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Plant Species Composition and Diversity in Tropical Dry Mixed-Deciduous Forest of Telangana, India

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***Abstract*:** Tropical dry deciduous forests (TDDF) are among the most threatened ecosystems in India, yet they play a critical role in biodiversity conservation and ecosystem service provision. The present study assessed the structure, composition, and diversity of plant species in the Narsapur Reserve Forest (NRF), Medak District, Telangana, India. The objective of the study was to document floral diversity to support management interventions and enhance ecosystem services. Thirty transects (250 m × 4 m) and 180 quadrats (1×1 m) were laid to record trees, shrubs, herbs, grasses, and climbers between March 2021 and February 2022. A total of 13,601 woody individuals (81 species, 31 families) and 4,881 herbaceous individuals (59 species, 26 families) were recorded, representing 140 species across 51 families. *Cleistanthus collinus* and *Chloroxylon swietenia* dominated the woody stratum, while *Justicia micrantha* was most abundant in the herbaceous layer. Diversity indices revealed higher species richness and evenness among trees and shrubs compared to the herbaceous community. The stand structure indicates low abundance of large and canopy forming trees. Ensuring protection and preventing biotic pressure in post-monsoon phase may support survival of seedlings and regeneration of canopy forming trees such as *Terminalia* spp., *Madhuca longifolia*, *Boswellia serrata*, *Albizia procera* and improve overall structure. The findings highlight the ecological significance of NRF and underline the need for regulating anthropogenic disturbances, controlling invasive species, and maintaining canopy cover to sustain biodiversity and ecosystem functioning. These results provide a baseline for developing effective conservation and management strategies in TDDF landscapes.

Keywords: Tropical dry deciduous forest, Species diversity, Community structure, Narsapur Reserve Forest, Ecosystem management

Forests play an important role of sustaining life and livelihoods of those associated with it, with its primary objective being ensuring the ecological and environmental stability for the landscape. Maintaining forests is thus a crucial way of ensuring these objectives and can be done by improving management practices and sustainable utilization of forested landscapes (Anderson-Teixeira et al., 2013). Forest structures are influenced by disturbances and this further influence sits development and dynamics (Zenner 2005). Understanding forest structure is essential for analyzing the intricate relationships between patterns and processes within forest ecosystems. Tree diversity indices are important quantitative measures for describing forest structure (Aguirre et al., 2003, Lexerod and Eid 2006, Pommerening 2002). These indices are also essential variables for reconstructing forest structures in spatially explicit growth models and for computer visualizations (Hasenauer 2006). Anthropogenic factors frequently impact the diversity and structure of forests, making it essential to study forests based on their quantitative characteristics to predict future patterns (Khurana 2009). In past years, many researchers have undertaken studies regarding community structure and organization in natural forests in different climatic zones of India (Shadangi et al., 2000, Pande, 2001, Sagar et al., 2003, Thakur et 2005, Bhadra et al., 2010, Hegde et al., 2011, Ahmed, 2012, Bajpai et al., 2012, Jayakumar and Nair, 2012, Sahu et al., 2012, Thakur et al., 2017, Bilyaminu et al., 2021, Saharan et al., 2021). Among the sixteen subgroups of Indian forests, Tropical Dry Deciduous Forests (TDDF) are the most dominant, occupying 2,17,713 k, which constitutes 34.8% of the total forest cover in the country (Champion and Seth 1968, Reddy et al., 2015). TDDF are subject to natural disturbances such as drought, fire, and herbivory. However, human activities introduce additional disturbances, loss of movement corridor for the wildlife (Jaybhaye et al., 2022), including increased fire frequency (Pausas and Ribeiro 2013, Knorr et al., 2014) and the mortality of young trees (Chaturvedi et al., 2017), potentially altering long-term species composition (Zida et al., 2007). Recent studies suggest that TDDF are highly vulnerable to climate change, altered rainfall regimes, and invasive species, which further exacerbate biodiversity loss and regeneration failure (Deb et al., 2018, Lewis et al., 2004). Despite their ecological and socio-economic importance, these forests remain under-represented in long-term ecological monitoring programmes across India. Updated assessments of community structure and diversity are therefore necessary to evaluate ecosystem resilience and to inform adaptive management strategies (Sadia et al., 2024, Tiruvaimozhiet al., 2025).Given these challenges, detailed studies on the vegetation composition and structure of TDDF are essential for improving ecosystem functions. Over the years, numerous researchers have conducted studies on community structure and forest organization in various climatic zones of India, though, very few studies are focused on TDDF (Kumar et al., 2010, Sahu et al., 2012, Raha et al., 2023). In this context, site-specific studies on floristic diversity, forest structure, and disturbance regimes can generate crucial baselines for restoration and policy interventions, particularly under India's commitments to the Convention on Biological Diversity (CBD) and the UN Decade on Ecosystem Restoration (2021–2030) (Chaturvedi et al., 2023). The present study focuses on the structure, composition, and diversity of plant species in the TDDF of Medak district, Telangana, India. The primary aim is to document and assess the floral diversity to support future management interventions and enhance the ecosystem services provided by these forests.

MATERIAL AND METHODS

Study site: The study area lies between the latitude 17°42'54.55"N longitude 78°18'20.85"E and latitude 17°43'25.83"N longitude 78°18'17.55"E in the Narsapur reserved forests of Medak district (Fig. 1). The study area falls under Champion and Seth, 1969 forest type of 5 A/C 3, Southern tropical dry mixed-deciduous forest. The forest soil is of sandy loam type. Some regions of the Narsapur range also have black cotton soils comprising clay loams, clay and silt clay in some low-lying areas. The district generally experiences a dry climate. The climate of this region is characterized by a hot summer and generally dry weather except with some passing showers during the south-west monsoon season. The period of March to May is the hottest prolonged summer season followed by the south-west monsoon, which lasts from June to October. This is followed by a mild cold season from November to February, which is the winter season. The average annual rainfall of the district ranges from 700 to 800 mm. The average minimum temperature for the year 2022 was 20.29 °C, the average maximum temperature was 31.34 °C and the total rainfall was 982 mm. The meteorological trend for survey duration 2021 to 2022 (IMD 2023) showed that on an average minimum temperature was 20.29°C, average maximum temperature was 31.18°C, average rainfall was 1023.55 mm with total 445 rainy days in two years. In the study area, the effect of dry season is visible from mid-November month as the trees enter senescent stage and herbaceous species dry. The sampling was carried out from March 2021 to February 2022. Sampling was carried out avoiding locations prone to intensive biotic pressure, road, human habitations and urban park. During the study period no fire was recorded in the area. Trees and shrubs were recorded when the plants were identifiable with leaves and other phenological features. Seasonal sampling was carried out for herbaceous species in summary, monsoon and post-monsoon seasons.

Field sampling and calculation: Sampling was done by enumerating thirty transects of 250 m long and 4 m wide. Diameter and girth of woody plants was measured at breast height 1.37 m above ground level and trees of girth size ≥1 cm (dbh) were included in the sample. For herbs and grasses, quadrats of 1 m × 1 m were laid at every 50 m distance in each transect. Therefore, sampling was done in 6 quadrats per

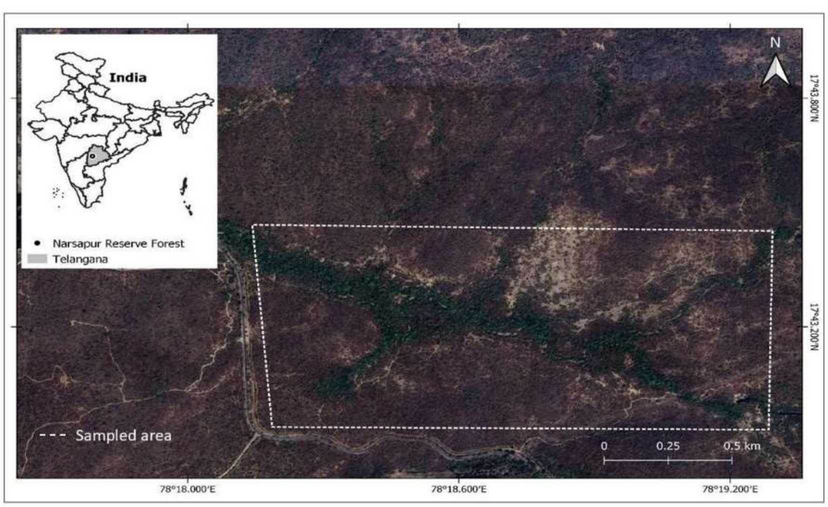

Fig. 1. Location of the study area in the Narsapur Reserve Forest, Medak District, Telangana, India

transect, total 180 quadrats (Fig. 3). Canopy cover was estimated as proportion of canopy open at each 1 m × 1 m quadrat using ocular observation to assess the influence of canopy openness on herb and grass community (if any). All the shrubs, herbs, climbers and grasses were also surveyed. Plant community structure (frequency, density, abundance, basal area, relative density, relative frequency, relative dominance and importance value index) were computed from the quadrat data following Misra (1968). The species density per hectare was calculated by dividing the total number of individuals across all transects by the total sampled area. Basal area for each individual was determined based on its girth, and for multi-stemmed individuals, the basal area of each stem was calculated separately (Shankar 2001). The basal areas of all individuals within a species were summed to determine the total basal area for that species. The stand basal area represented the sum of basal areas for all species in the community. For each species, the frequency, density, and basal area values were converted into relative values by dividing each respective value by the total frequency, density, and basal area of all species. The Importance Value Index (IVI) for species was calculated by adding together the relative density, relative frequency, and relative basal area.

