# STUDIES ON THE STRUCTURE OF PILARKAN RESERVE FOREST, INDIA

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**SHIVAPRASAD, P. V., VASANTHRAJ, B. K. & CHANDRASHEKAR, K. R. 2002. Studies on the structure of Pilarkan Reserve Forest, India.** Structural studies were carried out at Pilarkan Reserve Forest, a secondary forest in Udupi District of Karnataka. In the 3000 $m^2$ study area, 27 tree species with gbh > 10 cm were recorded, out of which 11 species were endemic to the Western Ghats. The forest was homogeneous with the dominance of *Hopea parviflora* of Dipterocarpaceae. Canopy characters were unique and there is a gradual change in the forest composition towards evergreen. This secondary forest is a good example of the involvement of local people in conservation. The high stand density and straight boles of *H. parviflora* were remarkable for such a forest which lies in the center of a more or less degraded inland plateau of coastal Karnataka.

Key words: Dipterocarps - structure - density - canopy

**SHIVAPRASAD, P. V., VASANTHRAJ, B. K. & CHANDRASHEKAR, K. R. 2002. Kajian mengenai struktur Hutan Simpan Pilarkan, India.** Kajian struktur dijalankan di Hutan Simpan Pilarkan, iaitu hutan sekunder di Daerah Udupi, Karnataka. Di kawasan kajian seluas 3000 $m^2$, 27 spesies pokok berlilitan aras dada > 10 cm dicatatkan. Daripada jumlah ini 11 spesies adalah endemik di Ghat Barat. Hutan tersebut adalah homogen dan spesies dominannya ialah *Hopea parviflora* daripada Dipterocarpaceae. Ciri-ciri kanopi adalah unik dan komposisi hutan berubah beransur-ansur kepada hutan malar hijau. Hutan sekunder ini merupakan contoh yang baik bagi menunjukkan penglibatan penduduk tempatan dalam pemuliharaan hutan. Ketumpatan dirian yang tinggi dan batang yang lurus *H. parviflora* sungguh menarik bagi hutan tersebut yang terletak di tengah-tengah penara pedalaman yang ternyahgred di pantai Karnataka.

## Introduction

The characteristic features of secondary evergreen or semi-evergreen forests are the preservation of a dense cover and structure, which are very similar to the initial climax forest but lacking the characteristic species of the initial climax forest (Pascal 1988). These forests, found in regions where anthropogenic pressure was initially very high, were protected after they were designated as reserve forests. In India, one such secondary forest is the Pilarkan Reserve Forest (74° 51' E and 13°12' N), covering an area of 124.32 hectares situated 3 km south-east of Shirva in Udupi District of Karnataka (Figure 1).

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The vegetation in this reserve forest is dominated by *Hopea parviflora*, a semi-evergreen type. Bhat (1993) reported 160 species of angiosperms belonging to 135 genera and 75 families as well as the soil and climatic characteristics of this reserve forest. The soil is lateritic with an underlying rock of peninsular gneiss. The climate is of wet monsoon type with an annual rainfall of about 3500 mm. This reserve forest is partly natural and partly the result of massive planting of *H. parviflora* and other species after the First World War (Bhat 1993).

