Assessment of Forest Biological Diversity. A FAO training course. 2- Case study in India

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PONDY PAPERS IN ECOLOGY

ASSESSMENT OF FOREST BIOLOGICAL DIVERSITY

A FAO TRAINING COURSE

2. CASE STUDY IN INDIA

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Table of contents

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Summary

This booklet is based on data collected mainly during a FAO Training Programme entitled "Assessment of forest biological diversity" conducted at the French Institute of Pondicherry. The aim of this programme was to impart training to foresters from three Southeast Asian countries (Vietnam, Laos and Cambodia) on biodiversity assessment. The field-work and data collection were undertaken by the trainees in three forest types, viz., evergreen, moist deciduous and dry deciduous forests, in Karnataka, South India. Three methods were used: establishment of a single plot of 40x40 m, cluster of 20x20 m plots and cluster of variable-area plots.

The field-work was done with the following objectives:

- Demonstrate the use of tools to characterise and assess a forest stand: height, girth, biovolume, density, basal area, population stages of trees, saplings and seedlings, species richness estimator (Chao) and species diversity indices (Simpson and Shannon);
- Compare the methods used in the three habitat types sampled and get a proper choice of the method and tools to use that would be more appropriate for an assessment of the forest stand studied.

The analyses on the structure and characteristics of the population and on the species richness and diversity were based on the data collected in the field. The results of this case study have been compiled in this booklet as a reminder of the analyses that can be done to assess the structure and biodiversity of a forest stand. This report does not aim to give an assessment of the biological diversity in these three different forests, as the sampling was not done thoroughly, due to time constraints within the frame of the Training Programme.

Introduction

The field training presented here was part of a FAO training programme entitled "Assessment of forest biological diversity" conducted at the French Institute of Pondicherry. The objective of this programme was to impart training to foresters from three Southeast Asian countries (Vietnam, Laos and Cambodia) on diversity assessment. Part of the programme was theoretical, while field-work involved the application of methods to assess diversity. Five days were devoted to field-work, with a stop-over at Bangalore for meetings with the Karnataka Forest Department and Survey of India.

The field work and data collection were undertaken in three forest types, viz., evergreen, moist deciduous and dry deciduous forests, in Karnataka, South India. The evergreen forest type is located in Makut Reserve Forest, Kodagu (Coorg) District; the moist deciduous and dry deciduous forests are located in Bandipur National Park, Mysore District.

The participants of the training programme were divided into two groups: one group worked in Makut Reserve Forest to collect data on the evergreen forest type, and the other in Bandipur National Park to collect data on the moist deciduous and dry deciduous forest types. Dr. Rani M. Krishnan led the first group 'evergreen' team and Dr. C. Elouard led the second group ('deciduous' team). The data were analyzed in Pondicherry.

From the viewpoint of the participants there were two major limitations: their lack of knowledge of the species in the area (especially in the evergreen forest) and working conditions in the field (including language problem). Despite these, both teams could successfully accomplish the work.

Material and Methods

Data collection

Three methods were used for assessing forest biological richness and diversity and to illustrate and compare the performances of three alternative methods:

- *Single 40x40 m fixed-area plot:* plot which can be established and monitored on a permanent basis;
- *Cluster of 20x20 m plots:* the plots, whose number can vary, can also be established and monitored on a permanent basis;
- *Cluster of variable-area plots* (with a fixed number of individuals): temporary plots lay to assess diversity within a short period of time.

Fixed-area plot method

Measurements may be made only once in a selected area, or can be established permanently with regular assessments within the plot.

Establishment of a single plot 40x40 m (P40 method)

This method was intended for monitoring forest diversity and dynamics in the Agastyamalai region (Southern Western Ghats, South India). One-hectare plots (100x100 m) were established with three replicates for each vegetation type. Due to the short time allocated for field-work, the method was converted to a 1 600 m^2 plot (40x40 m).

The method is as follows:

- The 40x40 m plot is divided into 10x10 m subplots *(Fig. 1);*
- All individuals with gbh ≥30 cm (trees) are located (co-ordinates x and y) within the 40x40 m plot and measured for height and girth;
- All individuals with 30>gbh ≥3 cm (saplings are located in alternate 10x10 m subplots and measured for height and girth;
- In the subplots is laid a 5x5 m quadrat and all individuals with gbh<3 cm (seedlings) are measured for height, and classified into height classes with 20 cm intervals;
- The area covered by grasses, *Strobilanthes,* bamboo and reeds is estimated within this 5x5 m quadrat;
- The slope is measured and all individuals with gbh ≥30 cm in the 40x40 m plot are spatially mapped.

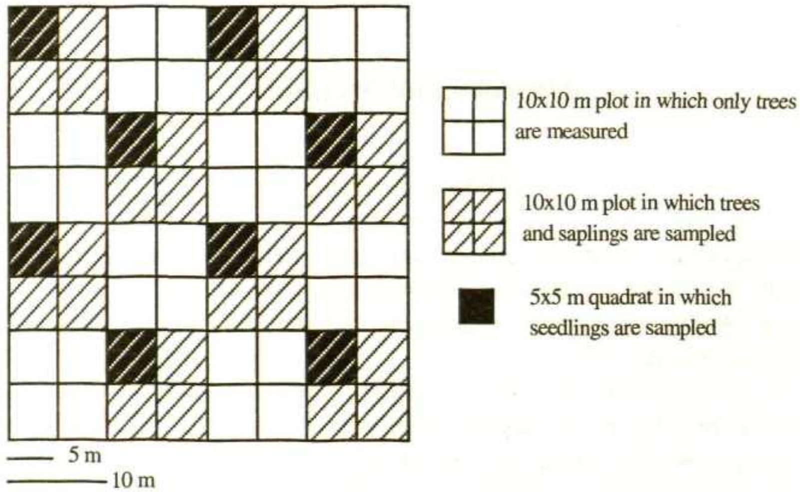


Figure 1.: Sampling protocol of the 40x40 m plot.

Cluster methods

Establishment of a cluster of 20x20 m plots (C20 method)

Using compass, a square is established. Measurement points are made at intervals of 20 m in evergreen forest (thus constituting a continuous band) and 50 m in deciduous forest where variability is less and walking along the boundaries is easier. These measurements refer only to the boundary of the square established. At every measurement point, a 20x20 m plot is established with the following measurements:

- The 20x20 m plots are divided into 10x10 m subplots (*Fig.* 2);
- All individuals with gbh ≥30 cm (trees) are located (co-ordinates X and Y) within the 20x20 m plots and measured for height and girth;
- All individuals with 3 ≤gbh<30 cm (saplings) are located within one 10x10 m subplot and measured for height and girth;
- In the same subplot, a smaller 5x5 m plot is laid and the height of all individuals with gbh<3 cm (seedlings) is measured; they are classified into height classes of 20 cm intervals;
- Within this 5x5 m subplot, the percentage of the area covered by grasses, *Strobilanthes,* bamboo and reeds is estimated in the deciduous forest;
- The slope is measured and all individuals with gbh≥30 cm in the 20x20 m plot are spatially mapped.

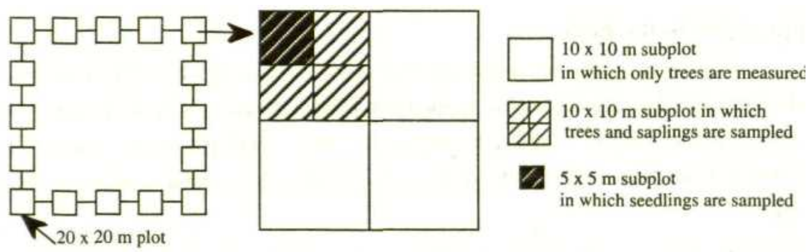


Figure 2. Sampling protocol of the cluster of 20x20 m plots with the sampled subplots.

Establishment of a cluster of variable-area plots (CVA method)

This method, designed by C. Gimaret-Carpentier for assessing diversity in the Western Ghats, is aimed at estimating the diversity in order to identify the trends in species richness and floristic diversity over a large area (minimum 1 ha) within a short period of time (4-5 hours for one vegetation type).

The settling of the sampling area is the same as for the cluster of 20x20 m plots. At each of the 20 measurement points *(Fig. 3),* the nearest 10 trees of gbh≥30 cm and 10 saplings of gbh≥3 cm are identified. The following parameters are enumerated for each tree sapling:

- Species identification;
- Distance of the tree from the point;
- Girth at breast height (gbh), or above buttresses if any;
- Total height;
- Slope angle;
- Altitude;
- Additional parameters such as crown diameter can be also measured.

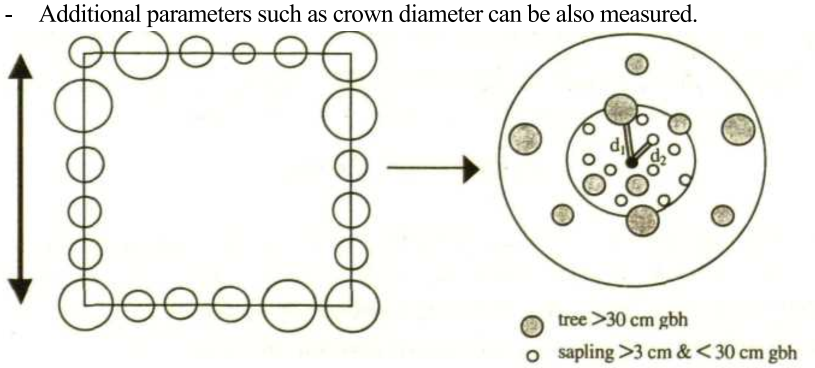


Figure 3. Sampling protocol of the cluster of variable-area plots (d_1 = distance to the 10^{th} tree, d_2= distance to the 10^{th} sapling).

Application in the field

The single 40x40 m plots were established prior to the training course by the French Institute's team. Though established in the same Reserve Forests as the C20 and CVA methods, it was laid in a different area in the Makut Reserve Forest (evergreen vegetation type). This explains the differences found in the vegetation structure and richness.

The 20x20 m and variable-area plots were adjusted to the field conditions: each team had to experiment both methods within a few days. Therefore, the total number of measurement points — which should be at least 20 according to the method — was reduced to 9 in the evergreen and moist deciduous forests and 4 in the dry deciduous forest. The area therefore varied in between the forest types and methods (Table 1).

Table 1. Number of plots and areas within each sampling method used for the study.

Methods	40x40 m plot		Cluster 20x20 m plots		Cluster variable areas	
Forest types	Nb plots	Area (m^2)	Nb plots	Area (m^2)	Nb plots	Area (m^2)
Evergreen	1	1600	9	3600	9	1769
Moist deciduous	1	1600	9	3600	9	2728
Dry deciduous	1	1600	4	1600	4	1816

The 20x20 m plots and the variable-area plots were set up at the same spots in order to facilitate comparisons between the two methods *(Fig. 4).*

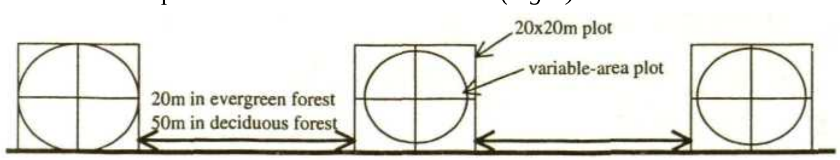


Figure 4. Application and combination of the two methods.

Organisation of data

The data were entered and analyzed using Microsoft Excel. Spreadsheets were used to enter the data of each forest type, with separate spreadsheets for trees (gbh≥30 cm), saplings (3≤gbh<30 cm) and seedlings (gbh<3 cm).

Height and girth data of trees and saplings were divided into classes.

Data analysis

Structural analysis was made for all the forest types with the tree data (gbh≥30 cm). Diversity was analyzed separately for the trees, saplings and seedlings of the C20 method and for only trees and saplings for the CVA method (seedlings are not measured in this method).

Structural analysis

Structural analysis involves basal area, biovolume, density, girth and height distribution among the trees, height-diameter relationships with representation of the past, present and future populations of evergreen trees for data obtained from both fixed-area plot and cluster methods. The past population is represented by old trees (growth in height completed and growth in girth slowed down); the present population gathers the natural trees whose growth in height is mostly completed (they have reached their strata level), still growing in girth; the future population is represented by young trees who first grow in height to reach their strata level before growing in girth. The data were analyzed as follows:

- ***Frequency histograms*** for height and girth classes;
- ***Height and diameter relationship*** following Oldeman (1984) method plotting h=100d. The girth (gbh) is converted into diameter (dbh) using the formula $dbh\text{-}gbh/\pi$.

The ratio h/d will be over 100 for future populations, below 100 for present populations and far below 100 for past populations. This relationship was designed for evergreen forests and cannot be applied for deciduous forests, as the ratio is different (smaller trees).

Basal area: $C^2/4\pi\,(C = gbh)$

It corresponds to the sum of the cross sectional area of trees measured;

- ***Biovolume:*** d^2h estimated by non-destructive method.

Diversity analysis

Different estimators and indices can be used for assessing species richness and diversity. The aim of this study was to give simple and reliable tools for foresters to be used in the forest inventories. The data were collected with this aim; it is obvious that these data cannot be used to test the estimators and indices or to assess the forest species richness and diversity, being not sufficient in quantity (a minimum of 1000 trees is requested for diversity assessment in evergreen forest (Gimaret *et al.* 1998)). With reference to analysis already conducted by these authors stating that Chao estimator is better than Jackknife for assessing species richness, while Simpson index is better than Shannon for species diversity. We therefore chose to estimate the species richness with the total number of observed species and Chao estimator, and species diversity with Simpson and Shannon-Wiener indices (Magurran 1988):

- ***Number of observed species***

  The number of species is represented as S_{obs}.

- ***Chao estimator of species richness*** (Chao 1987)

The Chao estimator, who corrects S_{obs} with additional terms by taking the role of rare species into account, was calculated using the formula:

$$S_{Chao} = S_{obs} + a2/2b$$

Where a^2 = number of species represented by 1 individual; b = number of species represented by 2 individuals; S_{obs} = total number of species observed.

- *Simpson index* (Simpson 1949)

The Simpson index is defined as the probability that two individuals randomly and independently selected belongs to the same species.

This index is calculated using the formula:

$$D = \sum_{i=1}^{n} \frac{n_i(n_i - 1)}{N(N-1)}$$

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

The Simpson index can be defined in two ways:

- as λ = 1-D, also called dominance index; it varies between 0 (for a one-species community) and 1-1/S (for an even community composed of *S* species);
- as λ' = 1/D; it varies between 1 (for a one-species community) and *S*.

- ***Shannon index*** (Shannon 1948)

The Shannon diversity index was calculated using the formula:

$$H' = -\sum_{i=1}^{s} p_i . \log_2 p_i$$

Where p_i = probability of a sample individual belonging to species $i(p_i = \frac{n_i}{N})$

For a given species richness S, the maximum value of the Shannon index is obtained when the species distribution is even *(i.e.,* $p_i = 1 / S$, $\max(H') = \log_2 S$*).*

The Evenness value is therefore calculated as follows: E=H'/Hmax.

Study area

Vegetation maps of the two study areas, Bandipur and Makut, were drawn from IRS geocoded false color composite satellite image (1: 50,000 scale) of the area obtained during the dry season. An area of the size of an A4 paper was demarcated on the satellite image so as to include the study area. From these, the major forest types were segregated based on the color contrasts and their boundaries often verified with an earlier map (Pascal 1986) and toposheets. False color composite satellite image on band 123 was visually interpreted. The image was then transferred on to a tracing paper, digitized with different layers of data such as road networks, drainage patterns of streams, forest types, plantations and cultivated area. These information layers were stored in GIS (Geographic Information System, ARC-INFO) from which the final output was obtained as a map. The percentage of area of each forest type was calculated using GIS.Makut. The area covered by the vegetation map is 157.5 km^2 at 1:50,000 scale (Map 1).

Major habitat types

- ***<u>Forests</u>***

  Evergreen forests at low (0-850 m) or medium (650-1400 m) elevation and their degradation stages including:

  a. Disturbed evergreen to semi-evergreen forests

  b. Secondary or highly degraded evergreen to semi-evergreen forests

  c. Thickets

  d. Tree savannah to grass savannah

  - Moist deciduous secondary forests represented by woodland to savannah woodland.

