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# TROPICAL DRY EVERGREEN FORESTS ON THE COROMANDEL COAST OF INDIA: STRUCTURE, COMPOSITION AND HUMAN DISTURBANCE

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*Abstract*. The impact of human disturbances on forest stands was investigated in two tropical dry evergreen forests, which are also sacred groves or temple forests at Arasadikuppam (site AK) and Oorani (OR) on the Coromandel (east) coast of India. The two sites differ in their degree of disturbance. Site disturbances were classified into site encroachment, temple visitors' impact, degree of cattle and goat browsing, and resource removal. The total score of disturbance level at AK was more than twice (16) that (7) of the less disturbed site OR. A one-hectare permanent study plot was established at each of these sites. The highly disturbed site AK is characterized by short-statured forest (stand height ~ 5 m) with two strata, whereas the less disturbed site OR is comparatively tall-statured (~ 8 m tall) with three strata. The tree density (stems ≥ 10 cm girth at breast height – gbh) at site AK was twice that at OR (2815 and 1286 stems $ha^{-1}$ respectively). Site AK was composed of 75% more multi-stemmed individuals than OR, but the less disturbed site OR was 55% more voluminous (basal area 27.3 $m^2$ $ha^{-1}$) than the highly disturbed site AK (17.6 $m^2$ $ha^{-1}$). Site OR comprised 77% evergreen species as against 65% at AK. Site AK contained a greater density (85%) of stems in the lowest girth class of 10–30 cm gbh, indicating a greater state of recovery from past disturbance than the less disturbed site OR (64%), which represents a mature forest stand or climax forest. The forest stand structure exhibited a reversed 'J' curve at AK, which was steeper for both girth frequency as well as basal area, while at OR the girth frequency curve was shallow but the basal area distribution was bell-shaped. The species-abundance-based similarity score between the highly disturbed site AK and the less disturbed site OR was 0.45. Tree diversity data of the two study sites are compared with three other comparable tropical dry evergreen forest sites (Kuzhanthaikuppam-KK, Thirumanikkuzhi-TM and Puthupet-PP) located within ~ 50 km radius on the Coromandel coast of India. Based on the degree of disturbance, the five sites can be represented as OR<TM<AK<KK<PP. There was not much difference in the forest composition (number of species, genera and families) of the two present study sites, but, when all the five sites are considered, species diversity was 20% less in the highly disturbed site PP. Evidently, human disturbances have an impact on forest stand characteristics such as stand height, number of strata, tree density, and basal area. *Accepted 25 January 2003.*

*Key words*: *Anthropogenic disturbances, dominance, forest structure, permanent plots, sacred groves, tree diversity.*

## INTRODUCTION

Most studies on forest composition worldwide have been conducted on rainforest vegetation, and there are relatively few data available on tropical dry forest communities (Sussman & Rakotozafy 1994). The dry forest ecosystems in the tropics have received attention in recent years as threats to their conservation have become recognized by biologists. An effective and rapid method of obtaining this information is to conduct floristic inventories at specific localities, so that biogeographical affinities can be discerned and rare or endemic species of special conservation interest identified. Quantitative inventories provide information on the nature of species and the diversity of forests, as well as precise data on the structure of these ecosystems. The general world situation concerning tropical dry forests as a whole is in far worse shape conservationally than moist and wet forests (Lerdau *et al.* 1991).

Seasonal dry evergreen forests are closed-canopy forests in which the main canopy is predominantly evergreen with scattered individuals of deciduous trees (Santisuk 1988) and are ecologically important because of their unique biotic communities (Bunyavej-

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chewin 1999). Tropical dry evergreen forests have been distinguished by various authors (Sebastine & Ellis 1967, Champion & Seth 1968, Rao & Meher-Homji 1993) and they represent a peculiar type that is confined to the eastern (Coromandel) coast of India, northeast Sri Lanka (Blasco & Legris 1973), northeastern Thailand (Bunyavejchewin 1999), and Jamaica (Kelly *et al.* 1988). These are relatively poorly known forest types even within the Indian subcontinent and are species-poor when compared to tropical wet forests (Parthasarathy & Karthikeyan 1997). Studies on the quantitative ecological inventory of plant diversity in dry evergreen forests include Visalakshi (1995), Parthasarathy & Karthikeyan (1997), Parthasarathy & Sethi (1997) and Ramanujam & Kadamban (2001). Information on tropical plant diversity is needed because of its potential usefulness in understanding the relative extent of diversity across the tropics and the implications for conservation and management (Parthasarathy & Sethi 1997).

This paper on two tropical dry evergreen forests has two main objectives, aimed at generating baseline data of use to conservation:

– to assess the impact of human disturbances on forest stands in two tropical dry evergreen forests that differ in their degree of disturbance and

– to compare the data of these two forests with three other similar sites on the Coromandel coast of India.

