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Tree species diversity and soil nutrient status in three sites of tropical dry deciduous forest of western India

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Abstract: The present work aimed to study the tree species diversity and soil nutrient status in three sites of tropical dry deciduous forest of western India (23° 3' N latitude to 69° 30' E, 23° 3' N latitude to 70° 32' E and 23° 3' N latitude to 72° 33' E). A total of 93 tree species of 85 genera belonging to 24 families were encountered. The tree stand density varied from 458-728 individuals ha^{-1} with the average basal area ranging from 5.96 - 19.31 m^2 ha^{-1}. Shannon-Weiner Index (H') ranged from 0.67 - 0.79. The Simpson Index of dominance varied from 0.08 - 0.16, the Margalef's Species Richness Index varied from 21.41 - 23.71, Equitability or evenness index varied from 0.02 - 0.05, the species heterogeneity index varied from 2.53 - 3.61 and ß diversity varied from 2.05 - 4.87. A greater number of tree species fell in 41 - 50 cm DBH followed by 21 - 30 cm, 0 - 10 cm diameter class, but less number of tree individuals are represented in above 100 cm diameter class. The Combretaceae was represented by the highest number of species (9 spp.) followed by Rutaceae (7 spp.). Each of the individual soil variables showed a high positive correlation with tree species richness while tree density showed a clearly negative correlation with variables like phosphorous and nitrogen and positive correlation with carbon.

Resumen: El propósito de este trabajo fue estudiar la diversidad de especies arbóreas y el estatus de los nutrientes del suelo en tres sitios de bosque tropical seco caducifolio del occidente de la India (23° 3' N latitud a 69° 30' E, 23° 3' N latitud a 70° 32' E y 23° 3' N latitud a 72° 33' E). Se encontraron en total de 93 especies arbóreas de 85 géneros pertenecientes a 24 familias. La densidad de árboles en los rodales varió entre 458 y 728 individuos ha^{-1} y el área basal promedio fluctuó entre 5.96 y 19.31 m^2 ha^{-1}. El índice de Shannon-Wiener (H') fluctuó entre 0.67 y 0.79. El índice de dominancia de Simpson varió de 0.08 a 0.16, el índice de riqueza de especies de Margalef varió de 21.41 a 23.71, la equitabilidad fluctuó entre 0.02 y 0.05, el índice de heterogeneidad de especies varió de 2.53 a 3.61 y la diversidad ß varió de 2.05 a 4.87. El mayor número de especies arbóreas cayó en la categoría diamétrica de 41 - 50 cm, seguida por las clases de 21 - 30 cm, y de 0 - 10 cm de d.a.p.; un número menor de individuos arbóreos tuvieron diámetros superiores a 100 cm. Combretaceae estuvo representada por el mayor número de especies (9), seguidas por Rutaceae (7). Todas las variables edáficas mostraron una fuerte correlación positiva con la riqueza de especies, mientras que la densidad de árboles mostró una clara correlación negativa con variables como el fósforo y el nitrógeno, y una correlación positiva con el carbono.

Resumo: O presente trabalho teve como objectivo estudar a diversidade de espécies de árvores e estado dos nutrientes do solo em três locais de floresta tropical seca decídua do oeste da Índia (23º 3'N de latitude a 69º 30' E, 23° 3'N de latitude e 70º 32' E a 23° 3' N de latitude a 72º 33' E). Foi encontrado um total de 93 espécies de 85 géneros pertencentes a 24 famílias. A densidade de árvores na parcela variou entre os 458 - 728 indivíduos ha^{-1} com uma média da