The community characteristics were estimated using standard methods. Species dispersion was analyzed through the variance-to-mean ratio (Greig-Smith, 1983), where a ratio of 1 signifies random dispersion, > 1 indicates uniform dispersion and < 1 suggests increasingly clumped dispersion.

Species diversity was calculated by using the Shannon diversity index following Magurran (2004) as:

$$D_{Mg} = \frac{S-1}{ln\ (N)}$$

where, *H'* = Shannon index of general diversity, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), In is the natural

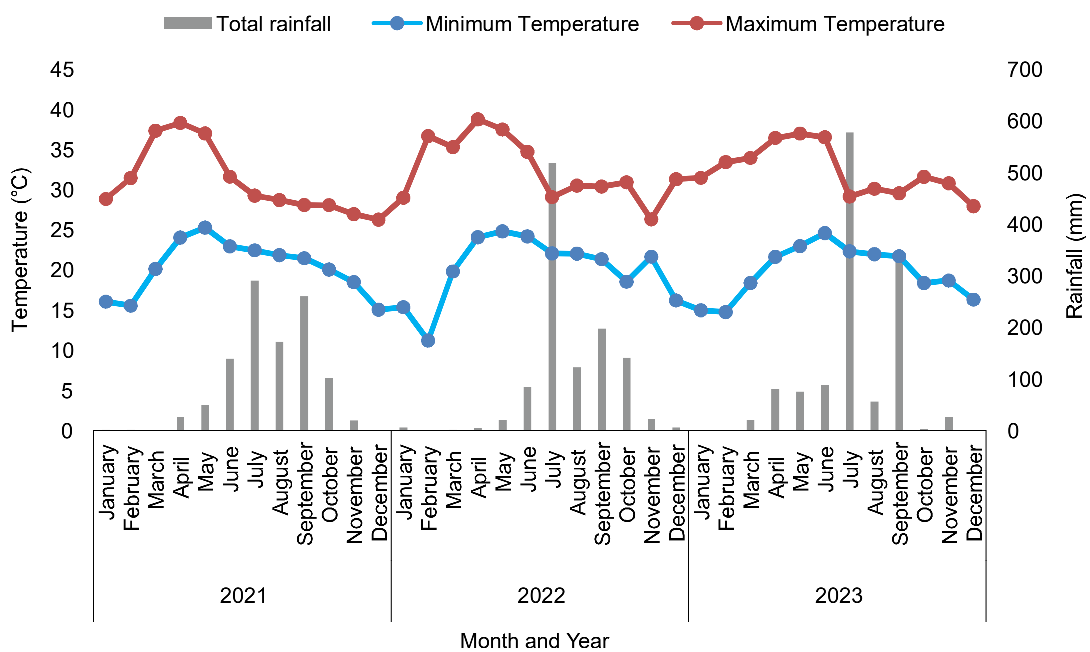

Fig. 2. Climatic pattern of Narsapur during the study period (2021 to 2023)

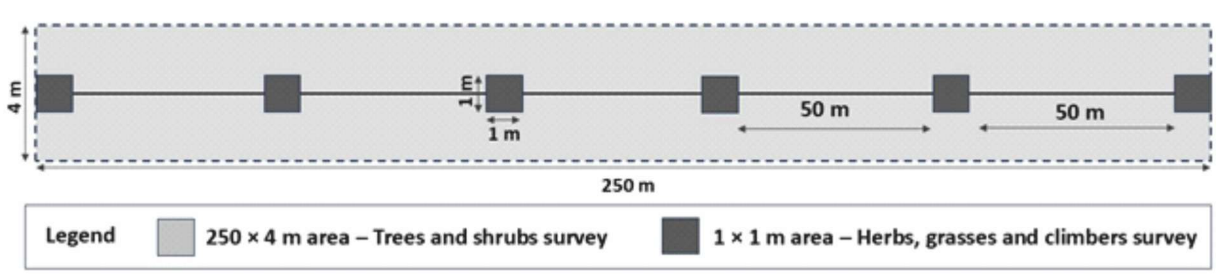

Fig. 3. Transect layout and placement of quadrats on each transect

log, 'Σ' is the sum of the calculations, and 's' is the number of species. The index of dominance was calculated following Simpson, 1949 (Magurran 2004) as:

$$H^{'} = -\sum_{i=1}^{N} p_i \times lnp_i$$

where, Cd =Simpson's index of dominance, *pi* = proportion of the IVI of i^{th} species. Margalef index was used as a simple measure of species richness within a community Species richness was calculated by counting the total number of species observed in each habitat and also by the Margalef index as given by Magurran (2004):

$$Cd = \sum p_i^2$$

where, *S* = number of species, *N* = total number of individuals in the sample. Dominance=1-Simpson index. Ranges from 0 (all taxa are equally present) to 1 (one taxon dominates the community completely). Fisher's alpha was used as a diversity index, defined implicitly by the formula S=×ln(1+n/ α) where S is the number of taxa, n is the number of individuals and α is Fisher's alpha. The data were statistically tested in PAST Version 2.17c (Hammer et al., 2001) and visualized using MS-Excel. An exponential curve was fitted to depict the stand's population structure (girth and height class distributions) and chi-square test of goodness of fit evaluated the curve fit. The transects were clustered using a paired-group algorithm and Bray-Curtis similarity measure in PAST software. Family Importance Value (FIV) was calculated according to Mori et al., (1983) as a sum of relative diversity, relative dominance, and relative density. For herbs, grasses, and climbers Family Importance Value (FIV) was calculated according to Uranov (1935), where the Family Importance Index (I_b) is the multiplication of the Abundance (A_b) and Frequency (F_b) of the species. Species were organized according to decreasing IVI values and were placed under four different classes: 0-1%, 1-3%, 3-5% and >5%.

RESULTS AND DISCUSSION

Species composition: A total of three hectares of the Narsapur Reserve Forest in Telangana State were sampled across 30 randomly selected transects, documenting 13,601 individuals. The survey identified 81 tree and shrub species (Group A) belonging to 31 families. Transect 10 recorded the highest number of species. Additionally, 4,881 individuals of herbs, grasses, and climbers (Group B) were documented, representing 59 species from 26 families (Fig. 4). Overall, the study identified 140 plant species (81 from Group A and 59 from Group B) spanning 51 unique families in the Narsapur Reserve Forest. *Cleistanthus collinus* (Roxb.) Benth. ex. Hook. f. was the most abundant species with an absolute abundance of 1,941 individuals, contributing to 14.27% of the relative abundance. Following *Cleistanthus collinus*, *Chloroxylon swietenia* DC. were the second most abundant species with 1,318 individuals (9.69% relative abundance). Together, these two species contribute to over 23% of the cumulative abundance (19.05% for *Chloroxylon swietenia*), highlighting the skewness in species distribution where a few species dominate. *Holarrhena pubescens* Wall. ex G. Don and *Tectona grandis* L. rank third and fourth in terms of abundance, contributing 6.74% and 5.94% relative abundance respectively. These species account for a significant proportion of the cumulative abundance, reaching

