REGENERATION CHARACTERISTICS OF SELECTION FELLED FOREST GAPS OF DIFFERENT AGES IN THE EVERGREEN FORESTS OF SHOLAYAR, KERALA, INDIA

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RAJESH, N., MOHAN KUMAR, B. & VIJAYAKUMAR, N.K. 1996. Regeneration characteristics of selection felled forest gaps of different ages in the evergreen forests of Sholayar, Kerala, India. A field study was conducted in the wet evergreen forests of Sholayar in the Western Ghats to characterise vegetation development as a function of time after selection felling. Four quadrats (40 x 40 m) were established in selected patches of forests selection felled 7, 16, 21 and 28 years before 1992. All trees and shrubs (≥ 10 cm girth at breast height) were enumerated. Species-wise counts of seedlings (<10 cm GBH) were also made in four 5 x 5 m quadrats within each of the main quadrats. In addition, soil physico-chemical properties (top 15 cm layer) such as moisture content, pH, organic C, total N, available P and K were evaluated. The current suite of species in the selection felled forest gaps exhibited both early and late seral characteristics. About 62 to 83% of the tree species encountered at these sites (logging coupes) were, however, common. Further, the relative proportion of early and late successional species was dependent on gap age. As the gap age increased, abundance of late successional species such as *Palaquium ellipticum, Mesua nagassarium* and *Vateria indica* increased. Floristic diversity declined as time after gap formation increased. Moreover, floristic diversity indexes were generally lower than many other formations in the Western Ghats. Soil moisture content, organic C, N and K levels were high at the 7- and 16- year-old sites compared to the 21- and 28- year-old sites.

Key words: Diversity - gap dynamics - edaphic attributes - Western Ghats

RAJESH.N., MOHAN KUMAR, B. & VIJAYAKUMAR, N.K. 1996. Ciri-ciri pemulihan bagi jarak penebangan hutan pilihan daripada umur yang berbeza di hutan malar hijau di Sholayar, Kerala, India. Satu kajian lapangan telah dijalankan di hutan malar hijau basah di Sholayar di Ghats Barat untuk mencirikan perkembangan tumbuhan sebagai satu fungsi masa selepas penebangan pilihan. Empat kuadrat (40 x 40m) telah diasaskan di petak tanah terpilih bagi pemilihan hutan yang telah ditebang 7, 16, 21 dan 28 tahun sebelum 1992. Kesemua pokok dan pokok-pokok renik (≥ 10 cm diameter pada aras dada) telah dibanci. Kiraan spesies anak benih (< 10 cm diameter pada aras dada) juga telah dibuat di dalam empat kuadrat berukuran 5 x 5 m di dalam setiap kuadrat utama. Di samping itu, ciri-ciri kimia-fizikal tanih (lapisan 15 cm teratas) seperti kandungan kelembapan, pH, C organik , jumlah N, dan K telah dinilai. Spesies semasa di dalam pemilihan jarak hutan yang ditebang menunjukkan ciri-ciri sere awal dan akhir. Bagaimanapun, lebih kurang 62 hingga 83% daripada spesies pokok yang ditemui di tapak-tapak ini (catuan tebangan) adalah biasa. Kadar relatif bagi spesies sesaran awal dan akhir adalah bergantung kepada jarak umur. Dengan bertambahnya jarak umur, bilangan spesies sesaran akhir seperti *Palaguium ellipticum, Mesua nagassarium,* dan *Vateria indica* akan bertambah. Kepelbagaian flora merosot apabila masa selepas pembentukan jarak bertambah. Di samping itu, indeks-indeks kepelbagaian flora umumnya lebih rendah berbanding dengan banyak lagi pembentukan di Ghats Barat. Kandungan kelembapan tanah, tahap C organik, N, dan K adalah tinggi di tapak-tapak berumur 7 dan 16 tahun berbanding dengan tapak-tapak berumur 21 dan 28 tahun.

