STUDIES ON THE STRUCTURE OF JADKAL FOREST, UDUPI DISTRICT, INDIA

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VASANTH RAJ, B. K., SHIVAPRASAD, P. V. & CHANDRASHEKAR, K. R. 2005. Studies on the structure of Jadkal forest, Udupi district, India. A floristic survey and structural studies of Jadkal forest, which forms a part of the Mookambika Wild Life Sanctuary, near Kollur, India, were carried out. In the 5000 m^2 study area, 103 species belonging to 46 families, of these 62 tree species belonging to 30 families, had girth at breast height (gbh) > 10 cm. The endemism is fairly high; 32 species were endemic to the Western Ghats. This secondary semi-evergreen forest with the dominance of members of Dipterocarpaceae like *Hopea parviflora*, *H. ponga* and *Vateria indica* is not homogeneous. Canopy characters are unique and there is no change in the forest composition towards evergreen. The regeneration in the forest is rated to be good. This forest is partly natural and partly the result of planting of *H. parviflora* and other tree species. Because of exploitation by the local people the forest is partially degraded which has resulted in openings in the canopy of the forest.

Key words: Mookambika Wild Life Sanctuary — dipterocarps — regeneration — density — canopy

VASANTH RAJ, B. K., SHIVAPRASAD, P. V. & CHANDRASHEKAR, K. R. 2005. Kajian struktur hutan Jadkal di wilayah Udupi, India. Satu tinjauan flora dan struktur hutan Jadkal yang membentuk sebahagian daripada Kawasan Perlindungan Hidupan Liar Mookambika dekal Kollur, India dijalankan. Di dalam kawasan seluas 5000 m^2 ini terdapat 103 spesies pokok daripada 46 famili. Daripada jumlah ini, 62 spesies pokok daripada 30 famili mempunyai ukur lilit pada aras dada (gbh) > 10 cm. Endemismenya agak tinggi. Sejumlah 32 spesies adalah endemis di Ghats Barat. Hutan semimalar hijau sekunder dengan ahli dominan daripada famili Dipterocarpaceae seperti *Hopea parviflora*, *H. ponga* dan *Vateria indica* tidak homogen. Ciri-ciri sudurnya unik dan tidak terdapat perubahan dalam komposisi hutan menjadi malar hijau. Pemulihan dalam hutan adalah baik. Hutan ini sebahagiannya semula jadi dan sebahagiannya hasil penanaman *H. parviflora* dan spesies lain. Eksploitasi hutan oleh penduduk tempatan mengakibatkan kemerosotan hutan. Ini menyebabkan pembukaan sudur di dalam hutan.

Introduction

Ecological studies on four rain forests such as Agumbe, Bannadpare, Kagneri and south Bhadra forests of Karnataka have been undertaken by Rai and Proctor (1986). Elourd *et al.* (1997) studied the structure and dynamics of Kadamakal reserve forest, a dense moist evergreen forest of Kodagu district of Karnataka. Quantitative inventories of the species-rich forests (Johnston & Gillmann 1995) and also species-

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poor forests (Davis & Richards 1934) have been undertaken. Recent works on the aspects of structure of forests include those from the deciduous forests of Madhumalai in Nilgiris (Sukumar *et al.* 1992), the semi-evergreen forests of the Eastern Ghats (Kadavul & Parthasarathy 1999), the wet evergreen forests of the Western Ghats (Rai & Proctor 1986, Pascal & Pelissier 1998, Bonadie & Bacon 1999, Shivaprasad *et al.* 2001) and the lowland dipterocarp forests of Southeast Asia (Whitemore 1984, Newbery *et al.* 1992).

According to Pascal (1988), the characteristic feature of secondary evergreen or semi-evergreen forests is the preservation of a dense cover and a structure, which is very similar to the initial climax forest, but lacking the characteristic species of the initial climax forest. These forests are found in regions where anthropogenic pressure was initially very high, but were relatively protected later on mostly because they were designated as reserve forests. One such secondary forest is Jadkal forest (13°46' N, 74°47' E), covering an area of 157 ha situated 7 km away from Kollur Mookambika Temple in Udupi district of Peninsular India (Figure 1). The vegetation is semi-evergreen with the dominance of members of Dipterocarpaceae, viz. *Hopea parviflora, H. ponga* and *Vateria indica.* This corresponds to the "West Coast Secondary Evergreen Dipterocarp Forests" of Champion and Seth (1968).

Materials and methods

Sampling area

The experimental plot is located inside the Mookambika Wild Life Sanctuary (Udupi district, Karnataka, India) near Kollur Mookambika Temple at an elevation of 50 to 150 m. The forest has semi-evergreen type of vegetation, with many streams

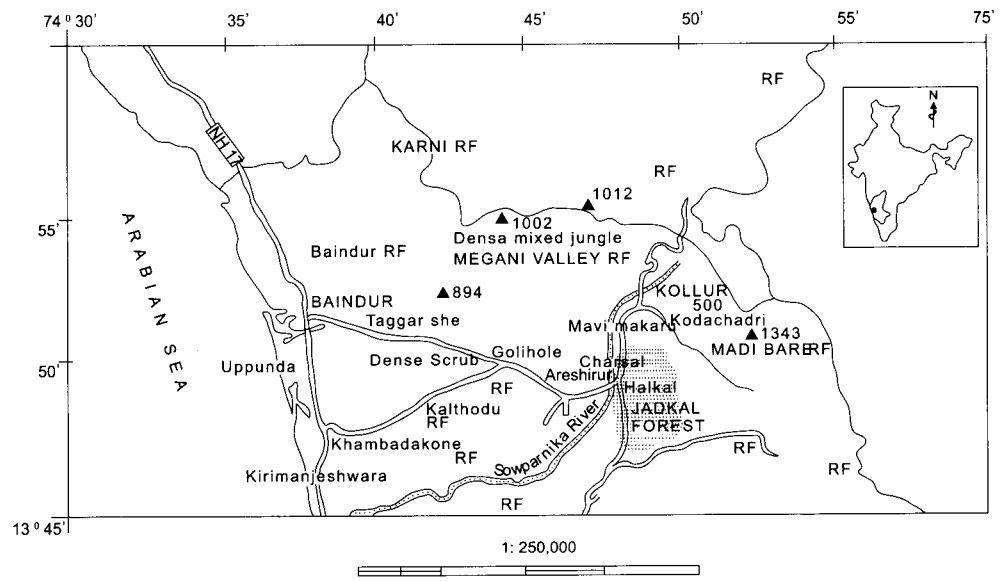

Figure 1 Location map of Jadkal forest

which dry up during the summer. The forest is partially degraded due to exploitation by the locals for fuelwood and other purposes. The ground vegetation is dense due to the growth of number of seedlings of different species.