- ***<u>Plantations</u>***
  - Coffee;
  - Rubber;
  - Cardamom;
  - Cultivation.

Proportional area of the forest types

Low elevation dense evergreen forests occupy a large area followed by medium elevation dense evergreen forests. In both, the higher reaches of the slopes have tree savanna to grass savanna. Large areas of medium elevation evergreen forests have been disturbed and converted into cardamom plantations. Away from these plantations, to the evergreen patches have already become highly fragmented and are low in various stages of degradation ending in thickets. Most of these patches have become moist deciduous woodland to savanna woodland. Establishment of plantations and inclusion of the cultivated areas seem to be the major cause for habitat fragmentation. The wetter forest types are more disturbed than the drier ones, especially by plantations and cultivation.

Floristic composition

The low elevation evergreen forests belong to the *Dipterocarpus indicus-Kingiodendron pinnatum-Humboldtia brunonis* type and the medium elevation evergreen forests to the *Mesua ferrea-Palaquium ellipticum* type, as defined by Pascal (1984). The moist deciduous forests are secondary in origin (Pascal 1986). The complete floristic list is given in Appendix.

Bandipur

The area covered by the vegetation map is 150 km^2 at 1:50,000 scale (Map 2). It corresponds to a small part of the Mercara-Mysore sheet of the Western Ghats map series at 1:250,000 scale (Pascal 1986).

Major habitat types

The major types of habitats encountered are the following:

- ***Forests***
  - Dense moist deciduous forest;
  - Moist deciduous forest: woodland to savannah woodland;
  - Dense dry deciduous forest;
  - Dry deciduous forest: woodland to savannah woodland;

  Riparian forest.
- ***Plantations***
  - Coffee;
  - Teak;
  - Eucalyptus;
  - Cultivation.

Proportional area of the forest types

The vegetation in this area is dominated by dry deciduous -woodland to savanna woodland- forest types. Patches of dense evergreen forests are found among these vegetation types. Moist deciduous forests occupy most of the area. Eucalyptus plantations break the continuity of the forest cover. There is a clear separation of the transition from dry deciduous woodland to savanna woodland and from moist deciduous woodland to savanna woodland covering a large area. In some areas, a transition from dense dry deciduous forest to dense moist deciduous forest with riparian evergreen patches is observed. The riparian forests are found in discontinuous patches along the two perennial streams flowing through the area: Nuguhole and Mulehole. Mostly plantations of coffee, teak, eucalyptus and also the cultivated areas significantly deplete the moist deciduous forests. Eucalyptus plantations are the only major habitat modifications encountered in the dry deciduous forests.

Floristic composition

The moist deciduous forests belong to the *Lagerstroemia microcarpa-Tectona grandis-Dillenia pentagyna* type and the dry deciduous forests to the *Anogeissus latifolia-Pterocarpus marsupium-Terminalia* spp. type, as defined by Pascal (1986, 1988). The floristic type of the riparian forest is yet to be determined. The complete floristic list is given in Appendix.

Results

The data were analyzed to summarize the data collection and help interpretation. The main objectives of these analyses were to:

- Demonstrate the use of estimators and indices for the assessment of species richness and diversity;
- Assess the best method to be used in the three habitat types sampled so that richness and diversity are fairly representative of the area sampled.

Structural analysis

The analysis is illustrated here with the example of the tree data collected with the three methods employed in the evergreen, moist deciduous and dry deciduous forest types. The analysis uses the frequency data to understand the distribution of species and individuals across vertical and horizontal space and the application of the relationship between height and girth to understand the structural stratification of the forest.

Evergreen forest

Height distribution

The relative height of the ensembles in the forest is an important criterion for understanding the nature of the forest. The average height of the forest stand varies depending on the history of the site, topography, abiotic factors and climatic climax of the area under consideration. Generally, low and medium elevation evergreen forests harbor tall and emergent trees which can grow to a height of more than 40 m. At higher elevations, stunted forests are found where the tallest trees rarely exceed 20 m. Given below is an example of a low elevation evergreen forest of the *Dipterocarpus indicus-Kingiodendron pinnatum-Humboldtia brunonis* type as defined by Pascal (1988).

Most of the trees were encountered at the understorey (<15 m height; between 25 and 45% of the individuals for the three methods) and sub-canopy (15-25 m height; between 30 and 50% of the individuals) levels *(Fig.* 5). The canopy level (25-40 m) is represented by about 20% of the individuals in the three methods. The emergent level (≥40-m height) is almost absent (less than 2% in each method). The tallest tree is 43 m high.

Usually, individuals with gbh≥30 cm girth are taller than 5 m: the representation of individuals in the low height class (1-5 m) is due to the disturbance (natural and man-made); with half broken or bent trees due to tree-falls, or lopping. The trees can have a girth ≥30-cm, but be less than 5 m in height.

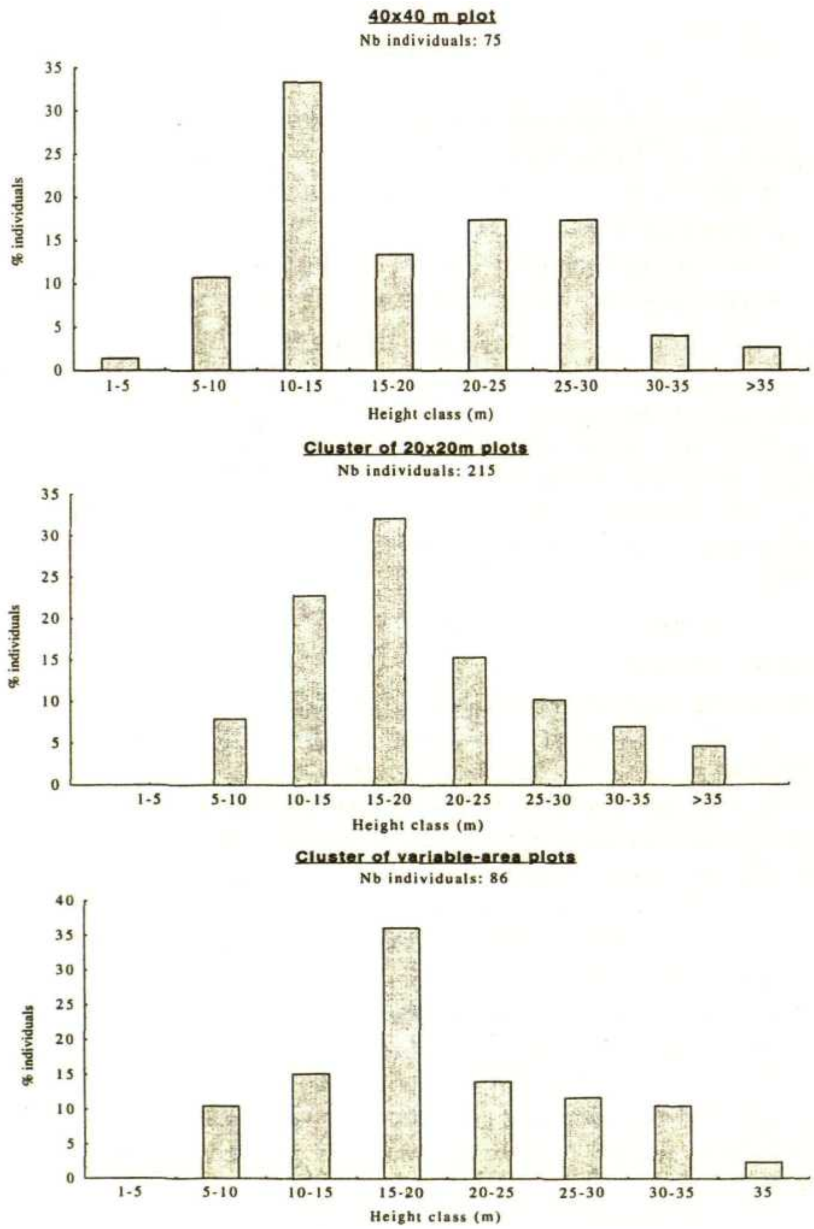


Figure 5. Distribution of trees per height class in evergreen forest.

Girth distribution

The frequency of girth classes is also used to obtain the same kind of information as for height. In timber-oriented surveys, they are important criteria for exploiting a species at an optimum girth class. The current studies on biodiversity use this kind of data available to understand girth class distribution patterns and characterize the forest stand (structure and degree of disturbance).

The trees are distributed in all the girth classes, with even a peak in the 100-160 cm girth classes seen in the P40 method (Fig. 6). Some trees are even bigger than 200 cm gbh (the biggest tree has a girth of 356 cm). The presence of such large trees is an indication of minimal disturbance and is an important seed source for regeneration of the species.

Most of the trees are in the small girth classes (30-50 cm), including trees of the four strata, *e.g.,* understorey (III), sub-canopy (II), canopy (I) and emergent (Em) (Table 2). Though the understorey is well represented, the presence of sub-canopy and canopy species within the small girth classes shows that this forest population contains an important part of young trees, ensuring the regeneration and permanence of the forest stand.

Table 2. Strata potential of the evergreen trees in the 30-50 cm girth classes.

Method	**P40**	**C20**	**CVA**
Strata	(%)	(%)	(%)
Em, **I**	12	51	39
II	64	33	41
III	24	16	20

Em: emergent; I: canopy; II: sub-canopy; III: understorey

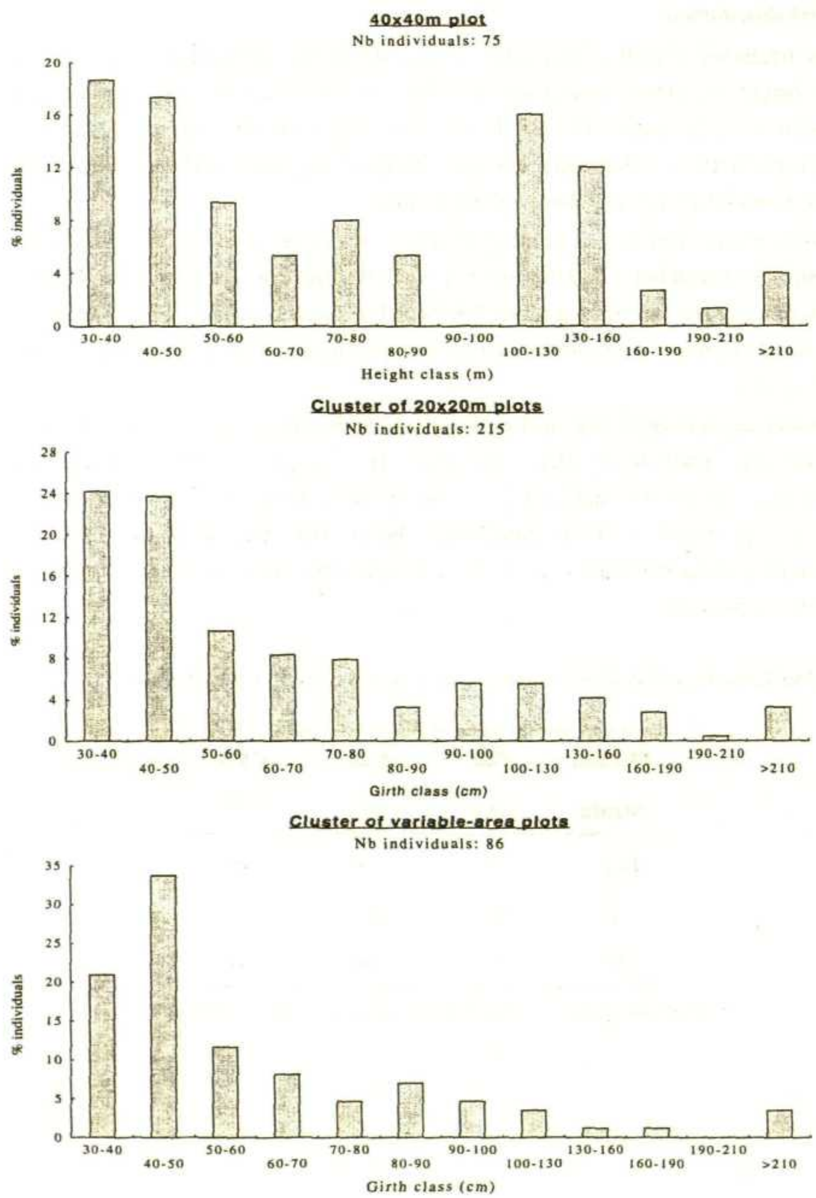


Figure 6. Distribution of trees per girth class in evergreen forest.

Diameter-height relationship

The relationship between the diameter and height is an expression of the growth rate, which determines the successive architectural phases of the trees (Oldeman 1974). The simple average model for expressing the relationship between height (h) and trunk diameter (d) in evergreen forests is defined as h=100d. Trees growing spontaneously are found on or to the right of the line and represent the ‘set of the present’. The older trees are located on the right of the set of the present and belong to the 'set of the past'. They are characterized by a large girth. Trees to the left of the line form the 'set of the future'; these individuals grow in height to reach light and therefore have not yet fully expressed their architectural development. In the natural forest, the layering of ensembles is not always distinct due to the presence of trees of the future, which fill all the gaps. The model has been found valid for tall evergreen forests in French Guyana (Oldeman 1974), Indonesia (Laumonier 1980), Africa (Devineau 1975), and in Western Ghats, India (Pascal 1984, Ramesh 1989, Pélissier 1997).

In the present example *(Fig. 7),* the set of the future is strongly represented in the C20 and CVA methods, with accumulation of several trees ready to take over (10-30 cm diameter and 10-30 m height), belonging to all the strata. The set of the present is largely represented to the right of the line. As already shown by the girth graphs *(Fig. 7),* the set of the past is also present in this forest stand, as we can see on the far right of the line. The P40 method shows a small set of the future; the trees are mostly distributed in the set of the present and partly to the set of the past. Most of the trees with small girth belong to species of the canopy strata. This shows that the population of this area is in a good state, with mother-trees (sets of the past and present) ensuring the reproduction and young trees (set of the future) ensuring the permanence of the forest.

Some trees may be accidentally broken (tree-fall, *etc.).* Their presence as adult trees is taken into account *(see Fig. 5)* though very small, as observed in the P40 method.

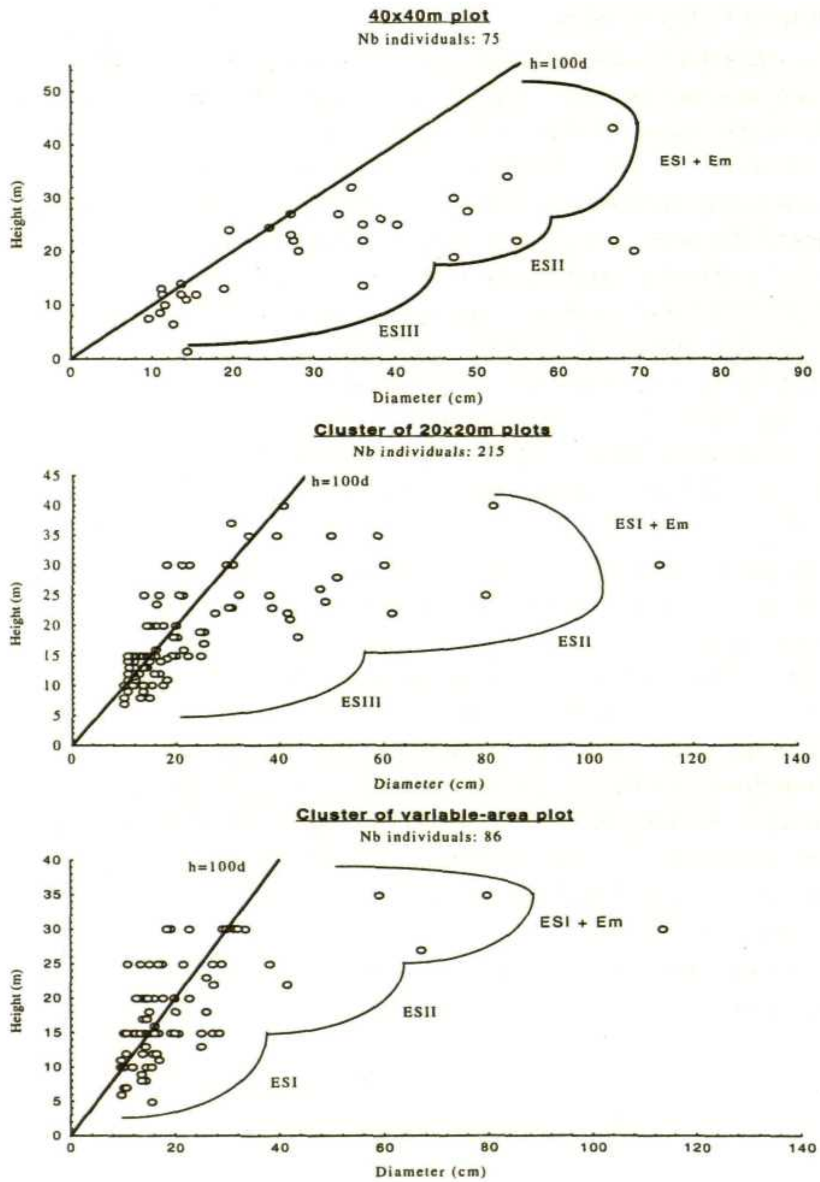


Figure 7. Diameter-height relationship in evergreen forest.