Introduction

The polycyclic felling system, commonly known as selection felling involves the removal of a part of the growing stock volume from natural forests. As a silvicultural process it is popular in many parts of the tropics, e.g. India (Parkash & Khanna 1979, Balasubramanyan 1987, Kushalappa 1988), Malaysia (Thang 1987), Suriname (Graaf 1986) and Australia (Vanclay 1990). In general, selection felling provides a mechanism for regenerating natural forests through creation of large canopy gaps. Furthermore, in many studies, the effects of selection felling have been equated with natural gap forming processes (Denslow 1987, Whitmore 1989, Welden *et al.* 1991).

Serious concerns, however, are being expressed of late regarding the merits of selection felling as a silvicultural system in the natural evergreen forests of Kerala. The canopy disturbance following selection felling may favour light demanding species (Hartshorn 1989). Further, many workers have reported changes in the floristic spectrum and vegetation structure of the forests following such disturbances (Brandani *et al.* 1988, Lieberman *et al.* 1989). Chandrasekhara and Ramakrishnan (1993) observed relatively rapid growth and germination of early secondary species in the selection felled forest gaps at Nelliampathy in the Western Ghats. They also suggested that selection felling may impair the regeneration of primary species (e.g. *Palaquium ellipticum*) and catalyse invasion by exotics such as *Chromolena odorata* (Chandrasekhara & Ramakrishnan 1994), thus raising concerns about the composition of regenerants in the selection felled forest gaps.

It is, nevertheless, imperative to develop ecologically sustainable management techniques for tropical evergreen forests, especially in view of the rising demand for timber and other forest products (FAO 1985). An understanding of the gap dynamics is fundamental to this. In this context, Chandrasekhara (1991), evaluated the regeneration of tree species of differing successional status in 1-, 5- and 10- year-old selection felled forest gaps of Nelliampathy (Kerala). Nonetheless, gap regeneration dynamics, particularly concerning older gaps (more than 10 years of age) have been only sparingly analyzed. Therefore, a comparative account of the vegetation composition in selection felled gaps of different ages is significant.

Many workers (Vitousek & Denslow 1986, Denslow 1987, Becker *et al.* 1988) have also shown that the soil nutrient status of natural forest gaps is higher than that of undisturbed areas. This may be applicable to selection felled gaps as well. Chandrasekhara and Ramakrishnan (1994) showed that, though in natural gaps, soil nutrient level increased with gap age and the selection felled gaps (age 1, 5 and 10 years) depicted a reverse pattern (release of nutrients in a flush from the debris of the felled tree). Although the nutrient cycling pattern and processes during secondary successional pathways has been emphasised (Vitousek & Melillo 1979, Ramakrishnan 1989, Chandrasekhara & Ramakrishnan 1994), studies dealing with nutrient characteristics of forest gaps are limited to natural gaps and/or selection felled gaps of relatively younger age.

To determine the impact of selection felling on the floristic composition, species recruitment and stand structure, long term studies are necessary, which may also allow generalization on the time taken by the secondary stand to regain the original floristic composition. However, such studies are rare. The present paper provides a descriptive account on the regenerant composition and density of the selection felled forest gaps of different ages (up to 28 years of age) in the evergreen forests of Western Ghats and explains vegetation structure, floristic diversity and edaphic attributes, as a function of logging history.

Materials and methods

Study areas

Study areas were located in the Sholayar range of Vazhachal Forest Division, Kerala State (between 10° 16' N and 10° 20' N latitude; 76° 42' E and 76° 50' E longitude; altitude 760 m a.s.l) in the Western Ghats, forming part of the Sholayar valley with vast stretches of evergreen forests. The area is characterised by undulating topography with a general westerly aspect. Underlying rock formation consists principally of gneiss with quartz, feldspar and mica. Soils are Oxisols of varying depth. Original vegetation of the area belonged to the category of west coast tropical evergreen forests (1A/C4; Champion and Seth 1968) with *Palaquium ellipticum, Mesua nagassarium, Vateria indica, Cullenia excelsa,* etc. forming the dominant elements.

The climate is typically monsoonic (warm-humid) with a mean annual precipitation of 3780 mm and following a bimodal distribution pattern with two distinct peaks during June-July (main peak) and October-November. Generally all months except December, January and February receive some precipitation. Mean maximum monthly temperature ranges from 21.1 to 32.2 °C and the mean minimum temperature from 14.4 to 23.8 °C. March to May represents the hottest period while December to February forms the coldest period.