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área basal variando entre os 5,96 - 19,31 m ^{2} ha^{-1}. O índice de Shannon-Weiner (H') variou entre 0,67 e 0,79. O índice de dominância de Simpson variou no intervalo de 0,08 - 0,16, enquanto o índice de riqueza específica de Margalef se situou entre 21,41 - 23,71; o índice de equidade ou igualdade variou no intervalo de 0,02 - 0,05, variando o índice de heterogeneidade específica no intervalo de 2,53 - 3,60 e situando-se a diversidade ß entre os 2,05 - 4,87. Um maior número de espécies de árvores situou entre o DAP de 41 - 50 cm seguido pelas classes de diâmetro dos 21 - 30 cm, e 0 - 10 cm; o menor número de indivíduos situou-se nos diâmetros acima de 100 cm. As Combretaceae estão representadas pelo maior número de espécies (9 spp.) seguidas pelas Rutaceae (7 spp). Cada uma das variáveis individuais do solo mostrou uma alta correlação positiva com a riqueza de espécies arbóreas, enquanto a densidade de árvores mostrou uma clara correlação negativa com variáveis como o fósforo e o azoto e uma correlação positiva com o carbono.

Key words: Diversity index, dominance-diversity curve, Dry deciduous forest, soil nutrients, species diversity.

Introduction

The tropical dry forests occupy 38 % of the total forest area in India (Dixit 1997). Tropical forests are often referred to as one of the most species diverse terrestrial ecosystems, and generate a variety of natural resources to help sustain the livelihood of local communities (Kumar *et al.* 2006). The vegetation communities of tropical dry forests have been recognized as comprising some of the most endangered ecosystems in the tropics (Hoekstra *et al.* 2005). These forests are disappearing at alarming rates owing to deforestation for extraction of timber and other forest produce (Murphy & Lugo 1986; Raghubanshi & Tripathi 2009). Trees form the major structural and functional basis of tropical forest ecosystems and can serve as robust indicators of changes and stresses at the landscape scale.

In Rajasthan, the hilly topography in Aravalli mountain ranges provides a wide variety of microhabitats which support rich biodiversity of plant species. However, many tropical forests are under great anthropogenic pressure and require management intervention to maintain the overall biodiversity, productivity and sustainability. Understanding species diversity and distribution patterns is important for helping managers evaluate the complexity and resources of these forests.

In tropical forest ecosystems, soil nutrients play an important role in the formation of plant communities, their species and structural diversity, thus soil conservation has fundamental significance for biodiversity conservation and sustainable land use (Karpachevsky 1977). Additionally, diversity change may be related to initial nutrient condition of the community, for example, Theresa & Bowman (1997) showed that nutrient enrichment increased biodiversity in poor soils.

The exploitation of natural resources by the local populations has resulted in depletion of the biodiversity of forest communities (Ramakrishnan 2003). Forest degradation is usually accompanied by species extinction, reduction in biodiversity and decrease in primary productivity. Consequently, there is a growing interest in quantifying habitat characteristics like forest structure, floristic composition and species richness in Indian forests (Nirmal Kumar *et al.* 1999, 2000, 2001, 2002; Yadav & Yadav 2005). There exists little authentic quantitative ecological information pertaining to vegetation aspects in relation to the soil nutrient status in this region. This study investigates tree species diversity and soil nutrient status in three sites of tropical dry deciduous forest of western India.

Materials and methods

Site description

The study was conducted in three sites: site-1 *Butea* dominated forest (BF) (23° 3' N latitude, 69° 30' E longitude), site-2 Teak forest (TF) (23° 3' N latitude, 70° 32' E) and site-3 Mixed forest (MF) (23° 3' N latitude, 72° 33' E longitude); altitude 579.4 to 582 m above the mean sea level, located in the Udaipur district of Rajasthan (Fig. 1). It is 85 km away from Udaipur city. The climate of the study area is tropical and monsoonal. There are

Fig. 1. Location of study area in Udaipur, Rajasthan, western India.

three distinct seasons in a year; winter (November to February), summer (March to mid June), and a rainy season (mid June to October). The climate is tropical with a maximum of 43.3 °C and a minimum of 28.8 °C during summers. Winters are cold with the maximum temperature rising to 26.8 °C and the minimum dropping to 2.5 °C. The average annual rainfall is 61 cm occurring during June to September. At all the sites, a similar pattern of temperature and rainfall prevails throughout the year. As per the classification of Champion & Seth (1968), the forests of the area are categorized under group 5A/ (1b) as 'tropical dry deciduous forest'.