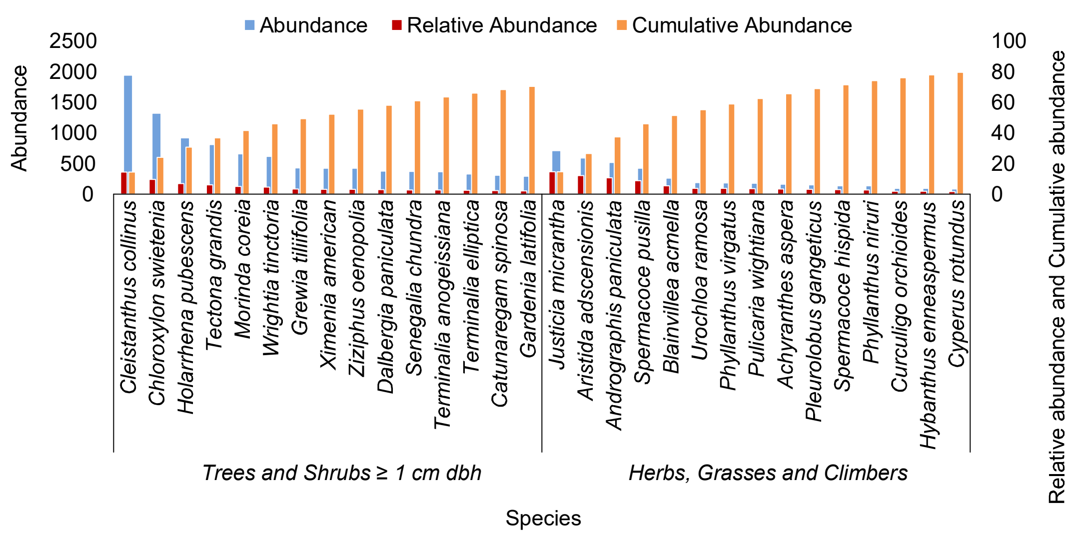

Fig. 4. Abundance values of top 15 species according to decreasing relative abundance

36.64%. The cumulative abundance reaches 70.25% by the inclusion of these species, reflecting the presence of many low-abundance species that contribute minimally to the overall abundance such as *Madhuca longifolia* var. *latifolia* (Roxb.) A. Chev., *Diospyros melanoxylon* Roxb., *Ficus mollis* Vahl, *Aegle marmelos* (L.) Corrêa and *Morinda coreia* Buch. Ham., but are crucial for maintaining ecological balance. In the herbaceous and climbing plant layer, *Justicia micrantha* Wall. was the most abundant species with 711 individuals and 14.57% of the herbaceous community. *Aristida adscensionis* L. and *Andrographis paniculata* (Burm. f.) Wall. with relative abundances of 12.07% and 10.63%, follow *Justicia micrantha* in dominance, accounting for 37.27% of the cumulative abundance. The dominance of *Justicia micrantha* as an herb in the understory vegetation is likely attributed to its adaptability and competitive advantage such as rigorous fruiting or maybe attributed to efficient photosynthesis, under the given ecological conditions of TDDF; however, further research is needed to confirm this.

The Importance Value Index (IVI) of dominant species like *Cleistanthus collinus* and *Lannea coromandelica* (Houtt.) Merr.were observed to be 32.64% and 22.49% respectively, followed by co-dominant species *Tectona grandis*(18.61%) and *Chloroxylon swietenia* (14.05%) with the lowest values belonging to *Senegalia chundra* (Roxb. ex Rottler) Maslin (6.25%) and *Grewia tiliifolia Vahl* (6.10%) amongst the top 15 species with highest IVI values of all species in the transects (Table 1). Amongst herbs, grasses and climber's category, *Justicia micrantha* (22.30%), *Andrographis paniculata* (18.37%) and *Aristida adscensionis* L. (18%), were found to be dominant over others. *Phyllanthus virgatus* G. Frost and *Curculigo orchioides* Gaertn. constitute the dominated category with IVI values of 7.69%, 7.62% and 7.30% respectively and *Hemidesmus indicus* (L.) R. Br., *Cryptolepis dubia* (Burm. f.) M. R. Almeida and *Spermacoce hispida* L. have the lowest IVI values of 5.03%, 4.64% and 4.03%.

Considering all 81 species of trees and shrubs, in terms of IVI values, 26 species were between 0-1%, 24 species were in the range of 1-3% IVI values and 14 species in range 3-5%, and 17 species had IVI values of more than 5%. For herbs, grasses and climbers, out of a total of 59 species, 23 were in the range of 0-1% IVI values, 17 species fall in 1-3% IVI values and 6 species in range 3-5%, while 13 species were found to have IVI more than 5%.

The summary of diversity indices for trees and shrubs (≥1 cm dbh) and herbs, grasses, and climbers reveals notable patterns in species richness, diversity, and dominance across the plant life forms sampled (Table 2). However, the number of species was higher than the average number of herbs, grasses, and climbers recorded in the area 12.93 . The species richness observed in the sampled area of Narsapur reserved forest is similar to the species reported by Suthariet al., (2016) in protected area of Mallur Gutta sacred groove, Telangana. Since the number of individuals of trees and shrubs were also higher in the sample, the Shannon diversity index (H') for trees and shrubs was high 2.92, while the corresponding value for herbs, grasses, and climbers was 2.11. The index value stands close to the observations from other dry deciduous forests for Telangana as well as other dry deciduous forests of India such as reported by Naidu et al. (2017), Sahu et al. (2012) and Murthy et al. (2022). The Simpson index (1-*D*) for trees and shrubs was relatively high at 0.91 indicating low dominance and a high degree of diversity. In contrast, the herbaceous layer exhibited a lower Simpson index of 0.84 suggesting a higher dominance of some species and low variation in the composition among the sampling locations in the understory. It is probably due to the canopy cover. The average canopy cover in the sampling was recorded as 55 ranging from 80 to 25%. It was observed that higher canopy cover facilitated the herbaceous communities, with invasive species like *Lantana camara* L. intensely invaded the areas with low canopy cover of native tree species. The results of the present study coincide with the results of the studies by Sagar et al. (2012) as well as Sharma and Raghuvanshi (2011) in similar habitats. Fisher's alpha diversity index for trees and shrubs was 10.07, markedly greater than that of herbs, grasses, and climbers, which had a value of 3.42. The dominance index (D) for trees and shrubs was 0.09 ± 0.03 (CV% = 36.60), reflecting low dominance by any single species within this group. However, the dominance in the herbaceous layer was higher at 0.16, indicating that a few species tend to dominate in this layer. The evenness index for trees and shrubs was 0.49, which was lower than that for herbs, grasses, and climbers, which had an evenness of 0.66 Margalef's index for species richness in trees and shrubs was 6.10, while for herbs, grasses, and climbers was 2.36 .

The higher Shannon index in the woody vegetation suggests a more even distribution of species compared to the herbaceous stratum, which displays lower species evenness. Phytosociological analysis of the herbaceous vegetation indicated that tropical forests can harbor a variety of herbs and climber species according to changes in vegetation and availability of space and light. Fisher's alpha index indicates that the tree and shrub stratum support a higher degree of rare species diversity compared to the herbaceous stratum. Similar results were also reported by Sagar et al. (2012). The significantly higher value of Margalef's index for trees and shrubs reflects a richer species composition in this stratum, consistent with the findings for species richness and diversity. The results indicate that trees and shrubs exhibit greater species richness, diversity, and evenness than herbs, grasses, and climbers, while dominance is higher in the herbaceous layer. The woody vegetation tends to host more rare species, as evidenced by the higher Fisher's alpha values, while the herbaceous vegetation has a more uniform distribution of species, as indicated by the higher evenness index for present observations. Margalef's index in the present study is comparable to that done in Kawal Wildlife Sanctuary, Telangana by Murthy (2015), where he reported that the Margalef's species richness index was 5.20. The present data can be compared with the large number of similar plots

Table 2. Different diversity indices of plant species for all transects [Values = mean ± SD (CV%)]

Indices/Variables	Trees and shrubs ≥1 cm dbh	Herbs, grasses and climbers
Species richness	38.23±6.97 (18.23)	12.93±3.53 (27.31)
Shannon diversity	2.92±0.29 (9.82)	2.11±0.30 (14.23)
Simpson	0.91±0.03 (3.67)	0.84±0.05 (6.25)
Fisher's α	10.07±1.72 (17.08)	3.42±1.03 (29.98)
Dominance	0.09±0.03 (36.60)	0.16±0.05 (32.90)
Evenness	0.49±0.07 (15.91)	0.66±0.08 (12.30)
Margalef	6.10±0.91 (14.95)	2.36±0.60 (25.47)