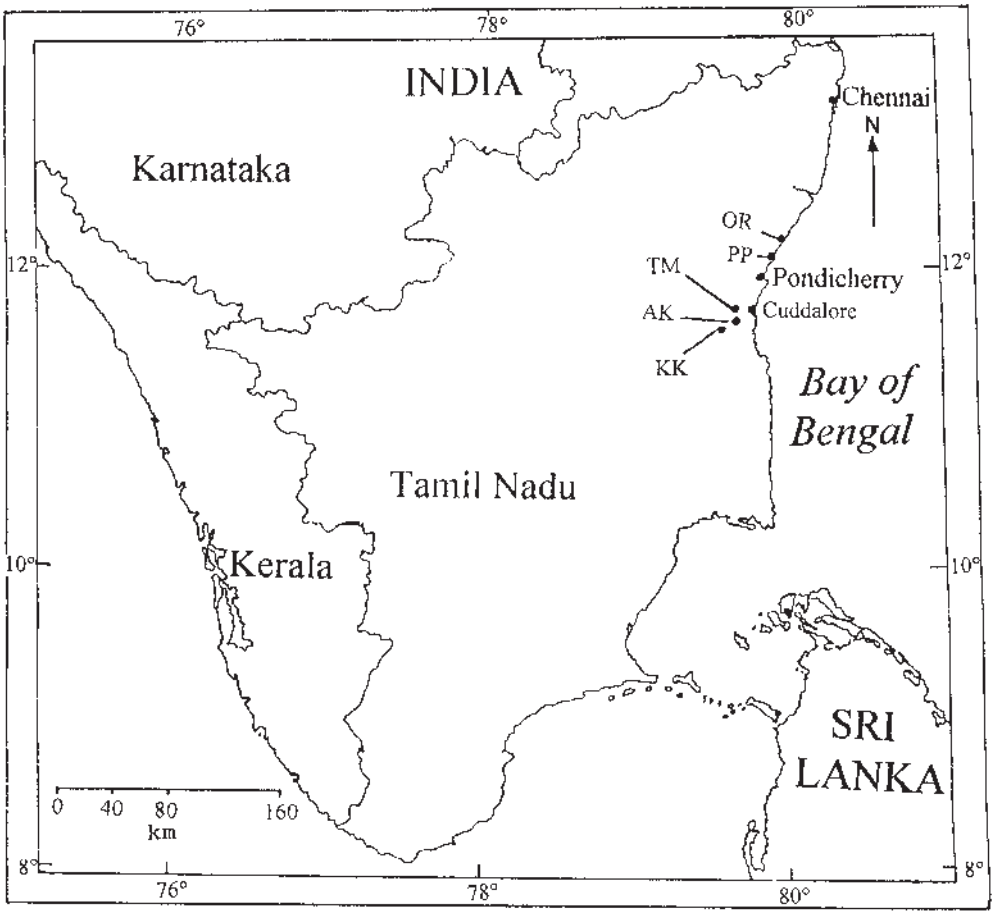


FIG. 1. Map showing the location of the five tropical dry evergreen forest sites on the Coromandel coast of southern India.

## MATERIALS AND METHODS

*Study sites.* The present tree diversity inventory was conducted in two tropical dry evergreen forests, Arasadikuppam (AK) and Oorani (OR) on the Coromandel coast of Tamil Nadu, southern India. Site AK (11°42'N, 79°36'E) is located 39 km south of Pondicherry (and 16 km southwest of Cuddalore town), and OR (12°11'N, 79°57'E) is located 28 km north of Pondicherry (Fig. 1). They occupy an area of about 1.5 ha and 1.8 ha respectively. Site AK is closer to human habitation, but OR is ~200 m away from human habitation.

*Climate.* Climate data for Pondicherry (12°03'N, 79°52'E), available for 21 years (1980–2000), reveal a mean annual temperature of 28.5°C and a mean annual rainfall of 1311 mm (Fig. 2). The mean number of annual rainy days is 55.5. The mean monthly temperature ranges from 24.1°C to 32.4°C for the same period. The climate is tropical disymmetric with the bulk of the rainfall during the northeast monsoon in October–November.

*Vegetation.* The vegetation in this region is described as tropical dry evergreen forest (Champion & Seth 1968, Rao & Meher-Homji 1993), degraded to thorny scrub due to anthropogenic disturbance in various areas. Site AK exhibits a stunted growth with an average tree height of 5 m, while OR is a comparatively tall forest with an average height of 8 m. Site AK is composed of two-layered forest with a high density of trees in the lower story and fewer trees in the middle story. By contrast, OR is a three-layered forest with a fair representation of trees in the middle and upper stories.

*Field methods.* Two 1-ha permanent study plots were established, one each in the highly disturbed site AK and the less disturbed site OR. Fieldwork on a quantitative inventory was carried out in April–August 2001. In AK a 100 m × 100 m plot was subdivided into one hundred 10 m × 10 m quadrats, while in OR two 200 m × 25 m plots, located one on either side of the temple (as a mud road of ~3–4 m wide divides the forest into two blocks) were selected. They were subdivided into forty 10 m × 10 m and twenty 5 m × 10 m quadrats in each sub-plot. All trees ≥10 cm girth at breast height (gbh, 1.3 m) were measured and their girths recorded. Although the majority of forest studies utilize 10 cm diameter at breast height (dbh) as the lower size limit, in the present study a lower girth threshold of ≥10 cm gbh was chosen because of the low stature of dry evergreen forests (Parthasarathy & Karthikeyan 1997), many stems ≥10 cm gbh contributing to forest tree diversity and density. Since the majority of the trees are small, measurements of circumference have been used, which is more accurate than that of diameter (Strasberg 1996). Trees ≥30 cm gbh were tagged with sequentially numbered aluminum tags using nails and the trunk marked where the measurement was taken. In the case of trees with multiple stems, each stem was measured separately and basal area calculated and summed. Voucher specimens were collected and deposited in the herbarium of the Salim Ali school of Ecology and Environmental Sciences, Pondicherry University.

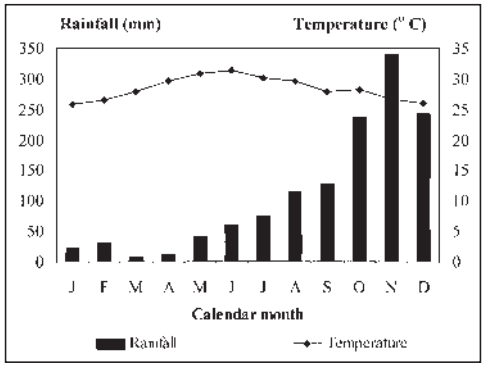


FIG. 2. Climatic diagram of Pondicherry, the nearest station to the two tropical dry evergreen forest sites AK and OR, based on 21 years of data (1980–2000).

Human disturbance was estimated for sites AK and OR, and for comparison similar estimates were made in three other tropical dry evergreen forest sites, viz. Kuzhanthaikuppam (KK), Thirumanikkuzhi (TM), and Puthupet (PP) located respectively 41and 36 km south, and 16 km north of Pondicherry on the Coromandel coast. Disturbances were qualitatively classified (as in Veblen *et al.* 1992, with modifications). All the sub-classes in various types of disturbance were ranked into relatively none (score 0), relatively low (1), medium (2) and high (3) levels of disturbance (Table 1). The sum of all scores for each site provides an overall ranking of anthropogenic disturbance in the forests. High ranks signify high levels of anthropogenic disturbance and low ranks low levels of disturbance.

*Data analysis.* For species diversity and evenness, the Shannon (H′), Simpson (λ) (as in Magurran 1988), and the Hill diversity (Hill 1973) indices were calculated. For importance value index (IVI) the relative density, relative frequency, and relative dominance were calculated according to the formulae of Cottam and Curtis (1956). A species-area curve was plotted as species increments in every 0.1 ha area.

## RESULTS

*Site disturbance.* The estimated disturbance levels at the five sites varied from a minimum score of 7 for site OR to a maximum score of 30 for site PP (Table 1). Arranged in increasing disturbance scores the results from the five sites were OR<TM<AK<KK<PP. All five sites are subjected to disturbance by construction of roads, by cattle and goat browsing, firewood and fodder collection, and extraction of medicinal plants. Site AK had 3 times greater disturbance scores than OR because of its proximity to human habitation. Overall, site PP was ranked as highly disturbed in all categories (except for soil removal) because of the extensive temple development activities. The degree of cattle and goat browsing was high in sites KK and PP mainly because of the presence of nearby water sources in the form of an annual stream and a pond respectively.