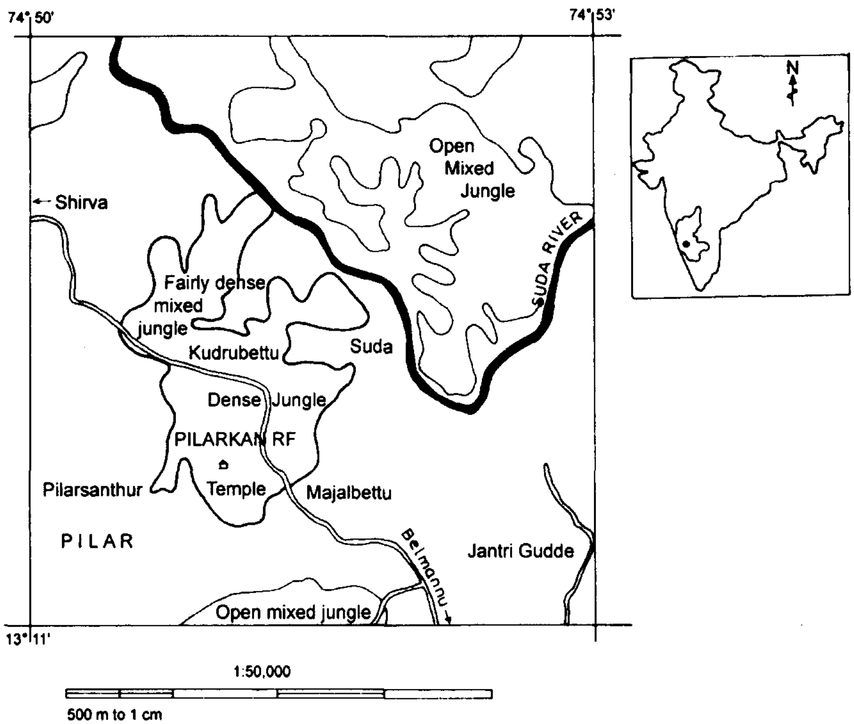


**Figure 1** Location map of Pilarkan Reserve Forest

## Materials and methods

### *Sampling area*

The entire reserve forest comes under a *kan* or *Devara kadu* (sacred grove) containing a small temple in the middle. The people around this forest consider this forest a sacred place and they are against any felling of trees. They strongly believe that any felling inside the forest will result in unforecastable happenings. There is a small stream in the middle of the forest which dries up during the summer. There are fewer number of trees towards the exterior, which may be due to the collection of dry leaves and branches, which is permitted to the locals.

### *Field work*

Three transects each covering an area of 1000 $m^2$ were laid in such a way so as to include the areas with variation in the density and were divided into 25 plots of 10 × 4 m. In these plots, all the individuals having a girth of 10 cm at breast height (1.33 m) were identified according to Gamble (1921–1935) as well as Pascal and Ramesh (1987). Heights of these trees were measured using a clinometer. The 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 the status of regeneration. The voucher specimens of the plants bearing flowers were collected and deposited in the herbarium of the Department of Applied Botany, Mangalore University, Mangalagangotri.

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

### *Analysis of data*

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

The number of individuals of different gbh 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 0.3 ha according to Pascal (1988).

The density ($n_i$) of each species was recorded by counting the total number of individuals. The frequency (f) was determined by using the following formula:

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

where

$c_i$ = number of quadrats in which the species was present and

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 by using the formula:

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

where
f = frequency of the species and
F = $\Sigma$f.

Relative density (rD) was calculated by using the formula

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

where
$n_i$ = number of individuals of species i and
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 individuals of the species and
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 index (FIV) for botanical families were calculated by adding the IVI for different species of the same family. The floristic diversity was measured by 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 and
S = number of species in the plot

and Shannon-Wiener's index:

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

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

### *Canopy characteristics*

The canopy of this forest was made up of three layers without any "emergents" (the solitary individuals which grow above the canopy) (Figure 2). The absence of emergents was re-confirmed by plotting height vs. gbh (Figure 3). The upper-most layer was dense and continuous which, unlike a primary forest, normally did not exceed 25–30 m height. This suggested that the whole forest was planted earlier. The upper canopy was made up of trees with massive canopies like that of *H. parviflora*, *Vateria indica*, *Artocarpus hirsutus* and *Syzygium cumini*. The intermediate layer was characteristically poor. The lower storey was dense and visually clear. This contained very large number of growing trees and bushy under-growth, which was dense near the stream. Mosses were present and abundant only in the boles of *H. parviflora*.

The canopy projection diagram indicates that the canopy of *H. parviflora* was massive, occupying nearly 60% area in the sample plot (Figure 4).

