



Tree Species Composition and Forest Stratification along the Gradients in the Dry Deciduous Forests of Godavari Valley, Telangana, India

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ABSTRACT

It is important to understand the tree species composition, abundance, species diversity and stratification in tropical dry deciduous forests that are under threat. A quadrat study was attempted in the dry deciduous forests along the ecological gradients in the Godavari Valley of northern Telangana, India. The study records the presence of 110 flowering plant taxa belonging to 82 genera and 37 families in 120 sampled plots, and there was enumeration of 15,192 individuals of ≥ 10 cm girth at breast height. *Tectona grandis* (teak) is the principal forest cover component in the region, which often formed pure stands in Adilabad and, to some extent, in Nizamabad districts. Further down to the Warangal district, teak was gradually replaced by *Terminalia alata*. Twenty tree species were found dominant at one place to the other, and the top 10 dominant taxa have shared nearly 41% of the total density of the forest cover. The tree relative density ranged from 0.007% to 20.84%. The values of Importance Value Index were between 0.245 (12 spp. including some exotics) and 32.6 (teak). These baseline data help to know the change detection along the gradients in the tropical forest ecosystem of a major river valley in the region and the drivers of change.

KEYWORDS

Godavari Valley, tropical dry deciduous, diversity indices, forest stratification, tree species composition

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INTRODUCTION

Biodiversity is an important factor in nature conservation and natural resources in which the species diversity plays a vital role and it's the key component (Itô 1997). Of the terrestrial ecosystems, tropical forests are very productive in ecological services. Although tropical forests cover about 10% of the total geographical area, they are structurally and functionally complex ecosystems and provide livelihoods, timber and other forest products to about 1.6 billion people. Of the plant growth forms, trees recycle nutrients, reduce the soil erosion, regulate the course of rain water and provide ecological services such as oxygen, food, clothes, shelter, timber, fuel wood and medicine. To the tropical forests, tree diversity is the principal component as they provide resources to all the forest elements (FAO 2010), whereas the biotic factors such as seed quality, rate of dispersal, seedling survival and regeneration are important in maintaining the tree composition of the tropical forests (Baraloto & Goldberg 2005).

The aspects of biodiversity monitoring and quantifying have increased on regional, national and global levels in scientific and political writings since 1990s (Magurran 2004). Overexploitation and degradation are the factors contributing to the loss of forests and are recognized to be the major problems for the natural environment loss around the world (Mani & Parthasarathy 2006). The rapid inventory of species that provides information on diversity is an important tool to enhance our ability to maximize biodiversity conservation (Baraloto et al. 2013).

India is an example of areas known for its rich biological diversity. There are 91,200 species of animals and 45,500 plant taxa residing in its 10 biogeographic regions of the country (MoEF 2009). Anthropogenic factors such as clear cutting, shifting cultivation, uncontrolled non-timber forest product (NTFP) collections, illegal lopping, encroachment of forest areas, habitats fragmentation and spread of alien plant species are responsible for the decline of biodiversity and affect the

structure and functioning of forest ecosystems in India (Raju et al. 2010). The species composition, structure and distribution pattern of tree species vary along the environmental gradients such as rainfall, temperature, pH and physico-chemical parameters of soil. How the floristic life-form composition and proportions vary along the environmental and ecological gradients was demonstrated in the tropical deciduous forests (Raju et al. 2014).

The River Godavari, second largest in India, supports high primary production in Telangana state. For its water resource, a number of lift-irrigation and drinking water projects are contemplated and initiated in the Valley. There will be a change in the water regime in the region through creations of reservoirs; the attendant activities such as laying of canals, erecting the power lines, inroads into the forests and its further fragmentation and increased biotic pressure. In the current scenario of continuous loss of these tropical dry deciduous forests, it is essential to understand the forest stratification, the tree species composition, associations and their spatial distribution. In the absence of such a case study, the tree diversity, richness and forest stratification in the tropical dry deciduous forests along the gradients of the Godavari Valley in northern Telangana, India, were contemplated and thus formed the subject matter of this article. The main aims of the present study are to recognise the tree species diversity in dry deciduous forests, as an example of tropical dry forest, and to assume the changes in tree species composition through the environmental gradient of the Godavari Valley and to record the baseline data for change detection in the future.