Vegetation sampling and analysis

The methodology for determination of biodiversity, as prescribed by the Center for Ecological Sciences, Indian Institute of Science, Bangalore (Gadgil 1996) is followed in the present study. The vegetation study was carried out at monthly interval from September 2007 to June 2008. The tree species were identified using regional floras (Cooke 1901-1903; Shah 1978). A total of 25 quadrats (10 m × 10 m each) were laid out for enumerating trees in a straight line transect. Diameter at breast height (DBH at 1.37 m from the ground) of all the trees in each quadrat was calculated and recorded for each species (Supriya Devi & Yadava 2006). To determine the maturity of the forest trees, individuals were classified in a series of DBH classes at intervals of 10 cm. Analytical features such as frequency, density, abundance, basal cover and importance value index (IVI) were computed. Importance Value Index (IVI) was calculated by summing up relative frequency, relative density and relative dominance values in a particular stand. Density distribution was studied by determining the number of individuals in different size classes starting from 0 - 10 cm to 90 - 100 cm and above 100 cm.

Soil analysis

Composite soil samples (0 - 10 cm) were collected from each study site and sub-samples were brought to the soil laboratory at ISTAR, Sardar Patel University. They were air-dried, rolled and passed through a 2 mm sieve for analyses. The total organic carbon (Walkley and Black method), total nitrogen (Micro Kjeldahl method) and total Phosphorus (Molybdenum-blue method) of each soil sample were estimated according to standard method (Maiti 2003).

Data analysis

Diversity indices reflect the manner in which abundance is distributed among the different species constituting the community. Species diversity index (H') was determined separately from the Shannon-Wiener's information function (Shannon & Weaver 1963).

$$H' = -\Sigma\, p_i \log_2 p_i$$

Where, $p_i = n_i/N$, which denotes the importance probability of each species in a population;
n_i = importance value for species "i", N = total of importance values. Concentration of dominance (Cd), known as Simpson index, was measured according to Simpson (1949).

$$Cd = \Sigma\, p_i^2$$

Species richness or variety index (d) is the mean number of species per sample and determined using the formula of Margalef (1958).

$$d = S/\sqrt{N}$$

Where, S = number of species, N = number of individuals of all species.
Equitability or evenness (e) refers to the degree of relative dominance of each species in that area. It was calculated according to Pielou (1966) as:

$$\text{Equitability (e)} = H'/\log S$$

Where, H' = Shannon Wiener's index; S = Number of species.

Table 1. Population size, plant diversity and mathematical indices of plant diversity at three sites of dry tropical forests of western India.

Parameter	Value		
	BF	TF	MF
Number of families	16	23	20
Number of genera	18	34	33
Number of species	18	38	37
Tree density (individuals ha^{-1})	538	728	458
Basal area (m^2 ha^{-1})	5.96	19.31	10.52
Shannon-Wiener's index	0.77	0.79	0.67
Simpson index	0.14	0.08	0.16
Margalef's species richness	21.41	23.72	22.41
Equitability or evenness index	0.05	0.02	0.03
Species heterogeneity	2.68	2.53	3.61
ß-diversity	4.87	3.25	2.05

BF = Butea forest, TF = Teak forest, MF = Mixed forest.

Species heterogeneity is defined as the reciprocal of Simpson's index or under root of concentration of dominance (Cd).

Beta diversity (ß-diversity) at a zone was computed following Whittaker (1972) as:
(ß) = Total number of species in all sites/average number of species of all sites.
The dominance-distribution pattern of species was determined on the basis of IVI values.

Results

Floristic composition

A total of 24 families, 85 genera, 93 tree species, and 1724 individuals of trees were encountered in tropical dry deciduous forest of western India. Out of these, 16 families comprising 18 genera, 18 tree species and 538 individuals were recorded in site-BF, where as 23 families comprising 34 genera, 38 species and 728 individuals were recorded in site-TF and 20 families comprising 33 genera, 37 tree species and 458 individuals were recorded in site MF (Table 1).