The soil is lateritic in nature and the forest receives an annual rainfall of 370–4300 mm mainly during the southwest monsoon, i.e. June–September. The mean annual temperature is 26 °C. According to the locals, the forest is partly natural and partly the result of massive plantings of *H. parviflora* and other tree species.

Field work

Five transects, each covering an area of 1000 m^2, were randomly laid in such a way to include the areas with variation in the density and were divided into 25 plots of 10 x 4 m. In these plots, all the individuals having a girth of 10 cm at breast height (1.33 m) were identified referring to the floras and with the help of field key (Gamble 1921–35, Pascal & Ramesh 1987). The endemic plants were listed according to Ahmedullah and Nayar (1988). Heights of the trees were measured with the help of a clinometer. The girth at breast height (gbh) of individuals was also measured. The association of trees with other species including epiphytes and mosses was noted. Seedlings in each plot were identified, counted and recorded to get an idea of their status of regeneration. The voucher specimens of the plants bearing flowers/fruits were deposited at the Herbarium of the Department of Applied Botany, Mangalore University, Karnataka.

A plot of 20 x 50 m near one of the transects was chosen to prepare a plan showing slopes, rock, dead trees, fallen wood, strangling lianas, etc. A canopy diagram was also prepared for the same area. A profile diagram was prepared for an area of 5 x 50 m within this plot.

Analysis of the data

The trees were divided into three sets based on their architecture, i.e. set of the past (senescent and badly damaged trees), set of the present (the trees which have attained their maximum size and reached maturity) and set of the future (the trees which are still in rapid vegetative growth phase) following Halle *et al.* (1978).

The number of individuals of different gbh classes and height classes were calculated. The density, basal area, dominance, frequency, importance value index (IVI) and stand density for each species were calculated in a plot size of 0.5 ha (Pascal 1988). The density *(D)* of each species was recorded by counting the total number of individuals. The frequency *(f)* was determined using the following formula:

$$\text{Frequency } (f) = \frac{c_i}{c} \times 100$$

where c_i = number of quadrats in which the species is present

c = number of quadrats studied

The dominance *(d)* was determined by the basal areas (at 1.3 m height) of individuals of the same species.

Relative frequency *(rf)* was determined using the formula:

$$rf = \frac{f_i}{F} \times 100$$

where f = frequency of the species i
$F = \Sigma f$

Relative density *(rD)* was calculated using the formula:

$$rD = \frac{n_i}{N} \times 100$$

where n_i = number of individuals of species i
N = total number of individuals in the plot

Relative dominance *(rd)* was determined using the formula:

$$rd = \frac{d_i}{d} \times 100$$

where d_i = sum of the basal area of all the individuals of the species i
d = total basal area of the plot

Importance value index (IVI) of a species was calculated by adding relative frequency *(rf)*, relative density *(rD)* and relative dominance *(rd)*. The family importance value (FIV) index for botanical families was calculated by adding the IVI for different species of the same family. The dominance was measured using Simpson's index:

$$D = 1 - \sum_{i=1}^{S} (n_i/N)^2$$

where n_i = number of individuals of the species i
N = total number of individuals in the plot
S = number of species in the plot

The floristic diversity was calculated following Shannon-Wiener's index:

1) $H' = 3.3219 \left(\log_{10} N - 1/N \sum_{i=1}^{S} n_i \log_{10} n_i\right)$

where n_i, N and s are the same as in Simpson's index and 3.3219 is the conversion factor from $\log_2$ to $\log_{10}$.

2) $H\ max = 3.3219 \log_{10} S$

3) Equitability *(E)* = H' /$H\ max$

Results

Floristic studies

A total of 103 species belonging to 85 genera and 46 families were collected and identified from the sampling plot, of which only 62 species had a gbh > 10 cm. The dominant members of the forest are dipterocarps. The genera *Diospyros, Garcinia, Ixora, Memecylon* and *Terminalia* are represented by three species each and family Fabaceae has the highest number of eight species. There were some deciduous species in the sampling area like *Aglaia lawii, Dillenia pentagyna, Macaranga peltata, Terminalia* spp., *Xylia xylocarpa* and *Zanthoxylum rhetsa*. Climbers were poorly represented in the plot, most of the trees being associated either with *Piper* sp. or *Pothos scandens*. The list of plants recorded from the forest is given in Appendix 1.

The endemism in this forest is fairly high. Out of 103 species, 32 species are endemic to the Western Ghats which means about 31% of the species are endemic. Species like *Holigarna arnottiana, Hopea parviflora, H. ponga, Ixora brachiata* and *V. indica*, which have high IVI, are endemic to the Western Ghats.

Canopy characteristics

The canopy of this forest is stratified into four layers without any "emergents" (the solitary individuals which grow above the canopy) (Figure 2). This is again confirmed by plotting height vs. gbh (Figure 3). The upper canopy does not exceed 35 m height and is almost continuous.

The canopy (the trees of height > 20 cm) consists mostly of *Aglaia lawii, Dipterocarpus indicus, Holigarna ferruginea, Hopea parviflora, Terminalia paniculata, T. tomentosa* and *V. indica*. The intermediate layer consists of species like *Flacourtia montana, Holigarna arnottiana, H. ferruginea* and *X. xylocarpa*. The lowermost layer consists of *Aporosa lindleyana, Psychotria dalzelli, Ixora brachiata*, etc. The association of *Piper* sp., *Pothos scandens* and lichens is seen on most of the trees in the forest.

The canopy projection diagram indicates that the canopy of *H. parviflora* occupies nearly 60% of the area in the sample plot (Figure 4). A total of about 90% of the sampling plot is covered by the canopy. This may be the result of the high seedling growth in the forest.