Logging history

Evergreen forests of Sholayar valley were subjected to selection felling until 1985. The whole area was divided into several felling coupes for this purpose. The process typically involved removal of 20-30% basal area. Mostly dominant overstorey tree species (e. g. *Palaquium ellipticum, Vateria indica, Cullenia excelsa* and the like) were harvested. The selection felling process, however, did not involve the use of heavy machinery. Felled trees were hauled to the nearest roads by elephants and from there by trucks. The movement of elephants might have caused some soil compaction. Presumably the extent of soil disturbance was not substantial to cause marked variations in the regeneration pattern.

Methods

Vegetation analysis

After a preliminary reconnaissance of the area, and assessment of the records maintained at the Sholayar Forest Range Office, four patches of forests (of almost equal size) selection felled during 1985, 1976, 1971 and 1964 were selected (hereinafter called the "7-, 16-, 21- and 28-year-old sites") during April-May 1992. Four quadrats (40 × 40 m) were established in each of the selected patches of forests (almost in the middle). Height and girth at breast height (GBH) of all trees (≥ 10 cm) were measured using a Suunto Clinometer and tape respectively. Seedling enumeration was done by making species-wise counts (< 10 cm GBH) in four random (determined from a map representing the main quadrats) subquadrats of size 5 × 5 m within each 40 × 40 m quadrat.

Density, relative density (number of individuals of a given species × 100/ number of individuals of all species), basal area, relative basal area (basal area of a given species × 100/basal area of all species) and importance value index (IVI, Curtis & McIntosh 1950) were calculated. In addition, Simpson's floristic diversity index (Simpson 1949), Shannon-Wiener Indices (H', Shannon & Wiener 1963) and Sorenson's similarity index (Sorenson 1948) were calculated to characterise floristic diversity/similarity.

Soil analysis

Soil samples (0-15 cm soil depth) were collected from 10 random points in each of the 40 × 40 m quadrats using a soil auger. The soil samples were immediately transferred to moisture cans, double-sealed in polythene bags and transported to the laboratory, where they were weighed, oven-dried and re-weighed to estimate the *in situ* variations in soil moisture status of different gaps.

Two further samples from each of the ten locations in a quadrat (20 samples per site) were also analysed as follows: soil pH in 1:2 mixture of soil and distilled water, organic C by Walkley-Black method, total N by the micro-Kjeldahl method, extractable P by the Bray-Kurtz method and available K by flame photometry following extraction with normal neutral ammonium acetate (Jackson 1968). The data on soil physico-chemical properties were statistically analysed using the two-way ANOVA technique and the site (age) means compared using Student-Newman-Kuel test.

Results and discussion

Floristic richness

Floristic elements of different sites exhibited only modest differences. The majority of species encountered at the four sites were common, although their relative proportions varied (Table 1). Sorenson's similarity index ranged from 61.5 to 83% (Table 2) and number of species from 13 to 20 (Table 3). Density of individuals (≥ 10cm GBH), however, was profoundly variable (325, 250, 213 and 275 respectively for the 7-, 16-, 21- and 28-year-old sites). In the < 10 cm category, the number of species ranged from 10 to 12 and their density from 14 200 plants ha^{-1} (21-year-old site) to 47 400 plants ha^{-1} (16-year-old site). The 7- and 28-year-old sites were intermediates in this respect (Table 4).