Family-wise distribution

A total of 93 tree species belonging to 24 families was recorded (Table 2). Among all families, Combretaceae had maximum number of species (9 species) followed by Rutaceae (7 species), Annonaceae, Euphorbiaceae, Fabaceae and Mimoseae (6 species) and Apocynaceae, Bignoniaceae and Caesalpiniaceae (5 species) and Burseraceae, Moraceae and Verbenaceae (4 species) and Arecaceae, Myrtaceae, Sterculiaceae and Ulmeae (3 species) and Anacardiaceae, Bombacaceae, Meliaceae, Sapotaceae and Simaroubaceae (2 species) and Balantiaceae, Ehretiaceae and Sapindaceae (1 species) (Table 3).

Tree species diversity

Table 1 shows the species diversity of tree populations in these three forest types. In the studied forests, tree density ranged from 458 (MF), 538 (BF) to 728 (TF) individuals ha^{-1} and basal area ranged from 5.9 (in BF; 10.52 in MF) to 19.31 m^2 ha^{-1} (TF).

The trend of Shannon-Weiner index in present forest can be depicted as TF > BF > MF. The maximum (0.79) value of tree diversity was recorded in site TF followed by BF (0.77), whereas minimum (0.67) was observed for site MF. The concentration of dominance was in the order MF > BF > TF. The Margalef's species richness index ranged from 21.41 for site BF to 23.41 for site TF. The Equitability or evenness index was 0.02 for site TF, 0.03 for site MF and 0.05 for site BF. Species heterogeneity was higher in site MF followed by site BF and site TF. ß-diversity was highest in site BF (4.87) and lowest in site MF (2.05).

Density-distribution pattern

The distribution of plants in different age groups (A-shaped curve) suggests a medium-age forest (Fig. 2). Low tree density in lower girth class could be attributed to grazing activity. Suppressed growth of young plants due to dense overhead canopy may be one of the reasons for the presence of a large population of young plants.

Soil

There was little variation in organic carbon, nitrogen, phosphorus on all the three study sites. Organic carbon ranged from 2.23 - 2.81 %, while concentration of nitrogen fluctuated from 0.16 - 0.21 %, and that of phosphorus varied from 0.021-0.033 % in all three sites. The C : N ratio ranged from 10.61 - 20.06, where as C : P ratio fluctuated from 97.9 - 106.2, and N : P ratio ranged from 4.8 - 10.0 (Table 3).

Table 2. Family-wise distribution of tree species in three sites of dry tropical forests of western India.

Name of the family	BF	TF	MF	Total
Anacardiaceae	1	1	0	2
Annonaceae	2	2	2	6
Apocynaceae	1	2	2	5
Arecaceae	1	1	1	3
Balantiaceae	0	1	0	1
Bignoniaceae	0	2	3	5
Bombacaceae	0	1	1	2
Burseraceae	1	2	1	4
Caesalpiniaceae	1	2	2	5
Combretaceae	1	3	5	9
Ehretiaceae	0	1	0	1
Euphorbiaceae	2	2	2	6
Fabaceae	1	3	2	6
Meliaceae	0	1	1	2
Mimoseae	1	3	2	6
Moraceae	1	1	2	4
Myrtaceae	1	2	0	3
Rutaceae	1	3	3	7
Sapindaceae	0	0	1	1
Sapotaceae	0	1	1	2
Simaroubaceae	0	1	1	2
Sterculiaceae	1	1	1	3
Ulmeae	1	1	1	3
Verbenaceae	1	1	2	4

BF = Butea forest, TF = Teak forest, MF = Mixed forest.

No significant differences were registered in organic carbon, nitrogen and phosphorus levels of the three sites at 0 - 10 cm depth. Each of the individual soil variables showed a high degree of positive correlation with tree species richness while tree density showed negative correlation with variables like phosphorus and nitrogen and positive correlation with carbon (Table 4).