*Species diversity.* The tree diversity inventory (stems ≥10 cm gbh) of the two tropical dry evergreen forests, at Arasadikuppam (AK) and at Oorani (OR), yielded a total of 46 species belonging to 43 genera and 25 families. Tree species richness was almost equal in both study sites (Table 2). Fifteen species were shared by the two sites. Of the 46 species at the two sites, 67% were evergreen trees and the remaining were brevideciduous (24%) and deciduous (9%) species. The less disturbed site OR contained more evergreen species (77%) than the much disturbed AK (65%).

*Species-area curve.* The species-area curve for the two sites was initially steep up to 0.4 ha, followed by a gradual species accumulation; but from 0.4 ha to 0.6 ha area there was no species addition at site OR. Later it increased and reached an asymptote at 0.9 ha (Fig. 3). In AK, the species-area curve had an addi-

TABLE 1. Degree of site disturbance arranged in increasing order of total disturbance scores in five tropical dry evergreen forest sites, which include the two present study sites AK-Arasadikuppam and OR-Oorani and three other sites TM-Thirumanikkuzhi, KK-Kuzhanthaikuppam, and PP-Puthupet on the Coromandel coast of southern India.

| Disturbance | Site | | | | |
|---|---|---|---|---|---|
| | OR | TM | AK | KK | PP |
| 1. Site encroachment (land use within the forest) | | | | | |
| i. for construction of roads | 1 | 2 | 2 | 3 | 3 |
| ii. for construction of temple | 0 | 0 | 1 | 1 | 3 |
| 2. Temple visitors' impact: area used for | | | | | |
| i. vehicle parking | 0 | 0 | 0 | 1 | 3 |
| ii. cooking inside the forest | 0 | 1 | 1 | 1 | 3 |
| iii. festive occasion use | 1 | 0 | 2 | 1 | 3 |
| 3. Degree of cattle and goat browsing | 2 | 2 | 2 | 3 | 3 |
| 4. Resource removal | | | | | |
| i. firewood | 1 | 2 | 2 | 1 | 3 |
| ii. fodder | 1 | 2 | 3 | 2 | 3 |
| iii. medicinal plants | 1 | 1 | 2 | 2 | 3 |
| iv. timber | 0 | 2 | 1 | 2 | 2 |
| v. others: soil | 0 | 1 | 0 | 3 | 1 |
| Total score | 7 | 13 | 16 | 20 | 30 |

TABLE 2. Consolidated details of quantitative tree diversity inventory (stems ≥ 10 cm gbh) in two 1-ha permanent plots of the tropical dry evergreen forest at Arasadikuppam (AK) and Oorani (OR) on the Coromandel coast of India.

| Variable | Site | | Total for 2 ha |
|---|---|---|---|
| | AK | OR | |
| Species richness | 31 | 30 | 46 |
| Number of genera | 29 | 29 | 43 |
| Number of families | 20 | 19 | 25 |
| Diversity indices | | | |
| Shannon | 1.82 | 2.33 | |
| Simpson | 0.22 | 0.16 | |
| Hill diversity 1 (N0) | 31 | 30 | |
| Hill diversity 2 (N1) | 6.17 | 10.28 | |
| Hill diversity 3 (N2) | 4.65 | 6.25 | |
| Evenness index (E5) | 0.71 | 0.57 | |
| Stand density (stems $ha^{-1}$) | 2815 | 1286 | 4101 |
| Stand basal area ($m^2$ $ha^{-1}$) | 17.63 | 27.30 | 44.93 |
| Number of multi-stemmed trees | 961 | 549 | 1510 |

tion of one species (*Syzygium cumini*) even in the last block because of the site heterogeneity, since a broader stream flows along the last stretch of the plot. Nonetheless a 1-ha sample size is adequate to document all the tree species of the two study sites.

The diversity and evenness indices varied greatly between the two study sites (Table 2). The Shannon and the Hill diversity 2 and 3 were greater for AK than for OR. A total of 1510 trees (36.8%) in the forest stand had multi-stemmed individuals at the two sites. Sixty-four per cent of the trees at site AK were multi-stemmed individuals. The wild coffee *Tricalysia sphaerocarpa* (Rubiaceae) alone contributed 50% of multi-stemmed individuals in AK, while in OR *Memecylon umbellatum* formed 33%.

*Species density, dominance, and rarity.* The population density of different species varied considerably between the two sites (Table 3). Site AK was dominated by *Tricalysia sphaerocarpa* (33% of the stand), whereas site OR was dominated by *Memecylon umbellatum* (31%). *Tricalysia sphaerocarpa*, *Pterospermum canescens*, *Memecylon umbellatum*, *Diospyros ebenum*, and *Lepisanthes tetraphylla* formed 93% of the forest stand density at site AK; while *Memecylon umbellatum*, *Drypetes sepiaria*, *Glycosmis pentaphylla*, *Pterospermum canescens*, and *Diospyros ferrea* together formed 73% of the total stand density at the less disturbed site OR.

Based on the stem density, tree species were classified into very rare (those represented by < 1% of stand density), rare (1–5%), common (5–15%), dominant (15–30%) and predominant (> 30%). There were more rare species at the highly disturbed site AK (77%) than at the less disturbed site OR (50%), while rare species were numerically more in OR (37%) than in AK (6.5%). Common species included *Diospyros ebenum* and *Lepisanthes tetraphylla* at site AK, and *Glycosmis pentaphylla* and *Pterospermum canescens* at OR. The highest frequency (94) was recorded for *Pterospermum canescens* in AK and for *Memecylon umbellatum* (91) in OR.

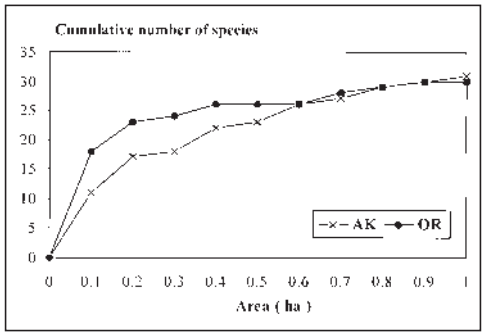


FIG. 3. Species-area curve for the two tropical dry evergreen forest sites Arasadikuppam (AK) and Oorani (OR).