Table 1. Phytosociological parameters of selection felled gaps of different ages in the evergreen forests of Sholayar (≥10 cm GBH)

Name of species	Density (no ha^{-1})	Basal area ($m^2 ha^{-1}$)	Relative density (%)	Relative basal area (%)	Importance value index
I. 7-year-old site (Area: 1600 m^2)					
Palaquium ellipticum	50.00	0.84	15.38	30.73	52.36
Macaranga peltata	56.25	0.65	17.31	23.78	47.33
Aglaia lawii	68.75	0.23	21.15	8.41	35.82
Chukrasia tabularis	6.25	0.37	1.92	13.53	21.71
Knema attenuata	18.75	0.26	5.77	9.51	21.53
Otonephelium stipulaceum	31.25	0.04	9.62	1.46	17.33
Eugenia bracteata	12.50	0.12	3.85	4.39	14.49
Vateria indica	12.50	0.05	3.85	1.83	11.93
Aporusa acuminata	12.50	0.03	3.85	1.10	11.19
Symplocos macrophylla	12.50	0.02	3.85	0.73	10.83
Dimocarpus longan	12.50	0.01	3.85	0.37	10.46
Dimorphocalyx lawianus	6.25	0.05	1.92	1.83	10.00
Drypetes elata	6.25	0.02	1.92	0.73	8.90
Microtropis wallichiana	6.25	0.02	1.92	0.73	8.90
Cullenia exarillata	6.25	0.01	1.92	0.37	8.54
Xanthophyllum arnottianum	6.25	0.01	1.92	0.37	8.54
Total	325.00	2.73	100.00	100.00	
II. 16-year-old site (Area: 1600 m^2)					
Aglaia lawii	93.75	0.82	37.50	18.14	63.33
Otonephelium stipulaceum	37.50	0.63	15.00	13.93	36.63
Knema attenuata	12.50	0.79	5.00	17.47	30.16
Syzygium gardneri	12.50	0.77	5.00	17.03	29.72
Palaquium ellipticum	18.75	0.49	7.50	10.84	26.03
Macaranga peltata	18.75	0.13	7.50	2.88	18.07
Cinnamomum keralense	12.50	0.21	5.00	4.64	17.34
Dimocarpus longan	12.50	0.11	5.00	2.43	15.13
Artocarpus heterophyllus	6.25	0.19	2.50	4.20	14.39
Cullenia exarillata	6.25	0.18	2.50	3.98	14.17
Actinodaphne malabarica	6.25	0.09	2.50	1.99	12.18
Eugenia bracteata	6.25	0.04	2.50	0.88	11.08
Chukrasia tabularis	6.25	0.05	2.50	1.11	11.30
Total	250.00	4.50	100.00	100.00	

continued

Table 1. (continued)

III. 21-year-old site (Area: 1600 m²)					
Palaquium ellipticum	37.50	0.72	17.65	17.58	40.23
Mesua nagassarium	18.75	0.52	8.82	12.70	26.52
Vateria indica .	18.75	0.43	8.82	10.50	24.32
Aglaia lawii	25.00	0.28	11.76	6.84	23.60
Cullenia exarillata	6.25	0.49	2.94	11.96	19.91
Dimorphocalyx lawianus	18.75	0.21	8.82	5.13	18.95
Artocarpus heterophyllus	6.25	0.33	2.94	8.06	16.00
Knema attenuata	6.25	0.31	2.94	7.57	15.51
Dimocarpus longan	6.25	0.09	2.94	2.20	10.14
Syzygium gardneri	6.25	0.09	2.94	2.20	10.14
Lannea coromandelica	6.25	0.09	2.94	2.20	10.14
Symplocos macrophylla	6.25	0.05	2.94	1.22	9.16
Aporusa acuminata	6.25	0.08	2.94	1.95	9.89
Xanthophyllum arnottianum	6.25	0.08	2.94	1.95	9.89
Microtropis wallichiana	6.25	0.08	2.94	1.95	9.89
Macaranga peltata	6.25	0.06	2.94	1.46	9.41
Evodia lunu-ankenda	6.25	0.06	2.94	1.46	9.41
Chukrasia tabularis	6.25	0.04	2.94	0.98	8.92
Eugenia bracteata	6.25	0.04	2.94	0.98	8.92
Otonephelium stipulaceum	6.25	0.04	2.94	0.98	8.92
Total	212.50	4.09	99.97	100.00	
IV. 28-year-old site (Area: 1600 m²)					
Palaquium ellipticum	68.75	1.58	25.00	27.30	59.99
Aglaia lawii	62.50	0.57	22.73	9.85	40.27
Knema attenuta	31.25	1.06	11.36	18.32	37.37
Mesua nagassarium	31.25	0.99	11.36	17.11	36.16
Cullenia exarillata	18.75	0.25	6.82	4.32	18.83
Macaranga peltata	18.75	0.26	6.82	4.49	19.00
Chukrasia tabularis	6.25	0.46	2.27	7.95	17.91
Vateria indica	6.25	0.32	2.27	5.53	15.49
Drypetes elata	6.25	0.08	2.27	1.38	11.35
Otonephelium stipulaceum	6.25	0.09	2.27	1.56	11.52
Evodia lunu-ankenda	6.25	0.06	2.27	1.04	11.00
Eugenia bracteata	6.25	0.05	2.27	0.86	10.83
Symplocos macrophylla	6.25	0.01	2.27	0.17	10.14
Total	275.00	5.78	99.98	100.00	