Discussion

The main vegetation types encountered in tropical dry deciduous forest can be grouped into three communities, i.e. *Butea* forest, Teak forest and Mixed forest. Both species richness and diversity differed among the three sites. Species diversity is an important attribute of a natural community that influences functioning of an ecosystem (Hengeveld 1996).

In the present study, maximum tree species diversity occurred on the site TF (38), followed by site MF (36) and site BF (18). The number of tree species recorded in the present study was found to be lower than the number of species reported by several workers in other tropical forests (Chowdhury *et al.* 2000, 85 species ; Fox *et al.* 1997, 94 species ; Kadavul & Parthasarathy 1999, 89 species ; Khera *et al.* 2001, 92 species). The comparison of the floristic diversity of the three sites shows that site TF and site MF are more diversified than the site BF. The values for stand density (458 - 728 tree ha^{-1}) in the present study are within the range of 276 - 905 tree ha^{-1} reported in the tropics (Sundarapandian & Swamy 2000) and are closer to the value reported by Jha & Singh (1990) for dry tropical forest of Vindhyan region of India.

In the present study, basal area ranged from 5.9 (BF) to 19.31 m^2 ha^{-1} and the values are comparable with the ranges reported for dry and wet forests of the world, 17 to 40 and 20 to 75 m^2 ha^{-1}, respectively (Murphy & Lugo 1986).

The Shannon-Wiener index varied among sites (0.67, 0.77 and 0.79). Shannon-Wiener values for tree species diversity in the present study are lower compared to 2.20 - 2.65 reported for the tropical forests of Kodayar in the Western Ghats of southern India (Sundarapandian & Swamy 2000). The concentration of dominance (Simpson's index) in the present study sites are within the reported range (0.21 to 0.92, 0.10 to 0.99) for tropical forests by several workers (Knight 1975; Visalakshi 1995).

The Margalef's index ranged from 21.41 for site BF to 23.41 for site TF, which is quite higher compared to 18.5 and 4.54 reported for the subtropical humid forest of Meghalaya (Mishra *et al*. 2005).

Table 3. Soil nutrient analysis in three sites of dry tropical forests of western India.

Sites	Depth (cm)	C %	N %	P %	C:N	C:P	N:P
Butea forest (BF)	0-10	2.23	0.16	0.021	13.93	106.19	7.62
Teak forest (TF)	0-10	2.79	0.19	0.028	14.68	99.64	6.78
Mixed forest (MF)	0-10	2.81	0.21	0.033	13.38	85.15	6.36

BF = Butea forest, TF = teak forest, MF = Mixed forest.

Table 4. Pearson correlation coefficients between concentrations of different nutrients measured at 0-10 cm soil depth, tree density, tree species richness at three study sites in the tropical dry deciduous forest of western India.

	P %	N %	Tree species richness	Tree density
C %	0.92	0.93	0.99	0.20
P %		0.99	0.92	-0.19
N %			0.93	-0.17
Tree species richness				0.18

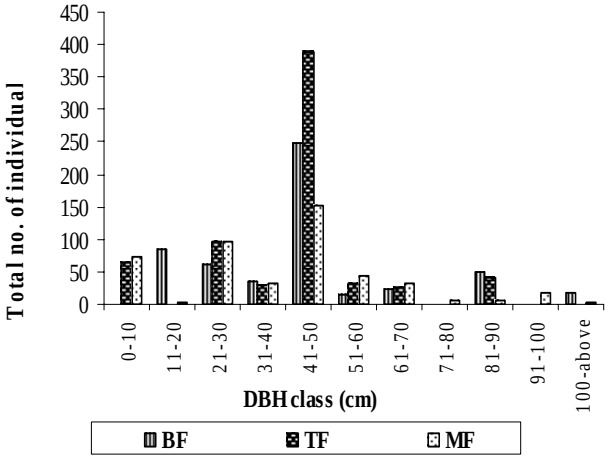

Fig. 2. Density-distribution patterns in three sites of dry tropical forests of western India. BF = Butea forest, TF = teak forest, MF = Mixed forest.