In order to fully understand the implications of forest structure on the permanence of the forest, it is necessary to sample an area greater than 1 ha. Under this Training Programme, the total area sampled for the evergreen forest was less than 1 ha: 1600 m^2 for the P40 method, 3600 m^2 for the C20 method and 2826 m^2 for the CVA method (see Table 1). The objectives of this analysis were (*i*) to train foresters to characterize a forest type and asses its biological diversity, and *(ii)* to identify the more suitable method to characterize a forest stand and assess its species richness and diversity in a fast and low consuming way. Detailed studies can be undertaken once the stand is characterized.

The total basal area and the biovolume calculated for the forest types concern only the tree stand of the forest area (saplings not included). The total basal area ranges from 24.84 to 37.66 mVha (Table 3). These values are lower than the one obtained for other low elevation evergreen forests of the Western Ghats: 60 to 70 m^2/ha (Pascal 1988) and 40 rnVha (P61issier 1997). The total biovolume is also lower, ranging from 813 to 1102 m'/ha, than the one observed by Pascal (1988) in other low elevation evergreen forests: 1920 to 3086 mVha. The density ranges from 469 to 597 stems/ha, lower than the one of 635 stems/ha obtained by Pelissier (1997) in a low elevation evergreen forest.

Table 3. Structure of the evergreen forest type studied.

Method	**Nb individuals**	**Basal area (m^2/ha)**	**Biovolume (m^3/ha)**	**Density (Nb stems/ha)**
P40	75	37.66	1186.47	469
C20	215	34.63	1102.32	597
CVA	86	24.84	812.83	*

*Not calculated: only 10 trees are sampled with the CVA method within the area that may contain more than those 10 trees.

Moist deciduous forest

Height distribution

Moist deciduous forests are generally not higher than 30 m. The first structural ensemble (canopy level) varies from 20 to 30 m. The canopy level which is much lower than in evergreen forests (where it exceeds 40 m in height), and is one of the important structural differences between evergreen and deciduous forests. The number of structural ensembles is also reduced, and the emergent level is absent in deciduous forests (Pascal 1986). The tallest trees measured 18 m with the 40x40m plot, and 30.5 m with the cluster methods *(Fig. 8).*

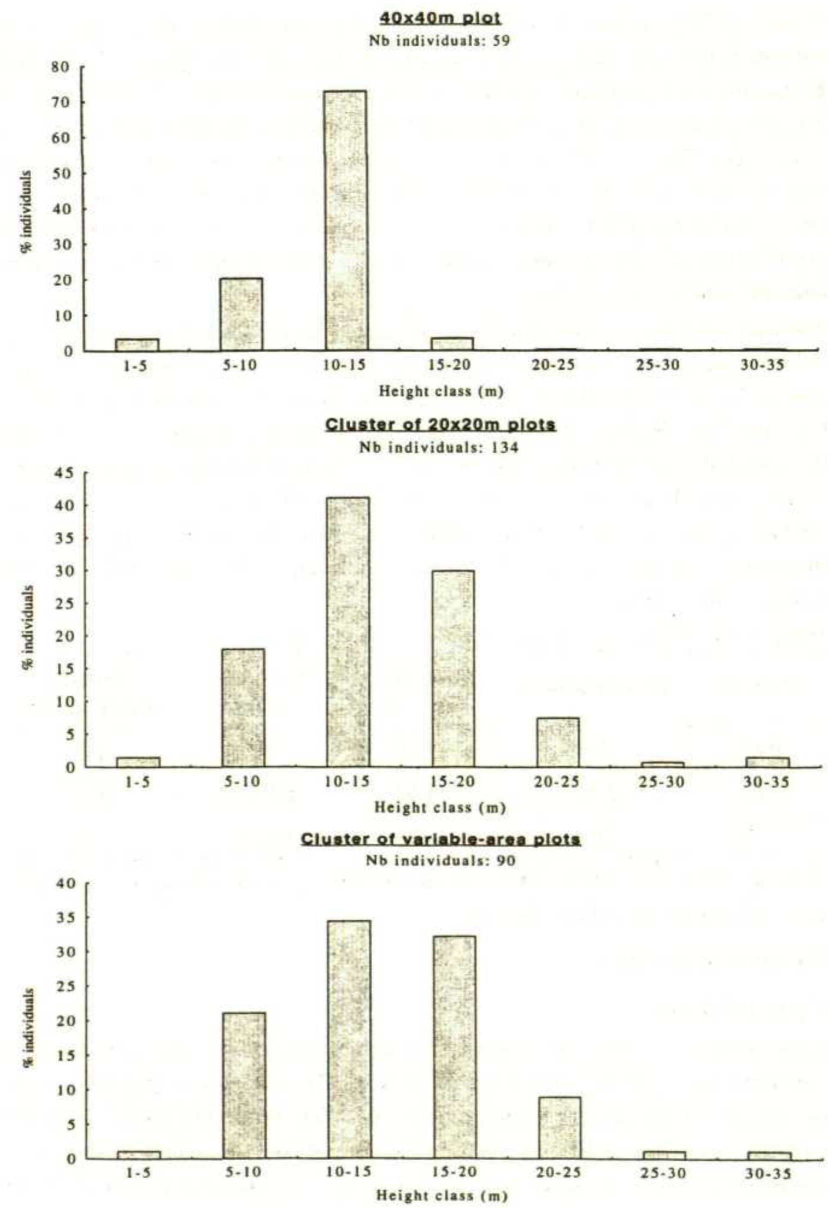


Figure 8. Distribution of trees per height class in moist deciduous forest.

Though the three methods were applied in the same area, the 40x40 m plot did not sample tall trees. The major part of the trees belong to the height class 10-15 m, sub-canopy level, for the P40 method (73%) whereas they are distributed in both the height classes 10-15 m and 15-20 m (respectively 41% and 30% for the C20 method and 34% and 32% for the CVA method).

Girth distribution

The distribution of the trees appears wider in the cluster methods than in the P40 method. Nonetheless, the presence of trees of large girth (≥100 cm) shows that the forest area sampled has had minimal disturbance at the tree level.

A large number of trees belong to the small girth classes (30-50 cm): respectively 42%, 29% and 46% for the P40, C20 and CVA methods (Fig. 9). These girth classes comprise trees belonging to the different strata (Table 4). The high presence of trees of the canopy level in these small girth classes shows that young trees are ready to take over the adult stand, though in small number of individuals.

Table 4. Strata potential of the moist deciduous trees within the girth classes 30-50 cm.

Method **Strata**	**P40** (%)	**C20** (%)	**CVA** (%)
Em**, I**	88	89	83
II	12	11	18
III	0	0	0

Em: emergent; I: canopy; II: sub-canopy; III: understorey

The total basal area calculated for the tree stand that ranged respectively from 15 to 23 m^2/ha (Table 5). These values are lower to the one presented in other moist deciduous forests of Western Ghats by Pascal (1988), 32 to 40 m^2/ha. The total biovolume ranges from 228 to 547 m^3/ha, lower also than Pascal's results (1988): 839 to 956 m^3/ha. The density varies from 369 to 372 stems/ha, far higher than the one presented by Pascal (1988) as 95 stems/ha.

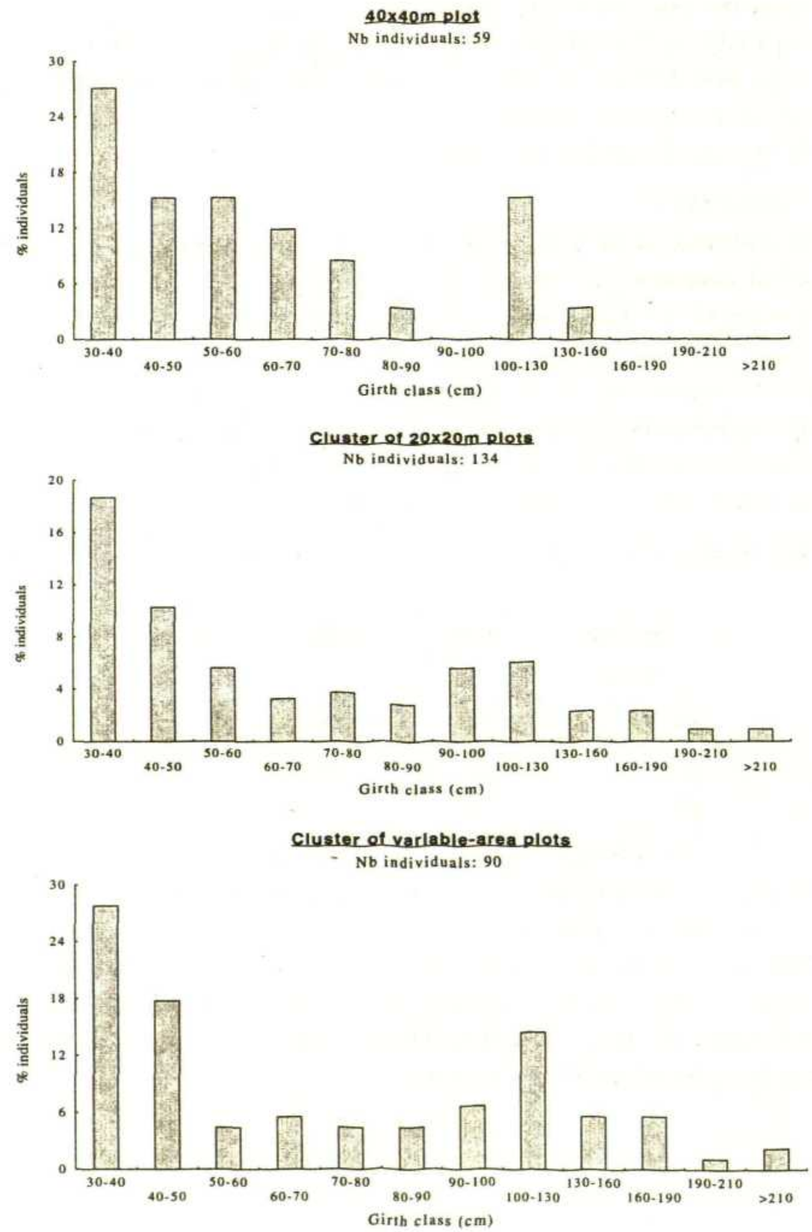


Figure 9. Distribution of trees per girth class in moist deciduous forest.

Table 5. Structure of the moist deciduous forest type.

Method	Nb individuals	Basal area (m^3/ha)	Biovolume (m^3/ha)	Density (Nb stems/ha)
P40	59	14.66	228.00	369
C20	134	21.22	491.54	372
CVA	90	22.45	547.12	*

*Not calculated: only 10 trees are sampled with the CVA method within the area that may contain more than those 10 trees.

Dry deciduous forest

Height distribution

The total height of the trees is lower in dry deciduous forests. Most of the trees belong to the height class 10-15 m, and few tall trees (20-25 m) are observed *(Fig. 10).*

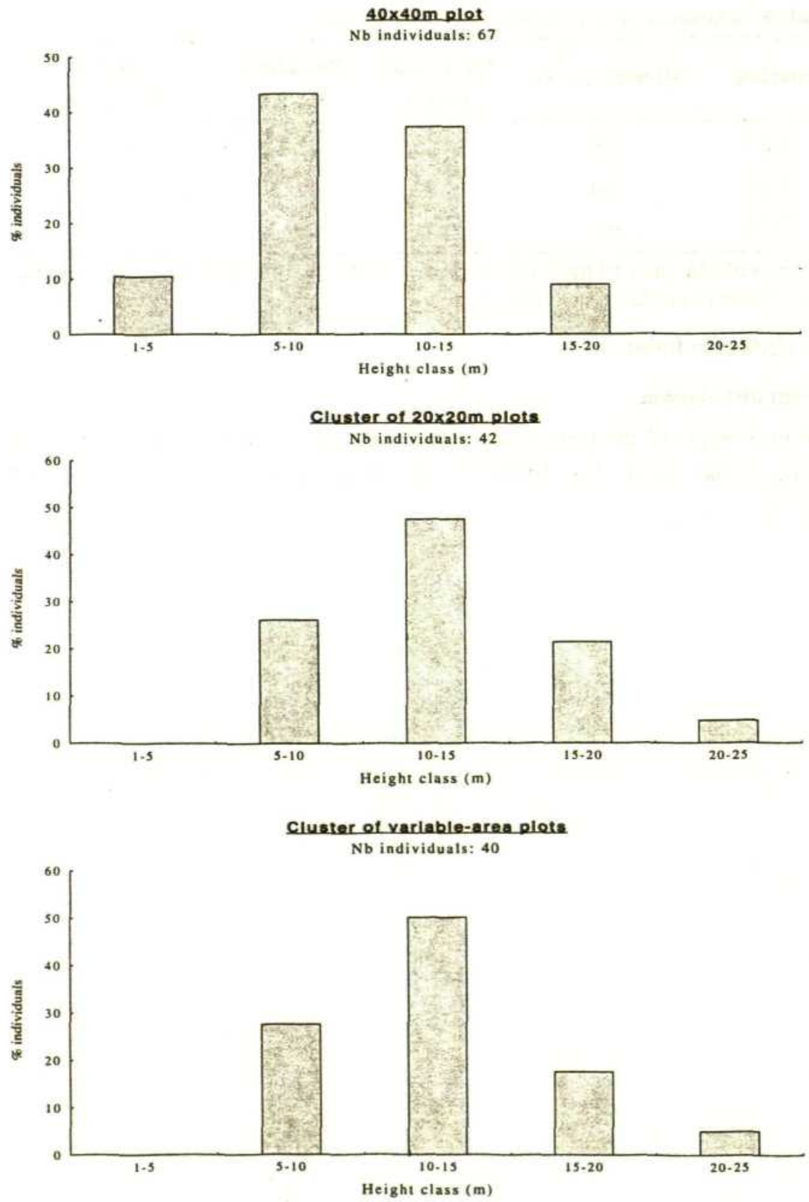


Figure 10. Distribution of trees per height class in dry deciduous forest.

Girth distribution

The girth classes range from 30 to 110 cm with the P40 method and from 30 to 210 cm with the two cluster methods *(Fig. 11).* This wider distribution and therefore the presence of large mature trees ensure the reproduction of the stand. Though trees are largely present in the 30-50 cm classes with the P40 method (42%), it represents only 21 and 23% of the stand in the two other methods. The fact that trees are poorly represented in the smaller girth classes can be related to fire occurring each year in this dry ecosystem, injuring or destroying the saplings and young trees. Though large trees are present in this dry deciduous forest, the major part of the trees is distributed within the girth classes 50-100 cm (respectively 46%, 52% and 53% for the three methods P40, C20 and CVA). This feature is common in dry deciduous forests, where very few species reach a large girth, with a preponderance of small and medium girth species. This shows the precariousness of this forest stand, with an almost absent regenerative pool due to regular fires, though mature trees can ensure the reproduction and young trees of the canopy strata are present in the small girth classes. Most of the trees within the small girth classes (30-50 cm) potentially belong to the canopy strata (Table 6).