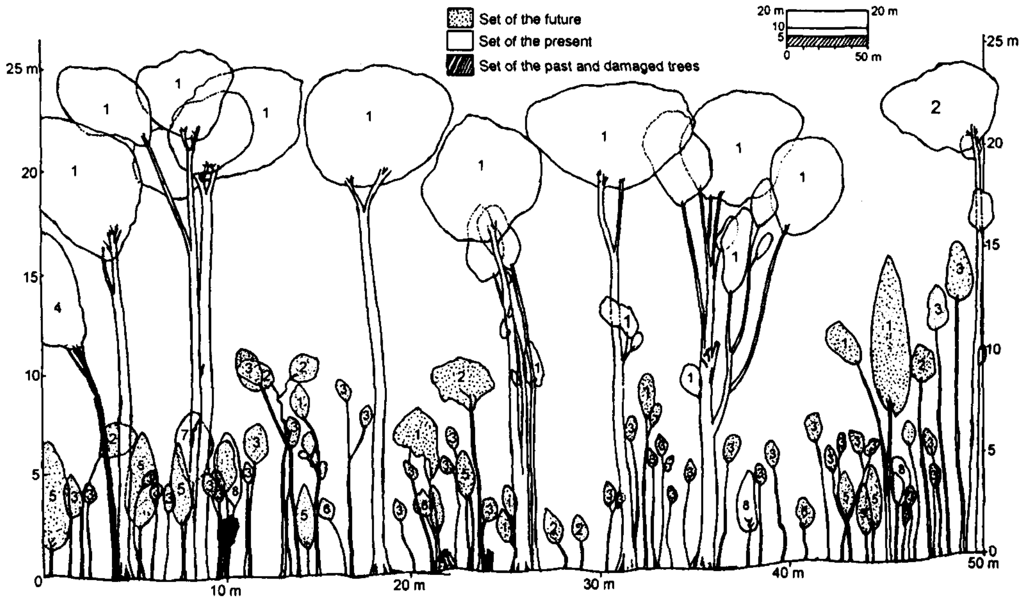


**Figure 2** Profile diagram of Pilarkan Reserve Forest

The tree species shown are 1 = *Hopea parviflora* 2 = *Artocarpus hirsutus*, 3 = *Diospyros buxifolia*, 4 = *Syzygium cumini*, 5 = *Knema attenuata*, 6 = *Holigarna ferruginea*, 7 = *Myristica malabarica* and 8 = *Garcinia morella*

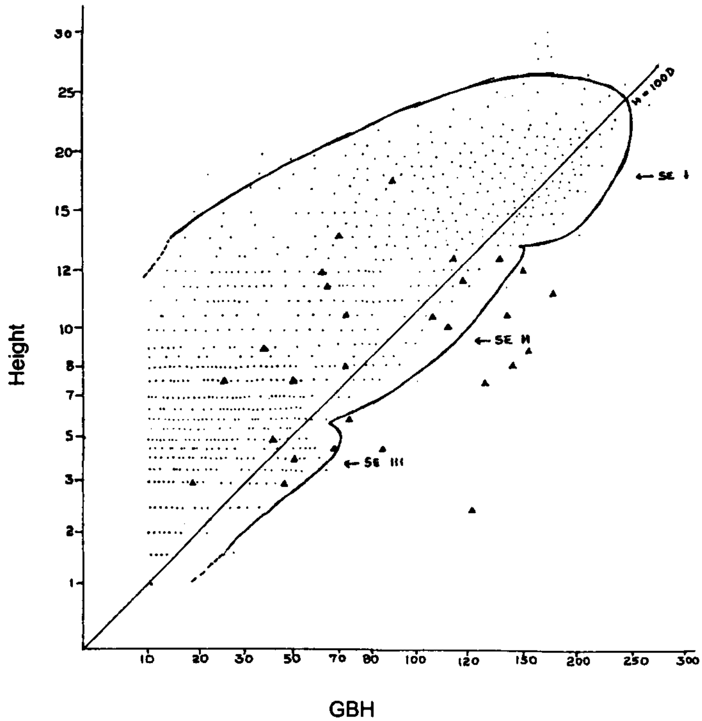


**Figure 3** Height vs. gbh graph of Pilarkan Reserve forest

SE I = Structural ensemble I, SE II = Structural ensemble II
SE III = Structural ensemble III, • = Set of the future and present
▲ = Dead and damaged individuals.