Values = Mean ± SD (CV%)

Table 1. IVI values of top 15 plant species in the order of decreasing IVI values

Life form	Species	RD	RF	RBA	IVI
Trees and shrubs ≥1 cm dbh	*Cleistanthus collinus* (Roxb.) Benth.	14.27	2.62	15.76	32.65
	Lannea coromandelica (Houtt.) Merr.	1.96	2.62	17.92	22.49
	Tectona grandis L.	5.94	2.53	10.14	18.61
	Chloroxylon swietenia DC.	9.69	2.62	1.75	14.06
	Morinda coreia Buch-Ham.	4.82	2.62	3.84	11.28
	Dalbergia paniculata (Roxb.) Thoth.	2.77	2.62	5.37	10.76
	Holarrhena pubescens Wall.	6.74	2.62	1.05	10.41
	Boswellia serrata Roxb.	0.67	1.40	7.76	9.82
	Terminalia anogeissiana Gere and Boatwr.	2.66	2.53	3.01	8.20
	Wrightia tinctoria (Roxb.) R.Br.	4.49	2.27	0.81	7.57
	Madhuca longifolia (Roxb.) A.Chev.	1.63	2.62	3.17	7.41
	Terminalia elliptica Willd.	2.42	2.53	2.44	7.39
	Ximenia americana L.	3.10	2.53	1.43	7.05
	Senegalia chundra (Roxb.) Maslin	2.71	2.53	1.01	6.25
	Grewia tiliifolia Vahl	3.15	2.35	0.60	6.10
Herbs, grasses and climbers	*Justicia micrantha* Wall.	14.57	7.73	-	22.30
	Andrographis paniculata (Burm.f.) Wall.	10.63	7.73	-	18.37
	Aristida adscensionis L.	12.07	5.93	-	18.00
	Spermacoce pusilla Wall.	8.60	5.41	-	14.02
	Blainvillea acmella (L.) Philipson	5.35	5.15	-	10.50
	Pleurolobus gangeticus (L.) J.St.-Hil.	3.05	4.64	-	7.69
	Phyllanthus virgatus G. Forst.	3.75	3.87	-	7.62
	Curculigo orchioides Gaertn.	1.88	5.41	-	7.30
	Urochloa ramosa (L.) T.Q.Nguyen	3.81	3.35	-	7.16
	Pulicaria wightiana (DC.) C.B. Clarke	3.59	3.35	-	6.94
	Achyranthes aspera L.	3.24	2.84	-	6.07
	Phyllanthus niruri L.	2.68	2.58	-	5.26
	Hemidesmus indicus (L.) R.Br.	1.17	3.87	-	5.03
	Cryptolepis dubia (Burm.f.) M.R.Almeida	0.78	3.87	-	4.64
	Spermacoce hispida L.	2.75	1.29	-	4.03

D- Density, F- Frequency, BA- Basal area, RD- Relative density, RF- Relative frequency, RBA- Relative basal area, IVI- Importance Value Index

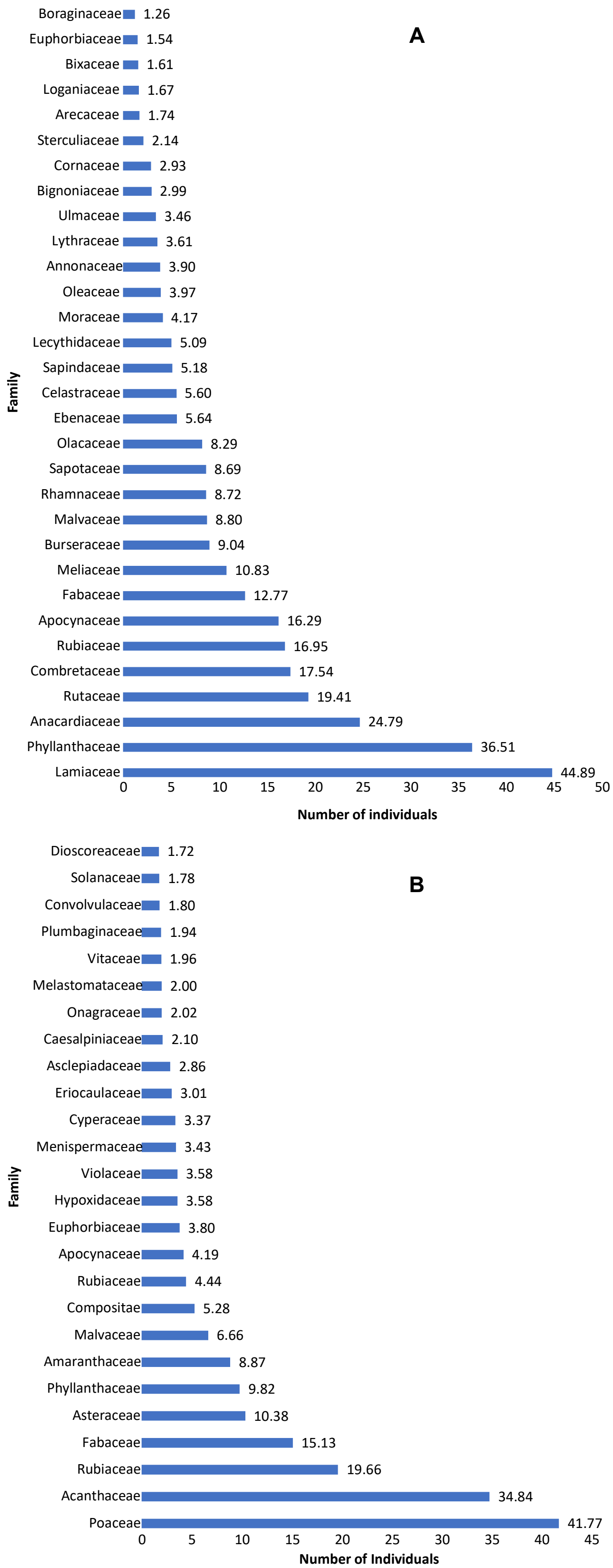

Fig. 5. Family index values (FIV) of different plant species of Narsapur forest. (A) Trees and shrub families, (B) Herb, grasses and climber families

inventoried in India and elsewhere in the tropics. Species richness ranging from 51 to 24 ha^{-1} with mean value of 38.2 ha^{-1} was recorded during the present study in case of woody vegetation. The mean value in the present study is higher than that of 21 species ha^{-1} in Kolli hills of India (Chittibabu and Parthasarathy 2000), 31 species ha^{-1} in dry deciduous forests of western India (Kumar et al., 2010), and similar to species composition in reserved forests of southern Eastern Ghats of Andhra Pradesh (Rao et al., 2011).

Total 31 families were observed constituting tree and shrub species while 26 families were recorded for the herbs, grasses and climbers. For the trees and shrubs, Lamiaceae (FVI = 44.89) was the most dominant family, followed by Phyllanthaceae (36.51) and Anacardiaceae (24.79). Together these three families constitute more than 100 % in the index value (Fig. 5A). For herbs, grasses and climbers, Poaceae was the most dominant family (FVI = 41.77), followed by Acanthaceae (34.84), Rubiaceae (19.66) and Fabaceae (10.38) (Fig. 5B). These families have the highest representation of tree and shrub species within the sampled area. This suggests that species within these families play a crucial role in shaping the structure and function of the ecosystem in this forest. In terms of woody plants (trees and shrubs), the top 10 families comprised of 82.60% of the total number of stems, while for herbaceous plants (herbs, grasses and climbers) constituted to 89.36% of the total number. Fabaceae was found to be the most speciose family in the present study with 17 species. Pragasan and Parthasarathy (2010), indicated dominance of Mimosaceae, followed by Euphorbiaceae, Rubiaceae, Rutaceae and Melastomataceae, a trend similar to the current study. Panda et al., (2013) observed that Euphorbiaceae, Rubiaceae, Fabaceae and Combretaceae were the families having highest abundance in terms of tree numbers in the northern part of the Eastern Ghats. In present study also Phyllanthaceae (closely related to Euphorbiaceae), Fabaceae and Rubiaceae were the dominant families.