1. STUDY AREA

The study area is northern Telangana, excluding Khammam district. It lies between the latitudes 17°17'3" and 19°55'2"N and

longitudes 77°28'6" and 80°40'4"E (Figure 1). The study area covers four districts, namely, Adilabad, Nizamabad, Karimnagar and Warangal. Today, these districts of northern Telangana are reorganised into 15 districts (Figure 1B). The study presents the research finding as per the former district boundaries because the scenario of physiography of the land does not change with political boundaries.

Telangana state has an area of 503.35 km², and the following land-use categories cover very dense forest: 9,052.41 km² of moderately dense forests, 9,209.91 km² of open forest, 5305.85 km² of scrub jungle, 2,649.79 km² of non-forest area and 183.36 km² of under water bodies (Anonymous 2015). Whilst the geographic area of the state is 1,12,101 km², the study area occupies 48,754 km² (i.e. 42.44%), with the forest cover spread of 13,604.57 km². The natural forest regeneration potential in the Godavari Valley was largely through seed recruitment whilst the stocks and root suckers play a limited role (Gopalkrishna et al. 2017).

The landscape characterisation of the study area and the biotic and abiotic factors operating are presented in Table 1.

2. METHODOLOGY

2.1. Sampling Design and Collection of Data

The documentation of vegetation composition in the study area was performed during 2009–2013. The ground sample locations were chosen as selected by Indian Institute of Remote Sensing (IIRS), Dehra Dun (2009), based on forest density and NDVI values. One hundred and twenty quadrats of 31.62 m × 31.62 m (0.1 ha) size plots were laid to collect the tree and shrubby layer data for the present work, and herbaceous layer is excluded because it comes under ground layer. The plant taxa

Table 1. Landscape characterisation of northern Telangana with abiotic and biotic factors.