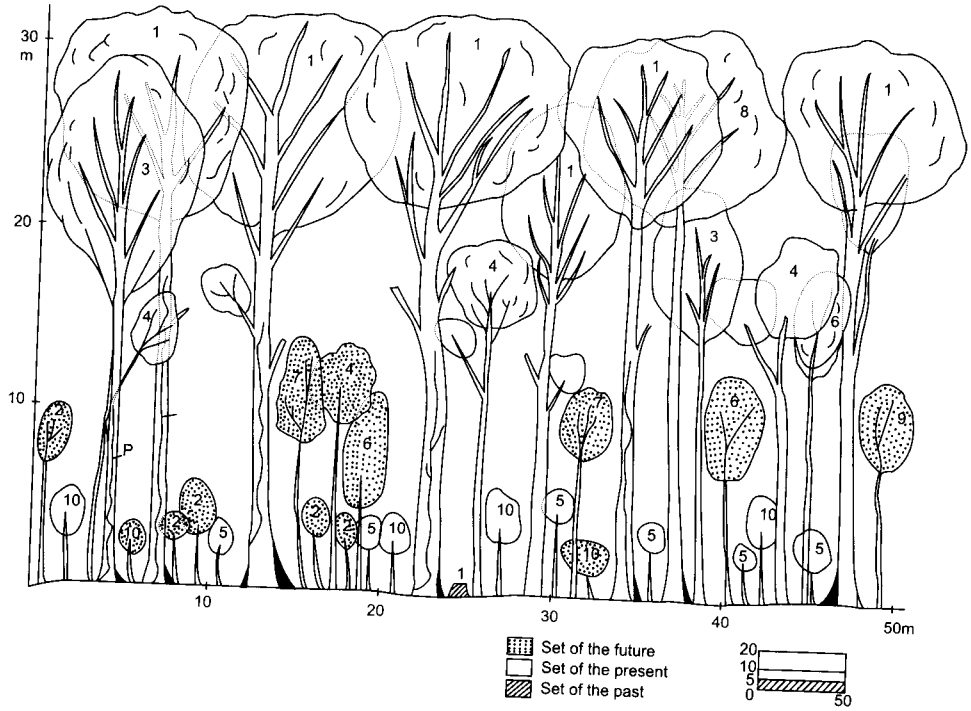

Figure 2 Profile diagram of Jadkal forest. The tree species shown are 1.*Hopea parviflora* Beddome, 2. *Aporosa lindleyana* (Wight) Baillon, 3. *Terminalia tomentosa* Wight & Arn., 4. *Holigarna arnottiana* Hook. f., 5. *Psychotria dalzelli* Hook. f., 6. *Xylia xylocarpa* (Roxb.) Taub., 7. *Zanthoxylum rhetsa* DC., 8. *Terminalia paniculata* Roth, 9. *Artocarpus hirsutus* L. and 10. *Ixora brachiata* Roxb.

Importance value index

The IVI of dipterocarps, i.e. *H. parviflora, H. ponga* and *V. indica,* are higher (IVI of 31.02, 26.22 and 25.89 respectively) than the IVI of other species in the forest (Table 1). These are followed by *Aporosa lindleyana* (IVI of 17.65). Only 9 species have IVI more than 10. A total of 53 species showed IVI less than 10. The family importance value (FIV) of Dipterocarpaceae is high (86.71) but less compared with the FIV of dipterocarps (109.75) in Pilarkan reserve forest (Shivaprasad *et al.* 2000) (Table 2). This is followed by Combretaceae (33.74), Anacardiaceae (19.44), Euphorbiaceae(17.96), Rubiaceae (13.59), Fabaceae (12.71), etc.

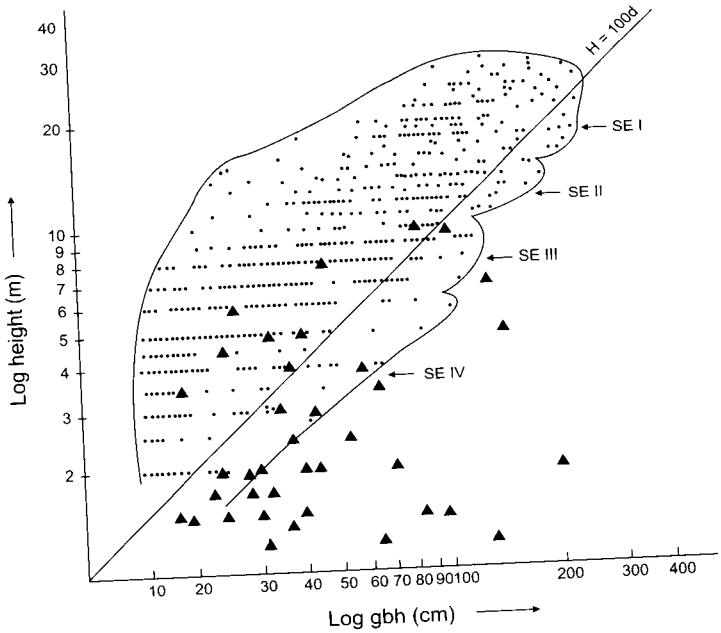

Figure 3 Height /gbh graph of Jadkal forest
SE I, SE II, SE III and SE IV - Structural ensembles I, II, III and IV respectively
– Sets of the present and future
▲- Set of the past

