may become equal to that in a primary forest within 20-25 years after logging. However, even in 23 years after logging, the forest structure and composition of logged forest had not recovered as evidenced by a comparatively more growing stock of late and early secondary species. It is also estimated that more 80-90 years may be required for the secondary forests to recover from the logging damages. Thus it can be concluded that the degree of disturbance caused by selective logging in the moist evergreen forest seems to be so severe and thus the prescribed 40-45 year felling cycle is not enough for the forest to completely recover. In this context, the decision of the Indian Government to abandon the selective logging operation in natural forests since 1987 is commendable. However, a section of the people demanded for the revival of selective logging in natural forests to meet the timber requirements of the States. It may be worth to caution here that in an evergreen forest, even the second time natural gap formation before the gap area is recovered from the previous natural gap incidence will lead to the dominance of late secondary species over the primary species (Chandrashekara, 2002). Thus it can also be cautioned that if the forests were subjected to selective logging before they resemble both structurally and floristically a primary forest, they would experience arrested succession and the resultant vegetation would be dominated by late secondary or early secondary species, depending on the severity of disturbance.

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Appendix 1. Tree species belonging to different successional categories recorded in un-logged and selectively logged sites in the wet evergreen forest of Nelliampathy, Kerala, India.

Primary species	
Aglaia tomentosa Teijsm & Binn.	*Litsea bourdillonii* Gamble
Calophyllum polyanthum Wall. Ex Choisy	*Litsea laevigata* (Nees) Gamble
Canarium stictum Roxb.	*Meiogyne pannosa* (Dalz.) Sincl.
Cassine glauca (Rottb.) O.Ktze.	*Mesua nagassarium* (Burm.f.) Kosterman
Cinnamomum malabatrum (Burm.f.) Blume	*Myristica dactyloides* Gaertn.
Cullenia exarillata Robyns	*Palaquium ellipticum* (Dalz.) Baill.
Dimocarpus longan Lour.	*Persea macrantha* (Nees) Kosterman
Drypetes oblongifolia (Bedd.) Airy Shaw	*Phoebe lanceolata* Nees
Drypetes wightii (J.Hk.) Pax and Hoffm.	*Polyalthia coffeoides* Hk.f. & Thoms.
Garcinia morella (L.) Robs.	*Syzygium laetum* (Buch-Ham.) Gandhi
Holigarna arnottiana J.Hk.	*Syzygium lanceolatum* (Lamk.) Wt.&Arn.
Holigarna beddomei Hk.f.	*Toona ciliata* Roem.
Isonandra lanceolata Wt.	
Late secondary species	
Actinodaphne malabarica Balak.	*Fahrenhetia zeylanica* (Thw.) Airy Shaw
Agrostistachys meeboldii Pax ex Hoffm.	*Heritiera papillo* Bedd.
Antidesma menasu Miq. Ex Tul.	*Mastixia arborea* (Wt.) Bedd.
Euodia lunu-ankenda (Gaertn.) Merr.	*Olea dioica* Roxb.
Early secondary species	
Ardisia pauciflora Heyne ex Wall.	*Macaranga peltata* (Roxb.) M.-A.
Bombax ceiba L.	*Maesa indica* (Roxb.) DC.
Clerodendrum viscosum Vent.	*Memecylon malabaricum* (Cl.) Cogn.
Dendrocnide sinuata (Bl.) Chew.	*Pterospermum diversifolium* Bl.
Glochidion sp.	*Pterospermum reticulatum* Wt. & Arn.