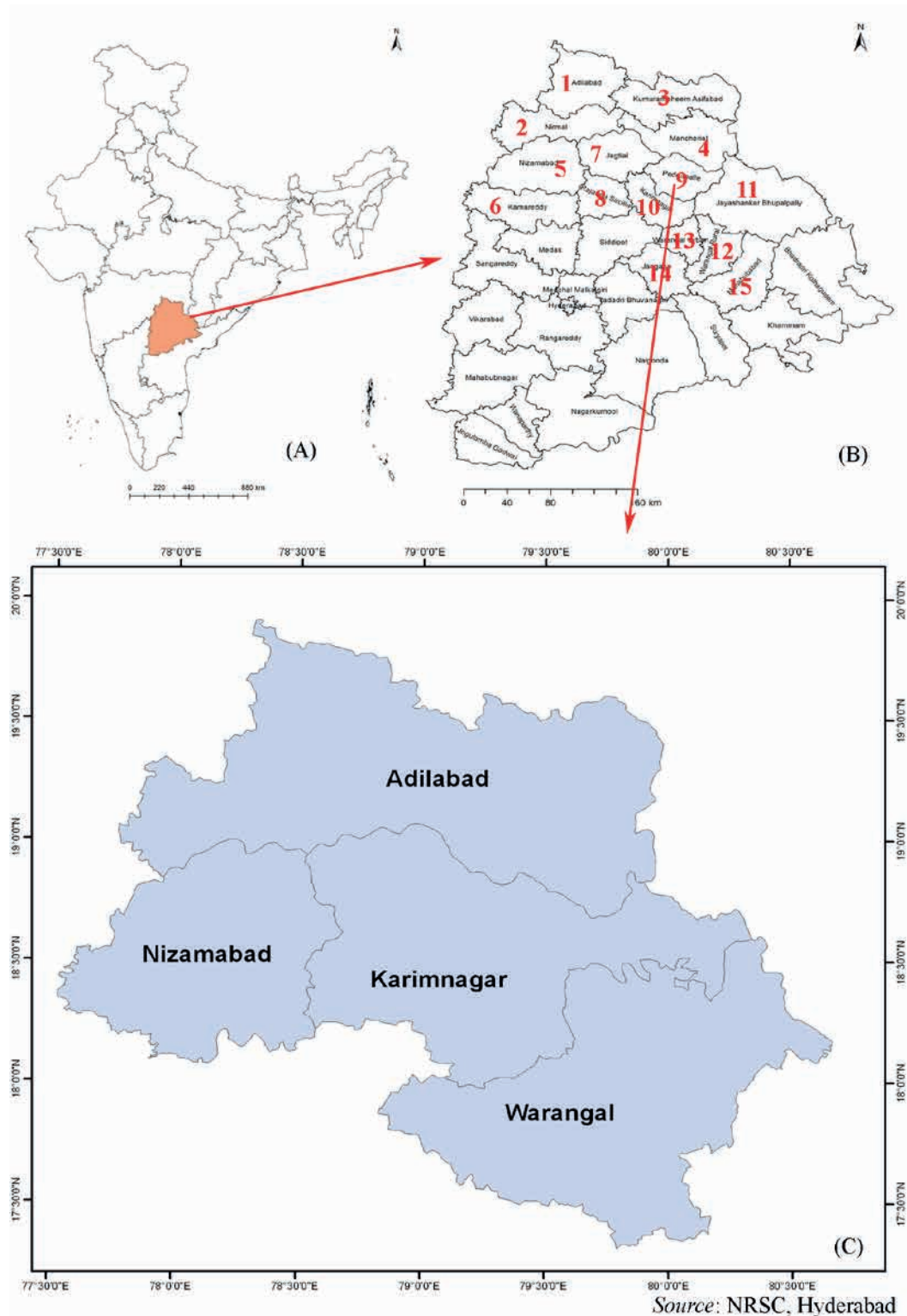
District ¹	MAP (mm)	MAT (°C)	Typical soil	Fire ²	Biotic factors	<i>Tectona grandis</i>		Characteristic tree associates ⁴
						%	Position ³	
Adilabad	742	34.5	Lime, sand stones	+	Grazing, teak, NTFP extraction	46.58	1	TG, LP, HP, AL, TA, CS, BS, DM, WT, LC
Nizamabad	1000	32.0	Black cotton, Sandy loams	+	Grazing, fuel wood, NTFP extraction	30.90	1	TG, WT, DP, LP, MT, AL, MLL, BM, WA, CS
Karimnagar	914	29.5	Red soils with loamy, black cotton	++	Grazing, timber, NTFP extraction	10.77	2	HP, TG, TA, AL, DM, MP, GF, LC, MT, CS
Warangal	970-1,050	29.5	Black cotton, Sandy loams	++	Grazing, timber, fuel wood, NTFP extraction	6.06	4	TA, XX, LP, TG, DM, HP, CS, BH, CC, LC

¹Adilabad includes currently Adilabad, Nirmal, Asifabad and Mancherial districts. Nizamabad was split into Nizamabad and Kamareddy; Karimnagar into Jagtial, Sircilla, Peddapalli and the residual Karimnagar; Warangal into Jayashankar Bhupalpally, Warangal Rural, Warangal Urban, Jangaon and Mahabubabad districts.

²Fire–fire frequency.

³Position indicates the rank or predominance of teak (*Tectona grandis* in the area) which is indicated by bold 'TG' among the tree associates in the next column.