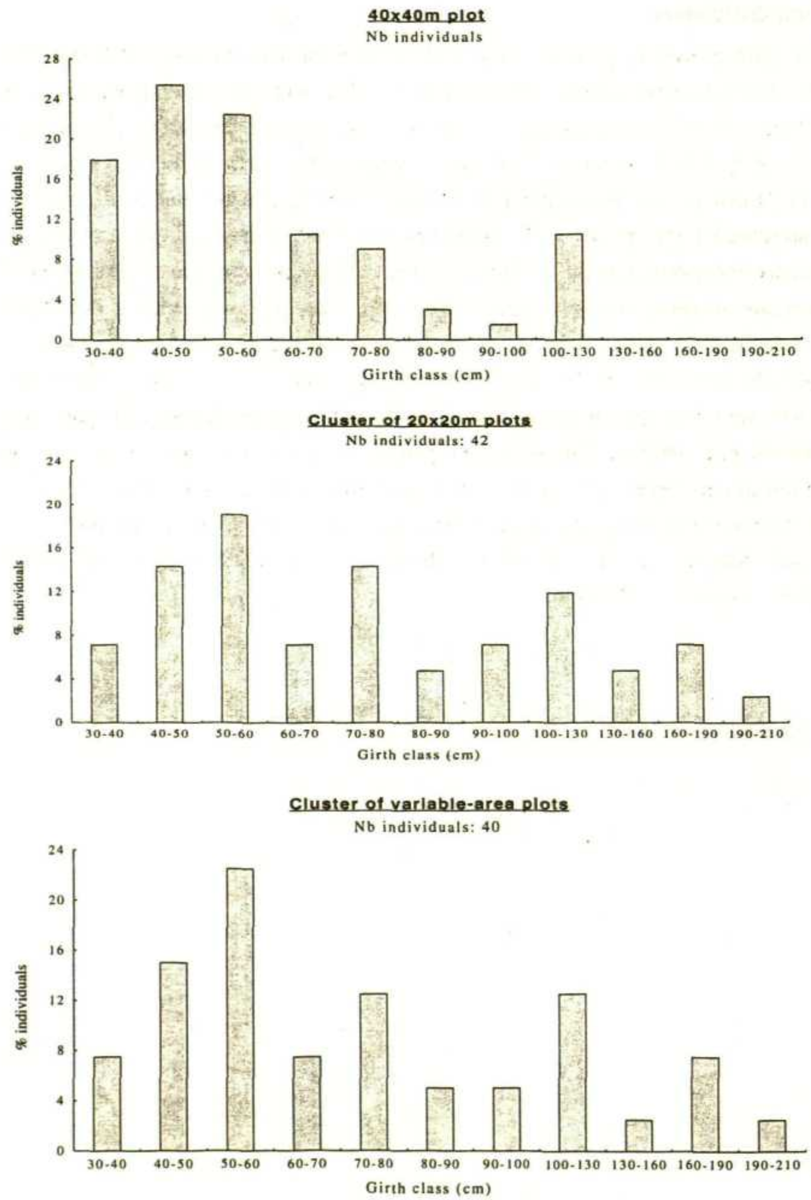


Figure 11. Distribution of trees per girth class in dry deciduous forest.

Table 6. Strata potential of the dry deciduous trees within the girth classes 30-50 cm.

Method **Strata**	**P40** (%)	**C20** (%)	**CVA** (%)
Em, I	62	67	67
II	7	11	11
III	31	22	22

Em: emergent; I: canopy; II: sub-canopy; III**:** understorey

The total basal area is quite low, ranging from 13 to 18 m^2/ha (Table 7). The lower basal area is calculated from the P40 method data, related to the fact that trees are not bigger than 130-cm girth. The biovolume ranges from 200 to 362 m^3/ha, which is also low, even for a dry deciduous forest type. Density is rather high, ranging from 263 to 419 stems/ha.

Table 7. Structure of the dry deciduous forest type.

Method	**Nb individuals**	**Basal area (m^2/ha)**	**Biovolume (m^3/ha)**	**Density (Nb stems/ha)**
P40	67	13.24	191.88	419
C20	42	18.44	362.42	263
CVA	40	14.87	290.65	*

*Not calculated: only 10 trees are sampled with the CVA method within the area that may contain more than those 10 trees.

Species richness and diversity analysis

To estimate the species richness and diversity in habitats, simple estimators and indices, easy to calculate, were used: Chao estimator, Simpson and Shannon indices. The results are presented in two steps. At the first step, all the data are analyzed for each quadrate or sampling point and then pooled for the entire community sampled to facilitate the comparison between methods. As indicated earlier, several considerations should be used to decide if a particular method is suitable or not. They include the time and staff available, the history or previous knowledge about the area, the scale of work, the overall objective and data handling. Several general conclusions should also be understood before rigorously adopting a method for a habitat type. For instance, evergreen forests will be one of the richest; the scrub forests would be one of the poorest. The three methods could be tested before deciding on a sampling strategy for a habitat for each country or biogeographical area. Such standardization should be ideally carried out for each vegetation zone or type for all the countries before national level standards can be formulated.

Abbreviations used

- N: Total number of individuals;
- Sobs: Total number of observed species;
- Chao: Chao estimator of species richness;
- (a, b): number of species with only 1 individual (a) or only 2 individuals (b); Chao index cannot be calculated if b= 0;
- Simpson (D): Simpson index (species diversity);
- Shannon (H'): Shannon index (species diversity);
  Hmax: maximal value of diversity (in comparison with H');
- E: Evenness;
- *: No data.

Evergreen forest

Evergreen forests have been reported to be the richest forests in the Western Ghats, in comparison with deciduous forests. Along with the bioclimatic gradient is a species richness and diversity gradient from the evergreen forests to the moist deciduous and dry deciduous forests. Endemic species, largely present in the Western Ghats (Ramesh *et al.* 1997), are mainly distributed in the evergreen forests.

Fixed-area 40x40 m plot (P40) method

<u>Trees</u>

The total number of tree species observed is 36 in this 1600 m^2 plot (Table 8). The observed species richness is quite low, if we compare it to the estimated value (99) given by Chao estimator. This means that there is an important amount of rare species, which have not been captured with this method. Most of the species recorded are rare (only represented by one or two individuals), representing 83% of the observed species. The population is quite evenly distributed, except for the species *Dimocarpus longan* (Sapindaceae), dominant (23 individuals, 31% of the population). The dominance index (1-D) value of 0.90 means that 90 pairs over 100 taken at random are composed of individuals belonging to different species whereas 10 pairs are constituted by individuals belonging to the same species. This dominance value is not very high, related to the fact that only one species is dominant and that 69% of the individuals are distributed among 35 species. The Simpson (1/D) and Shannon indices reflect a rather low diversity.

Table 8. Diversity and richness of evergreen forest trees estimated by P40 method.

Nb Plots	Area (m^2)	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H' (H max)	Evenness E
1	1600	75	36	99 (25,5)	9.95	0.90	4.30 (5.17)	0.83

Saplings

The total number of species observed, in 800 m^2, is 43 (Table 9), with an estimated value of 82. The species richness is therefore quite low (however higher than for the trees), most of the rare species existing in the area have not been captured, as shown by the difference between the number of species observed and the estimated Chao value. The stand is uneven, a mixture of rare species and dominant species: 52% of the individuals belong to three species, *Aglaia simplicifolia* (Meliaceae; 40 individuals, 27% of the population), *Syzygium* sp. (Myrtaceae; 21 individuals, 14%) and *Dimocarpus longan* (Sapindaceae; 17 individuals, 11%). The later species is also dominant in the tree stand. The sapling populations in not very diverse, as for the tree stand.

Table 9. Diversity and richness of evergreen forest saplings estimated by P40 method.

Nb Plots	Area (m^2)	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H' (H max)	Evenness E
1	800	150	43	82 (25,8)	9.33	0.89	4.16(5.43)	0.77

Seedlings

The total number of species observed, in 200 m^2 is 38 (Table 10), with an estimated value of 74. The species richness is rather low; some rare species have not been captured with this method. The stand is a mixture of rare species (63% of the species) and dominant species, with 42% of the individuals belonging to four species: *Humboldtia brunonis* (Fabaceae; 29 individuals, 23% of the population), *Reinwardtiodendron anaimalaiense* (Meliaceae; 9 individuals, 7%), *Syzygium gardneri* (Myrtaceae) and *Dipterocarpus indicus* (Dipterocarpaceae), both with 8 individuals (6%). The diversity is higher than the trees and saplings diversity.

Table 10. Diversity and richness of evergreen forest seedlings estimated by P40 method

Nb Plots	Area (m^2)	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H^1 (H max)	Evenness E
1	200	127	38	74 (19,5)	13.77	0.93	4.45 (5.25)	0.85

With this method, trees, saplings and seedlings have been sampled in areas respectively of 1600 m^2, 800 m^2 and 200 m^2. The species richness assessed for the three stages is quite low and far from the estimated values (Chao): some rare species have not been captured with this method. The number of species observed for the seedlings is similar to the trees' one, though the area sampled is 8 times smaller: the number would probably increase with the area, particularly because some rare species were not captured, as demonstrated by the Chao value.

The population is dominated by one species in the tree stage, three species in the sapling stage and four species in the seedling stage, representing respectively 31%, 52% and 42% of the population. Though *Dimocarpus longan* is dominant in the tree and sapling stages, it is part of the low frequency species (2 individuals) in the seedling stage. The other two dominant species in the sapling stage are few in numbers in the seedling stage. Since this sampling is punctual, it is not possible to state if this is part of a possible floristic change or if it is only a punctual change (bad fruiting years, *etc.).* Diversity is rather low, as demonstrated by the low values of Simpson and Shannon indices. This can be related with the low amount of species observed.

Cluster of 20x20 m plots (C20) method

Trees

The number of tree species observed is 59 in an area of 3 600 m^2 (Table 11), with an estimated value of 104. There is a great gap in between the number of species observed and the estimated number (Chao): many rare species were not sampled with this method. The stand is represented by many species with 1 to 2 individuals (33 species, 56% of the species). The dominance index (Simpson 1-D) is high: 35% of the individuals are represented by 4 species, the remaining 65% are distributed within 55 species. *Dipterocarpus indicus* (Dipterocarpaceae) dominates (39 individuals, 18% of the individuals), followed by *Knema attenuata* (Myristicaceae; 14 individuals, 7%), and in a smaller extent *Dimocarpus longan* (Sapindaceae; 11 individuals, 5%) and *Mesua ferrea* (Clusiaceae; 11 individuals, 5%). Though these four species dominate, the diversity is quite high due to the presence of many rare species in this forest type.

The variability of the number of individuals (14-30) and species (9-21) among the nine plots is quite high, leading to an important variability in the richness and diversity estimator and indices. This reveals the important variability of the forest composition. The mean values cannot be used for analysis, as they have no meaning the data from each 20x20-m plot are pooled together for a general analysis.

Table 11. Diversity and richness of evergreen forest trees estimated by C20 method.

N° Plots	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H' (Hmax)	Evenness E
1	14	10	15 (6,4)	22.75	0.96	3.24	0.97
2	30	18	33 (11,4)	22.90	0.96	3.95	0.95
3	29	15	26 (8,3)	16.92	0.94	3.66	0.94
4	34	11	14 (4, 3)	5.29	0.81	2.83	0.82
5	30	18	14 (11,5)	18.91	0.95	3.90	0.93
6	16	14	* (13,0)	40.00	0.98	3.70	0.97
7	16	9	* (7,0)*	6.67	0.85	2.73	0.86
8	17	12	32 (9,2)*	17.00	0.94	3.38	0.94
9	32	21	38 (13,5)	35.43	0.97	2.06	0.47
Total	**215**	**59**	**104 (25,8)**	**19.00**	**0.95**	**4.97 (5.88)**	**0.85**

* The corrective term $a^2/2b$ could not be computed, for b= 0.

Saplings

The maximum number of sapling species observed on the plot was 50 in an area of 900 m^2 (Table 12). The estimate value for species richness is 68. The observed value is therefore closer to the estimated one than for the trees, showing that the sampling includes most of the rare species present in the stand. The amount of rare species is high (50%). The dominance index (1-D) reveals an important part of dominant species (40%) over the population: *Humboldtia brunonis* (Fabaceae) dominates the stand (66 individuals, 23% of the population), followed by *Syzygium* sp. (Myrtaceae;

26 individuals, 9%) and *Dipterocarpus indicus* (Dipterocarpaceae; 22 individuals, 8%). The evenness, despite the dominance of three species, remains quite high due to the presence of the 47 species represented by few individuals of which 25 are rare species. The diversity is lower than for the trees, as the dominance is higher in the saplings than in the trees.

Table 12. Diversity and richness of evergreen forest saplings assessed by the C20 method (all plots pooled together).

Area (m^2)	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H' (H max)	Evenness E
900	289	50	68 (17,8)	12.84	0.92	4.56 (5.64)	0.81

Seedlings

There was very poor regeneration in the first 2 plots laid. The results indicate that the seedlings were rather clumped in dispersion. The total number of species observed was 39 in an area of 225 m^2 and estimated to 69 (Table 13). Dominance (1-D) is high, 4 species representing 42% of the population: first, *Humboldtia brunonis* (Fabaceae) with a high dominance (29 individuals, 23% of the population), followed by *Reinwardtiodendron anaimalaiense* (Meliaceae; 9 individuals, 7% of the population), *Dipterocarpus indicus* (Dipterocarpaceae) and *Syzygium gardneri* (Myrtaceae), both with 8 individuals (6% of the population). The remaining individuals are distributed quite evenly among the 36 other species, with an important amount of rare or of low frequency species (63% of the species). Diversity is therefore quite high (and higher than for the saplings).

Table 13. Diversity and richness of evergreen forest seedlings estimated by the C20 method (all plots pooled together).

Area (m^2)	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H' (Hmax)	Evenness E
225	129	39	69 (19,6)	14.19	0.93	4.50 (5.29)	0.85

The species richness is rather low for this forest type. The method did not allow capturing the rare species in the tree and seedling stages, although most of the rare sapling species seemed to be captured. Diversity is quite high within the three stages. The stand is dominated by 4 species in the tree stage (35% of the population), three species in the sapling stage (40%) and four species in the seedling stage (42%), but also includes many rare or low frequency species (respectively 56%, 50% and 63% of the species).

Among the dominant species, *Dipterocarpus indicus* appears to be present in the three stages, with a different level of dominance. *Dipterocarpus indicus,* a dominant species in this evergreen forest type, is a species with irregular flowering and fruiting (with mass fruiting years), as for many dipterocarp species. *Humboldtia brunonis,* highly dominant in the sapling and seedling stages, is recorded in the tree stage as represented by 9 individuals (4%).

Cluster of variable-area plots (CVA) method

Trees

The number of trees species observed are 36 in 1 769 m^2 area (Table 14), and the estimated value is 62, indicating that many rare species were not captured with this method. The species richness is quite low, whereas the diversity is rather high, due to the presence of an important amount (72% of the species) of low frequency or rare species. The distribution of the individuals is even, with only one dominant species, *Dipterocarpus indicus* (15 individuals, 17% of the population).

The variability is less important among the plots than in the C20 method.

Table 14. Diversity and richness of evergreen forest trees estimated by the CVA method.

Nb Plots	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H' (H max)	Evenness E
1	10	8	17(6,2)	22.50	0.96	2.92 (3.00)	0.97
2	7	6	19 (5,1)	21.00	0.95	2.52 (2.58)	0.98
3	10	8	* (7,0)	15.00	0.93	2.85 (3.00)	0.95
4	10	9	41(8,1)	45.00	0.98	3.12(3.17)	0.98
5	10	4	* (3,0)	2.14	0.53	1.36(2.00)	0.68
6	10	8	17 (6,2)	22.50	0.96	2.92 (3.00)	0.97
7	9	8	33 (7,1)	36.00	0.97	3.30(3.17)	1.04
8	10	8	* (7,0)	15.00	0.93	2.85 (3.00)	0.95
9	10	8	* (7,0)	15.00	0.93	2.85 (3.00)	0.95
Total	**86**	**36**	**62 (19,7)**	**20.53**	**0.95**	**4.64 (5.17)**	**0.90**

*The corrective term $a^2/2b$ could not be computed, for b= 0.