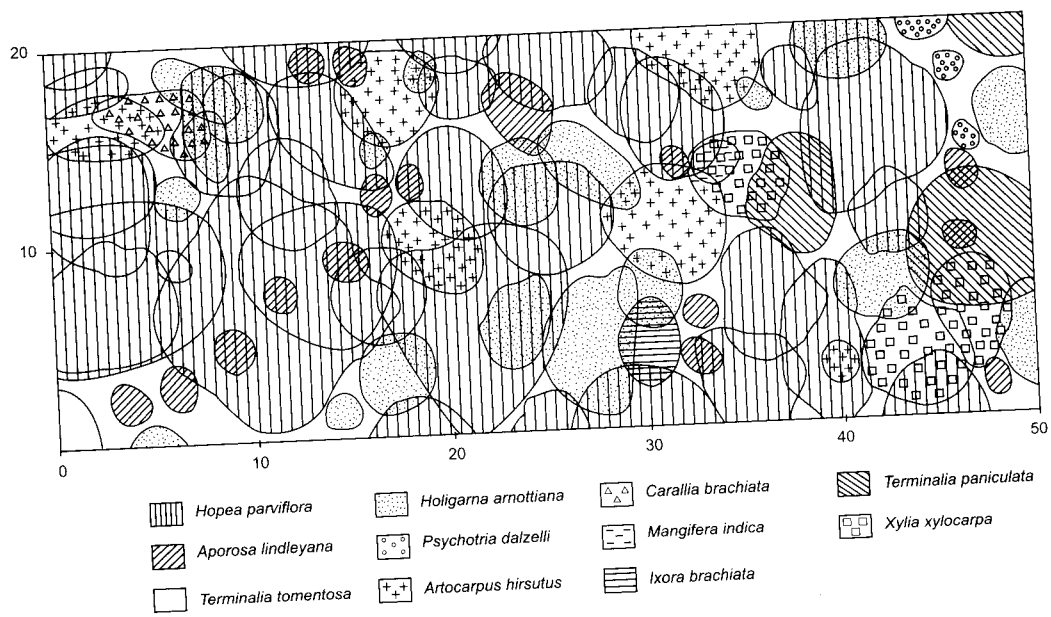

Figure 4 Canopy projection diagram of Jadkal forest

Table 1 The frequency *(f)*, density *(D)*, dominance *(d)*, relative frequency *(rf)*, relative density *(rD)*, relative dominance *(rd)* and importance value index (IVI) of Jadkal forest

Species name	*f*	*D*	*d*	*rf*	*rD*	*rd*	IVI
Hopea parviflora	28.80	71	4.7590	6.92	8.44	15.66	31.02
Hopea ponga	24.80	88	2.9777	5.96	10.46	9.80	26.22
Vateria indica	18.40	58	4.4272	4.42	6.90	14.57	25.89
Aporosa lindleyana	29.60	71	0.6354	7.12	8.44	2.09	17.65
Terminalia tomentosa	20.80	31	2.6273	5.00	3.69	8.64	17.33
Holigarna arnottiana	22.40	35	1.9116	5.38	4.16	6.29	15.84
Terminalia paniculata	15.20	25	2.0793	3.65	2.97	6.84	13.47
Xylia xylocarpa	15.20	26	1.2942	3.65	3.09	4.26	11.00
Ixora brachiata	18.40	35	0.6197	4.42	4.16	2.04	10.62
Climber	16.80	45	0.1345	4.04	5.35	0.44	9.83
MF-156	15.20	33	0.2795	3.65	3.92	0.92	8.50
Vitex altissima	4.00	9	1.7600	0.96	1.07	5.78	7.82
Aglaia lawii	12.80	25	0.4331	3.08	2.97	1.43	7.47
Olea dioica	13.60	18	0.3943	3.27	2.14	1.30	6.71
Diospyros buxifolia	12.80	22	0.1433	3.08	2.62	0.47	6.16
Flacourtia montana	8.00	19	0.3800	1.92	2.26	1.25	5.43
Gnetum ula	8.0	12	0.3423	1.92	1.43	1.13	4.48
Syzygium sp.	5.60	7	0.4964	1.35	0.83	1.63	3.81
Tabernaemontana heyneana	8.00	14	0.0595	1.92	1.66	0.20	3.78
Dipterocarpus indicus	4.00	18	0.1437	0.96	2.14	0.47	3.57
Memecylon talbotianum	7.20	13	0.0271	1.73	1.55	0.09	3.37
Psychotria dalzelli	7.20	10	0.0151	1.73	1.19	0.05	2.97
Vepris bilocularis	4.00	6	0.3598	0.96	0.71	1.18	2.86
Alstonia scholaris	5.60	9	0.0951	1.34	1.07	0.31	2.73
Actinodaphne malabarica	3.20	10	0.1151	0.77	1.19	0.38	2.34
Zanthoxylum rhetsa	4.00	6	0.1947	0.96	0.71	0.64	2.32
Cinnamomum malabatrum	4.00	5	0.1935	0.96	0.59	0.64	2.19
Combretum latifolium	4.00	9	0.0373	0.96	1.07	0.12	2.15
Holigarna ferruginea	1.60	2	0.3574	0.38	0.24	1.18	1.80
Careya arborea	2.40	3	0.2619	0.58	0.36	0.86	1.80
Strychnos nux-vomica	1.60	2	0.3157	0.38	0.24	1.04	1.66
Hydnocarpus pentandra	3.20	4	0.0506	0.77	0.48	0.17	1.41
Mangifera indica	2.40	4	0.0957	0.58	0.48	0.31	1.37
Diospyros saldanhe	2.40	5	0.0127	0.58	0.59	0.04	1.21
Garcinia morella	2.40	4	0.0349	0.58	0.48	0.11	1.17
Carallia brachiata	0.80	1	0.2438	0.19	0.12	0.80	1.11
Ailanthus malabarica	1.60	2	0.1434	0.38	0.24	0.47	1.09
Strychnos colubrina	1.60	2	0.0988	0.38	0.24	0.33	0.95
Schleichera oleosa	1.60	2	0.0988	0.38	0.24	0.33	0.95
Naringi crenulata	1.60	4	0.0233	0.38	0.48	0.77	0.94
Calophyllum apetalum	1.60	3	0.0041	0.38	0.36	0.01	0.75
Dalbergia latifolia	1.60	2	0.0360	0.38	0.24	0.12	0.74
Gymnacranthera farquhariana	1.60	2	0.0351	0.38	0.34	0.16	0.74
Elaeocarpus serratus	1.60	2	0.0334	0.38	0.24	0.11	0.73
Machillus macrantha	1.60	2	0.0201	0.38	0.24	0.07	0.69
Diospyros paniculata	0.80	2	0.0756	0.19	0.24	0.25	0.68

(continued)

(Table 1 - continued)