Table 2. Sorenson's similarity indices (per cent) for selection felled gaps of different ages in the evergreen forests of Sholayar (≥10 cm GBH)

Age (y)	7	16	21	28
7	00.0			
16	64.2	00.0		
21	83.3	66.7	00.0	
28	81.5	61.5	72.7	00.0

Table 3. Floristic diversity indices for selection felled gaps of different ages in the evergreen forests of Sholayar (≥10 cm GBH)

Age (y)	Area (m^2)	Number of species (S)	Number of individuals (N)	N/S	Simpson's index (D)	Shannon-Wiener's index H'	Hmax	E=H'/Hmax
7	1600	16	52	3.25	0.879	3.452	4.000	0.863
16	1600	13	40	3.08	0.813	3.032	3.701	0.819
21	1600	20	34	1.70	0.919	3.977	4.322	0.920
28	1600	13	44	3.38	0.847	3.096	3.701	0.837

Table 4. Frequency, density and relative density of selection felled gaps of different ages (≤10 cm GBH)

Name of the species	Frequency (%)	Density (no. ha^{-1})	Relative density (%)
I. 7-year-old site (Area: 100 m^2)			
Aglaia lawii	100	9 800	59.39
Strobilanthes	100	2 900	17.57
Mesua nagassarium	75	900	5.45
Otonephelium stipulaceum	100	700	4.24
Evodia lunu-ankenda	50	600	3.63
Laportea crenulata	75	500	3.03
Palaquium ellipticum	100	400	2.42
Eugenia bracteata	100	200	1.21
Polyalthia fragrens	25	200	1.21
Actinodaphne malabarica	25	100	0.60
Clerodendron infortunatum	75	100	0.60
Psychotria	25	100	0.60
Total		16 500	100.00
II. 16-year-old site (Area: 100 m^2)			
Aglaia lawii	100	36 000	75.94
Clerodendron infortunatum	75	4 400	9.28
Palaquium ellipticum	100	2 000	4.21
Leea indica	75	1 800	3.79
Otonephelium stipulaceum	100	1 000	2.10
Strobilanthes	100	800	1.68
Tabernaemontana hyeneana	50	600	1.26
Cinnamomum keralense	25	300	0.63
Eugenia bracteata	100	300	0.63
Chromolena odorata	25	200	0.42
Total		47 400	100.00

continued

Table 4. (continued)

III. 21-year-old site (Area: 100 m²)			
Strobilanthes	100	4 300	30.28
Aglaia lawii	100	2 500	17.60
Mesua nagassarium	75	2 200	15.49
Palaquium ellipticum	100	2 000	14.08
Otonephelium stipulaceum	100	900	6.33
Leea indica	75	700	4.92
Eugenia bracteata	100	600	4.22
Vateria indica	25	300	2.11
Clerodendron infortunatum	75	200	1.40
Laportea crenulata	75	200	1.40
Tabernaemontana hyeneana	50	200	1.40
Evodia lunu-ankenda	50	100	0.70
Total		*14 200*	*100.00*
IV. 28-year-old site (Area: 100 m²)			
Strobilanthes	100	6 700	28.15
Aglaia lawii	100	5 000	21.00
Leea indica	75	4 600	19.32
Palaquium ellipticum	100	2 500	10.50
Mesua nagassarium	75	1 800	7.56
Laportea crenulata	75	1 600	6.72
Eugenia bracteata	100	700	2.94
Otonephelium stipulaceum	100	700	2.94
Cullenia exarillata	25	200	0.84
Total		23 800	100.00