*Plant families.* Twenty-five plant families were recorded in the two 1-ha plots (Table 4). There were 20 families in AK and 19 in OR. Twelve families were common to both sites. The most species-rich family was Rubiaceae with a total of 5 species in AK and 4 species in OR. The percentage of families represented by single species was higher (70%) at the more disturbed site AK than at the less disturbed OR (58%). Two families were represented by 3 species each and 3 families by 2 species each in AK. In OR, 6 fami-

TABLE 3. Population density (no. of stems ha$^{-1}$) of all trees ≥ 10 cm gbh at the two tropical dry evergreen forest sites at Arasadikuppam (AK) and Oorani (OR) on the Coromandel coast of India, along with details of family, density, and frequency.

| Sl. no. | Species | Family | Density | | | Frequency | |
|---|---|---|---|---|---|---|---|
| | | | AK | OR | Total | AK | OR |
| 1 | *Memecylon umbellatum* Burm. f. | Melastomataceae | 566 | 396 | 962 | 85 | 91 |
| 2 | *Tricalysia sphaerocarpa* (Dalz.) Gamble | Rubiaceae | 914 | – | 914 | 84 | – |
| 3 | *Pterospermum canescens* Roxb. | Sterculiaceae | 651 | 75 | 726 | 94 | 41 |
| 4 | *Diospyros ebenum* Koen. | Ebenaceae | 281 | 39 | 320 | 90 | 30 |
| 5 | *Drypetes sepiaria* (Wight & Arn.) Pax & Hoffm. | Euphorbiaceae | – | 258 | 258 | – | 84 |
| 6 | *Lepisanthes tetraphylla* (Vahl) Radlk. | Sapindaceae | 194 | 38 | 232 | 83 | 29 |
| 7 | *Glycosmis pentaphylla* (Retz.) DC. | Rutaceae | 38 | 149 | 187 | 26 | 58 |
| 8 | *Diospyros ferrea* (Willd.) Bakh. var. *buxifolia* (Rottb.) Bakh. | Ebenaceae | 1 | 57 | 58 | 1 | 37 |
| 9 | *Canthium dicoccum* (Gaertn.) Teijsm and Bin. | Rubiaceae | 14 | 41 | 55 | 6 | 18 |
| 10 | *Atalantia monophylla* (L.) Correa | Rutaceae | 47 | 5 | 52 | 29 | 5 |
| 11 | *Chionanthus zeylanica* L. | Oleaceae | 4 | 32 | 36 | 3 | 22 |
| 12 | *Lannea coromandelica* (Houtt.) Merr. | Anacardiaceae | – | 31 | 31 | – | 21 |
| 13 | *Garcinia spicata* (Wight & Arn.) J.D. Hook. | Clusiaceae | – | 30 | 30 | – | 15 |
| 14 | *Eugenia bracteata* (Willd.) Roxb. ex DC. | Myrtaceae | – | 27 | 27 | – | 14 |
| 15 | *Syzygium cumini* (L.) Skeels | Myrtaceae | 1 | 24 | 25 | 1 | 15 |
| 16 | *Morinda pubescens* J.E. Smith | Rubiaceae | 23 | – | 23 | 18 | - |
| 17 | *Ochna obtusata* DC. | Ochnaceae | – | 22 | 22 | – | 14 |
| 18 | *Aglaia elaeagnoidea* (Juss.) Benth. | Meliaceae | – | 16 | 16 | – | 13 |
| 19 | *Mallotus rhamnifolius* Muell.-Arg. | Euphorbiaceae | 14 | – | 14 | 4 | – |
| 20 | *Tarenna asiatica* (L.) Kuntze | Rubiaceae | 13 | 1 | 14 | 10 | 1 |
| 21 | *Borassus flabellifer* L. | Arecaceae | 1 | 11 | 12 | 1 | 11 |
| 22 | *Chloroxylon swietenia* DC. | Flindersiaceae | 12 | – | 12 | 12 | – |
| 23 | *Albizia amara* (Roxb.) Boivin | Mimosaceae | 2 | 7 | 9 | 2 | 7 |
| 24 | *Pterospermum xylocarpum* (Gaertn.) Sant. & Wagh | Sterculiaceae | 8 | – | 8 | 7 | – |
| 25 | *Benkara malabarica* (Lam.) Tirven. | Rubiaceae | 1 | 5 | 6 | 1 | 4 |
| 26 | *Azadirachta indica* A. Juss. | Meliaceae | 2 | 3 | 5 | 2 | 2 |
| 27 | *Cadaba trifoliata* (Roxb.) Wight & Arn. | Capparaceae | 5 | – | 5 | 5 | – |
| 28 | *Cassia fistula* L. | Caesalpiniaceae | 5 | – | 5 | 5 | – |
| 29 | *Dalbergia paniculata* Roxb. | Papilionaceae | 4 | – | 4 | 4 | – |
| 30 | *Walsura trifolia* (A. Juss.) Harms | Meliaceae | – | 4 | 4 | – | 4 |
| 31 | *Ficus benghalensis* L. | Moraceae | – | 3 | 3 | – | 3 |
| 32 | *Flacourtia indica* (Burm. f.) Merr. | Flacourtiaceae | – | 3 | 3 | – | 3 |
| 33 | *Maytenus emarginata* (Willd.) Ding Hou | Celastraceae | – | 3 | 3 | – | 3 |
| 34 | *Vitex altissima* L.f. | Verbenaceae | 3 | – | 3 | 2 | – |
| 35 | *Allophylus serratus* (Roxb.) Kurz | Sapindaceae | – | 2 | 2 | – | 1 |
| 36. | *Suregada angustifolia* (Baill. ex. Muell-Arg.) Airy Shaw | Euphorbiaceae | 2 | – | 2 | 1 | – |
| 37 | *Ficus microcarpa* L.f. | Moraceae | 2 | – | 2 | 2 | – |
| 38 | *Lantana camara* L. | Verbenaceae | 2 | – | 2 | 2 | – |
| 39 | *Phyllanthus polyphyllus* Willd. | Euphorbiaceae | 2 | – | 2 | 2 | – |
| 40 | *Casearia elliptica* Willd. | Flacourtiaceae | 1 | – | 1 | 1 | – |
| 41 | *Cordia obliqua* Willd. | Boraginaceae | – | 1 | 1 | – | 1 |
| 42 | *Ixora pavetta* Andr. | Rubiaceae | – | 1 | 1 | – | 1 |
| 43 | *Pleurostylia opposita* (Wall.) Alston | Celastraceae | – | 1 | 1 | – | 1 |
| 44 | *Premna serratifolia* L. | Verbenaceae | 1 | – | 1 | 1 | – |
| 45 | *Semecarpus anacardium* L.f. | Anacardiaceae | – | 1 | 1 | – | 1 |
| 46 | *Terminalia bellirica* (Gaertn.) Roxb. | Combretaceae | 1 | – | 1 | 1 | – |
| Total | | | 2815 | 1286 | 4101 | 585 | 550 |