__Saplings__

The number of sapling species encountered is 34 in an area of 788 m^2 (Table 15), with an estimated value of 60. As for the trees, many rare species were not captured, the richness is rather low and the diversity average, with the presence of 4 dominant species representing 50% of the population and many rare or low frequency species (77% of the species). The distribution remains quite even due to the high number of rare species. The four dominant species are *Humboldtia brunonis* (Fabaceae; 28 individuals, 31% of the population), followed by *Dimocarpus longan* (Sapindaceae) and *Dipterocarpus indicus* (Dipterocarpaceae) with 6 individuals (7%), and *Reinwardtiodendron anaimalaiense* (Meliaceae; 5 individuals, 6%).

Table 15. Diversity and richness of evergreen forest saplings estimated by the CVA method (all plots pooled together).

Area (m^2)	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H' (Hmax)	Evenness E
788	90	34	60 (19,7)	9.16	0.89	4.16 (5.09)	0.82

The species richness is low for both tree and sapling stages, for this evergreen forest type. The species diversity is quite high for the trees and average for the saplings, linked with the evenness of the distribution of the individuals among the different species of which many are rare or with low frequency (respectively 72% and 77% of the species for the trees and saplings). *Dipterocarpus indicus,* dominant in the tree stage, is as well represented in the sapling stand, though with average dominance. *Humboldtia brunonis,* highly dominant within the saplings, is only represented by 5% of the individuals in the tree stand.

Moist deciduous forest

40x40 m plot (P40) method

__Trees__

The number of tree species recorded with this method is very low (10) in 1 600 m^2, and the estimated value is 23 (Table 16), meaning that some rare species were not captured. The stand is dominated (66% of the population) by four species, *Anogeissus latifolia* (Combretaceae; 20 individuals, 34%), *Terminalia alata* (Combretaceae; 19 individuals, 32%), *Tectona grandis* (Verbenaceae; 7 individuals, 12%) and *Emblica officinalis* (Euphorbiaceae; 6 individuals, 10%). The remaining six species are poorly represented. The sampled stand is therefore unevenly distributed and lowly diversified.

Table 16. Diversity and richness of moist deciduous forest trees estimated by the P40 method

Nº Plots	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H' (Hmax)	Evenness E
1	59	10	23 (5,1)	4.30	0.77	2.42 (3.32)	0.73

Saplings

The number of saplings species observed with this method is low (6), but close to the estimated value for the stand (9; Table 17). The number of rare species is therefore low and most of them have mostly been captured by the method. Among the 23 individuals sampled, 4 are represented with low frequency, and two are representing 70% of the population: *Anogeissus latifolia* (Combretaceae; 10 individuals, 50% of the population) and *Terminalia alata* (Combretaceae; 4 individuals, 20%). The stand is somehow showing a slightly greater diversity than the trees' one, as only two species are dominant and 67% of the species are rare or with low frequency.

Table 17. Diversity and richness of moist deciduous forest saplings estimated by the P40 method

Nb plots	Area (m^2)	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H' (Hmax)	Evenness E
1	800	20	6	9 (2,2)	4.77	0.79	2.06 (2.58)	0.80

Seedlings were not encountered with this method. The sampling was done during the dry season and the seedlings stand was absent, due to fire.

Species richness assessed with this method in this moist deciduous forest type is low, and many rare species were not captured with the method. Some species (four in the tree stand and six in the sapling stand) dominate. *Anogeissus latifolia* and *Terminalia alata* are highly dominant in both stages. *Tectona grandis* and *Emblica officinalis,* poorly represented among the saplings, are among the dominant species in the tree stand. The regeneration is poor in this area, prone to fire, and it shows a low ability of the forest to regenerate and a state of threat for the future of the stand.

Cluster of 20x20 m plots (C20) method

Trees

The number of tree species recorded with this method is 18, with 134 individuals in 3 600 m^2 *(Table 18).* The estimate species value (Chao) is rather close to the observed one, showing that most of the rare species present in this forest type were captured. Dominance is clearly shown by three species (75% of the population): *Anogeissus latifolia* (Combretaceae; 59 individuals, 44%), *Terminalia crenulata* (Combretaceae; 27 individuals, 20%) and *Tectona grandis* (Verbenaceae; 15 individuals, 11%). Though 61% of the species are rare or with low frequency, diversity is rather low due to the high frequency of those three species along with other species represented by few individuals. Evenness is therefore low as well as the diversity index values.

Table 18. Diversity and richness of moist deciduous forest trees estimated by the C20 method.

N° Plot	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H^1 (Hmax)	Evenness E
1	13	4	4(0,2)	3.98	0.74	2.72(4.17)	0.65
2	16	5	7(2,1)	3.43	0.71	1.83 (2.00)	0.92
3	11	5	5(1,3)	6.11	0.84	1.88(2.32)	0.81
4	19	6	14 (4,1)	2.16	0.54	2.19(2.32)	0.94
5	16	7	9(3,3)	5.00	0.80	1.61 (2.58)	0.62
6	11	4	* (3,0)	1.96	0.49	2.40 (2.81)	0.85
7	8	4	* (2,0)	4.67	0.79	1.81(2.00)	0.91
8	13	6	11(3,1)	5.57	0.82	2.29 (2.58)	0.89
9	27	7	* (6,0)	1.67	0.40	1.34(2.81)	0.48
Total	**134**	**18**	**24(7,4)**	**3.98**	**0.75**	**2.72 (4.17)**	**0.65**

* The corrective term $a^2/2b$ could not be computed, for b= 0.

Saplings

Very few sapling individuals were sampled, compared to the trees, in 900 m^2 (Table 19). Sapling richness (6 species) in the moist deciduous forest was far lower than that of the tree richness observed. The estimated species value (Chao) could not be calculated for the saplings because of the absence of species represented twice

(Table 19). The stand is uneven and dominated by two species (86% of the population), *Anogeissus latifolia* (Combretaceae; 18 individuals, 67% of the population) and *Tamilnadia uliginosa* (Rubiaceae; 5 individuals, 19%). The high dominance of *Anogeissus latifolia,* already dominant within the tree stand (44%), can lead towards a stand mainly constituted of this species.

Table 19. Diversity and richness of moist deciduous forest saplings estimated by the C20 method (all plots pooled together).

Area (m^2)	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H^1 (Hmax)	Evenness E
900	27	6	* (4,0)	2.15	0.54	3.35 (4.25)	0.79

* The corrective term $a^2/2b$ could not be computed, for b= 0.

Seedlings

An important number of seedlings were observed in 225 m^2, on the contrary to the saplings (Table 20). It is therefore possible to assume that sapling's mortality is important (area with recurrent fires). Species richness is higher than for the saplings and similar to the trees and close to the estimate value: the rare species, few in number, have been captured with this method. The stand is rather diverse, though two species represent 44% of the population: *Kydia calicina* (Malvaceae; 55 individuals, 29% of the population) and *Dalbergia latifolia* (Fabaceae; 28 individuals, 15%). The population is unevenly distributed among the species, with 37% of rare or low frequency species, and other species represented by few individuals (4 species totalize 35% of the individuals, besides the two dominant ones).

Table 20. Diversity and richness of moist deciduous forest seedlings estimated by the C20 method (all plots pooled together)

Area (m^2)	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H' (Hmax)	Evenness E
225	193	19	22 (4, 3)	7.44	0.87	3.35 (4.25)	0.79

The species richness is quite low in this moist deciduous forest area, though close to the estimate values for trees and seedlings. This means that the stand is really poor, since most of the rare species have been captured with this method. The population is uneven, a mixture of dominant species (three, 75%, in the tree stage, two, 86%, in the sapling stage and two, 44%, in the seedling stage, and rare or low frequency species (respectively 61%, 67% and 37% of the species for the three stages). Diversity is low in the tree and sapling stands and quite high in the seedling stand (dominance less pronounced).

Anogeissus latifolia is dominant within trees and saplings, but few in number in the seedlings. *Tectona grandis,* dominant within the trees, is absent from the sapling stage and present (4% of the population) in the seedling stage. *Terminalia crenulata,* also dominant in the trees, is rare in the saplings and well represented (8% of the population) in the seedlings. This shows that the mature trees have the ability to reproduce, but survival is poor in this area prone to fire.

Cluster of variable-area plots (CVA) method

Trees

The number of species recorded by cluster method is 16 in 2 728 m^2 (Table 21) with an estimated value of 57 most of the rare species were not captured. Species richness sampled is therefore low. Diversity is low and the stand is unevenly distributed, with 63% of rare species and three dominant species representing 74% of the population. The three dominant species are *Anogeissus latifolia* (Combretaceae; 31 individuals, 34%), *Terminalia crenulata* (Combretaceae; 22 individuals, 24%) and *Tectona grandis* (Verbenaceae; 14 individuals, 16%).

Table 21. Diversity and richness of moist deciduous forest trees estimated by the CVA method

N° Plot	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H' (Hmax)	Evenness E
1	10	3	*(3,0)	3.46	0.71	1.52(1.58)	0.96
2	10	5	10(3,1)	4.09	0.76	1.16(2.32)	0.50
3	10	6	14(4,1)	6.43	0.84	1.19(2.58)	0.46
4	10	5	10(3,1)	4.09	0.76	1.13(2.32)	0.49
5	10	5	10(3,1)	4.09	0.76	1.13(2.32)	0.49
6	10	3	* (2,0)	1.61	0.38	0.92(1.58)	0.58
7	10	5	7(2,1)	6.43	0.84	1.32(2.32)	0.57
8	10	6	8 (3,2)	9.00	0.89	1.19(2.58)	0.46
9	10	2	* (1,0)	1.25	0.20	0.47(1.00)	0.47
Total	**90**	**16**	**57 (9,1)**	**4.95**	**0.80**	**2.80 (4.00)**	**0.70**

* The corrective term $a^2/2b$ could not be computed, for b= 0.

<u>Saplings</u>

The number of sapling species recorded by this CVA method in 5010 m^2 is lower than the trees one (Table 22). The estimate value for species richness could not be calculated, as there are no low frequency species within the stand. Along with low species richness, diversity appears to be low as well, with an uneven stand: 77% of the population is distributed among three dominant species, four species are rare and few individuals represent three other species. The dominant species are *Anogeissus latifolia* (46 individuals, 51% of the population), *Tamilnadia uliginosa* (13 individuals, 14%) and *Terminalia crenulata* (12 individuals, 13%).

Table 22. Diversity and richness of moist deciduous forest saplings estimated by the CVA method.

Area (m^2)	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H' (Hmax)	Evenness E
5010	90	11	* (4,0)	3.33	0.70	2.33 (3.46)	0.67

* The corrective term $a^2/2b$ could not be computed, for b = 0.

Species richness is low, though higher in the tree stand. Both stands are uneven, with three dominant species in the two stages (respectively 74% and 77% of the population), mixed with rare or low frequency species (respectively 63% and 36% of the species). Diversity is low for both stages.

Tectona grandis, dominant in the tree stage, is absent from the sapling stands of the two cluster methods, and present as a rare species in the P40 method. This might be a threat for the future population.

Dry deciduous forest

40x40 m plot (P40) method

<u>Trees</u>

The number of tree species recorded with this method is 13 in 1 600 m^2 (Table 23), close to the estimated value (15): most of the rare species have been captured. The stand is uneven and with low diversity, with three dominant species (65% of the population), six rare species and four other species with few individuals. The dominant species are *Terminalia alata* (Combretaceae; 26 individuals, 39%), *Anogeissus latifolia* (Fabaceae) and *Tamilnadia uliginosa* (Rubiaceae), both with 9 individuals (13%).

Table 23. Diversity and richness of dry deciduous forest trees estimated by the P40 method.

N° Plot	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H' (Hmax)	Evenness E
1	67	13	15(3,3)	5.29	0.81	2.92(3.70)	0.79

Saplings

The saplings population sampled is poor and with low species richness. 7 species were observed in 800 m^2, with a stand estimated at 15 species: many rare species were not captured with this method (Table 24). Diversity is also low, and two species dominate, gathering 75% of the population. The other species are rare or low frequency species. The sampled stand shows a poor regeneration in this area prone to fire. The dominant species are *Tamilnadia uliginosa* (12 individuals, 50% of the population) and *Anogeissus latifolia* (6 individuals, 25%). This dominance can lead on a long-term basis to an adult stand mainly composed of those two species. The present mature stand (trees) is already with low diversity and dominated by these two species along with *Terminalia alata.* The latest species is among the rare species observed.

Table 24. Diversity and richness of dry deciduous forest saplings estimated by the P40 method.

Area (m^2)	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H^1 (Hmax)	Evenness E
800	24	7	15 (4,1)	3.37	0.70	2.06(2.81)	0.73

Both tree and sapling stands present a low species richness. This method allowed the rare species to be captured within the tree stand, but not within the sapling stand. This can be related to the sampled area, twice for the tree stand compared to the sapling stand.

Both stands are unevenly distributed, being a mixture of rare species (respectively 46% and 71% of the species for the trees and saplings) and dominant species (three for the trees (65% of the population) and two for the saplings (75%)). Diversity is low for both stages.

Anogeissus latifolia and *Tamilnadia uliginosa* are both dominant species in the tree and saplings stages. *Terminalia alata,* dominant in the trees, is rare in the saplings.

Though punctual, this study can outline the increase of poverty of the stand for the future.

The seedling stand, eliminated by fire, was absent at the study period.

Cluster of 20x20 m plots (C20) method

Trees

The number of tree species recorded with this method was 11 in 1 600 m^2, (Table 25), estimated to 12. It appears then that all the rare species have been captured. However, this sampled stand presents a low species richness. The population is distributed among three dominant species (62% of the individuals), six low frequency or rare species and two other species represented by few individuals. The dominant species are *Terminalia crenulata* (13 individuals, 31%), *Anogeissus latifolia* (7 individuals, 17%) and *Tectona grandis* (6 individuals, 14%).

Table 25. Diversity and richness of dry deciduous forest trees estimated by the C20 method.

N° Plot	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H^1 (Hmax)	Evenness E
1	10	5	10(3,1)	4.09	0.76	1.96(2.32)	0.84
2	9	3	3(0,1)	3.60	0.72	1.53(1.58)	0.97
3	12	5	5 (0,3)	7.33	0.86	2.29 (2.32)	0.99
4	11	6	14(4,1)	5.00	0.80	2.22 (2.58)	0.86
Total	**42**	**11**	**12(2,4)**	**6.94**	**0.86**	**2.99 (3.46)**	**0.87**

Saplings

An almost total lack of the sapling cover is indicated for the dry deciduous forest in the sampling area (400 m^2) (Table 26). This is due to the fact that fire constantly regulates regeneration. This characteristic can be contrasted to the other communities studied, although significant conclusions cannot be drawn from that, due to the small sampling of the area. The stand is even, with all the sampled species represented by very few individuals (1 to 2). The Simpson (1/D) value is rather high, due to the closeness of the numbers of individuals and species. However, the Shannon value is low but rather close to the maximum estimated value.

Table 26. Diversity and richness of dry deciduous forest saplings estimated by the C20 method (all plots pooled together).

Area	N	S	Chao(a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H^1 (Hmax)	Evenness E
400	5	4	9(3,1)	10	0.90	1.92(2.00)	0.96

Seedlings

High seedling richness is evident in the community, with more species observed than for the trees, in 100 m^2 (Table 27). The estimated value (19) is quite close to the observed one (15), showing that most of the rare species have been sampled. The stand is distributed among four dominant species (65% of the population), 8 rare or low frequency species and three other species with few individuals. The dominant species are *Dalbergia latifolia* (17 individuals, 30% of the population), *Terminalia crenulata* (8 individuals, 14%), *Grewia tiliifolia* (7 individuals, 12%) and *Albizzia marginata* (5 individuals, 9%).

The presence of the seedlings in the area was very irregular, the sampling was higher in one of the 4 plots, gathering 65% of the sampled individuals and nil in an other plot, depicting an aggregative behavior for the seedlings. Most of the seedling richness has been derived from a single plot, which could represent a special microhabitat. Only increased sampling can answer this question.

Table 27. Diversity and richness of dry deciduous forest seedlings estimated by the C20 method (all plots pooled together).

Area (m^2)	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H^1 (Hmax)	Evenness E
100	57	15	19(5,3)	7.71	0.87	3.29(3.91)	0.84

The species richness is low in the tree, sapling and seedling stages, lower in the saplings and higher in the seedlings. The seedling stage is well furnished on the contrary to the sapling one: fruiting is available from the mature stand, but survival is low in this area prone to fire, with disappearance of some of the species. Two dominant species in the seedlings, *Dalbergia latifolia* and *Albizzia marginata* are not present in the sapling and tree stands. Though some hypothesis concerning the impoverishment of the stand can be put forward (fire, grazing, *etc.),* the sampling size is too small to put any conclusive statement.