AL, *Anogeissus latifolia*; BH, *Bridelia montana*; BM, *Butea monosperma*; BS, *Butea superba*; CC, *Cleistanthus collinus*; CS, *Chloroxylon swietenia*; DM, *Diospyros melanoxylon*; DP, *Dalbergia paniculata*; GF, *Gitonia floribunda*; HP, *Holarrhena pubescens*; LC, *Lannea coromandelica*; LP, *Lagerstroemia parviflora*; MAP, mean annual precipitation; MAT, mean annual temperature; MLL, *Madhuca longifolia* var. *latifolia*; MP, *Morinda pubescens*; MT, *Milisia tomentosa*; NTFP, non-timber forest product; TA, *Terminalia alata*; TG, *Tectona grandis*; WA, *Wrightia arborea*; WT, *Wrightia tinctoria*; XX, *Xylia xylocarpa*.



Source: NRSC, Hyderabad

Figure 1. Map showing the study area as administrative districts during the study and at present. (A) India; (B) Telangana with its current districts in the northern part numbered: 1. Adilabad, 2. Nirmal, 3. Asifabad, 4. Mancherla, 5. Nizamabad, 6. Kamareddy, 7. Jagtial, 8. Sircilla, 9. Peddapalli, 10. Karimnagar, 11. Bhupalpally, 12. Warangal Rural, 13. Warangal Urban, 14. Jangaon, 15. Mahabubabad; (C) Northern Telangana (except Khammam district).

were identified with the help of the *Flora of the Presidency of Madras* (Gamble & Fischer 1915-1935), *Flora of the Presidency of Bombay* (Cooke 1903) and latest the *e-Floras* whilst the plant names were as per the www.theplantlist.org. The girth

at breast height (GBH) was measured in the field at 1.37 m and a total of 15,192 individual stems of ≥ 10 cm GBH were measured. The values of relative frequency (RF), relative density (RD), relative dominance (RDom) and Importance Value Index

(IVI) (Misra 1968) were determined to describe the tree species composition, abundance (Table 2) and species richness (Suthari 2013; Gopalkrishna et al. 2017).

$$\text{Frequency} = \frac{\text{Total number of quadrats in which a species occur}}{\text{Total number of quadrats studied}} \times 100$$

$$\text{Density} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrats studied}} \times 100$$

$$\text{Abundance} = \frac{\text{Total number of individuals of the species occurring}}{\text{Total number of quadrats in which the species occur}} \times 100$$

$$\text{Relative frequency (RF)} = \frac{\text{Frequency of one species}}{\text{Sum of all frequencies}} \times 100$$

$$\text{Relative density (RD)} = \frac{\text{Number of individuals of a species}}{\text{Total number of individuals of all species}} \times 100$$

$$\text{Relative dominance (RDom)} = \frac{\text{Combined basal area of a single species}}{\text{Total basal area of all species}} \times 100$$

$$\text{IVI} = \text{RF} + \text{RD} + \text{RDOM}$$

Alpha diversity for the study sites was calculated using the Shannon–Weiner Diversity Index (1963) formula:

$$\text{Shannon's Diversity Index (H')} = -\sum_{i=1}^s \pi_i \ln(\pi_i)$$

where H' is Shannon's Diversity Index, $\pi_i = n/N$, s is the number of species; n is the number of all individuals of one species; N is the number of all individuals of all species and ln is the natural logarithm.

$$\text{Whittaker's Index} = (a + b + c) / ((2a + b + c) / 2)$$

where a is the number of species common to both sites; b is the number of species that occur in site 1 but not site 2; c is the number of species that occur in site 2 but not site 1 (Whittaker 1960).