Species name	*f*	*D*	*d*	*rf*	*rD*	*rd*	IVI
Lagerstroemia microcarpa	0.80	1	0.0929	0.19	0.12	0.31	0.62
Acacia sinuata	0.80	2	0.0271	0.19	0.24	0.09	0.52
Terminalia bellerica	0.80	1	0.0497	0.19	0.12	0.16	0.47
Entada pusaetha	0.80	2	0.0058	0.19	0.24	0.02	0.45
Nothopegia racemosa	0.80	2	0.0029	0.19	0.24	0.01	0.44
Elaeocarpus tuberculatus	0.80	1	0.0336	0.19	0.12	0.11	0.42
Dillenia pentagyna	0.80	1	0.0268	0.19	0.12	0.09	0.40
Chionanthus malabaricus	0.80	1	0.0191	0.19	0.12	0.06	0.37
Artocarpus hirsutus	0.80	1	0.0134	0.19	0.12	0.04	0.36
Ficus sp.	0.80	1	0.0050	0.19	0.12	0.02	0.33
Ancistrocladus heyneanus	0.80	1	0.0061	0.19	0.12	0.04	0.33
Pterospermum diversifolium	0.80	1	0.0034	0.19	0.12	0.01	0.32
Syzygium caryophyllatum	0.80	1	0.0018	0.19	0.12	0.01	0.32
Calycopteris floribunda	0.80	1	0.0008	0.19	0.12	0.003	0.31
Murraya sp.	0.80	1	0.0010	0.19	0.12	0.003	0.31
Macaranga peltata	0.80	1	0.0008	0.19	0.12	0.003	0.31
Dead	18.40	29	0.7200	4.42	3.45	2.38	10.25
Unidentified	12.80	17	0.6019	3.08	2.02	1.98	7.08

Structural ensembles

The sets of the past, present and future were represented by 88, 110 and 643 individuals respectively. The set of the present was divided into four structural ensembles (SE) on the basis of height–gbh graph (Figure 3). Some trees of *Hopea parviflora, H. ponga, Terminalia tomentosa* and *V. indica* vary between 30 and 15 m in height from the SE I and comprise about 2.3% of the individuals. Emergents are, however, absent in this forest. Some of the dominant species in the ensemble II are *Diospyros buxifolia, Holigarna arnottiana, X. xylocarpa,* etc. which range from 15 to 10 m height and represent 2.5% of the individuals. The SE III with tree height ranging from 10 to 7 m and SE IV with tree height less than 7 m are represented by moderate-sized trees and shrubs like *Aporosa lindleyana, Ixora brachiata, Memecylon talbottianum, Psychotria dalzelli,* etc. comprising 7.6% of the individuals. There are more trees belonging to the set of the future, indicating that the forest has not attained equilibrium. The growing immature trees constantly influence the environment and thus there will be a dynamic change. Also, due to the disturbances in the forest, there are a large number of individuals belonging to the set of the past. Most of the individuals belonging to the set of the past are of *H. parviflora,* which were cut by the locals for timber. However, the ground vegetation is dense except in the peripheral zones where there is disturbance by the locals.

Density

A total of 841 individuals were recorded in the 5000 m^2 study area (Table 1). The members of Dipterocarpaceae are represented by about 28% (285 individuals)

Table 2 Family importance value (FIV) index of Jadkal forest

Family	No. of species	FIV
Dipterocarpaceae	4	86.71
Combretaceae	5	33.74
Anacardiaceae	4	19.44
Euphorbiaceae	2	17.96
Rubiaceae	2	13.59
Fabaceae	4	12.71
Ebenaceae	3	8.06
Verbenaceae	1	7.82
Meliaceae	1	7.48
Oleaceae	2	7.08
Flacourtiaceae	2	6.85
Apocynaceae	2	6.51
Rutaceae	4	6.43
Lauraceae	3	5.22
Gnetaceae	1	4.48
Myrtaceae	2	4.13
Melastomataceae	1	3.37
Cluciaceae	2	1.92
Lecithydaceae	1	1.80
Loganiaceae	1	1.66
Elaeocarpaceae	2	1.15
Rhizophoraceae	1	1.11
Simaroubaceae	1	1.09
Sapindaceae	1	0.95
Myristicaceae	1	0.74
Moraceae	2	0.68
Lythraceae	1	0.62
Dilleniaceae	1	0.40
Ancistrocladaceae	1	0.33
Sterculiaceae	1	0.32

of the total number of individuals; *H. ponga is* represented by 88 individuals, *H. parviflora* by 71 individuals, *V. indica* by 58 individuals and *D. indicus* by 18 individuals. Among the species other than dipterocarps, *Aporosa lindleyana* is represented by 71 individuals, an unidentified climber (a member of Fabaceae, *Bauhinia* sp. ?) by 45 individuals, *Holigarna arnottiana* and *Ixora brachiata* by 35 individuals each and *T. tomentosa* by 31 individuals. There are more individuals belonging to the set of the future in the forest.

Floristic richness

The indices of floristic diversity are given in Table 3. The high value of Simpson's index (0.95) indicates that out of 100 pairs of individuals taken randomly, only 5 pairs will be of the same species. Thus the above value indicates

Table 3 Diversity indices of Jadkal forest

Area (m^2)	Number of species = S (g ≥10 cm)	Number of individuals = N (g ≥10 cm)	N/S	Simpson's index	Shannon-Wiener's index		
					H'	H max	$E = H'/H$ max
5000	62	841	13.35	0.95	5.23	5.97	0.88

a high floristic richness of the forest. The N/S ratio of the plot is low being 13.35, which suggests that the number of individuals of different species in the plot is low.

The Shannon-Wiener's index (H' = 5.23) is quite high and the equitability ratio (E = 0.88) is also high. The high value of H' is due to the large number of species and the poor representation of most of them.

Stand density

The total stand density of this reserve forest is approximately 60.78 $m^2 ha^{-1}$ (1682 individuals ha^{-1}). Of these, members of the Dipterocarpaceae constitute nearly 40% (approximately 24.61 $m^2 ha^{-1}$ with 570 individuals ha^{-1}), which is low when compared with the planted secondary forests of Pilarkan reserve forest (45.08 $m^2 ha^{-1}$ with 597 individuals ha^{-1}) (Shivaprasad *et al.* 2001). *Hopea parviflora* represents a stand density of 9.52 $m^2 ha^{-1}$ (142 individuals ha^{-1}), followed by *V. indica* (8.85 $m^2 ha^{-1}$ and 116 individuals ha^{-1}) and *H. ponga* (5.96 $m^2 ha^{-1}$ and 176 individuals ha^{-1}). The stand densities of *Terminalia tomentosa, T. paniculata, H. arnottiana* and *Vitex altissima* are also considerably high (5.25, 4.16, 3.83 and 3.52 $m^2 ha^{-1}$ respectively).