Cluster of variable-area plots (CVA) method

Trees

The number of tree species recorded with this method is 12 in 1816 m^2 (Table 28) close to the estimated number (16). The stand is dominated by two species (56% of the individuals), 8 species rare or of low frequency and two other species lowly represented. The stand is therefore relatively diverse due to the high ratio of rare species. The dominant species are *Terminalia crenulata* (13 individuals, 33%) and *Anogeissus latifolia* (9 individuals, 23%).

Table 28. Diversity and richness of dry deciduous forest trees estimated by the CVA method.

N° Plot	N	S	Chao (a,b	Simpson (1/D)	Simpson (1-D)	Shannon H^1 (Hmax)	Evenness E
1	10	5	10(3,1)	4.09	0.76	1.96(2.32)	0.84
2	10	5	10(3,1)	4.09	0.76	1.96 (2.32)	0.84
3	10	5	7 (2,1)	6.43	0.84	2.17(2.32)	0.93
4	10	6	14(4,1)	6.43	0.84	2.32 (2.58)	0.90
Total	**40**	**12**	**16 (5,3)**	**6.19**	**0.84**	**2.98 (3.58)**	**0.83**

Saplings

10 species were observed among the saplings with this method in 5 303 m^2 value quite far from the estimated one: rare species were not captured (Table 29). The regenerative stand is almost as rich as the mature stand. The population is dominated by four species (78% of the individuals): *Tamilnadia uliginosa* (12 individuals, 30% of the population), *Anogeissus latifolia* (8 individuals, 20%), *Terminalia crenulata* (6 individuals, 15%) and *Lagerstroemia parviflora* (5 individuals, 13%). Half of the species are rare or of low frequency. The poor sapling richness and diversity could be due to extreme patchiness in their observed distribution.

Table 29. Diversity and richness of dry deciduous forest saplings estimated by the CVA method (all plots pooled together).

Area (m^2)	N	S	Chao (a,b)	Simpson (1/D)	Simpson (1-D)	Shannon H^1 (Hmax)	Evenness E
5303	40	10	18(4,1)	6.34	0.84	2.80 (3.32)	0.84

The species richness is low for both stands, though the estimate number of species is close to the observed one in the tree stand: most of the species, including the rare ones, have been captured.

The stands have a low diversity, and are composed of dominant species (two species (56% of the population) in the trees and four species (78%) in the saplings) and rare species or low frequency species (67% and 50% of the species respectively in the tree and sapling populations).

Since this method limits the total number of sampling to 10 and the area covered in the frame of this Training Programme is small (4 plots), it is difficult to put forward statements. However, the results are similar to those obtained with the C20 method.

Discussion and conclusions

Attributes of the forest types studied

With the data collected, certain differences within the tree stands can be discerned with the following basis:

- *Vertical distribution of individuals, as indicated by the height of the tree species:* The height distribution is bell-shaped, narrower for the moist and dry deciduous forests than for the evergreen forest: the trees are taller in evergreen forest and the stand is usually constituted of four strata (emergent, canopy, sub-canopy and understorey) whereas only the last three strata are present in the deciduous forest types;
- *Horizontal distribution of individuals, as indicated by the girth class distribution of the individuals encountered:*

  The girth distribution is decreasing regularly from small girth to large girth for the evergreen and moist deciduous forests whereas it is irregular in the dry deciduous forest. Paucity of individuals in the dry deciduous forest and greater number of individuals in all classes for moist deciduous and evergreen forests are observed;
- *These differences are also reflected in the three other structural measures used (biovolume, basal area and density):*

The biovolume *(Fig. 12)* is higher in the evergreen forest (813 to 1187 m^3/ha) than in the moist and dry deciduous forests (respectively 228 to 547 m^3/ha and 192 m^3/ha to 362 m^3/ha). However, all these values are lower than the one presented by Pascal (1988). The P40 method appears to be the one giving the higher biovolume in the evergreen forest sampled followed by the C20 method. The CVA method, with only 10 trees sampled by plot, is giving the lower value. This is however not the case in the moist and dry deciduous forests sampled, where the order is reversed.

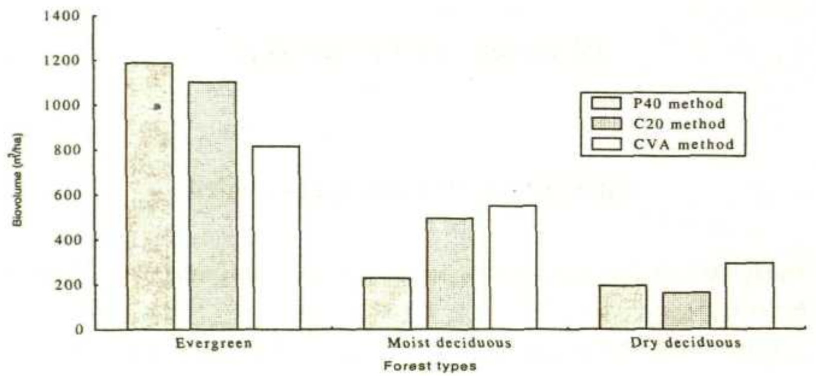


Figure 12. Comparison of biovolume estimates for the 3 methods.

The basal area (Fig. 13) is higher in evergreen forest (25 to 38 m^2/ha) than in the deciduous forests (respectively 15 to 23 m^2/ha and 13 to 18 m^2/ha for the moist and dry deciduous forests). However, all these values are similar to the one presented by Pélissier (1997) in a low elevation evergreen forest but far lower than the one published by Pascal (1988) in evergreen and deciduous forests. The basal area values are higher with the P40 method, followed by the C20 method, in evergreen forest. This order is reversed in the moist deciduous forest. In the dry deciduous forest, the C20 method is giving the highest value, followed by the CVA method.

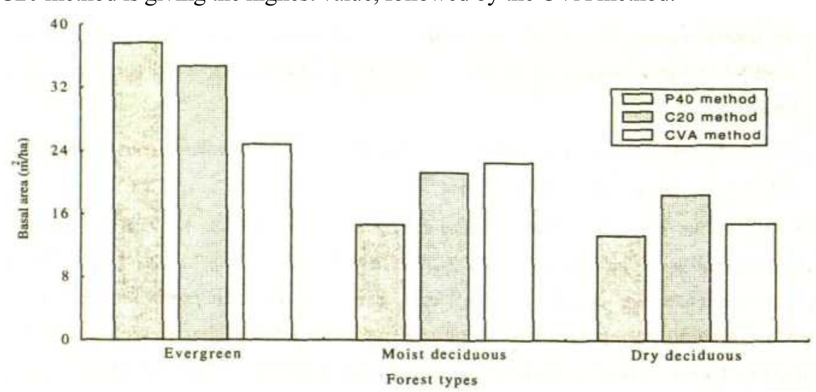


Figure 13. Comparison of basal area estimates for the 3 methods.

Further, the spatial dispersion of individuals indicates that the density of the individuals are not likely to be the same (Fig. 14): it varies from 469 to 597 stems/ha in the evergreen forest sampled, from 369 to 372 stems/ha in the moist deciduous forest sampled and from 263 to 419 stems/ha in the dry deciduous forest sampled. The density of the evergreen forest studied is lower than the one found by Pélissier (1997).

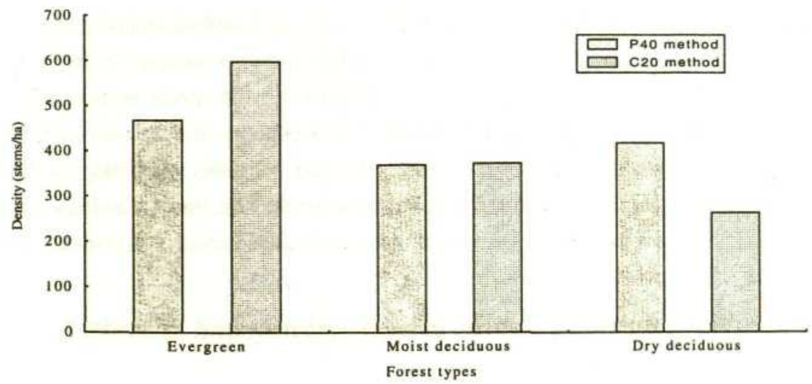


Figure 14. Comparison of density estimates for the 3 methods.

The mean distances covered to locate these were also varied *(Fig. 15).* It is evident that the shortest distances were covered for the evergreen forests and the longest for the dry deciduous forest.

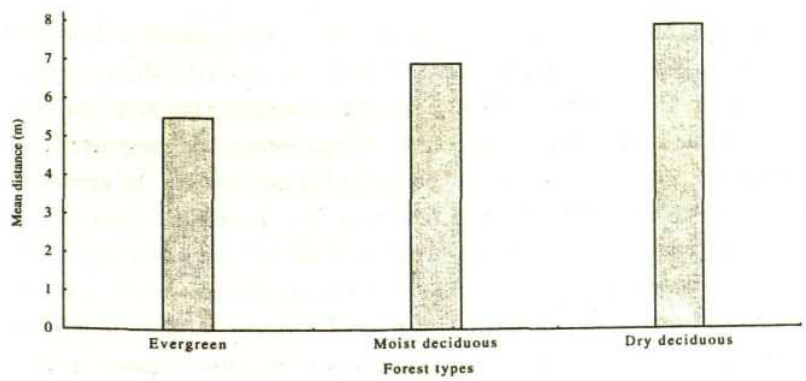


Figure 15. Mean distances covered to locate 10 trees by CVA method in various forest types. These patterns reveal that the underlying regulatory factors increase in the order of complexity and significance as we move from dry deciduous forest to evergreen forest through moist deciduous forests.

Comparisons of diversity

Attempts to compare the diversity between methods and ecosystems have some underlying constraints. These arise due to differences in sampling intensity and also to the differential sensitivity of the various indices used to measure richness and diversity. The absence of prior estimate of true richness and diversity in these forests does not allow any corrections to be made while accounting for the area sampled. Despite these, some answers can be found for the questions regarding the best method to sample diversity and comparisons between the efficiency of a single large plot as against several serially laid small plots to estimate richness, dominance and diversity of the community studied.

Which method captured greater richness and diversity?

Richness

Comparison of species richness by all methods measured as S_{obs} and the correction for rarity factor using Chao estimator indicates different points within the three forest types (Table 30):

- Evergreen forest: the highest number of species was captured with the C20 method; this is mainly related to the fact that the area sampled with this method is twice greater than with the two other methods. Considering this fact, none of the three methods did capture a high number of tree species, and many rare or low frequency species are missing, regarding the big gap between the numbers of species observed and the estimated value from Chao. It therefore appears that the samplings done with only one single plot of 40x40 m is not sufficiently large to estimate the species richness in evergreen forest. Besides, due to time allotted to the study, the number of plots laid was small, reaching one-third of a hectare (Table 30). The number can be increased to capture more low frequency species.
- Moist deciduous forest: The higher species number was also observed with the C20 method, which gives quite a good estimate as it is not very far from the estimate value taking into account the rare species (Chao estimator). The CVA method provided a similar number of observed species, which is however far from the estimate value: sampling 10 trees per plot (90 individuals totally) does not allow to capture all the rare species. The P40 method provided the lower

number of species observed, also far from the estimate value given by Chao. The number of observed species increased therefore from the P40 method to the CVA method to the C20 method, linked with the increase of sampling area.

- Dry deciduous forest: The number of species observed is low in the three methods, though higher with the CVA method. This can be explained by the fact that a larger area was sampled with the latter method: the density of the trees was so low that greater distances had to be covered to sample 10 trees than in the two other forest types. The three observed values are close to the estimated values: most of the rare species have been captured. This means that the species richness of this area is very low. The area sampled with the C20 method is lower (only 4 points made) than the area sampled in the two other forest types, but equivalent to the area sampled by the two other methods.

Table 30. Comparisons of tree species richness (S_{obs}) and corrected estimates using Chao estimator for the methods used in the study.

Methods	40x40 m plot				Cluster of 20x20 m plots				Cluster of variable-area plots			
Forest type	area in m^2 (Nb plots)	N	Sobs	Chao (a,b)	area in m^2 (Nb plots)	N	Sobs	Chao (a,b)	area in m^2 (Nb plots)	N	Sobs	Chao (a,b)
Evergreen	1600 (1)	75	36	99 (25,5)	3600 (9)	215	59	104 (25,8)	1769 (9)	86	36	62 (19,7)
Moist deciduous	1600 (1)	59	10	23 (5,1)	3600 (9)	134	18	24 (7,4)	2728 (9)	90	16	57 (9,1)
Dry deciduous	1600 (1)	67	13	15 (3,3)	1600 (4)	42	11	12 (2,4)	1816 (4)	39	15	19 (5,3)

It is therefore possible to state that the P40 method does not provide a good assessment of the species richness for the evergreen and moist deciduous forest types. This is directly linked with the sampling area: as pointed out by several other studies (Southwood *et al.* 1979, Condit *et al.* 1996, Gimaret-Carpentier *et al.* 1998), richness is a function of sample size. As large areas get incorporated into sampling, more species richness is observed. In very rich forest types, as it is the case in Southeast Asia, species richness cannot be sampled in its fullness, whatever the sample size is (Gimaret-Carpentier *et al.* 1998). However, large number of clusters or very large plots (eg. ≥50 ha as in the lowland rainforest of Pasoh, Malaysia), can approximate the total species richness of these forests.

The species richness would be better assessed by the cluster methods, providing that a greater number of points are made: Gimaret-Carpentier *et al.* (1998) showed that a systematic or stratified sampling design of 1000 individuals in evergreen forest should provide a satisfactory assessment of the species richness by using Chao estimator.

With the CVA method applied in a moist deciduous forest of the Western Ghats (Coorg District, Karnataka), 39 species were observed with a Chao estimate of 51 (corrective term equal to 12). The 20 points made (198 individuals) did not give a sufficient area to estimate the species richness of this forest type. The number of trees sampled should however be less than in evergreen forests, richer in species. The CVA method applied in two dry deciduous forest areas of Karnataka (Coorg District) gave the following assessment: 24 and 22 species observed (among respectively 183 and 199 individuals), with Chao values of respectively 27 and 23 (corrective terms of 3 and 1).

It is therefore possible to get a good assessment of species richness in dry deciduous forests with cluster methods, laying 20 points.

The case of the CVA method is somewhat different due to the fact that sampling was restricted to the 10 nearest individuals: with the sole exception of the dry deciduous forest type, this method could not capture greater richness than the C20 method. Faster than the latter one, the CVA method could be used to get a rapid assessment of the forest richness before identifying the suitable area for settling a plot.

Diversity

The differences in diversity estimates are due to methods by which diversity is sampled. Simpson index measures diversity as a function of the total number of individuals per species sampled. As a result, it is affected by dominant species in the sample. Shannon index measures diversity as a function of the total number of species sampled, by averaging the values for the observed species diversity and richness. It seems better to obtain these 2 measures for comparison, using Simpson (1/D) as the upper limit of the diversity estimate and Shannon as the lower limit.

Using Simpson (1/D) index as a measure of community diversity, the cluster methods were observed to capture greater species diversity than the P40 method, except for the moist deciduous forest type (Table 31): the C20 method showed a lower Simpson value, related to the fact that a large number of individuals has been sampled, distributed in a small number of species (Table 31). An increase of the number of plots in the cluster methods would also give a better assessment of the species diversity.

Using Shannon index, the P40 method gave the lower assessment of species diversity.

Table 31. Tree species diversity (Simpson 1/D and Shannon indices) captured in various forest types by the P40, C20 and CVA methods.