Number of tree species and their density, however, did not follow a predictable pattern with respect to gap age (Table 3). Lack of a clear trend concerning tree density in the present study can be explained based on the changes in the successional status of vegetation. In general late successional species such as *Palaquium ellipticum, Mesua nagassarium* and *Vateria indica* recorded the highest importance value indexes (IVI) in the 21-year-old site (Table 1). A similar trend was also discernible in the 28-year-old site. In contrast, *Aglaia lawii,* a mid-successional species registered the highest IVI in the 16-year-old site. Although *Palaquium ellipticum* formed the most abundant species at this site, early and mid-successional species such as *Macaranga peltata, Aglaia lawii* and *Aporusa acuminata* were also abundant. Chandrasekhara and Ramakrishnan (1993) reported that although primary and secondary species established under gaps, early secondary species (*Macaranga peltata*) and late secondary species (*Actinodaphne malabarica*) were more responsive to resource availability than primary species.

The immediate and perhaps the most important effect of canopy opening is an increase in the duration and intensity of direct beam solar radiation on the forest floor (Chazdon & Fetcher 1984), which in turn may stimulate seed germination of early and mid seral species. Further, as gap age increases, due to canopy development, radiation levels reaching the forest floor may decline and the consequent shade may affect the abundance and distribution of tree seedlings (Brokaw 1983).

Changes in the relative abundance of early, mid and late seral species can be possibly attributed to the variations in understorey light availability as proposed by earlier workers. However, there are generalizations regarding gap regeneration dynamics such as that the initial phase of recruitment will be dominated by light demanders possessing efficient seed dispersal mechanisms and will be eventually replaced by non-pioneer (climax) species. But these are are mostly based on studies concerning slash and burn agriculture (Rao & Ramakrishnan 1989), clear felling impact assessment (Uhl *et al.* 1982), fire effects (Woods 1989), natural gap formation (Whitmore 1974, 1978, Hartshorn 1978, Runkle 1982, Cannon *et al.* 1994) or younger (≤ 10 years) selection felled forest gaps (Chandrasekhara 1991). Studies depicting the regeneration dynamics of older (> 10 years) selection felled forest gaps are rare. The present study attempts to bridge this gap.

Floristic diversity

Simpson's diversity index was highest for the 21-year-old site (D= 0.92), closely followed by the 7-year-old site (D= 0.88). It is suggested that species diversity increases initially as succession proceeds and it finally declines as the vegetation approaches a steady state (Table 3). Shannon-Wiener indices (Table 3) also followed a similar pattern. While Simpson's index expresses the probability of encountering dissimilar pairs of species in 100 random pairs of individuals, the Shannon-Wiener functions mainly portray the distribution of individuals among species. Pascal (1988) has shown that the climax evergreen forests of Western Ghats form a cloud of points between 3.6 and 4.3 for H'. However, the present H' values fall well below this broad range suggested by him. Implicit in the lower H' value is perhaps a high degree of gregariousness: two or three species accounting for about 50% of the relative density (as seen from Tables 1 and 4). The 21-year-old site registered the highest H' value of 4.0. This is perhaps due to the relatively large number of species and their low total density. The relatively high equitability probably is an artifact of the fewer number of individuals present. N/S ratio also was lower than the reported values for Western Ghats (Pascal 1988).

Immediately after gap formation, typically there is a pulse of recruitment under little or no competition, and after the initial pulse, recruitment slows. Initial recruitment may include both shade tolerants and intolerants. Consequently, floristic diversity may be higher in the gaps initially. However, subsequent recruitment may comprise only the shade tolerants. This may result in a gradual decline in floristic richness as competition intensifies in a mature stand, with eventual dominance of a few species (Langford & Buell 1969, George *et al.* 1993). The data presented in Table 3 broadly conform to this generalized pattern (except the 21-year-old site which incidentally recorded the highest Simpson's diversity index).