With respect to density-distribution of trees, the present forest is similar to the tropical dry evergreen forests of south India (Parthasarathy & Sethi 1997; Visalakshi 1995) and Western Ghats (Ayyappan & Parthasarathy 1999). In the present forest, the distribution of plants in different age groups (A-shaped curve) suggests that the forest is of medium age. Similar results have been reported by Cao *et al.* (1996), Johnston & Gillman (1995) and Kellman & Tackaberry (1998) for other forest ecosystems.

The concentrations of organic carbon, nitrogen and phosphorus in the present study, did not differ significantly among the three sites at 0 - 10 cm depth. Each of the individual soil variables showed a high degree of correlation with tree species richness. However, tree density was clearly negatively correlated to variables like phosphorus and nitrogen and positively correlated with carbon.

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References

Ayyappan, N. & N. Parthasarathy. 1999. Biodiversity inventory of trees in a large-scale permanent plot of tropical evergreen forest at Varagaliar, Annamalais, Western Ghats, India. *Biodiversity and Conservation* **8**: 1533-1554.

Cao, M.J., Z. Zhang, J.F. Deng & X. Deng. 1996. Tree species composition of a seasonal rain forest in Xishuangbanna, south west China. *Tropical Ecology* **37**: 183-192.

Champion, H.G. & S.K. Seth. 1968. *A revised survey of forest types of India*. Delhi Manager of Publication, Delhi, India.

Chowdhury, M.A.M., M.K. Auda & A.S.M.T. Iseam. 2000. Phytodiversity of *Dipterocarpus turbinatus* Gaertn. F. (Garjan) undergrowths at Dulahazara garjan forest, Cos'B Bazar, Bangladesh. *Indian Forester* **126**: 674-684.

Cooke, T. 1901-1903. *Flora of the Presidency of Bombay*. S.N. Guha Ray, Calcutta.

Dixit, A.M. 1997. Ecological evaluation of dry tropical forest vegetation: An approach to environmental impact assessment. *Tropical Ecology* **38**: 87-100.

Fox, B.J., E.T. Jennifer, D.F. Marelyn & C. Williams. 1997. Vegetation changes across edges of rainforest remnants. *Biological Conservation* **82**: 1-13.

Gadgil, M. 1996. Documenting diversity: An Experiment. *Current Science* **70**: 36-44.

Hengeveld, R. 1996. Measuring ecological biodiversity. *Biodiversity Letters* **3**: 58–65.

Hoekstra, J.M., T.M. Boucher, T.H. Ricketts & C. Roberts. 2005. Confronting a biome crisis: global disparities of habitat loss and protection. *Ecology Letters* **8**: 23-29.

Jha, C.S. & J.S. Singh. 1990. Composition and dynamics of dry tropical forest in relation to soil texture. *Journal of Vegetation Science* **1**: 609-614.

Johnston, M. & M. Gillman. 1995. Tree population studies in low-diversity forests, Guyana. I. Floristic composition and stand structure. *Biodiversity and Conservation* **4**: 339-362.

Kadavul, K. & N. Parthasarathy. 1999. Structure and composition of woody species in tropical semi-evergreen forest of Kalayan hills, Eastern Ghats, India. *Tropical Ecology* **40**: 247-260.

Kellman, M.R. & L.R. Tackaberry. 1998. Structure and

function in two tropical gallery forest communities, implication for forest conservation in fragmented system. *Journal of Applied Ecology* **35**: 195–206.

Khera, N., A. Kumar, J. Ram & A. Tewari. 2001. Plant biodiversity assessment in relation to disturbance in mid elevation forest of central Himalaya, India. *Tropical Ecology* **42**: 83-95.

Karpachevsky, L.O. 1977. *Variability of Soil Cover in Forest Ecosystem*. Moscow University Publishing House, Moscow.

Knight, D.H. 1975. A Phytosociological analysis of species rich tropical forest on Barro-Colorado Island: Panama. *Ecological Monograph* **45**: 259-289.