Height and gbh classes

Nearly 65% of the individuals are within 0–8 m height range which indicates that there is good regeneration in the recent past (Table 4). Only 5% of the individuals reach the height class above 20 m and most of them belong to the Dipterocarpaceae.

More than half of the individuals belong to the gbh range of 10–40 cm and about one fourth come under the gbh class 40–80 cm (Table 5). This suggests that the forest is of the regeneration type where more plants belonging to the set of the future are present. The individuals that represent the gbh classes above 200 cm are *H. parviflora* and *V. indica.* This is the reason for the high stand density of the dipterocarps in the forest.

Regeneration

The seedlings of dipterocarps, viz. *D. indicus, Hopea parviflora, H. ponga* and *V. indica,* account for about 24% (Table 6) indicating good regeneration of these species. While the seedlings of *Psychotria* species (*P. dalzelli* and *P. flavida*) account for 13%, *Ixora* species (*I. brachiata* and *I. coccinea*) account only for 6%. Other seedlings which are abundant in the forest are of *Entada pusaetha, Holigarna arnottiana, Aporosa lindleyana, Xylia xylocarpa, Olea dioica, Piper* sp., *Memecylon talbottianum, Aglaia lawii, Zanthoxylum rhetsa, Cinnamomum malabatrum, Calamus thwaitesii, Smilax zeylanica,* etc. Climbers are poorly represented in this forest, compared with evergreen forests. This indicates the semi-evergreen nature of the forest. Although, there are few openings in the canopy due to cutting of trees, heliophytes are lesser in number. The forest is not homogeneous even though it is partly the result of plantings of the tree species. The regeneration in this forest is very high which may be due to the presence of thick litter cover in the forest except in the peripheral regions where it is collected by the locals for agricultural and composting purposes. The deposition of thick litter indicates the green forest having prolonged dry periods.

Table 4 Height classes and density of Jadkal forest

Height class	Range (m)	No. of individuals	Percentage
1	0–4	299	35.55
2	4–8	250	29.73
3	8–2	127	15.10
4	12–16	65	7.73
5	16–20	55	6.54
6	20–24	22	2.62
7	24–28	21	2.49
8	28–32	2	0.24

Table 5 gbh classes and density of Jadkal forest

gbh class	Range (m)	No. of individuals	Percentage
1	10–40	458	54.46
2	40–80	198	23.54
3	80–120	113	13.44
4	120–160	48	5.71
5	160–200	13	1.54
6	200–240	10	1.19
7	>240	1	0.12

Table 6 Seedlings of different species recorded in Jadkal forest. (* - dipterocarp species)

Species name	No. of seedlings
Psychotria dalzelli	1579
Hopea parviflora *	1368
H. ponga *	1164
Entada pusaetha	612
Holigarna arnottiana	492
Aporosa lindleyana	428
Xylia xylocarpa	389
Olea dioica	385
Piper sp.	378
Vateria indica *	362
Memecylon talbotianum	360
Aglaia lawii	352
Ixora coccinea	313
Zanthoxylum rhetsa	305
Ixora brachiata	281
Cinnamomum malabatrum	217
Calamus thwaitesii	216
Smilax zeylanica	211
Pothos scandens	164
Naringi crenulata	146
Strychnos colubrina	146
Combretum latifolium	144
Randia sp.	143
Tabernaemontana heyneana	138
Calycopteris floribunda	114
Clerodendrum viscosum	107
Jasminum malabaricum	97
Actinodaphne malabarica	96
Diospyros buxifolia	95
Ixora polyantha	95
Calophyllum apetalum	87
Ancistrocladus heyneanus	84
Gymnacranthera farquhariana	74
Flacourtia montana	53
Carallia brachiata	52
Dipterocarpus indicus *	51
Caryota urens	50
Leea indica	50
Acacia pennata	46
Syzygium sp.	45
Elaeocarpus serratus	41
Uvaria narum	36
Chromolaena odorata	34
Mammea suriga	31
Psychotria flavida	27
Ziziphus mauritiana	27
Memecylon terminale	25
Pteris sp.	24

(continued)

(Table 6 - continued)

Species name	No. of seedlings
Acacia sinuata	20
Nothopegia racemosa	19
Holarrhina pubescens	16
Macaranga peltata	16
Memecylon malabaricum	15
Garcinia indica	14
Albizia chinensis	13
Asystasia dalzelliana	11
Curcuma sp.	11
Elaeocarpus tuberculatus	10
Lygodium sp.	10
Bauhinia variegata	9
Bambusa arundinacea	9
Chionanthus malabaricus	9
Murraya sp.	9
Ochlandra travancorica	7
Sterculia guttata	7
Cyclea peltata	6
Alstonia scholaris	5
Strychnos nux-vomica	5
Dalbergia latifolia	4
Garcinia morella	4
Pterospermum diversifolium	4
Syzygium caryophyllatum	4
Garcinia gummi-gutta	3
Hydnocarpus pentandra	3
Madhuca neriifolia	3
Polyalthia fragrans	3
Terminalia tomentosa	3
Artocarpus hirsutus	2
Cassia fistula	2
Croton sp.	2
Gnetum ula	2
Mallotus philippensis	2
Mangifera indica	2
Mimusops elengi	2
Mussaenda frondosa	2
Sapindus laurifolia	2
Vepris bilocularis	2
Ziziphus rugosa	2
Dillenia pentagyna	1
Ipomoea sp.	1
Phyllanthus emblica	1

Discussion

The canopy of the primary dipterocarp forests of Southeast Asia usually consists of 4–6 layers (Richards 1981). According to this author, the height of the uppermost

storey in a primary dipterocarp forest extends up to 45–60 m. In the Jadkal forest, the maximum height of the canopy is 35 m. Rai and Proctor (1986) have observed the height of emergents of up to 55 m in Agumbe, 42 m in Bannadpare and 35 m in Kagneri. However, they reported the absence of emergents in the south Bhadra forests. In all four of the sites studied by them, the members of Dipterocarpaceae were found to be dominant. In northwestern Borneo, *Dipterocarpus lanceolata,* as an emergent, reached a height of 76 m (Ashton & Hall 1992). In the rain forests of Bajo Calima, Choco region, western Colombia, the tree canopy rarely exceeded a height of 30–35 m (Faber-Langendoen & Gentry 1991). In the dipterocarp forest of Gunung Mulu National Park, Malaysia, the maximum height of *Shorea ferruginea* was reported to be 57.5 m (Proctor *et al.* 1983).