TABLE 4. Family diversity, density (stems $ha^{-1}$) and basal area ($m^2$ $ha^{-1}$), arranged in descending order of total tree density, at two tropical dry evergreen forest sites at AK and OR (*indicates BA < 0.01; - indicates family not represented).

| Sl. no | Family | Richness | | Density | | | Basal area | |
|---|---|---|---|---|---|---|---|---|
| | | AK | OR | AK | OR | Total | AK | OR |
| 1 | Rubiaceae | 5 | 4 | 965 | 48 | 1013 | 5.32 | 0.27 |
| 2 | Melastomataceae | 1 | 1 | 566 | 396 | 962 | 0.94 | 1.47 |
| 3 | Sterculiaceae | 2 | 1 | 659 | 75 | 734 | 6.58 | 5.51 |
| 4 | Ebenaceae | 2 | 2 | 282 | 96 | 378 | 1.56 | 1.32 |
| 5 | Euphorbiaceae | 3 | 1 | 18 | 258 | 276 | 0.04 | 6.44 |
| 6 | Rutaceae | 2 | 2 | 85 | 154 | 239 | 0.26 | 0.41 |
| 7 | Sapindaceae | 1 | 2 | 194 | 40 | 234 | 0.75 | 1.02 |
| 8 | Myrtaceae | 1 | 2 | 1 | 51 | 52 | * | 2.43 |
| 9 | Oleaceae | 1 | 1 | 4 | 32 | 36 | 0.01 | 0.42 |
| 10 | Anacardiaceae | – | 2 | – | 32 | 32 | – | 2.36 |
| 11 | Clusiaceae | – | 1 | – | 30 | 30 | – | 1.13 |
| 12 | Meliaceae | 1 | 3 | 2 | 23 | 25 | 0.03 | 0.25 |
| 13 | Ochnaceae | – | 1 | – | 22 | 22 | – | 0.08 |
| 14 | Arecaceae | 1 | 1 | 1 | 11 | 12 | 0.08 | 1.06 |
| 15 | Flindersiaceae | 1 | – | 12 | – | 12 | 0.03 | – |
| 16 | Mimosaceae | 1 | 1 | 2 | 7 | 9 | 0.16 | 0.67 |
| 17 | Verbenaceae | 3 | – | 6 | – | 6 | 0.08 | – |
| 18 | Caesalpiniaceae | 1 | – | 5 | – | 5 | 0.06 | – |
| 19 | Capparaceae | 1 | – | 5 | – | 5 | 0.01 | – |
| 20 | Moraceae | 1 | 1 | 2 | 3 | 5 | 0.04 | 2.38 |
| 21 | Celastraceae | – | 2 | – | 4 | 4 | – | 0.01 |
| 22 | Flacourtiaceae | 1 | 1 | 1 | 3 | 4 | * | 0.01 |
| 23 | Papilionaceae | 1 | – | 4 | – | 4 | 1.03 | – |
| 24 | Boraginaceae | – | 1 | – | 1 | 1 | – | 0.03 |
| 25 | Combretaceae | 1 | – | 1 | – | 1 | 0.67 | – |
| | Total | 31 | 30 | 2815 | 1286 | 4101 | 17.63 | 27.30 |

lies were represented by 2 species each, one family by 3 species (Meliaceae), and one by four (Rubiaceae). Some families were restricted to only one site (5 in OR and 4 in AK). Based on tree density, Rubiaceae (34% of stems) was ranked first, followed by Melastomataceae, Sterculiaceae, and Ebenaceae in AK, while in OR Melastomataceae, Euphorbiaceae, and Rutaceae were well represented families (Table 4).

*Importance value index*. The IVI of the top five species is shown in Fig. 4. Species IVI scores decreased gradually at both sites. The dominant species at the two sites and their IVI scores out of 300 were: *Pterospermum canescens* (IVI = 75.5) and *Tricalysia sphaerocarpa* (75.1) in AK; *Drypetes sepiaria* (59) and *Memecylon umbellatum* (52.7) in OR. *Pterospermum canescens* and *Memecylon umbellatum* constituted the most important species based on IVI scores.

*Forest stand density and basal area*. A total of 4101 trees was counted in the 2-ha study plots. The highly disturbed site AK had more than twice the number of stems than the less disturbed site OR (2815 and 1286 trees respectively) (Table 2). Although the stand density was less in OR trees were 55% more voluminous, with a basal area of 27.3 $m^2$ $ha^{-1}$, than at site AK (basal area 17.6 $m^2$ $ha^{-1}$). In AK, *Pterospermum canescens* and *Tricalysia sphaerocarpa* together contributed

65% of the stand basal area, while in OR, 44% of stand basal area was formed by *Drypetes sepiaria* and *Pterospermum canescens*.

*Tree girth class, species richness and density*. Species richness, Shannon index, and stem density decreased drastically with increasing tree girth class, at both study sites (Table 5). The lowest girth class (10–30 cm) contributed more (85%) to the stand density of the highly disturbed site AK than the less disturbed site OR (64%). Compared to site AK, the less disturbed site OR had a higher number of species and a greater basal area in higher girth classes. The two lower girth classes, 10–30 and 30–60 cm, contributed 66% of stand basal area at the highly disturbed site AK, but in the less disturbed site OR this figure was just 33%. In the 90–120 cm girth class the maximum basal area (6 $m^2$ $ha^{-1}$) was recorded in OR, but was ten times lower (0.59 $m^2$ $ha^{-1}$) in AK. The Shannon index showed little variation with increasing girth class. The trend in basal area distribution varied drastically between the two sites. In the less disturbed site OR the middle size-classes contributed more to stand basal area even though there were relatively less stems in those girth classes (Table 5).