3. RESULTS

3.1. Floristic Composition and Diversity

The present study resulted in documenting 110 flowering plant tree species (Table 2), representing 82 genera and 37 families. Leguminosae (Fabaceae) constitutes the predominant family with 26 species in strength, which is followed, but distantly, by Rubiaceae (9 spp.) and Combretaceae (7 spp.). In the 4 districts of northern Telangana, 20 dominant woody species constitute

local top 10 ranks. These include timber species of top storey species such as *Tectona grandis* (teak; with 3166 individuals), *Terminalia alata* (1508), *Holarrhena pubescens* (928), *Lagerstroemia parviflora* (876), *Anogeissus latifolia* (729), *Diospyros melanoxylon* (709), *Xylia xylocarpa* (570), *Chloroxylon swietenia* (542), *Lannea coromandelica* (423) and *Miliusa tomentosa* (400) as well as multi-use species such as *Madhuca longifolia* var. *latifolia* and *D. melanoxylon* and ecologically valuable open canopy species such as *H. pubescens*, *Wrightia arborea*, *Cleistanthus collinus* and *Bridelia montana* in the 12-ha quadrat area sampled. So, on the basis of the forest cover, the land may be called 'teak region' for its overall dominance. In facts, it almost forms pure stands in Adilabad and, to a minor extent, in Nizamabad. However, all these formations make the tropical dry deciduous forest typical as described in the forest manuals or floras except the inclusion of *Wrightia tinctoria*, which is generally a semi-moist teak forest element. Currently, *T. alata* as an associate is relegated to second place whilst *L. parviflora* retained its next position. *H. pubescens* and *D. melanoxylon* occupy the fourth and fifth ranks, bringing down *A. latifolia* to the sixth position whilst *X. xylocarpa* attained the seventh position in its predominance (Table 2). The teak is gradually displaced further down towards Warangal by the species of *Terminalia*, *Wrightia*, *Holarrhena*, *Xylia* and so on. Wherever the top canopies are removed, the soil is exposed to light and erosion. The dominant natural teak in this eco-floristic zone has given way to *T. alata* towards southwest, which is presented in Figure 2. As the conditions conducive to teak growth gradually deminish from Central India further down in northern Telangana where *T. grandis* gets out numbered by *T. alata*, *A. latifolia* and so on. The intersection happens in the forests of former Karimnagar district.

To evaluate species richness in the forest community, the IVI is used as an index. *T. grandis* shows the highest IVI value (32.6) followed by *T. alata* (17.96), *L. parviflora* (12.56), *H. pubescens* (12.42) and *D. melanoxylon* (11.39). *T. grandis* is the species with the highest values of RF (4.84), RD (20.84%) and RDom (6.92). Conversely, *T. grandis* was the most abundant species in northern Telangana region in terms of absolute values. Besides, 41% of the total tree abundance is due to the top 10 species (Table 2). On the other hand, *Acacia torta*, *Bu-*

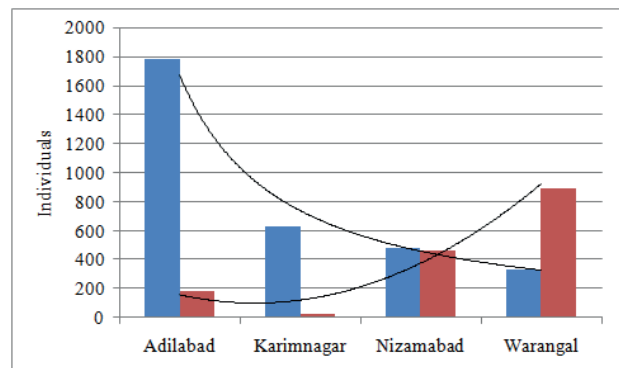


Figure 2. Individuals of *Tectona grandis* and *Terminalia alata* along gradients in the Godavari valley, northern Telangana.

Table 2. Species abundance and plant community indices of tropical dry deciduous forests of northern Telangana.