Diversity indices, however, do not reflect either the nature of regenerants or their relative size-class distribution, two cardinal aspects of vegetation development after disturbance. Despite having the second highest diversity index, the 7-year-old site was dominated by typical early seral species (e.g. *Macaranga peltata, Aglaia lawii,* *Symplocos macrophylla, Aporusa acuminata* and the like) accounting for 46% relative density. The respective figures for the 16-, 21- and 28- year-old sites were 21.0, 20.6 and 31.8% (Table 2). It is seen that the density of typical early species declined as gap age increased. On the other hand, the concentration of late seral species (e.g. *Palaquium ellipticum, Knema attenuata* and *Mesua nagassarium*) increased in the older gaps.

Nature of survivors and regenerants

Palaquium ellipticum, a major component of the medium elevation wet evergreen forests of the Western Ghats (Pascal 1988), was the most abundant tree species (≥10 cm GBH) in the selection felled forest gaps at Sholayar (Table 1). It recorded the highest importance value index (IVI), basal area and relative basal area in all plots except the 16-year-old site. It also recorded the highest tree density and relative density in the older gaps (21- and 28-year-old sites) and is well distributed in all height classes and diameter classes (data not presented). Implicit in the high relative basal area and significant presence of this species especially in the relatively larger size classes, is perhaps the presence of many residual trees, which in turn may ensure propagule availability at site.

In less than 10 cm GBH category also (Table 4), *P. ellipticum* dominated all sites. It recorded densities ranging from 400 (7-year-old site) to 2500 (28-year-old site) ha^{-1}. In contrast to the total density of plants, density of *P. ellipticum* increased as the gap age advanced showing very high levels of regeneration. According to Schupp *et al.* (1989), composition of regeneration is decided by the interplay of arrival and survival of species. Having an adequate source of small widely dispersed seeds at site and being a strong shade bearer (non-pioneer), *P. ellipticum* can germinate and establish under shade. Other late seral (shade tolerant) species (e.g. *Mesua nagassarium*) were also dominant in the lower size classes (Table 4). According to Whitmore (1989), juveniles of the climax (non-pioneer) species may survive in shade for many years.

Although non-pioneer (climax) species such as *P. ellipticum, M. nagassarium, Chukrasia tabularis, Eugenia bracteata, Vateria indica, Cullenia exarillata* and others (Troup 1921) were abundant, light demanders characterised by efficient seed dispersal mechanisms such as *Aglaia lawii, Macaranga peltata, Aporusa acuminata,* and *Symplocos macrophylla* were also present at all sites (Table 1). *Aglaïa lawii*, a moderate light demander having bird dispersed succulent fruits (Gamble 1916), recorded 7 to 21% relative basal area. *Macaranga peltata*, another strong light demander, having lightweight wind dispersed seeds and good coppiceability (George *et al.* 1993) formed the second most important tree component in both 7- and 16-year-old sites. *M. peltata* is an opportunist, colonizing most sites after a disturbance and as stand age advances its relative proportion may decline. Chandrasekhara and Ramakrishnan (1993) observed a higher establishment of this species in the selection felled forest gaps of Nelliampathy. Further, we did not observe any evidence of coppicing of the dominant overstorey tree species removed in the harvesting process.

Abundance of *Strobilanthes*, a ruderal species, in the understorey (Table 4) could possibly hinder the regeneration of light demanding species and may stimulate regeneration of climax species. Profuse regeneration of shade tolerant species such as *M. nagassarium* and *P. ellipticum* is possibly an indication of this fact. Although younger gaps were characterised by a higher tree density (Tables 1 and 4), older gaps exhibited higher stand basal area, implying fewer number of large trees. The observed reduction in density as gap age increases could be attributed to competition related processes. A decrease in the frequency of tree seedlings as the gap age increases was noticed by Balasubramanyan (1987) also for the selection felled forests of Nelliampathy.