*Population structure of dominant species*. The population structure of selected species, those most abun-

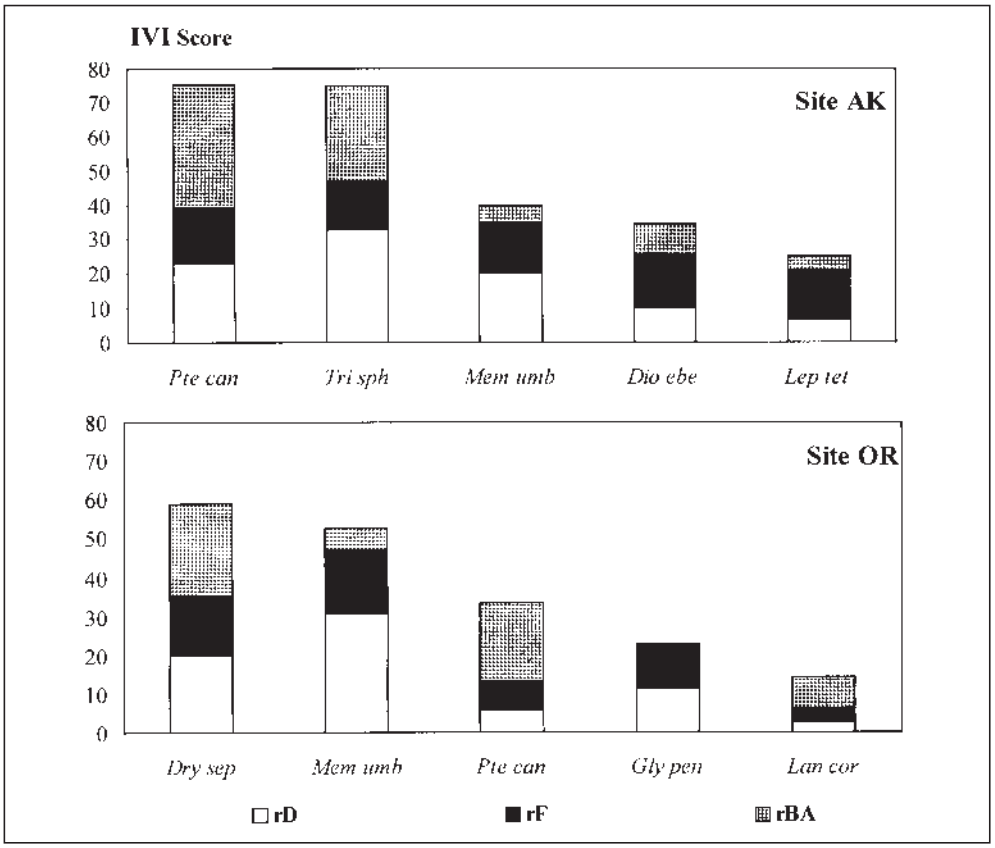


FIG. 4. Importance Value Index (IVI), relative density (rD), relative frequency (rF), relative basal area (rBA) scores of five selected dominant species in the two dry evergreen forest sites AK and OR. A six-letter species code is used; for full names refer to Table 3.

TABLE 5. Species richness, density (trees $ha^{-1}$), basal area ($m^2$ $ha^{-1}$), and Shannon index (H′) for various tree girth classes at the two tropical dry evergreen forest sites AK and OR.

| Girth class (cm) | Species richness | | Density | | Basal area | | (H′) | |
|---|---|---|---|---|---|---|---|---|
| | AK | OR | AK | OR | AK | OR | AK | OR |
| 10–30 | 27 | 24 | 2405 | 824 | 6.12 | 2.59 | 1.82 | 1.93 |
| 30–60 | 10 | 20 | 337 | 277 | 5.56 | 5.72 | 1.22 | 1.84 |
| 60–90 | 8 | 11 | 56 | 100 | 2.54 | 5.14 | 0.93 | 1.94 |
| 90–120 | 5 | 9 | 7 | 53 | 0.59 | 6.00 | 1.47 | 1.87 |
| 120–150 | 4 | 8 | 5 | 18 | 0.75 | 3.04 | 1.33 | 1.78 |
| 150–180 | 1 | 6 | 1 | 9 | 0.25 | 2.00 | 0.00 | 1.68 |
| 180–210 | 1 | 1 | 2 | 2 | 0.58 | 0.56 | 0.69 | 0.00 |
| > 210 | 2 | 2 | 2 | 2 | 0.27 | 2.09 | 0.00 | 0.69 |

dant with highest densities, at both sites (AK and OR) varied considerably (Fig. 5). In the highly disturbed site AK, all four selected species were well represented in the lowest (10–30 cm) girth class. *Pterospermum canescens* was well represented with an expanding population at site AK, whereas it exhibited a disturbed population structure with poor representation in OR. *Memecylon umbellatum* had representatives only in 10–30 cm gbh in AK, whereas it attained 30–60 cm girth in OR. *Tricalysia sphaerocarpa*, the species with the densest population in AK, had an expanding population structure, while it was totally absent in OR. *Drypetes sepiaria* was well represented in OR in the 30–60 cm girth class. *Diospyros ebenum* showed a growing population at site AK, with representation in all the girth classes, except in 150–180 cm and > 210 cm gbh. In OR, the lower story species *Glycosmis pentaphylla* was represented only in the lowest girth class (10–30 cm) (Fig. 5).

## DISCUSSION

A comparison of species diversity with other tropical dry forests becomes difficult due to variations in the criteria and methods employed. Hence, we adopted the same method as in many other tropical dry evergreen forest inventories (i.e., 1-ha plot survey and 10-cm girth threshold) to facilitate a valid comparison. Data on site characteristics, forest structure, and tree diversity from these two study sites are compared with three other tropical dry evergreen forest sites, all of which are located within a 50 km radius of Pondicherry town on the Coromandel coast of southern India (Table 6). At all the dry evergreen forest sites, the soil is alluvial and sandy in texture, except at site KK in which the soil is red ferralitic. All the dry evergreen forests are 3-layered forests with the exception of site AK. The percentage of evergreen species was lower in the human impacted sites AK and PP. Species richness, number of genera, and number of families were higher at the present study sites AK and OR than in the other dry evergreen forest sites (Table 6). The lowest stand density (856 stems $ha^{-1}$) was recorded at site TM, whereas more than three times this stem density was recorded at site AK (2815 stems $ha^{-1}$). The highly disturbed site PP scored the highest basal area followed by sites TM, OR, and AK. There was no species repetition among the five forest sites in terms of forest stand dominance, based on the number of stems per hectare. Cluster analysis of the five dry evergreen forest sites using the species- abundance-based similarity index revealed that the species composition of sites AK and KK was more similar (similarity score 0.85) than the other sites (Fig. 6). The similarity score between the highly disturbed site PP and the less disturbed site OR was 0.84. In conclusion, there is no relationship between species composition and site disturbance.