Dominance- diversity curve: Both the dominance diversity curve of trees and shrubs as well as of herbs, grasses and climbers shows log normal distributions. The dominance diversity curve expressed in log normal series (Fig. 6A) indicates that *Cleistanthus collinus* and *Chloroxylon swietenia* are the dominant tree species that utilize most of the available resources and ecological niches, while the remaining species utilize the leftover resources within the forest stand.

In terms of herbs, grasses and climbers the log series distribution indicates that *Justicia micrantha*, *Aristida adscensionis* and *Andrographis paniculate.* The distribution pattern here seems to follow a typical log-normal or geometric series model, which is common in ecological communities where a few species dominate while the majority are much rarer (Whittaker 1965).The steep initial decline suggests that a few species dominate the community in terms of abundance, while many others are less common and the long tail indicates that there are many species with low abundance, reflecting high species richness but unequal distribution of abundance across species.

Dispersion pattern of plant species: Dispersion of plant species can give valuable information on how individuals are arranged in a space. Many factors influence dispersion patterns like ecological functions, habitat requirements and niche occupancy. The ratio of the variance to the mean can then be used to determine whether the pattern is uniform or clumped, and is referred to as the index of dispersion (Krebs 1999). If the variance to mean ratio is more than one it

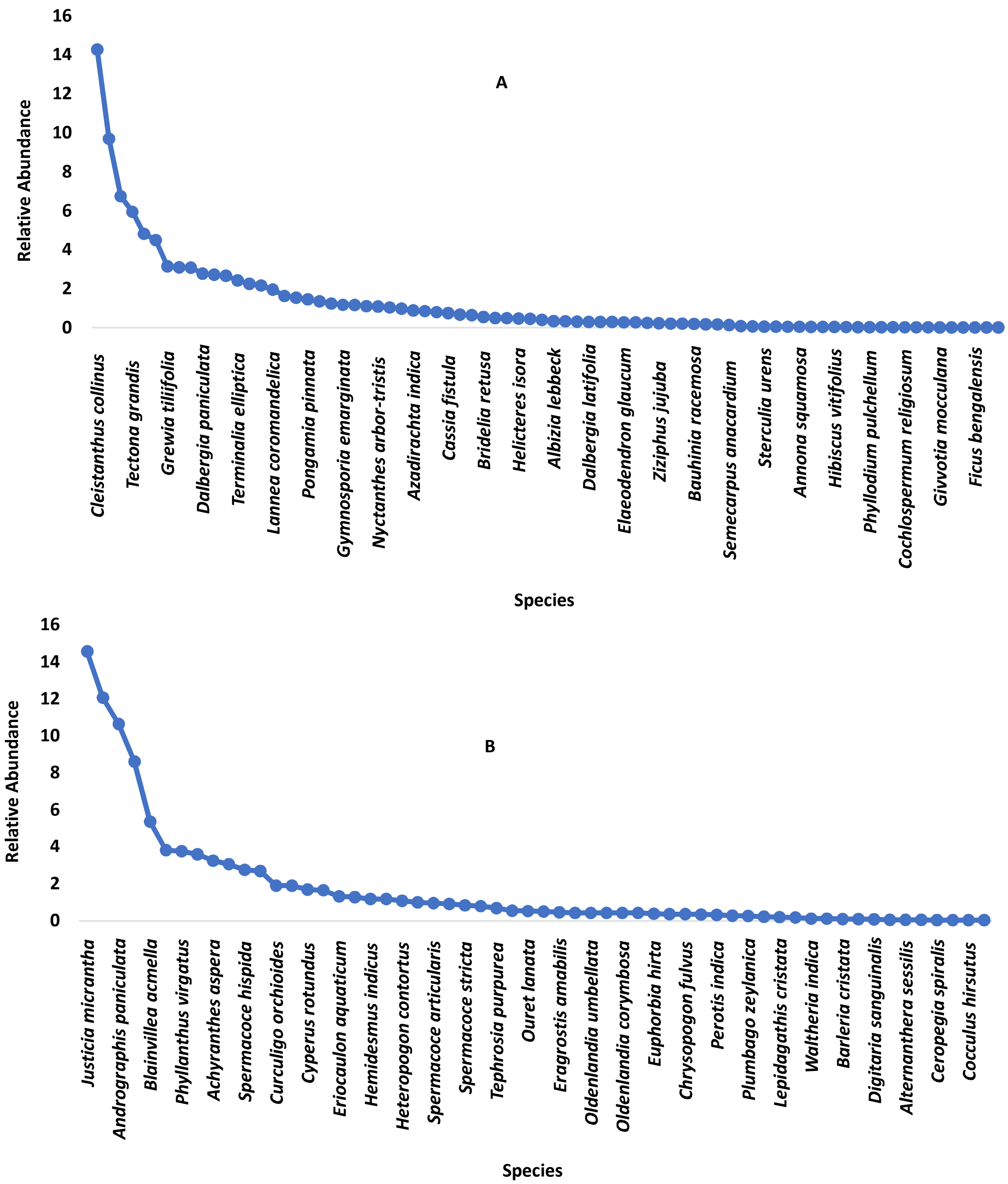

Fig. 6. Dominance – Diversity curve for plant species of Narsapur forest: (A) Tree and shrub species, (B) Herb, grass and climber species

Table 3. Dispersion pattern of trees and shrubs for all 30 transects of the 'Narsapur' forest of Telangana, arranged according to decreasing variance to mean ratio

Species	Variance	Mean	Chi-sq	Ratio	Aggregation
Wrightia tinctoria (Roxb.) R.Br.	1123.55	20.37	1599.82	55.17	Aggregated
Cleistanthus collinus (Roxb.) Benth.	954.56	64.70	427.86	14.75	Aggregated
Chloroxylon swietenia DC.	778.00	43.93	513.55	17.71	Aggregated
Holarrhena pubescens Wall. ex G.Don	634.32	30.57	601.81	20.75	Aggregated
Pongamia pinnata (L.) Pierre	378.19	6.57	1670.16	57.59	Aggregated
Tectona grandis L.f.	356.89	26.93	384.28	13.25	Aggregated
Ziziphus oenopolia (L.) Mill.	229.90	13.97	477.35	16.46	Aggregated
Grewia tiliifolia Vahl	223.86	14.27	455.04	15.69	Aggregated
Catunaregam spinosa (Thunb.) Tirveng.	198.10	10.20	563.22	19.42	Aggregated
Alangium salviifolium (L.f.) Wangerin	193.76	6.97	806.55	27.81	Aggregated
Grewia tiliifolia Vahl.	193.50	6.23	900.22	31.04	Aggregated
Gardenia latifolia Aiton	170.58	9.80	504.78	17.41	Aggregated
Terminalia anogeissiana Gere andBoatwr.	151.58	12.07	364.30	12.56	Aggregated
Ximenia americana L.	133.55	14.03	275.98	9.52	Aggregated
Nyctanthes arbor-tristis L.	122.02	4.90	722.18	24.90	Aggregated
Morindacoreia Buch.-Ham.	108.90	21.83	144.65	4.99	Aggregated
Phoenix sylvestris (L.) Roxb.	104.70	2.30	1320.13	45.52	Aggregated
Senegaliachundra (Roxb.) Maslin	92.42	12.30	217.91	7.51	Aggregated
*Ixora pavetta*Andrews	76.55	5.27	421.49	14.53	Aggregated
Diospyros chloroxylon Roxb.	65.87	3.83	498.30	17.18	Aggregated
Gymnosporia emarginata (Willd.) Thwaites	62.15	5.30	340.06	11.73	Aggregated
Dalbergia paniculata (Roxb.) Thoth.	54.87	12.57	126.63	4.37	Aggregated
Grewia hirsuta Vahl	48.39	5.60	250.57	8.64	Aggregated
Soymida febrifuga (Roxb.) A.Juss.	37.57	6.13	177.63	6.13	Aggregated
Bridelia retusa (L.) A.Juss.	37.36	2.47	439.24	15.15	Aggregated
Helicteresisora L.	37.06	2.10	511.76	17.65	Aggregated
Terminalia elliptica Willd.	36.86	10.97	97.47	3.36	Aggregated
Lagerstroemia parviflora Roxb.	29.15	4.43	190.68	6.58	Aggregated
Lannea coromandelica (Houtt.) Merr.	28.33	8.87	92.65	3.19	Aggregated
Miliusa tomentosa (Roxb.) Finet andGagnep.	26.79	2.20	353.09	12.18	Aggregated
Dolichandrone atrovirens (Roth) K.Schum.	25.60	4.70	157.94	5.45	Aggregated
Madhuca longifolia (Roxb.) A.Chev.	25.00	7.37	98.41	3.39	Aggregated
Mitragyna parvifolia (Roxb.) Korth.	24.82	2.07	348.32	12.01	Aggregated
Cassia fistula L.	21.77	3.40	185.65	6.40	Aggregated
Azadirachta indica A.Juss.	20.34	4.00	147.50	5.09	Aggregated
Olax scandens Roxb.	15.20	2.90	151.97	5.24	Aggregated
Boswellia serrata Roxb.	13.90	3.03	132.85	4.58	Aggregated
Elaeodendron glaucum (Rottb.) Pers.	13.70	1.23	322.19	11.11	Aggregated
Phyllanthus emblica L.	10.91	1.30	243.31	8.39	Aggregated
Diospyros melanoxylon Roxb.	9.86	5.00	57.20	1.97	Aggregated
Pterocarpus marsupium Roxb.	9.29	2.23	120.61	4.16	Aggregated
Strychnos potatorum L.f.	8.49	1.30	189.46	6.53	Aggregated
Albizia odoratissima (L.f.) Benth.	7.77	3.60	62.56	2.16	Aggregated

Cont...