Methods	**40x40 m plot**		**Cluster of 20x20 m plots**		**Cluster of variable-area plots**	
Forest type	**1/D**	**H' (Hmax)**	**1/D**	**H' (Hmax)**	**1/D**	**H' (Hmax)**
Evergreen	9.95	4.30 (5.17)	19.0	4.97 (5.88)	20.53	4.64 (5.17)
Moist deciduous	4.30	2.42 (3.32)	3.98	2.72 (4.17)	4.95	2.80 (4.00)
Dry deciduous	5.29	2.92 (3.70)	6.94	2.99 (3.46)	6.19	2.98 (3.58)

*Species represented by more than 10% of the individuals

Dominance

The dominance values reported for Simpson (1-D) index indicate the importance of rarity in determining the richness of the communities (Table 32). The differences in the various parameters observed with respect to the richness estimates in the moist deciduous forest as compared to the dry deciduous forest is due to the fact that the dominance of the community is obtained by two diverse processes. First, in species poor communities, dominance of one species is commonly observed, and the contribution of the rare species towards the diversity decreases. Second, in moderately species rich communities, it is evident that the dominance of a single species is not possible and the diversity is actually made up by several rare species in the community.

The areas sampled in the evergreen forest had a dominance of some species reaching from 17% of the population to 35% and at the same time an evenly distributed population, due to the high presence of rare or low frequency species (56% of the species to 83%). The two P40 and CVA methods showed the dominance of one species (respectively 31% and 17% of the population) whereas the C20 method showed the dominance of 4 species (35% of the population). The populations in evergreen forests are more likely to be represented and dominated by several species. It is therefore possible to put forward that the latter method, with a larger sampling area, gives a better assessment of the population's diversity and composition than the two other methods. Dominance in the moist deciduous forest sampled was high, from 66% to 75%: four species dominated the stand sampled by the P40 method, and three species dominated the stands sampled by the two cluster methods. The populations were not evenly distributed.

The same pattern can be observed in the dry deciduous forest studied: dominance was also high, from 56% to 65% of the population, with three dominant species recorded by the P40 and C20 methods, and two species recorded by the CVA method (56%). Evenness was also rather low. The number of rare species is lower in deciduous forests than in evergreen forests, and stands tend to be usually distributed within dominant species and other species represented by few individuals.

Table 32. Dominance indices (Simpson 1-D and Evenness) for the forest types as obtained by various sampling methods used in the study.

Methods	**40x40 m plot**		**Cluster of 20x20 m plots**		**Cluster of variable-area plots**	
Forest type	**1-D**	**Evenness**	**1-D**	**Evenness**	**1-D**	**Evenness**
Evergreen	0.90	0.83	0.95	0.85	0.95	0.90
Moist deciduous	0.77	0.73	0.75	0.65	0.80	0.70
Dry deciduous	0.81	0.79	0.86	0.87	0.84	0.83

Time required for each method

We estimated the time required for each method (Table 33). The work had two major limitations from the view of the participants: their lack of knowledge of species in the area (especially evergreen) and the working conditions in the field (including language problem). Despite these, both the teams could successfully undertake the work. Although data collection was faster towards the end of the fieldwork, we have averaged the time required by the participants to complete one round of work.

Table 33. Estimation of average time required for completion of protocol per method.

Methods	40x40 m plot		Cluster of 20x20 m plots		Cluster of variable-area plots	
Forest type	Single plot	All plots	Single plot	All plots	Single plot	All plots
Evergreen	4 days	4 days	3 hours	4 days 30 min	30 min	4 hours 30 min
Moist deciduous	3 days	3 days	1 hour 30 min	2 days	20 min	3 hours
Dry deciduous	2 days	2 days	1 hour	4 hours	15 min	1 hour

Field studies are essentially a compromise between several factors. The important factors are objectives, time and manpower availability. The P40 and C20 methods require more staff than the CVA method. However, the latter method does not provide assessment on the seedling population, which is time consuming.

Requirement of seedling study

Seedling stand assessment can give an estimate of the regeneration occurring in a forest. This allows understanding the reproductive patterns at the population and species levels. However, it appears useless if one wants only to study the present status and characteristics of a forest, considering that seedling mortality is high and the regenerative pool is addressed as the sapling stand. It is therefore needed to properly address the aim and objectives of the study before taking up an assessment of the seedling stand.

Do larger plots represent greater richness and diversity?

Clusters of small plots seemed to be ideal to depict the diversity of the forest types studied. This is obvious for the evergreen and moist deciduous forests, where clusters of 20x20 m plots captured marginally greater richness than the larger 40x40 m plots *(Fig. 16).* Sampling for species richness in evergreen forests usually results in a large number of species being represented only once. Therefore, the larger the area or the greater the number of small plots are, the better the assessment of species richness and diversity will be. As shown by Gimaret-Carpentier *et al.* (1998) in evergreen forest, a cluster of small plots containing 1000 individuals is sufficient to get a satisfactory assessment of species richness, while 500 individuals should be sufficient to assess the species diversity according to Simpson index. The number of individuals would decrease in the deciduous forest types along with the decrease of species richness.

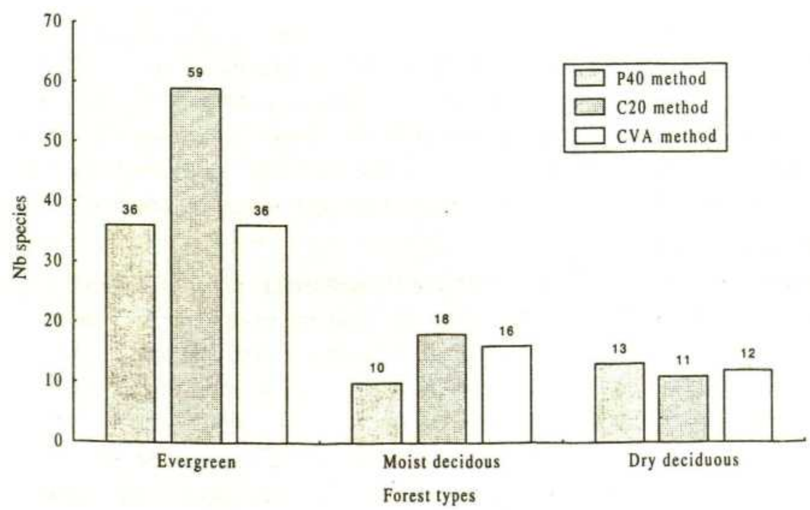


Figure 16. Comparison of the species richness captured by the 3 methods.

The larger number of individuals was sampled with the C20 method, in evergreen and moist deciduous forests *(Fig. 17).* However, the P40 method did capture more individuals than the other methods in the dry deciduous forest: this plot was probably laid in a very dense area of this forest.

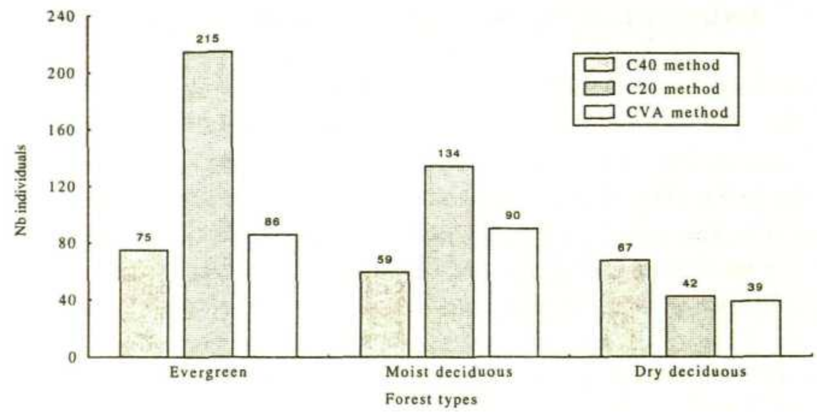


Figure 17. Comparison of the number of individuals sampled with the 3 methods

Do lower ensembles add greater richness?

The variation in richness where different levels of information are considered is illustrated by the figures 18, 19 and 20, for the two cluster methods. It is obvious that the C20 method gives more information on the species richness and regeneration potential of the forest type than the other method, since data on the seedling stand are collected. Species richness increases when all ensemble levels are considered.

Evergreen forest

In evergreen forest, total species richness is considerably lower as obtained by the CVA method than the C20 method (*Fig. 18).* With reference to the area sampled — which decreases from trees to seedlings (respectively 400, 100 and 25 m^2) —the species richness encountered in evergreen forests is therefore higher within the sapling and seedling stands than in the tree stand.

Only 16 and 17 species were common for all ensemble levels in the two methods, which represent respectively 17% and 32% of the species. The increased representation at the sapling level is due to the increased number of shrubs. Each level has an important number of species not represented in the other levels. Despite the fact that the sampled area was too small to capture all the tree species, many hypothesis can be put forward (aggregativity of the seedlings and saplings, fruiting patterns and dispersal abilities, survival of the seedlings, *etc.),* which would need a more complete study of the seedling and sapling stands to state about the regenerative potential of the forest (the present study sample of these two stands is too small to state that a tree species is really not present in the young stands). However, this puts forward the need for an assessment of the three levels to get a complete assessment of the species richness of an evergreen forest.

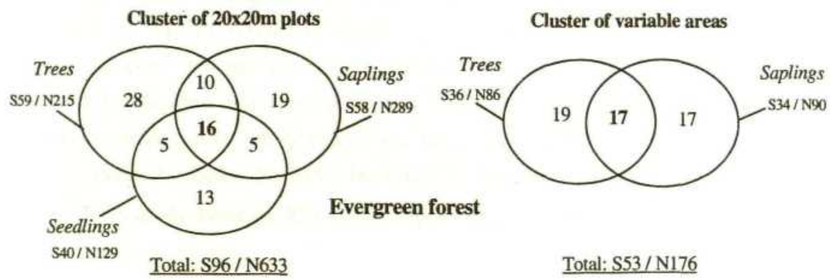
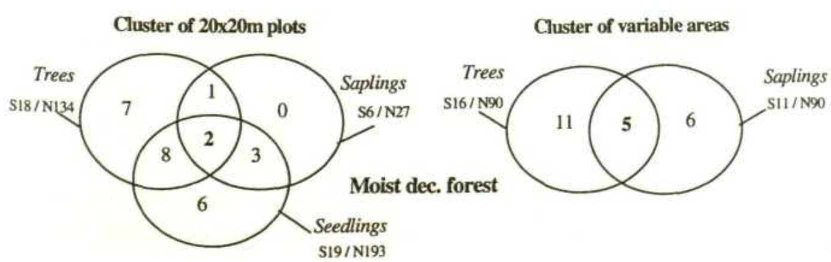


Figure 18. Species richness in evergreen forest for each ensemble of trees, saplings and seedlings using the cluster methods (S: Observed species; N: Number of individuals; Bold numbers: species common to all the stages).

Moist deciduous forest

The total species richness observed reaches 27 for the C20 method and 22 for the CVA method *(Fig. 19).* The species richness assessed for the trees was somewhat equivalent for the two methods, though the sampling area is smaller with the CVA method. The number of species observed is higher with the CVA method for the saplings, most probably directly related to the fact that the sampling was done in an area five times larger than for the other method. The numbers of common species for the three levels are very low (respectively 7% and 23% of the species for the C20 and CVA methods). The three levels present unique species. This can be related to the fact that the area sampled for truly capturing all the tree species was too small. However, the sapling stand was very poor (area prone to fire), with its entire species in common with the other stands in the C20 method.



Total: S27/N354 Total: S22/N180

Figure 19. Species richness in moist deciduous forest for each ensemble of trees, saplings and seedlings using the cluster methods (S: Observed species; N: Number of individuals; Bold numbers: species common to all the stages).

Dry deciduous forest

The total species richness observed is also quite similar for the two methods, reaching 18 for the C20 method and 16 for the CVA method *(Fig. 20).* The seedling stand contains an important part of its species (47%) exclusively present in this stand: mortality is high in this area prone to fire and some species are shrub species, not present in the tree stand (gbh ≥30 cm). The sapling stand was very poor, linked with the annual fires destroying the vegetation and harming the young trees. In order to collect data for 10 saplings with the CVA method, large areas had to be sampled. None of the species of saplings were unique in the C20 method, as all the 4 species were common.

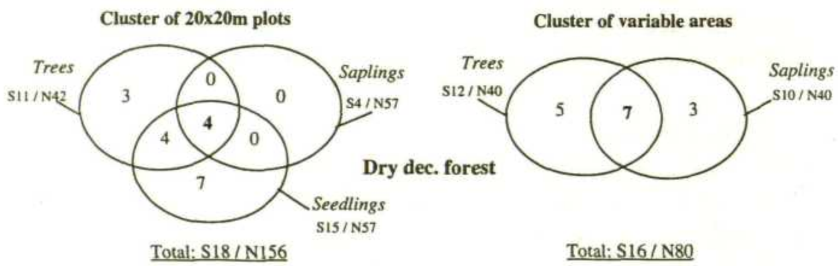


Figure 20. Species richness in dry deciduous forest for each ensemble of trees, saplings and seedlings using the cluster methods (S: Observed species; N: Number of individuals; Bold numbers: species common to all the stages).

Sampling seedlings increased richness estimates. Ideally, sampling strategies should include as many strata as possible in order to improve the richness estimates.

Conclusion

The objectives of the study were *i*) to train foresters in using tools to characterize and assess the structure and species richness and diversity of a forest stand, with sampling methods and indices, and *ii)* to compare three sampling methods used in three different forest types.

This study does not aim to give an assessment of the structure and biological diversity in these three different forests, as the sampling was not done thoroughly, due to time constraints within the frame of the Training Programme. From the comparison of the three methods used, it is possible to conclude that laying a single 40x40 m plot is not an advisable method: the area would be too small for capturing all the species richness and diversity as well as to represent the forest type. The cluster methods appear therefore to be better for species richness and diversity assessment, as the area sampled is larger and then would cover all the variability occurring in a forest type, if a large plot (1 ha minimum) cannot be established. According to Gimaret-Carpentier *et al.* (1998), "satisfactory assessment of species richness would need a systematic or stratified sampling design of 1000 individuals by using Chao estimator while 500 individuals would be sufficient to assess the species diversity according to Simpson's index", in an evergreen forest. These numbers of individuals would be decreasing in deciduous forest types as species richness is lower than in evergreen forest types.

The results from this study show that species richness is better sampled with the C20 method in evergreen and moist deciduous forests, followed by the CVA method. This is in agreement with the results exposed by Gimaret-Carpentier *et al.* (1998): as rare species are supposed to be scattered over the area than being locally aggregated, they are better sampled by numerous small clusters *(i.e.* they have higher frequencies). The C20 method would therefore be ideal if one does not want to established a large area (≥1 ha) plot. A transect of a certain number of plots (sampling at least 1000 individuals in an evergreen forest, number decreasing from evergreen to moist deciduous to dry deciduous) can be laid wjth minimum time and staff. The CVA method appears to be a limited method in evergreen forests, as only 10 individuals are sampled in the two levels of trees and saplings. This limits considerably the assessment and requires a high number of points to reach the right number of individuals for species richness and diversity assessment. However, this method remains of interest if one needs a rapid assessment of the floristic composition and structure of a forest type, before choosing the area in which to establish a large plot, to identify the forest type of an area or to get an assessment of the degree of degradation of the forest sampled.

Species richness can be assessed by both the numbers of observed species and Chao estimator value. The number of observed species is most of the time underestimating the species richness, as some rare species are not captured. Chao estimator gives a good estimate of the number of species that would be sampled in a chosen area, by taking into account the rare species present in this area.

Species diversity can be assessed by the indices of Simpson and Shannon. Simpson index tends to be affected by the presence of dominant species. This index is not sensitive to the low frequency of the rare species. However, it leads to stable unbiased estimate *ca.* 300 individuals in evergreen forest. Shannon index is more sensitive to the sample size and thus always underestimates the compartment diversity, and is always biased (Gimaret-Carpentier *et al.* 1998). Both indices can be used as complementary information on species diversity.

A proper characterization of the aim and objectives of the study is needed to decide which method and tools would be more appropriate for an assessment of the forest stand studied.

References

Chao A. 1987. Estimating the population size for capture-recapture data with unequal catchability. *Biometries,* **43**: 783-791.

Conduit R., Hubbell S.P., Lafrankie J.V., Sukumar R., Manokaran N., Foster R.N., Ashton P.S. 1996. Species-area and species-individual relationships for tropical trees: a comparison of three 50-ha plots. *Journal of Ecology,* **84**: 549-562.

Devineau J.-L. 1975. *Etude quantitative des forêts-galeries de Lamto (Moyenne Côte d'Ivoire).* Thèse 3ème Cycle, Paris.