The tree species richness of the five tropical dry evergreen forest sites on the Coromandel coast of India is low when compared with the range of 35–90 species recorded for dry forests of the world (Murphy & Lugo 1986). The species richness recorded in our five tropical dry evergreen forests on the Coromandel coast was less than that of the dry tropics of Thailand

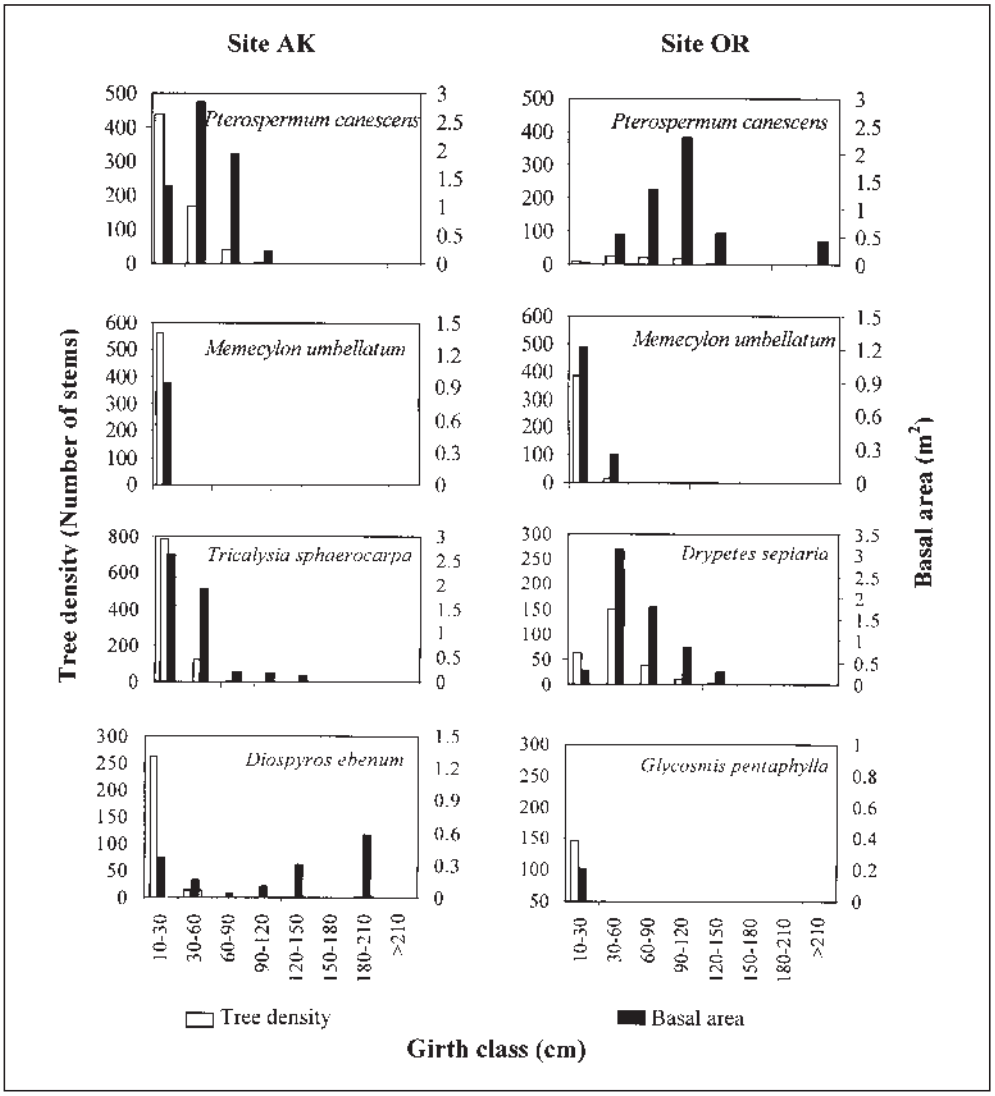


FIG. 5. Population structure of selected species at sites AK and OR.

(Bunyavejchewin 1999), the West Indies (Gonzalez & Zak 1996), Madagascar (Sussman & Rakotozafy 1994), Puerto Rico (Murphy & Lugo 1986), Nicaragua (Sabogal 1992), Costa Rica (Hubbell 1979), and other Central American sites (Gillespie *et al.* 2000). While the species richness of our dry forests is closer to the 31 species (≥10 cm dbh in 1.08 ha) recorded in the dry Afromontane forest at Mafai, central Tanzania (Lyaruu *et al.* 2000), but greater than some other dry forests within India (Bandhu 1970, Singh & Singh 1991).

The tree density of 410 and 462 stems $ha^{-1}$ for the girth threshold ≥ 30 gbh at the present study sites AK and OR, respectively, is well within the limit re-

TABLE 6. Comparative account of site characteristics, tree diversity and predominant species of the five tropical dry evergreen study sites OR, TM, AK, KK and PP, arranged in increasing order of disturbance.

| Variable | Site | | | | |
|---|---|---|---|---|---|
| | OR | TM | AK | KK | PP |
| I. Site characteristics | | | | | |
| a) Soil | | | | | |
| Type | Coastal alluvium | Alluvium | Alluvium | Red ferralitic | Alluvium |
| Texture | Sandy | Sandy | Sandy | Sandy | Sandy |
| b) Forest structural analysis | | | | | |
| Mean stand height (m) | 8 | 8 | 5 | 6 | 8 |
| Number of strata | 3 | 3 | 2 | 3 | 3 |
| % of evergreen species | 76.7 | 76.9 | 64.5 | 73.1 | 66.7 |
| % of brevi-deciduous species | 16.7 | 19.2 | 29.0 | 23.1 | 30.0 |
| % of deciduous species | 6.7 | 3.9 | 6.5 | 3.9 | 3.3 |
| II. Tree diversity | | | | | |
| Species richness | 30 | 26 | 31 | 26 | 24 |
| Number of genera | 29 | 24 | 29 | 23 | 21 |
| Number of families | 19 | 18 | 20 | 17 | 17 |
| Stand density | 1286 | 856 | 2815 | 1251 | 1329 |
| Basal area ($m^2$ $ha^{-1}$) | 27.3 | 28.9 | 17.6 | 14.6 | 37.6 |
| III. Dominant species* | *Mem umb* | *Tri sph* | *Tri sph* | *Mem umb* | *Mem umb* |
| | *Dry sep* | *Lep tet* | *Pte can* | *Tri sph* | *Can dic* |
| | *Gly pen* | *Ata mon* | *Mem umb* | *Dio ebe* | *Dry sep* |

* Species names are given in six letter codes; for full names refer to Table 3.