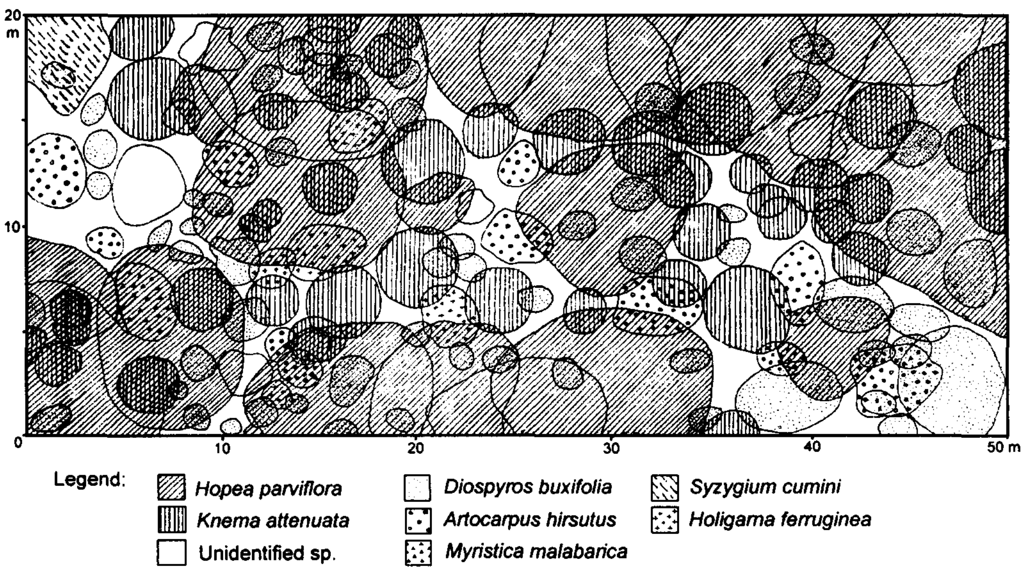


**Figure 4** Canopy projection diagram of Pilarkan Reserve Forest

### *Importance value index*

The IVI of *H. parviflora* (80.66) was highest in this reserve forest followed by *Diospyros buxifolia* (IVI = 61.72), *A. hirsutus* (IVI = 26.92) and *V. indica* (IVI = 26.16) (Table 1). Three other species showed an IVI range of 13.23–21.25 while 20 species showed IVI less than 10. The FIV of Dipterocarpaceae was 109.8, followed by Ebenaceae with 63.4, Moraceae (28.0) and Myristicaceae (25.6) (Table 2).

**Table 1** The frequency (f), density ($n_i$), dominance (d), relative frequency (rf), relative density (rD), relative dominance (rd), and importance value index (IVI) of Pilarkan Reserve Forest