Kumar, A., A.K. Gupta, B.G. Marcot, A. Saxena, S.P. Singh & T.T.C. Marak. 2006. *Management of forests in India for biological diversity and forest productivity, a new perspective*. Volume IV: Garo Hills Conservation Area (GCA). Wildlife Institute of India - USDA Forest Service collaborative project report, Wildlife Institute of India, Dehra Dun.

Maiti, S.K. 2003. *Hand book of methods in environmental studies: Air, Noise, soil and Overburden analysis* Vol. 2. ABD Publishers, Jaipur.

Margalef's, D.R. 1958. Information theory in ecology. *General System Bulletin* **3**: 36-71.

Mishra, B.P., O.P. Tripathi & R.C. Laloo. 2005. Community characteristics of a climax subtropical humid forest of Meghalaya and population structure of ten important tree species. *Tropical Ecology* **46**: 241-251.

Murphy, P.G. & A.E. Lugo. 1986. Ecology of tropical dry forests. *Annual Review of Ecology and Systematics* **17**: 67-88.

Nirmal Kumar, J.I., R.N. Kumar & S. Joseph. 2001. Tree species diversity of Khatana forest of south Gujarat. *Journal of Nature Conservation* **13**: 149-166.

Nirmal Kumar, J.I., R.N. Kumar & S. Joseph. 2002. Tree species diversity of Waghai forest of the Northern part of Western Ghats. *International Journal of Ecology, Environment and Conservation* **8**: 235-248.

Nirmal Kumar, J.I., R.N. Kumar, B.S. Hiren Kumar & Amit N. Gohil. 1999. Biodiversity and Socio-Cuilural status of Khatana and Waghai forests of North western Ghats, South Gujarat. *International Journal of Ecology, Environment and Conservation* **5**: 171-176.

Nirmal Kumar, J.I., R.N. Kumar, B.S. Hiren Kumar & Amit N. Gohil. 2000. Preliminary investigations of plant diversity of Khatana and Waghai forests of North western Ghats, South Gujarat. *International Journal of Ecology, Environment and Conservation* **6**: 87-92.

Parthasarathy, N. & P. Sethi. 1997. Tree and liana species diversity and population structure in a tropical dry evergreen forest in south India. *Tropical Ecology* **38**: 19-30.

Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology* **13**: 131-144.

Raghubanshi, A.S. & A. Tripathi. 2009. Effect of disturbance, habitat fragmentation and a line invasive plants on floral diversity in dry tropical forest of Vindhyan highlands : a review. *Tropical Ecology* **50**: 57-69.

Ramakrishnan, P.S. 2003. Linking natural resource management with sustainable development of traditional mountain societies. *Tropical Ecology* **44**: 43-54.

Shah, G.L. 1978. *Flora of Gujarat State*. Vols. I-II University press. S.P. University, Vallabh Vidyanagar.

Shannon, C.E. & W. Weaver. 1963. *The Mathematical Theory of Communication*. University of Illinois Press, Urbana.

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

Sundarapandian, S.M. & P.S. Swamy. 2000. Forest ecosystem structure and composition along an altitudinal gradient in the Western Ghats, south India. *Journal of Tropical Forest Science* **12**: 104-123.

Supriya Devi, L. & P.S. Yadava. 2006. Floristic diversity assessment and vegetation analysis of tropical semi evergreen forest of Manipur, north east India. *Tropical Ecology* **47**: 89-98.

Theresa, T.A. & W.D. Bowman. 1997. Nutrient availability, plant abundance, and species diversity in two alpine Tundra communities. *Journal of Ecology* **78**: 1861-1872.

Visalakshi, N. 1995. Vegetation analysis of two tropical dry evergreen forests in southern India. *Tropical Ecology* **36**: 117-127.

Whittaker, R.H. 1972. Evolution and measurement of species diversity. *Taxon* **21**: 213-251.

Yadav, A.S. & R.K. Yadav. 2005. Plant community structure of Bala-fort forest in Alwar, Rajasthan. *International Journal of Ecology and Environmental Sciences* **31**: 109-117.