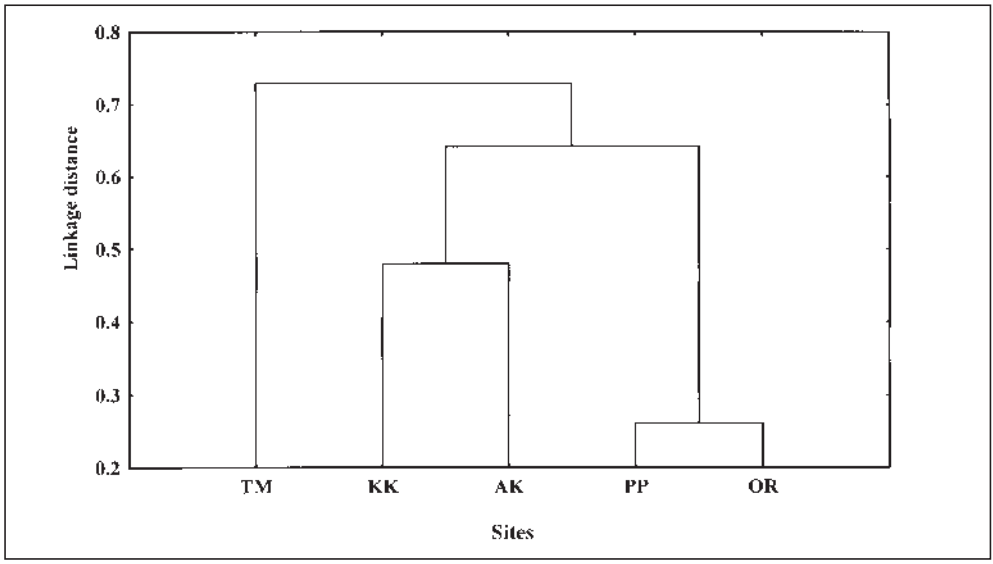


FIG. 6. Cluster analysis of species-abundance-based Morisita-Horn similarity index of five tropical dry evergreen forest sites.

ported for tropical forests, and is also comparable with the 441 trees (≥ 10 cm dbh) recorded in dry forest in Tanzania (Lyaruu *et al.* 2000). Among the five tropical dry evergreen forests, the tree density range of 856 trees $ha^{-1}$ at site TM to 2815 stems $ha^{-1}$ at site AK for ≥ 10 cm gbh is comparable with the 1115 trees $ha^{-1}$ (> 4.5 cm dbh) and 1499 trees $ha^{-1}$ recorded in the dry evergreen forests of Thailand (Bunyavejchewin 1999). The high proportion of trees with multi-stemmed individuals recorded at site AK could possibly be due to wood collection as also reported in other dry forests (Gonzalez & Zak 1996, Hare *et al.* 1997).

The basal area values recorded at our study sites AK (17.6 $m^2$ $ha^{-1}$) and OR (27.3 $m^2$ $ha^{-1}$) are well within the range of 17–40 $m^2$ $ha^{-1}$ reported for the dry tropics (Murphy & Lugo 1986). Of the two sites (AK & OR), the greater density but lower basal area of individuals in AK compared with OR, could be due to the short-statured condition of the forest and the higher levels of disturbance prevailing at this site than OR, which is comparatively tall-statured and less disturbed, with an expanding canopy and more voluminous trees. A similar trend has also been reported for the other two comparable sites KK and TM (Parthasarathy & Karthikeyan 1997).

Species abundance, based on the number of stems in dry forest sites, was never predictable and not a single species was repeatably most dominant (Gillespie *et al.* 2000), as evidenced by the dominance of *Memecylon umbellatum* (at four of our sites) and *Tricalysia sphaerocarpa* (at three sites). According to Hubbell (1979), species dominance is reported to be determined by stochastic processes.

The occurrence of small-population tree species, particularly mono-individual species, is highly correlated with tree species diversity of local forest vegetation, so they are crucial elements in local biodiversity (Cao & Zhang 1997). Twenty-seven percentage of species represented by a single individual at site AK is comparable with the 31% recorded in the nearby forest site TM (Parthasarathy & Karthikeyan 1997), while 17% of mono-individual species encountered in OR is close to the 19% reported at site KK (Parthasarathy & Karthikeyan 1997) and a 26% from *Shorea* plot of northeastern Thailand (Bunyavejchewin 1999). The percentage of mono-individual species recorded at our study sites is higher than the 9.7% recorded in central Tanzanian dry forest (Lyaruu *et al.* 2000).

Like other dry forests in Thailand (Bunyavejchewin 1999), West Indies (Gonzalez & Zak 1996), and semi-deciduous forest in western Ecuador (Josse & Balslev 1994), the present study sites are characterized by a high stem count in the smaller size classes.

*Disturbance.* In the five tropical dry evergreen forests, the relationship between the degree of site disturbance and tree species richness is notable. The highly disturbed site PP had just 24 species, while the less disturbed site OR had 30 species. These results support the supposition that total species diversity in dry forest is normally reduced when disturbance is severe and/or prolonged (Holdridge 1967). Thus the species paucity recorded at site PP could be assigned to the high levels of anthropogenic disturbance (score 30). In several studies, anthropogenic disturbance has significantly lowered the plant species richness of tropical dry forests (Sabogal 1992, Jayasingam & Vivekanantharaja 1994, Maass 1995). It is striking that the 31 species recorded at the moderately disturbed site AK among the five evergreen forest sites may support the intermediate disturbance hypothesis (Connell 1978, Grime 1979, Armesto & Pickett 1985).

There is no single dry forest in the world that has not been used at least as a source of firewood or for charcoal production, and in the tropics 80% of all harvested wood is used for fuel purposes (Murphy & Lugo 1986); the Indian dry evergreen forests are no exception to this. Resource removal such as firewood, fodder, medicinal plants, and timber harvest has been going on in all forests. The highly disturbed site PP is worse because of the temple development activities, such as the construction of roads, the many temple annex structures, and by the impact of temple visitors.

## CONCLUSION

Ewell (1980) claimed that dry tropical forests return to their original, predisturbance condition faster than other tropical forests. Therefore heavily disturbed dry forest sites deserve conservation because they quickly return to their original vegetation and thus serve as reserves for species or, if managed properly, as sources of timber for future generations (Josse & Balslev 1993). Our study confirms that human disturbance, has an impact on forest stand characteristics such as stand height, number of strata, tree density, and basal area. Hare *et al.* (1997) observed that human disturbance patterns probably significantly affect the struc-

ture and composition of forest sites. Although the results from sites AK and OR did not provide strong evidence of human impact on species composition, when all five dry evergreen forest sites are considered (Table 6), species diversity was 20% less in the highly disturbed site PP. For effective management and conservation of the remaining dry evergreen forest fragments, further research on forest regeneration and the biomonitoring of the permanently tagged individuals in these research plots for tree population dynamics and communities would be useful, because damage and disturbance are the driving forces of the dynamics of populations and communities (Burslem & Whitmore 1999).

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