Table 3. Dispersion pattern of trees and shrubs for all 30 transects of the 'Narsapur' forest of Telangana, arranged according to decreasing variance to mean ratio

Species	Variance	Mean	Chi-sq	Ratio	Aggregation
Holoptelea integrifolia (Roxb.) Planch.	7.57	1.47	149.64	5.16	Aggregated
Gmelina arborea Roxb.	6.00	0.93	186.29	6.42	Aggregated
Aegle marmelos (L.) Corrêa	5.98	1.23	140.57	4.85	Aggregated
Terminalia bellirica (Gaertn.) Roxb.	5.83	1.40	120.86	4.17	Aggregated
Buchanania lanzan Spreng.	4.92	1.80	79.33	2.74	Aggregated
Terminalia arjuna (Roxb.) Wight and Arn.	4.51	1.10	118.82	4.10	Aggregated
Rotheca serrata (L.) Steane and Mabb.	3.90	0.97	116.86	4.03	Aggregated
Dalbergia latifolia Roxb.	3.87	1.30	86.38	2.98	Aggregated
Butea monosperma (Lam.) Kuntze	3.43	0.77	129.61	4.47	Aggregated
Albizia amara (Roxb.) Boivin	3.37	0.93	104.86	3.62	Aggregated
Bridelia montana (Roxb.) Willd.	3.37	0.73	133.45	4.60	Aggregated
Albizia lebbeck (L.) Benth.	3.36	1.50	65.00	2.24	Aggregated
Ziziphus jujuba Mill.	2.90	1.00	84.00	2.90	Aggregated
Bauhinia racemosa Lam.	1.64	0.87	54.77	1.89	Aggregated
Semecarpus anacardium L.f.	0.87	0.60	42.00	1.45	Aggregated
Careya arborea Roxb.	0.86	0.37	68.09	2.35	Aggregated
Hibiscus vitifolius L.	0.83	0.17	145.00	5.00	Aggregated
Bergera koenigii L.	0.83	0.17	145.00	5.00	Aggregated
Ziziphus xylopyrus (Retz.) Willd.	0.83	0.17	145.00	5.00	Aggregated
Annona squamosa L.	0.58	0.20	84.00	2.90	Aggregated
Schleichera oleosa (Lour.) Oken	0.49	0.30	47.67	1.64	Aggregated
Vachellia leucophloea (Roxb.) Maslin, Seigler and Ebinger	0.46	0.23	57.29	1.98	Aggregated
Sterculia urens Roxb.	0.46	0.23	57.29	1.98	Aggregated
Tamarindus indica L.	0.37	0.20	54.00	1.86	Aggregated
Cordia dichotoma G.Forst.	0.30	0.10	87.00	3.00	Aggregated
Ficus mollis Vahl	0.26	0.13	56.00	1.93	Aggregated
Peltophorum pterocarpum (DC.) Backer	0.16	0.10	47.00	1.62	Aggregated
Phyllodium pulchellum (L.) Desv.	0.16	0.10	47.00	1.62	Aggregated
Limonia acidissima L.	0.13	0.07	58.00	2.00	Aggregated
Pterospermum xylocarpum (Gaertn.) Oken	0.13	0.07	58.00	2.00	Aggregated
Bombax ceiba L.	0.09	0.10	27.00	0.93	Uniform
Cochlospermum religiosum (L.) Alston	0.06	0.07	28.00	0.97	Uniform
Albizia procera (Roxb.) Benth.	0.03	0.03	29.00	1.00	Random
Cipadessa baccifera (Roxb. ex Roth) Miq.	0.03	0.03	29.00	1.00	Random
Ficus benghalensis L.	0.03	0.03	29.00	1.00	Random
Givotia moluccana (L.) Sreem.	0.03	0.03	29.00	1.00	Random
Premna tomentosa Willd.	0.03	0.03	29.00	1.00	Random
Prosopis cineraria (L.) Druce	0.03	0.03	29.00	1.00	Random

Table 4. Dispersion pattern of herbs, grasses and climbers for all 30 transects of 'Narsapur' forest of Telangana, arranged according to decreasing variance to mean ratio

Species	Variance	Mean	Chi-sq	Ratio	Aggregation
Aristida adscensionis L.	422.24	19.63	623.68	21.51	Aggregated
Justicia micrantha Wall.	279.46	23.70	341.95	11.79	Aggregated
Spermacoce pusilla Wall.	252.28	14.00	522.57	18.02	Aggregated
Urochloa ramosa (L.) T.Q.Nguyen	156.99	6.20	734.32	25.32	Aggregated
Achyranthes aspera L.	140.00	5.27	770.86	26.58	Aggregated
Spermacoce hispida L.	132.40	4.47	859.58	29.64	Aggregated
Blainvillea acmella (L.) Philipson	131.67	8.70	438.89	15.13	Aggregated
Andrographis paniculata (Burm.f.) Nees	128.36	17.30	215.16	7.42	Aggregated
*Phyllanthus virgatus*G.Forst.	114.30	6.10	543.39	18.74	Aggregated
Hybanthus enneaspermus (L.) F.Muell.	100.82	3.07	953.43	32.88	Aggregated
Heteropogon contortus (L.) P.Beauv.	83.24	1.73	1392.62	48.02	Aggregated
Pulicaria wightiana (DC.) C.B.Clarke	80.49	5.83	400.14	13.80	Aggregated
*Phyllanthus debilis*J.G.Klein	76.45	4.37	507.70	17.51	Aggregated
Eriocaulon aquaticum (Hill) Druce	66.19	2.13	899.75	31.03	Aggregated
Setaria pumila (Poir.) Roem. and Schult.	56.09	1.90	856.16	29.52	Aggregated
Cynodon dactylon (L.) Pers.	42.52	1.60	770.75	26.58	Aggregated
Spermacoce articularis L.f.	34.67	1.53	655.74	22.61	Aggregated
Pleurolobus gangeticus (L.) J.St.-Hil.	33.55	4.97	195.90	6.76	Aggregated
Abutilon indicum (L.) Sweet	29.10	2.07	408.32	14.08	Aggregated
Cyperus rotundus L.	27.10	2.73	287.51	9.91	Aggregated
*Spermacoce stricta*Sesséand Moc.	22.71	1.33	494.00	17.03	Aggregated
Curculigo orchioides Gaertn.	22.62	3.07	213.87	7.37	Aggregated
Eragrostis viscosa (Retz.) Trin.	13.37	0.73	528.91	18.24	Aggregated
Chamaecrista pumila (Lam.) V.Singh	13.33	0.67	580.00	20.00	Aggregated
Oldenlandia corymbosa L.	13.33	0.67	580.00	20.00	Aggregated
Pseudanthistiria umbellata (Hack.) Hook.f.	13.33	0.67	580.00	20.00	Aggregated
Hemidesmus indicus (L.) R.Br.	12.78	1.90	195.11	6.73	Aggregated
Blepharis maderaspatensis (L.) B.Heyne	12.40	1.47	245.09	8.45	Aggregated
Oldenlandia umbellata L.	9.82	0.67	427.00	14.72	Aggregated
Chrysopogon fulvus (Spreng.) Chiovenda	9.63	0.57	493.00	17.00	Aggregated
Ouret lanata (L.) Kuntze	9.52	0.83	331.40	11.43	Aggregated
Crotalaria pusilla Roxb.	7.06	0.80	256.00	8.83	Aggregated
Tephrosia purpurea (L.) Pers.	6.51	1.10	171.55	5.92	Aggregated
Grona triflora (L.) H.OhashiandK.Ohashi	5.29	0.87	177.08	6.11	Aggregated
Ludwigia hyssopifolia (G.Don) Exell	5.22	0.53	284.00	9.79	Aggregated
Cenchrus pedicellatus (Trin.) Morrone	4.78	0.67	208.00	7.17	Aggregated
Cryptolepis dubia (Burm.f.) M.R.Almeida	3.86	1.27	88.32	3.05	Aggregated
Perotis indica (L.) Kuntze	3.78	0.50	219.00	7.55	Aggregated
Euphorbia hirta L.	3.35	0.60	162.00	5.59	Aggregated
Vitis aestivalis Michx.	2.87	0.43	192.38	6.63	Aggregated
Plumbago zeylanica L.	2.80	0.40	203.00	7.00	Aggregated
Corchorus aestuans L.	1.68	0.33	146.00	5.04	Aggregated
Evolvulus alsinoides (L.) L.	0.83	0.17	145.00	5.00	Aggregated
Lepidagathis cristata Willd.	0.70	0.30	67.67	2.33	Aggregated
Waltheria indica L.	0.56	0.17	97.00	3.34	Aggregated
Solanum nigrum L.	0.53	0.13	116.00	4.00	Aggregated
Abrus precatorius L.	0.48	0.27	52.00	1.79	Aggregated
Barleria cristata L.	0.33	0.13	71.00	2.45	Aggregated
Digitaria sanguinalis (L.) Scop.	0.30	0.10	87.00	3.00	Aggregated
Acalypha indica L.	0.13	0.07	58.00	2.00	Aggregated
Alternanthera sessilis (L.) DC.	0.13	0.07	58.00	2.00	Aggregated
Crotalaria pallida Aiton	0.13	0.07	58.00	2.00	Aggregated
Ceropegia spiralis Wight	0.03	0.03	29.00	1.00	Random
Cissampelos pareira L.	0.03	0.03	29.00	1.00	Random
Cocculus hirsutus (L.) W.Theob.	0.03	0.03	29.00	1.00	Random
Dioscorea hispida Dennst.	0.03	0.03	29.00	1.00	Random