| Species name | f | $n_i$ | d | rf | rD | rd | IVI |
|---|---|---|---|---|---|---|---|
| *Hopea parviflora* * | 74.00 | 138 | 9.786 | 14.770 | 15.628 | 50.260 | 80.658 |
| *Diospyros buxifolia* | 97.33 | 315 | 1.389 | 18.914 | 35.674 | 7.133 | 61.721 |
| *Artocarpus hirsutus* * | 62.66 | 85 | 0.996 | 12.177 | 9.626 | 5.115 | 26.918 |
| *Vateria indica* * | 18.66 | 30 | 3.725 | 3.626 | 3.398 | 19.131 | 26.155 |
| *Knema attenuata* * | 44.00 | 98 | 0.311 | 8.550 | 11.099 | 1.597 | 21.246 |
| *Holigarna ferruginea* * | 26.66 | 26 | 1.048 | 5.181 | 2.945 | 5.382 | 13.508 |
| *Flocourtia montana* * | 40.00 | 41 | 0.158 | 7.773 | 4.643 | 0.811 | 13.227 |
| *Ixora brachiata* * | 20.00 | 23 | 0.029 | 3.890 | 2.605 | 0.149 | 6.644 |
| *Garcinia morella* | 18.66 | 24 | 0.045 | 3.626 | 2.718 | 0.231 | 6.575 |
| *Syzygium* sp. | 10.66 | 9 | 0.364 | 2.071 | 1.019 | 1.869 | 4.959 |
| *Aporosa lindleyana* | 13.33 | 11 | 0.104 | 2.590 | 1.246 | 0.534 | 4.370 |
| *Myristica malabarica* * | 10.66 | 9 | 0.238 | 2.071 | 1.019 | 1.222 | 4.312 |
| *Syzygium cumini* | 4.00 | 3 | 0.545 | 0.780 | 0.340 | 2.799 | 3.919 |
| *Hopea ponga* * | 9.33 | 11 | 0.015 | 1.813 | 1.246 | 0.077 | 3.136 |
| *Madhuca neerifolia* | 8.00 | 8 | 0.011 | 1.554 | 0.906 | 0.056 | 2.516 |
| Climber | 5.33 | 5 | 0.015 | 1.035 | 0.566 | 0.077 | 1.678 |
| *Diospyros paniculata* * | 5.33 | 5 | 0.009 | 1.035 | 0.566 | 0.046 | 1.647 |
| *Alstonia scholaris* | 2.66 | 2 | 0.125 | 0.517 | 0.227 | 0.642 | 1.386 |
| *Gnetum ula* | 2.66 | 6 | 0.037 | 0.517 | 0.680 | 0.190 | 1.387 |
| *Naringi crenulata* | 2.66 | 6 | 0.012 | 0.517 | 0.680 | 0.061 | 1.258 |
| *Caryota urens* | 4.00 | 3 | 0.013 | 0.780 | 0.340 | 0.066 | 1.186 |
| *Ficus* sp. | 1.33 | 1 | 0.119 | 0.258 | 0.113 | 0.611 | 0.982 |
| *Mimusops elengi* | 1.33 | 2 | 0.011 | 0.258 | 0.227 | 0.056 | 0.541 |
| *Pterospermum diversifolium* | 1.33 | 1 | 0.026 | 0.258 | 0.113 | 0.133 | 0.504 |
| *Vitex altissima* | 1.33 | 1 | 0.018 | 0.258 | 0.113 | 0.092 | 0.463 |
| *Olea dioica* | 1.33 | 1 | 0.009 | 0.258 | 0.113 | 0.046 | 0.417 |
| *Hydnocarpus pentandra* * | 1.33 | 1 | 0.001 | 0.258 | 0.113 | 0.005 | 0.376 |
| Unidentified | 12.00 | 9 | 0.134 | 2.332 | 1.019 | 0.690 | 4.041 |
| Dead | 12.00 | 9 | 0.179 | 2.332 | 1.019 | 0.919 | 4.270 |
| Total | 514.57 | 883 | 19.471 | | | | |

* Endemic species
The data are for 0.3 ha of the forest

### *Structural ensembles*

Three structural ensembles (SE) can be marked from the height-gbh graph (Figure 3). SE I contained mostly the tall trees including *H. parviflora, A. hirsutus* and *V. indica.* Emergents were absent. Some trees of the future set such as *D. buxifolia* and *Knema attenuata* had thin stems (< 20 cm gbh) and were comparatively taller (7–12 m). These showed that the upper canopy was very thick, causing young trees to grow quickly in order to attain the level of the upper canopy. The low representation of *H. parviflora* in the girth classes below 20 cm suggested poor regeneration of this species in the recent past. Interestingly, there was rapid increase in the density of *D. buxifolia* and *K. attenuata* in the recent past, which were fairly well represented in the girth classes below 20 cm.