Dipterocarps were dominant in two of the five plots and *Lagerstroemia calyculata* was dominant with the association of dipterocarps in the three plots of Cat Tien National Park, Vietnam (Blanc *et al.* 2000). According to Pascal and Pelissier (1996), *D. indicus* and *V. indica* form the emergents in Kadamakal forest reserve of the Western Ghats. Elourd *et al.* (1997) monitored the structure and dynamics of moist evergreen forests in the Western Ghats (Kodagu district of Karnataka, India) and reported the dominance of four species at different layers: *Humboldtia brunonis* as undergrowth, *Myristica dactyloides* in the intermediate layer, *V. indica* at the higher canopy and *D. indicus* as an emergent. In an ecological study of sal forest in Bankura north forest division, West Bengal, India, Lal *et al.* (1994) observed the presence of *Shorea robusta, Madhuca indica* and *Pterocarpus marsupium* in all the three layers.

In the present study there are no emergents but the topmost layer is dominated by *Hopea parviflora* and *V. indica,* the intermediate layer by *Holigarna arnottiana* and *Xylia xylocarpa* and the lower layer by *Aporosa lindleyana* and *Psychotria dalzelli.* The forest has a *Hopea–Vateria* association with a preponderance of *H. ponga.* According to Shivaprasad *et al.* (2000), *H. ponga* has a very wide distribution. A few larger trees are associated with woody climbers. Epiphytes are restricted to a few orchid species on the trunks. These factors indicate that this forest belongs to the category of secondary semi-evergreen forests of the west coast secondary evergreen dipterocarp forests of Champion and Seth (1968).

Shivaprasad *et al.* (2001) reported the stratification in Pilarkan reserve forest of the same district which is also a result of massive plantings earlier. But only three structural ensembles could be observed in this forest. The presence of stratification in Pilarkan reserve forest according to them may be because of the fact that the forest is considered a sacred grove and cutting is prohibited. Stratification of layers of vegetation has been observed in most Southeast Asian dipterocarp forests (Richards 1981, Manokaran *et al.* 1992, Manokaran & Swaine 1994). According to them, a typical dipterocarp forest will have a top layer with the biggest trees, the emergents form a discontinuous layer dominated by the members of the Dipterocarpaceae with an average height of about 38 m. There are four structural ensembles in Jadkal forest representing almost 13% of the total individuals.

Although Jadkal forest is classified as reserve forest, illegal felling is being practised. Normally, young trees are cut by the locals for the purpose of firewood, furniture, etc., and thus a large number of seedlings are only being retained under

the thick canopy of the mature trees. The presence of a large number of established seedlings of *Aglaia lawii, Entada pusaetha, Hopea parviflora, H. ponga, Memecylon talbotianum, Psychotria dalzelli,* etc. suggests that the forest is of secondary semi-evergreen type and there is no indication of transformation into evergreen type as is seen in Pilarkan reserve forest (Shivaprasad *et al.* 2001). On the basis of observation of Southeast Asian dipterocarp forests, Manokaran (1995) concluded that there will be less scope for transformation in the absence of large perturbations.

The Simpson's index value for Bhagavathi forest was 0.70, for Andar reserve forest 0.78, for Naravi reserve forest 0.87, for Magod and Attapadi reserve forests 0.90 (Pascal 1988), and for Kadamakal reserve forest 0.93 (Elourd *et al.* 1993). The Simpson's index value for Jadkal forest (0.95) indicates a fairly high floristic richness of the forest. This is again confirmed by the number of species (103) present in the sampling plot.

According to Proctor *et al.* (1983) the diversity of Gunung Mulu National Park, Sarawak, was 678 individuals ha^{-1}. In the semi-evergreen forests of Kalrayan Hills, India, it was 516 individuals ha^{-1} (Kadavul & Parthasarathy 1999). In Omo forest reserve, southwest Nigeria, the density was 312 individuals ha^{-1} (Okali & Ola Adams 1997). In the present study the density of forest was 1682 individuals ha^{-1} which is moderately high when compared with the forests studied elsewhere. However, in the primary lowland dipterocarp forest at Danum Valley, Sabah, Malaysia, Newbery *et al.* (1992) reported 2248 individuals ha^{-1} and in the rain forests of Bajo Calima, Choco region, western Colombia, the density of the forest was 3094 individuals ha^{-1} (Faber-Langendoen & Gentry 1991).

The stand density of Bajo Calima, Choco region, western Colombia, was 28.89 $m^2 ha^{-1}$ (Faber-Langendoen & Gentry 1991), and that of lowland dipterocarp forest at Danum Valley, Sabah, Malaysia, was 30.7 $m^2 ha^{-1}$ (Newbery *et al.* 1992). The stand density of Gunung Mulu National Park, Sarawak, was 38.6 $m^2 ha^{-1}$ (Proctor *et al.* 1983), that of Cat Tien National Park, Vietnam, was 43.3 $m^2 ha^{-1}$ (Bonadie & Bacon 1999). In the present study the stand density was 60.78 $m^2 ha^{-1}$ which is fairly high when compared with the other forests studied.

There is good regeneration in the forest. The dense forest canopy with fewer gaps which acts as a blanket providing shaded conditions and a cool environment may be the reason for the high germination percentage in the forest. A good regeneration has been observed by Lal *et al.* (1994) in the sal forest of Bankura north forest division, West Bengal, India. The seedlings usually accumulate near the parent trees for lack of their proper dispersal in the forest. The inefficient seed dispersal mechanism and poor dormancy are the reasons for gregarious formations of these species in the Western Ghats (Muralikrishna & Chandrashekar 1997). The present observation revealed that most of the mature trees are represented as seedlings which indicates that there is unlikely transformation of this forest. In East Kalimantan, Indonesia, Riswan (1982) observed the contrast between adult and juvenile species compositions indicating the changes in the future composition in the canopy.