Gimaret-Carpentier C, Pélissier R., Pascal J. -P. & Houllier F. 1998. Sampling strategies for the assessment of tree species diversity. *J. Of Vegetation Science,* **9**: 161-172.

Laumonier Y. 1980. Contribution à l'étude écologique et structurale des forêts de Sumatra. ICITV- Univ. Paul Sabatier.

Magurran A.E. 1988. *Ecological diversity and its measurement.* Croom Helm Ltd., London, 179 pp.

Oldeman R.A.A. 1974. L'architecture de la forêt guyanaise. *Mémoires O.R.S.T.O.M.,* **73**,204 p.

Pascal J.-P. 1986. *Explanatory booklet on the forest map of South India.* Institut Français de Pondichéry, 88 p.

Pascal J.-P. 1988. *Wet evergreen forests of the Western Ghats in India: ecology, structure, floristic composition and succession.* Travaux de la section scientifique et technique, **20bis**, Institut français de Pondichéry, 345 pp.

Pélissier R. 1997. *Hétérogénéité spatiale et dynamique d'une forêt dense humide des Ghâts occidentaux de l'Inde.* Publications du Département d'Ecologie, **37**, Institut Français de Pondichéry, 150 pp.

Ramesh B. R., 1989. *The evergreen forests of the Biligirirangan hills.* Ph.D. thesis, Madras University.

Ramesh B.R., Pascal, J.-P. and Nouguier C. 1997. *Atlas of endemic evergreen tree species of the Western Ghats.* Institut français de Pondichéry, Publications du département d'Ecologie, **38**,403 p.

Shannon, C.E. 1948. A mathematical theory of communications. *Bell. Syst. Tech. J.* **27**: 379-423,623-656.

Simpson, E.H. 1949. Measurement of diversity. *Nature* **163***:* 688.

Southwood TR.E., Brown V.K., Reader P.M. 1979. Relationship of plant and insect diversities in succession. *Biological journal of Linneanean Society,* **12***:* 327-348.

Appendix

Total species list

EG: evergreen forest type; MD: Moist deciduous forest; DD: Dry deciduous forest

Species	Family	Forest types
Actinodaphne lawsonii	LAURACEAE	EG
Actinodaphne bourdillonii	LAURACEAE	EG
Actinodaphne malabarica	LAURACEAE	EG
Aglaia lawsonii	MELIACEAE	EG
Aglaia simplicifolia.	MELIACEAE	EG
Aglaia sp.	MELIACEAE	EG
Agrostistachys indica	EUPHORBIACEAE	EG
Agrostistachys meeboldii	EUPHORBIACEAE	EG
Albizzia marginata	FABACEAE (MIMOSOIDEAE)	DD
Anogeissus latifolia	COMBRETACEAE	DD, MD
Antidesma menasu	EUPHORBIACEAE	EG
Apama siliquosa	ARISTOLOCHIACEAE	EG
Aphanamixis polystachya	MELIACEAE	EG
Aporosa bourdillonii	EUPHORBIACEAE	EG
Artocarpus gomezianus	MORACEAE	EG
Artocarpus hirsutus	MORACEAE	EG
Atlantia wightii	RUTACEAE	EG
Baccaurea courtallensis	EUPHORBIACEAE	EG
Bauhinia racemosa	FABACEAE (CAESALPINIOIDEAE)	MD
Beilschmiedia wightii	LAURACEAE	EG
Bischofia javanica	EUPHORBIACEAE	EG
Blachia denudata	EUPHORBIACEAE	EG
Blachia umbellata	EUPHORBIACEAE	EG
Buchanania lanzan	ANACARDIACEAE	MD
Butea monosperma	FABACEAE (FABOIDEAE)	MD
Calophyllum polyanthum	CLUSIACEAE	EG
Canarium strictum	BURSERACEAE	EG
Careya arborea	LECYTHIDACEAE	DD, MD
Casearia sp.	FLACOURTIACEAE	EG
Cassiafistula	FABACEAE (CAESALPINIOIDEAE)	EG
Catunaregam dumetorum	RUBIACEAE	EG

Catunaregam spinosa	RUBIACEAE	DD
Chionanthus leprocarpa	OLEACEAE	EG
Chrysophyllum lanceolatum	SAPOTACEAE	EG
Cinnamomum malabatrum	LAURACEAE	EG
Clausena indica	RUTACEAE	EG
Cleistanthus malabaricus	EUPHORBIACEAE	EG
Cryptocarya bourdillonii	LAURACEAE	EG
Cryptocarya sp.	LAURACEAE	EG
Cynometra travancorica	FABACEAE (CAESALPINIOIDEAE)	EG
Dalbergia latifolia	FABACEAE (FABOIDEAE)	DD, MD
Dichapetalum gelonioides	DICHAPETALACEAE	EG
Dillenia indica	DILLENIACEAE	EG
Dlllenia pentagyna	DILLENIACEAE	EG
Dimocarpus longan	SAPINDACEAE	EG
Diospyros bourdilloni	EBENACEAE	EG
Diospyros cf. *nilagirica*	EBENACEAE	EG
Diospyros candolleana	EBENACEAE	EG
Diospyros melanoxylon	EBENACEAE	DD
Diospyros montana	EBENACEAE	EG
Diospyros sylvatica	EBENACEAE	EG
Dipterocarpus indicus	DIPTEROCARPACEAE	EG
Drypetes elata	EUPHORBIACEAE	EG
Elaeocarpus serratus	ELAEOCARPACEAE	EG
Elaeocarpus tuberulatus	ELAEOCARPACEAE	EG
Emblica officinalis	EUPHORBIACEAE	DD,MD
Eriolaena hookeriana	STERCULIACEAE	MD
Euodia lunu-ankenda	RUTACEAE	EG
Euonymus crenulatus	CELASTRACEAE	EG
Euonymus dichotomus	CELASTRACEAE	EG
Euonymus indicus	CELASTRACEAE	EG
Ficus virens	MORACEAE	EG
Flacourtia montana	FLACOURTIACEAE	EG
Garcinia gummi-gutta	CLUSIACEAE	EG
Garcinia indica	CLUSIACEAE	EG
Garcinia morella	CLUSIACEAE	EG
Garcinia sp.	CLUSIACEAE	EG
Garcinia talbotii	CLUSIACEAE	EG

Glochidion malabaricum	EUPHORBIACEAE	DD, EG
Gomphandra tetrandra	ICACINACEAE	EG
Goniothalamus cardiopetalus	ANNONACEAE	EG
Gordonia obtusa	THEACEAE	EG
Grewia tiliaefolia	TILIACEAE	DD, MD
Holigarna arnottiana	ANACARDIACEAE	EG
Holigarna grahmii	ANACARDIACEAE	EG
Holigarna nigra	ANACARDIACEAE	EG
Hopea parviflora	DIPTEROCARPACEAE	EG
Hopea ponga	DIPTEROCARPACEAE	EG
Humboldtia brunonis	FABACEAE (CAESALPINIOIDEAE)	EG
Hydnocarpus alpina	FLACOURTIACEAE	EG
Hydnocarpus pentandra	FLACOURTIACEAE	EG
Isonandra lanceolata	SAPOTACEAE	EG
Ixora nigricans	RUBIACEAE	EG
Kingiodendron pinnatum	FABACEAE (CAESALPINIOIDEAE)	EG
Knema attenuata	MYRISTICACEAE	EG
Kydia calycina	MALVACEAE	DD
Lagerstroemia microcarpa	LYTHRACEAE	EG
Lagerstroemia parviflora	LYTHRACEAE	DD, MD
Leea indica	LEEACEAE	EG
Litsea bourdillonii	LAURACEAE	EG
Litsea floribunda	LAURACEAE	EG
Litsea mysorensis	LAURACEAE	EG
Litsea oleoides	LAURACEAE	EG
Litsea sp.	LAURACEAE	EG
Lophopetalum wightianum	CELASTRACEAE	EG
Madhuca latifolia	SAPOTACEAE	MD
Mallotus philipensis	EUPHORBIACEAE	EG
Mallotus stenanthus	EUPHORBIACEAE	EG
Mangifera indica	ANACARDIACEAE	DD,EG
Mastixia arborea	CORNACEAE	EG
Meiogyne pannosa	ANNONACEAE	EG
Meiogyne ramarowii	ANNONACEAE	EG
Meliaceae	MELIACEAE	EG

Memecylon malabaricum	MELASTOMATACEAE	EG
Mesua ferrea	CLUSIACEAE	EG
Microtropis latifolia	CELASTRACEAE	EG
Microtropis microcarpa	CELASTRACEAE	EG
Miliusa eriocarpa	ANNONACEAE	EG
Mitragyna parviflora	RUBIACEAE	MD
Mitrephora grandiflora	ANNONACEAE	EG
Murraya sp.	RUTACEAE	EG
Myristica dactyloides	MYRISTICACEAE	EG
Myristica malabarica	MYRISTICACEAE	EG
Neolitsea zeylanica	LAURACEAE	EG
Nothapodytes heyneana	ICACINACEAE	EG
Nothopegia beddomei	ANACARDIACEAE	EG
Nothopegia heyneana	ANACARDIACEAE	EG
Nothopegia travancorica	ANACARDIACEAE	EG
Olea dioica	OLEACEAE	EG
Otonephelium stipulaceum	SAPINDACEAE	EG
Pajanelia longifolia	BIGNONIACEAE	EG,MD
Palaquium ellipticum	SAPOTACEAE	EG
Polyalthia fragrans	ANNONACEAE	EG
Psychotria flavida	ANNONACEAE	EG
Psychotria nigra	RUBIACEAE	EG
Pterocarpus marsupium	FABACEAE (FABOIDEAE)	DD,MD
Pterospermum diversifolium	STERCULIACEAE	EG
Pterygota alata	STERCULIACEAE	EG
Radermachera xylocarpa	BIGNONIACEAE	MD
Reinwardtiodendron anaimalaiense anamallayanam	MELIACEAE	EG
Rinorea bengalensis	VIOLACEAE	EG
Schefflera racemosa	ARALIACEAE	EG
Schefflera stellata	ARALIACEAE	EG
Schrebera swietenioides	OLEACEAE	MD
Scolopia crenata	FLACOURTIACEAE	EG
Semecarpus auriculata	ANACARDIACEAE	EG
Shorea roxburghii	DIPTEROCARPACEAE	DD
Stereospermum chelonoides	BIGNONIACEAE	DD

Stereospermum personatum	BIGNONIACEAE	DD
Strobilanthes sp.	ACANTHACEAE	EG
Symplocos cochinchinensis	SYMPLOCACEAE	EG
Symplocos sp.	SYMPLOCACEAE	EG
Syzygium cumini	MYRTACEAE	MD
Syzygium gardneri	MYRTACEAE	EG
Syzygium laetum	MYRTACEAE	EG
Syzygium munronii	MYRTACEAE	EG
Tabernaemontana heyneana	APOCYNACEAE	EG,MD
Tamilnadiana uliginosa	RUBIACEAE	DD
Tectona grandis	VERBENACEAE	DD, MD
Terminalia alata	COMBRETACEAE	MD
Terminalia crenulata	COMBRETACEAE	MD
Terminalia paniculata	COMBRETACEAE	DD,MD
Vepris bilocularis	RUTACEAE	EG
Walsura trifoliata	MELIACEAE	EG
Zyziphus glaberima	RHAMNACEAE	DD
Zyziphus cf. mauritiana	RHAMNACEAE	DD

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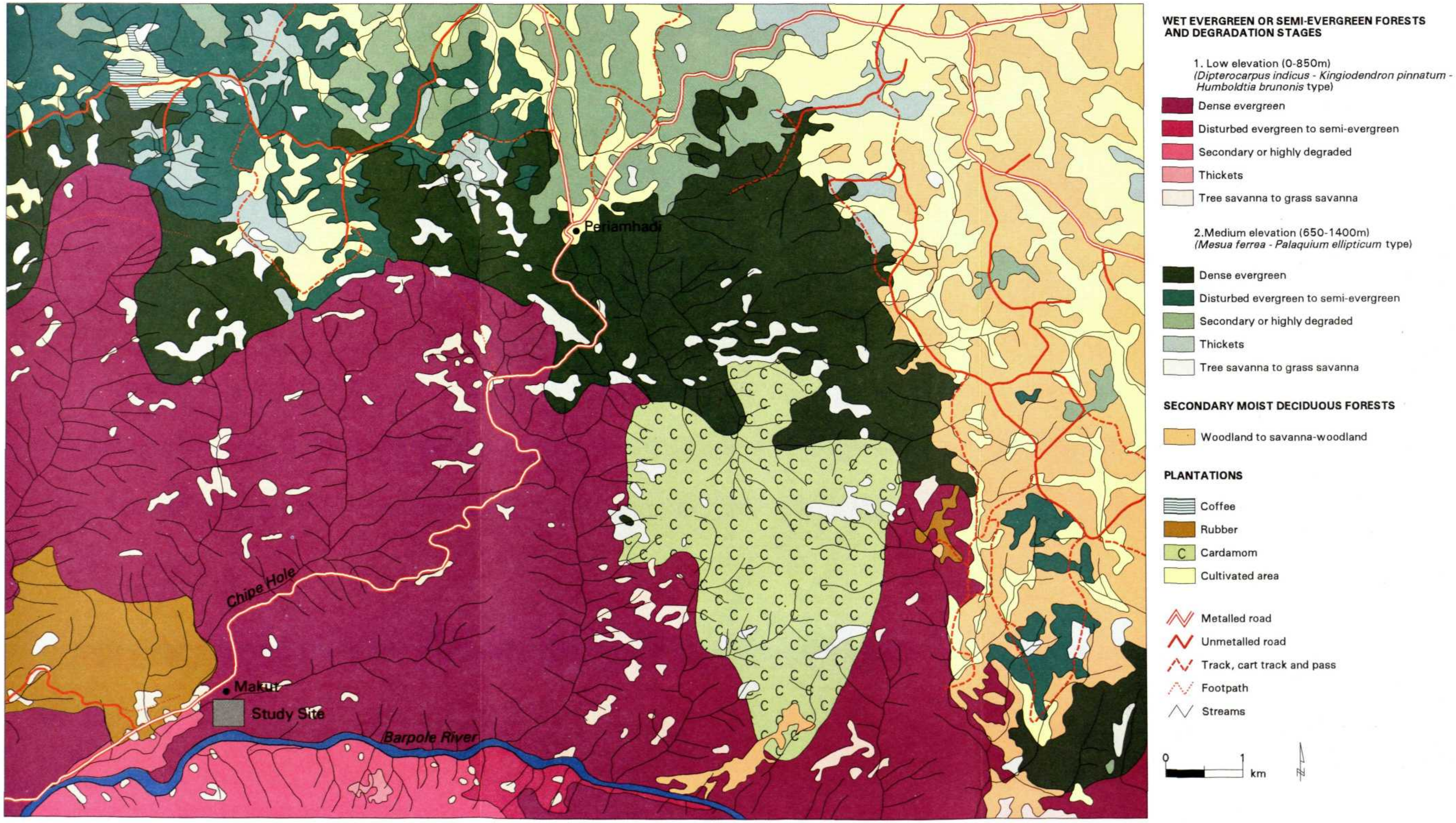
1. CLAIRE ELOUARD, FRANÇOIS HOULLIER, JEAN-PIERRE PASCAL, RAPHAEL PÉLISSIER, B.R. RAMESH, about Dynamics of the dense moist evergreen forests. Long Term Monitoring of an Experimental Station in Kodagu District (Karnataka, India), 1997, n°1, 23 p.

2. FRANÇOIS HOULLIER, YVES CARAGLIO, MURIEL DURAND, about Modelling Tree Architecture and Forest Dynamics. A Research Project in the dense moist evergreen forests of the Western Ghats (South India), 1997, n°2, 37 p.

3. MURIEL DURAND, Architecture and growth strategy of two evergreen species of the Western Ghats (South India), *Knema attenuata (J. Hk. & Thw.) Warb. (Myristicacece) and Vateria indica L. (Dipterocarpacece)* 1997, n° 3, 39 p.

4. FRANÇOIS HOULLIER, RANI M. KRISHNAN, CLAIRE ELOUARD, Assessment of Forest Biological Diversity. A FAO training course 1. Lecture Notes 1998, n° 4, 102 p.

VEGETATION MAP OF MAKUT REGION



VEGETATION MAP OF BANDIPUR REGION