## *Density*

A total of 883 individuals were recorded in the study area (Table 1). *Diospyros buxifolia* was represented by 315 individuals, *H. parviflora* by 138 individuals and *K. attenuata* by 98 individuals. Out of these 175 individuals of *D. buxifolia,* 7 individuals of *H. parviflora* and 26 of *K. attenuata* belonged to the set of the future with < 6 m height. These species, which could establish themselves in shaded condition, regenerated quickly and attained high density. This suggested that evergreen species were replacing the forest. Nearly half of the total individuals belonged to *H. parviflora* and *D. buxifolia.* This is quite interesting because *H. parviflora,* with its massive and scattered canopy, was associated with *D. buxifolia,* which had a tiny, but thick canopy. It should be noted that these two species occured in different strata.

**Table 2** Family importance value index (FIV) of families in Pilarkan Reserve Forest

| Family | No. of species | FIV |
|---|---|---|
| Dipterocarpaceae | 3 | 109.75 |
| Ebenaceae | 2 | 63.41 |
| Moraceae | 2 | 27.96 |
| Myristicaceae | 2 | 25.58 |
| Flacourtiaceae | 2 | 13.62 |
| Anacardiaceae | 1 | 13.52 |
| Myrtaceae | 2 | 8.88 |
| Rubiaceae | 1 | 6.65 |
| Clusiaceae | 1 | 6.59 |
| Euphorbiaceae | 1 | 4.38 |
| Sapotaceae | 2 | 3.06 |
| Apocynaceae | 1 | 1.39 |
| Gnetaceae | 1 | 1.39 |
| Rutaceae | 1 | 1.26 |
| Arecaceae | 1 | 1.18 |
| Sterculiaceae | 1 | 0.50 |
| Verbenaceae | 1 | 0.46 |
| Oleaceae | 1 | 0.42 |

### *Floristic richness*

The indices of floristic diversity are given in Table 3. The high value of Simpson's index indicated that out of every 100 pairs of individuals taken randomly, 19 will be of the same species. However, this is less compared to those obtained by Pascal (1988) in the climax forests of Karnataka. The N/S (number of individuals in the plot/number of species) value obtained in this study was very high, being 32.7. Shannon-Wiener's index (H'= 3.25) was quite low. The equitability ratio (E = 0.67) was moderate.

**Table 3** Diversity indices of Pilarkan Reserve Forest

| Area ($m^2$) | Number of species = S (gbh ≥ 10 cm) | Number of individuals = N (gbh ≥ 10 cm) | N/S | Simpson's index | Shannon-Wiener's Index H' | $H_{max}$ | $E = H'/H_{max}$ |
|---|---|---|---|---|---|---|---|
| 3000 | 27 | 883 | 32.7 | 0.81 | 3.25 | 4.85 | 0.67 |

### *Stand density*

The total stand density of this reserve forest was approximately 64.89 $m^2$ $ha^{-1}$ (2943 individuals $ha^{-1}$). Of these, members of Dipterocarpaceae constituted nearly 75% (approximately 45.08 $m^2$ $ha^{-1}$ with 597 individuals $ha^{-1}$), which was very high compared to the planted forests of Jadkal, inside the Mookambika Wild Life Sanctuary. *Hopea parviflora* alone represented a stand density of approximately 32.62 $m^2$ $ha^{-1}$ (460 individuals $ha^{-1}$).

### *Height and gbh classes*

Nearly three quarters of the individuals were within 1–8 m height range and nearly half of the individuals were within the range of 4–8 m (Table 4). Only 10% of the individuals were under the height classes above 20 m. Most of these belong to Dipterocarpaceae.