The current suite of regenerants in the selection felled forest gaps may thus include both late seral species and opportunists as discussed above. The relative proportion may, however, depend on time after disturbance and/or the extent of canopy opening. The question of gap sizes was not addressed in the present study. Nonetheless, Denslow (1987) had earlier concluded that gap size is a good index of resource availability and microclimatic changes and therefore, may significantly influence the regeneration dynamics of forest gaps. Further, the higher IVI values of *P. ellipticum, M. nagassarium* and other late seral species in the older gaps suggest the eventual development of a stand dominated by these species, as postulated in Egler's (1954) initial floristic model of succession.

Chandrasekhara and Ramakrishnan (1993) have shown that selection felling, unlike natural tree fall gaps, involves destruction of seedlings and saplings during felling operation and soil disturbance due to hauling of logs by elephants or mechanised means. This, in turn, may cause marked changes in the micro-environmental conditions. However, such differences among the sites selected for the present study are presumably small (though minor variations in logging intensity cannot be overruled). Therefore, we think that the observed variations in the regeneration pattern could be attributed to logging history (time after felling). Other factors like logging intensity, intrinsic differences between sites, amount of soil compaction and canopy cover removed could also play a major role in this respect.

Edaphic attributes

Field moisture content of soil (0-15 cm layer) was higher in the 7- and 16-year-old sites compared to the 21- and 28-year-old sites. Higher moisture content in the recent gaps might be due to the reduced evapo-transpiration losses owing to the lower stand basal area (Denslow 1987). However, interpretation of the present results is limited by the non-replicated nature of sites of the same age. Soil pH ranged from 5.4 (7-year-old site) to 4.7 (28-year-old site). The increase in soil acidity with increasing gap age could be attributed to the release of organic acids into the soil, often associated with a higher quantum of litterfall and/or faster litter turnover rates. In this context, Chandrasekhara (1991) observed that younger gaps (up to 10 years of age) were characterised by higher litter turnover rates. This, in turn, may have also favoured the soil organic C status. Both the

16-year and 7-year-old sites had significantly higher levels of soil organic C compared to the 21- and 28-year-old sites.

Similarly, total N in the soil was higher in the younger gaps (7- and 16-year-old sites) which could be due to enhanced N mineralization in tree fall gaps and faster turnover of organic matter as postulated by Vitousek and Denslow (1986). Soil N decreased as gap age increased. This, however, did not follow a systematic pattern (Table 5). Small non-significant increases were found in respect of available soil P. However, it was generally low in all gaps, presumably due to high rates of P fixation characteristic of acidic soils. Vitousek and Denslow (1986) also observed low available P levels in tree fall gaps of La Selva Biological Station. Availability of K in the 7-year-old site was markedly higher (126 ppm) and declined with gap age. The lowest value was recorded in the 21-year-old gap (45 ppm).

In short, gap formation may enhance soil mineral nutrient availability which, in turn, may favour pioneer species characterised by profuse seed production, efficient seed dispersal mechanisms and ability to use increased light intensities and other resource levels (Denslow 1987, Becker *et al.* 1988). However, Vitousek and Denslow (1986) suggested that increase in light availability within tree fall gaps represented a more important shift in resources than any change in nutrient availability. Apparently nutrient mineralisation rates of large selection felled forest gap are higher than those of undisturbed forests. However, it may not possibly form a major determinant of vegetation development after disturbance, because arrival and survival of species at a given site are more dependant on the vital attributes of the species and changes in the light regimes rather than changes in soil nutrient availability *per se.*

Table 5. Soil physico-chemical properties of selection felled gaps of different ages in the evergreen forests of Sholayar

Site (y-old)	Moisture content (%)	pH	Organic carbon (%)	Total N (%)	Available P (ppm)	Available K (ppm)
7	23.16[a]	5.41[b]	3.58[a]	0.37[a]	1.8[a]	126[b]
16	24.95[b]	5.06[a]	3.93[b]	0.38[a]	1.8[a]	79[c]
21	21.26[c]	4.98[a]	3.35[a]	0.29[b]	2.3[a]	45[a]
28	19.21[d]	4.75[c]	3.44[a]	0.35[a]	2.1[a]	53[a]
C.V. (%)	4.99	4.63	12.00	17.79	42.1	32.5

Values within colums having the same superscript are not significantly different.

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