indicates that individuals in this population are exhibiting a clumped spacing pattern in the sampled habitat. If this ratio is less than one, it indicates a uniform distribution. Whereas if it is one, that indicates individuals are randomly distributed in space. In case of trees and shrubs, out of 81 species, 73 species are clumped or aggregated and 2 species are uniform and 6 species are random in dispersion. In case of herbs, grasses and climbers, 55 are aggregated and 4 are random in dispersion. In trees, all of the 15 highest IVI values were aggregated while in herbs and climbers, also all were aggregated and, out of top 15 IVI values species (Table 3, 4).

CONCLUSION

The TDDFs of NRF, Telangana shows high species richness as well as wide species diversity. Difference in Fisher's alpha values indicate that the forest has more woody diversity as compared to herbaceous community, as it is in case of tropical dry deciduous forests. Although the number of species within individual transects (alpha diversity) remained relatively stable, there were notable differences in species composition between transects. This led to moderate compositional heterogeneity (beta diversity) and a substantial Shannon diversity index for trees and shrubs. The high species richness was due to presence of many rare species. The ongoing disturbances, such as small-scale timber extraction, fires, and grazing, are prevalent and impacting the regeneration of certain species. If these disturbances remain controlled, the Narsapur forests will likely retain a healthy demographic structure. However, an increase in disturbance levels could potentially weaken the forest structure and pose a serious threat to the tropical forest ecosystem. There is a significant demand for comprehensive information and updates on forests, which are essential for tracking progress toward sustainable forest management. The results of this study suggest that management actions should prioritize interventions to increase canopy cover, eradication of invasive species such as *Lantana camara*, and strict grazing controls to facilitate regeneration. Community-based forest management approaches, integrating local stakeholders, can further enhance conservation outcomes and ensure sustainable use of ecosystem services. Moreover, long-term monitoring plots should be established in TDDF landscapes to track changes in floristic composition under climate and anthropogenic pressures, thereby guiding adaptive restoration strategies. The information presented in this paper will provide a solid foundation for forest managers and other stakeholders to prioritize conservation actions aimed at conserving biodiversity in the forested landscapes of India.

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AUTHOR'S CONTRIBUTIONS

Ratnaker Jauhari, Bharati Patel: Conceptualization, Methodology, Software; Krishna Chaitanya, Yashwanth Reddy, Yasaswinee Rout: Data curation; Bharati Patel, Vivek N. Chovatiya: Writing- original draft preparation; Bharati Patel, Vivek N. Chovatiya: Visualization, investigation; Ratnaker Jauhari, Bharati Patel: Supervision; Bharati Patel, Vivek N. Chovatiya: Software, validation; Bharati Patel, Vivek . Chovatiya: Reviewing and editing.

REFERENCES

Aguirre O, Hui G, Gadow KV and Jimenez J 2003. An analysis of spatial forest structure using neighborhood-based variables. *Forest Ecology and Management* **183**: 137-145.

Ahmed A 2012. Analysis of forest vegetation in Ranikhet, Kumaon Himalayas, Uttarakhand, India. *Indian Journal of Fundamental and Applied Life Sciences* **2**(4): 16-23.

Anderson-Teixeira KJ, Miller AD, Mohan JE, Hudiburg TW, Duval BD and Delucia EH 2013. Altered dynamics of forest recovery under a changing climate. *Global Change Biology* **19**(7): 2001-2002.

Bajpai O, Kumar A, Mishra AK, Sahu N, Behera SK and Chaudhary L B 2012. Phenological study of two dominant tree species in tropical moist deciduous forest from the Northern India. *International Journal of Botany* **8**(2): 66-72.

Bhadra AK, Dhal NK, Rout NC and Raja Reddy V 2010. Phytosociology of the three community of Ghandhmardan hill ranges. *Indian Forester* **136**(5): 610-620.

Bilyaminu H, Vidyasagaran K, Gopakumar S and Vijaykumar N 2021. Ecological studies on southern secondary moist deciduous forest of Shendurney Wildlife Sanctuary, Kollam, Kerala, India. *Indian Journal of Ecology* **48**(6): 1747-1754.

Champion HG and Seth SK 1968. *A Revised Survey of the Forest Types of India*. Government of India Press.

Charbonneau NC and Fahrig L 2004. Influence of canopy cover and amount of open habitat in the surrounding landscape on proportion of alien plant species in forest sites. *Écoscience* **11**(3): 278-281.

Chaturvedi RK, Bhadouria R and Singh R 2023. Variation in plant strategies with levels of forest disturbance. *Frontiers in Forests and Global Change* **6**: 1197644.

Chaturvedi RK, Raghubanshi AS, Tomlinson KW and Singh JS 2017. Impacts of human disturbance in tropical dry forests increase with soil moisture stress. *Journal of Vegetation Science* **28**(5): 997-1007.

Chittibabu C and Parthasarathy N 2000. Attenuated tree species diversity in human-impacted tropical evergreen forest sites at Kolli hills, Eastern Ghats, India. *Biodiversity and Conservation* **9**: 1493-1511.

Curtis JT and McIntosh RP 1950. The interrelations of certain analytic and synthetic phytosociological characters. *Ecology* **31**: 435-455.

Deb J, Phinn S, Butt N and McAlpine C 2018. Climate change impacts on tropical forests: Identifying risks for tropical Asia. *Journal of Tropical Forest Science* **30**(2): 182-194.

Greig-Smith P 1983. *Quantitative Plant Ecology*. 3rd Edition, Blackwell Science Publications, Oxford, 359 p.

Hammer O, Harper DAT and Ryan PD 2001. PAST: paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* **4**(1): 9.

Hasenauer H 2006. *Sustainable Forest Management. Growth Models for Europe*. Springer, Berlin and Heidelberg, 397 pp.

Hegde GT, Murthy IK, Bhat PR, Swarnim S, Alipuria AK and Ravindranath NH 2011. Vegetation status in degraded forest, community and private lands of Himachal Pradesh. *Indian Forester* **137**(5): 544-553.