The straight boles of dipterocarps in this forest may have silvicultural implications as they are commercially valuable. According to Ashton (1978) the secondary forest can be managed as a productive and sustainable one if the interference by locals is controlled. The conservation of this forest should be made through the awareness of the locals about the importance of the forest. Since this forest consists of about 31% of species endemic to the Western Ghats, it needs to be protected.

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Appendix 1 Plants recorded from Jadkal forest. (* - Endemic to the Western Ghats)

Family	Species
Acanthaceae	**Asystasia dalzelliana* Santapau
Anacardiaceae	**Holigarna arnottiana* Hook. f.
	**H. ferruginea* Marchand
	Mangifera indica L.
	Nothopegia racemosa (Dalz.) Ramam.
Ancistrocladaceae	*Ancistrocladus heyneanus* Wall.
Anonaceae	**Polyalthia fragrans* Beddome
	Uvaria narum Wallich
Apocynaccae	*Alstonia scholaris* (L.) R. Br.
	Holarrhina pubescens (Buch.-Ham.)Wallich ex G. Don
	**Tabernaemontana heyneana* Wallich
Araceae	*Pothos scandens* L.
Arecaceae	*Calamus thwaitesii* Becc. & Hook. f.
	Caryota urens L.
Asteraccae	*Chromolaena odorata* (L.) King & Robinson
Clusiaceae	**Calophyllum apetalum* Willd.
	Garcinia gummi-gutta Desr.
	**G. indica* (Thouars) Choisy
	G. morella (Gaertn.) Desr.
	Mammea suriga (Roxb.) Kosterm.
Combretaceae	*Calycopteris floribunda* Lam.
	Combretum latifolium Blume
	Terminalia bellirica Roxb.
	T. paniculata Roth
	T. tomentosa Wight & Arn.
Convolvulaccae	*Ipomea* sp.
Dilleniaceae	*Dillenia pentagyna* Roxb.
Dipterocarpaceae	**Dipterocarpus indicus* Beddome
	**Hopea parviflora* Beddome
	**H. ponga (Dennst.)* Mabb.
	**Vateria indica* L.
Ebenaceae	*Diospyros buxifolia* (Blume) Hiern
	**D. paniculata* Dalz.
	**D. saldanhae* Kosterm.
Elaeocarpaceae	*Elaeocarpus serratus* L.
	E. tuberculatus Roxb.
Euphorbiaceae	*Aporosa lindleyana* (Wight) Baillon
	Croton sp.
	Macaranga peltata (Roxb.) Muell.-Arg.
	Mallotus philippensis (Lam.) Muell.-Arg.
	Phyllanthus emblica L.
Fabaceae	*Acacia pennata* (Lour.) Merr.
	A. sinuata (L.) Willd.
	Albizia chinensis (Osbeck) Merr.
	Bauhinia variegata L.
	Cassia fistula L.
	Dalbergia latifolia Roxb.
	Entada pusaetha DC.
	Xylia xylocarpa (Roxb.) Taub.
Flacourtiaceae	**Flacourtia montana* Graham
	**Hydnocarpus pentandra* (Buch.-Ham.) Oken
Gnetaceae	*Gnetum ula* Brogn.
Lauraceae	**Actinodaphne malabarica* Balak.
	**Cinnamomum malabatrum* (Burm. f.) Blume
	Persea macrantha (Nees) Kosterm.
Lecithydaceae	*Careya arborea* Roxb.
Leeaceae	*Leea indica* L.
Liliaceae	*Smilax zeylanica* L.

(continued)

(Appendix 1 - continued)

Family	Species
Loganiaceae	*Strychnos colubrina* C. B.Clarke
	S. nux-vomica L.
Lygodiaceae	*Lygodium* sp.
Lythraceae	**Lagerstroemia microcarpa* Wight.
Melastomataceae	**Memecylon malabaricum* (C.B.Clarke) Cogn.
	**M. talbotianum* Brandis
	**M. terminale* Dalz.
Meliaceae	**Aglaia lawii* (Wight) Saldanha
Menispermaceae	*Cyclea peltata* (Lam.) Hook. f. & Thomson
Moraceae	**Artocarpus hirsutus* L.
	Ficus amplissima Smith
Myristicaceae	**Gymnacranthera farquhariana* (Hook.f. &Thomson) Warb.
Myrtaceae	*Syzygium caryophyllatum* Gaertner
	Syzygium sp.
Oleaceae	*Chionanthus malabaricus* (G. Don) Beddome
	**Jasminum malabaricum* Wight
	Olea dioica Roxb.
Piperaceae	*Piper* sp.
Poaceae	**Bambusa arundinacea* Willd.
	**Ochlandra travancorica* (Bedd.) Gamble
Pteridaceae	*Pteris* sp.
Rhamnaceae	*Ziziphus mauritiana* Lam.
	Z. rugosa Lam.
Rhizophoraceae	*Carallia brachiata* (Lour.) Merr.
Rubiaceae	**Ixora brachiata* Roxb.
	I. coccinea L.
	**I. polyantha* Wight
	Mussaenda frondosa L.
	**Psychotria dalzelli* Hook. f.
	**P. flavida* Talbot
	Randia sp.
Rutaceae	*Murraya* sp.
	Naringi crenulata (Roxb.) Nicolson
	**Vepris bilocularis* (Wight & Arn.) Engl.
	Zanthoxylum rhetsa DC.
Sapindaceae	*Sapindus laurifolia* Vahl
	Schleichera oleosa (Lour.) Oken
Sapotacea	*Madhuca neriifolia* (Moon.) Lam.
	Mimusops elengi L.
Simaroubaceae	*Ailanthus malabarica* DC.
Sterculiaceae	*Pterospermum diversifolium* Blume
	Sterculia guttata Roxb.
Verbenaceae	*Clerodendrum viscosum* Vent..
	Vitex altissima L. f.
Zingiberaceae	*Curcuma* sp.