More than half of the individuals were in the gbh range of 10–20 cm (Table 5). Nearly one third of the individuals came under the gbh range 20–60 cm. There was a sharp decrease in the number of individuals as girth increased. This suggested that the forest was of regenerating type especially when a larger number of plants belonged to the set of future. The gbh classes above 200 cm contained mostly the individuals of *H. parviflora* and *V. indica*. This was the main reason for the high stand density of dipterocarps in this forest.

**Table 4** Height classes and density of Pilarkan Reserve Forest

| Height class | Range (m) | No. of individuals | Percentage |
|---|---|---|---|
| 1 | 1–4 | 243 | 27.5 |
| 2 | > 4–8 | 381 | 43.1 |
| 3 | > 8–12 | 116 | 13.1 |
| 4 | > 12–16 | 27 | 3.0 |
| 5 | > 16–20 | 26 | 2.9 |
| 6 | > 20–24 | 37 | 4.2 |
| 7 | > 24–28 | 24 | 2.7 |
| 8 | > 28–32 | 20 | 2.3 |
| 9 | > 32–36 | 4 | 0.5 |

**Table 5** Gbh classes and density of Pilarkan Reserve Forest

| Gbh class | Range (cm) | No. of individuals | Percentage |
|---|---|---|---|
| 1 | > 10–20 | 466 | 52.8 |
| 2 | > 20–60 | 302 | 34.2 |
| 3 | > 60–100 | 59 | 6.7 |
| 4 | > 100–140 | 27 | 3.1 |
| 5 | > 140–180 | 17 | 1.9 |
| 6 | > 180–220 | 12 | 1.4 |
| 7 | > 220 | 5 | 0.6 |

### *Regeneration*

*Ixora* species (*I. brachiata, I. coccinea* and *I. polyantha*) accounted for nearly 8% of seedlings and individuals with < 10 cm gbh in the study area. Seedlings of *Psychotria* species were numerous, about 28%. Seedlings of *D. buxifolia* and *K. attenuata* together constituted about 11%. The dominant tree species of the forest, *H. parviflora* constituted only about 2% (results not shown). The reasons for the poor regeneration of this species are discussed elsewhere (Shivaprasad *et al.* 1999). Interestingly, there were so much less climbers having a girth of > 10 cm, both in terms of species richness and density. Also there were very few canopy openings due to tree fall (chablis) and hence the small number of heliophytes. This may be another reason for the homogeneity of this forest other than planting.

## Discussion

The canopy of the primary dipterocarp forests of Southeast Asia usually consists of four to six layers (Richards 1981). According to the author the height of the uppermost storey in these forests extends up to 60 m. In Pilarkan Researve Forest, the height of canopy was 25 to 30 m with no emergents. There was less stratification compared to the primary forests. These differences in structure may be due to massive plantings carried out earlier. Even though the density of *D. buxifolia* was very high, there were very few mature trees of this species in this forest. However, the high number of established seedlings and young trees of few evergreen species including *D. buxifolia*, suggested the gradual transformation of this forest. The present transformation of this forest from semi-evergreen to evergreen indicated that this forest was still not stable. Stability may be possible only when all the evergreen species dominate the entire forest. This calls for the replacement of *H. parviflora*. It is difficult to conclude at this stage whether or not the high stand density and dominance of *H. parviflora* was due to the edaphic climax brought about by the earlier felling, since we do not know the details of earlier planting.

The boles of the species which were planted earlier were straight. This may have silvicultural implications since straight boles are commercially valuable. Few assume that secondary forests can be managed as a productive, sustainable wood crop (Ashton 1978). The nature of growth and development of different tree species of this reserve forest, under thick canopy and under open area, needs to be investigated.

The Pilarkan Reserve Forest is a good example of the involvement of local people in conservation. The concept of sacred groves has definitely helped to conserve a vast area in the middle of a more or less degraded inland plateau of this coastal district, which is witnessing major changes due to rapid industrialisation.

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