Jaybhaye RG, Badhe YP and Hingonekar PS 2022. Forest Fragmentation Analysis in Part of KalsubaiHarishchandragad Wildlife Sanctuary of Northern Western Ghats, Maharashtra. *Indian Journal of Ecology* **49**(2): 553-558.

Jaykumar R and Nair KN 2012. Beta diversity of angiosperms in the tropical forests of Nilgiri Biosphere Reserve, India. *Tropical Ecology* **53**(2): 125-136.

Khurana P 2009. Community structure and diversity of a tropical dry deciduous forest of Hastinapur region, India. *Journal of Applied and Natural Science* **1**(2): 227-230.

Knorr W, Kaminski T, Arneth A and Weber U 2014. Impact of human population density on fire frequency at the global scale. *Biogeosciences* **11**: 1085-1102.

Krebs CJ 1999. *Ecological Methodology*. 2nd Edition, Addison Wesley Longman, Menlo Park, 620 p.

Kumar JIN, Kumar RN, Bhoi RK and Sajish PR 2010. Tree species diversity and soil nutrient status in three sites of tropical dry deciduous forest of western India. *Tropical Ecology* **51**: 273-279.

Kumar S and Kumar BM 1997. Floristic biomass production and edaphic attributes in Mangrove Forest of Puduvyppu Kerala. *Indian Journal of Forestry* **20**(2): 136-143.

Laxmi K and Shrestha BB 2020. Forest regrowth reduces richness and abundance of invasive alien plant species in community managed Shorea robusta forests of central Nepal. *Journal of Ecology and Environment* **44**: 12.

Lewis SL, Malhi Y and Phillips OL 2004. Fingerprinting the impacts of global change on tropical forests. Philosophical Transactions of the Royal Society of London, *Series B: Biological Sciences* **359**(1443): 437-462.

Lexerod N and Eid T 2006. An evaluation of different diameter diversity indices based on criteria related to forest management planning. *Forest Ecology and Management* **222**: 17-28.

Magurran AE 2004. *Measuring Biological Diversity*. Blackwell Publishing, Oxford, 256 p

Misra R 1968. *Ecology Workbook*. Oxford and IBH Co., New Delhi, 244 p.

Mori SA, Boom BM, Carvalino AM and DosSantos TS 1983. The ecological importance of Myrtaceae in an eastern Brazilian wet forest. *Biotropica* **15**: 68-70.

Murthy EN 2015. Ecology and phytosociology of the tropical dry deciduous forests of Kawal Wildlife Sanctuary, Telangana, India. *Journal of Threatened Taxa* **7**(3): 6972-6979.

Murthy EN and Raju VS 2022. Phytosociology of dry deciduous forest in Pranahita Wildlife Sanctuary, Telangana, India. *Journal of Economic and Taxonomic Botany* **46**(3/4): 101.

Panda PC, Mahapatra AK, Acharya PK and Debata AK 2013. Plant diversity in tropical deciduous forests of Eastern Ghats, India: A landscape level assessment. *International Journal of Biodiversity and Conservation* **5**(10): 625-639.

Pande PK 2001. Quantitative vegetation analysis as per aspect and altitude and regeneration behavior of tree species in Garwhal Himalayan Forest. *Annals of Forestry* **9**(1): 39-52.

Pausas JG and Ribeiro E 2013. The global fire-productivity relationship. *Global Ecology and Biogeography* **22**: 728-736.

Pommerening A 2002. Approaches to quantifying forest structures. Forestry **75**: 305-324.

Pragasan LA and Parthasarathy N 2010. Landscape-level tree diversity assessment in tropical forests of southern Eastern Ghats, India. *Flora* **205**(11): 728-737.

Raha D, Subashree K, Dar JA and Khan LM 2023. Tree diversity, stand structure and species composition in three tropical dry deciduous forests of Madhya Pradesh, Central India. *Proceedings of the International Academy of Ecology and Environmental Sciences* **13**(4): 158-172.

Rao BRP, Babu MVS, Reddy MS, Reddy AM, Rao VS, Sunitha S and Ganeshaiah KN 2011. Sacred groves in southern Eastern Ghats, India: Are they better managed than forest reserves? *Tropical Ecology* **52**: 79-90.

Reddy CS, Jha CS, Diwakar PG et al 2015. Nationwide classification of forest types of India using remote sensing and GIS. *Environmental Monitoring and Assessment* **187**: 777.

Sadia S, Waheed M, Firdous S, Arshad F, Fonge BA and Al-Andal A 2024. Ecological analysis of plant community structure and soil effects in subtropical forest ecosystem. *BMC Plant Biology* **24**(1): 1275.

Sagar R, Pandey A and Singh JS 2012. Composition, species diversity, and biomass of the herbaceous community in dry tropical forest of northern India in relation to soil moisture and light intensity. *The Environmentalist* **32**(4): 485-493.

Sagar R, Raghubanshi AS and Singh JS 2003. Tree species composition, dispersion and diversity along disturbance gradient in dry tropical region of India. *Forest Ecology and Management* **186**(1/3): 61-71.

Saharan H, Dhiman H and Jakhar S 2021. Phytosociology of Invasive Alien Plant Species and Anthropogenic Disturbances in the Community Forests of Haryana, India. *Indian Journal of Ecology* **48**(5): 1358-1364.

Sahu SC, Dhal NK and Mohanty RC 2012. Tree species diversity, distribution and population structure in a tropical dry deciduous forest of Malyagiri hill ranges, Eastern Ghats, India. *Tropical Ecology* **53**(2): 163-168.

Shadangi DK, Banerjee SK, Shukla PK and Soni M 2000. Comparative studies on plant diversity in protected forest area under joint forest management and unprotected forest in Orissa. *Indian Journal of Tropical Biodiversity* **7-8**(1-4): 15-22.

Shankar U 2001. A case of high tree diversity in sal (Shorea robusta)-dominated lowland forest of eastern Himalaya: Floristic composition, regeneration and conservation. *CurrentScience* **81**: 776-786.

Sharma GP and Raghubanshi AS 2011. *Lantana camara* L. invasion and impact on herb layer diversity and soil properties in a dry deciduous forest of India. *Applied Ecology and Environmental Research* **9**(3): 253-264.

Suthari S, Kandagalta R, Ragan A and Raju SV 2016. Plant wealth of a sacred grove: Mallur Gutta, Telangana state, India. *International Journal of General Medicine* **9**: 369-381.

Tarakeswara Naidu M, Premavani D, Suthari S and Venkaiah M 2018. Assessment of tree diversity in tropical deciduous forests of North central Eastern Ghats, India. *Geology, Ecology and Landscapes* **2**(3): 216-227.

Thakur NS, Attar SK, Hegde HT and Bhusara JB 2017. Diversity and importance of shrubs in traditional agroforestry systems in India. In: Gupta S K, Panwar P and Kaushal R (Eds), *Agroforestry for increased production and livelihood security in India*. New India Publishing Agency New Delhi, India. pp. 379-400.

Thakur NS, Gupta NK and Gupta B 2005. An appraisal of biological diversity in agroforestry systems in North-Western Himalaya. *Indian Journal of Ecology* **32**(1): 7-12.

Tiruvaimozhi YV, Borah J, Kala CP, Kunte K, Patel B, Sreejith KA, Thadani R, Osuri AM and Ghosh-Harihar M 2025. Long-term ecological monitoring in India: A synthesis. *Biological* Conservation **310**: 111344.

Tripathi AK and Shankar U 2014. Patterns of species dominance, diversity and dispersion in Khasi hill sal forest ecosystem in northeast India. Forest *Ecosystems* **1**: 23.

Uranov A 1935. On the coupling of components of a plant coenosis. *Uchenye Zapiski Moskovskogo Gosudarstvennogo Pedagogicheskogo Instituta* **1**: 59-85.

Whittaker RH 1965. Dominance and diversity in land plant communities: Numerical relations of species express the importance of competition in community function and evolution. *Science* **147**(3655): 250-260.

Zenner EK 2005. Development of tree size distributions in Douglas-Fir forests under differing disturbance regimes. *EcologicalApplications* **15**: 701-714.

Zida D, Sawadogo L, Tigabu M, Tiveau D and Odén PC 2007. Dynamics of sapling population in savanna woodlands of Burkina Faso subjected to grazing, early fire, and selective tree cutting for a decade. *Forest Ecology and Management* **243**: 102-115.

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