	Species	No. of Stems	Relative Frequency	Relative Density	Relative Dominance	Importance Value Index
1	<i>Tectona grandis</i>	3166	4.841	20.840	6.920	32.600
2	<i>Terminalia alata</i>	1508	3.601	9.926	4.431	17.958
3	<i>Lagerstroemia parviflora</i>	876	4.900	5.766	1.892	12.557
4	<i>Holarrhena pubescens</i>	928	3.542	6.108	2.772	12.422
5	<i>Diospyros melanoxylon</i>	709	5.313	4.667	1.412	11.392
6	<i>Anogeissus latifolia</i>	729	3.837	4.799	2.010	10.646
7	<i>Xylia xylocarpa</i>	570	1.417	3.752	4.257	9.425
8	<i>Chloroxylon swietenia</i>	548	3.601	3.607	1.610	8.818
9	<i>Lannea coromandelica</i>	423	4.014	2.784	1.115	7.913
10	<i>Miliusa tomentosa</i>	400	2.597	2.633	1.629	6.860
11	<i>Dalbergia paniculata</i>	393	2.715	2.587	1.531	6.834
12	<i>Cleistanthus collinus</i>	342	2.125	2.251	1.703	6.079
13	<i>Wrightia tinctoria</i>	321	1.535	2.113	2.213	5.860
14	<i>Ziziphus xylopyrus</i>	236	3.011	1.553	0.829	5.393
15	<i>Morinda pubescens</i>	241	1.240	1.586	2.057	4.883
16	<i>Gitonia floribunda</i>	191	0.708	1.257	2.853	4.818
17	<i>Bridelia montana</i>	234	1.240	1.540	1.997	4.777
18	<i>Madhuca longifolia</i> var. <i>latifolia</i>	197	2.656	1.297	0.785	4.738
19	<i>Acacia chundra</i>	216	2.302	1.422	0.993	4.717
20	<i>Butea superba</i>	192	2.007	1.264	1.012	4.283
21	<i>Gardenia resinifera</i>	177	1.063	1.165	1.762	3.990
22	<i>Hardwickia binata</i>	172	1.063	1.132	1.713	3.907
23	<i>Cassia fistula</i>	81	2.715	0.533	0.316	3.564
24	<i>Bauhinia racemosa</i>	117	2.184	0.770	0.567	3.521
25	<i>Albizia amara</i>	111	0.590	0.731	1.989	3.310
26	<i>Dalbergia latifolia</i>	128	1.535	0.843	0.882	3.260
27	<i>Butea monosperma</i>	133	1.299	0.875	1.083	3.258
28	<i>Wrightia arborea</i>	44	0.177	0.290	2.629	3.095
29	<i>Buchanania cochinchinensis</i>	109	1.535	0.717	0.751	3.004
30	<i>Azadirachta indica</i>	97	1.535	0.638	0.669	2.842
31	<i>Nyctanthes arbor-tristis</i>	60	0.295	0.395	2.151	2.841
32	<i>Gymnosporia emarginata</i>	99	1.476	0.652	0.710	2.837
33	<i>Gardenia latifolia</i>	100	0.767	0.658	1.379	2.804
34	<i>Diospyros chloroxylon</i>	89	0.767	0.586	1.227	2.580
35	<i>Carissa spinarum</i>	44	0.236	0.290	1.971	2.497
36	<i>Helicteres isora</i>	60	1.358	0.395	0.468	2.220
37	<i>Benkara malabarica</i>	64	0.649	0.421	1.043	2.113
38	<i>Acacia eburnea</i>	34	0.236	0.224	1.523	1.983
39	<i>Acacia sinuata</i>	56	0.708	0.369	0.836	1.913
40	<i>Grewia tiliifolia</i>	51	1.063	0.336	0.508	1.906
41	<i>Ziziphus oenopolia</i>	55	0.885	0.362	0.657	1.905
42	<i>Dalbergia volubilis</i>	44	1.181	0.290	0.394	1.865
43	<i>Pterocarpus marsupium</i>	48	1.004	0.316	0.506	1.826
44	<i>Bauhinia vahlii</i>	39	0.413	0.257	0.999	1.668
45	<i>Woodfordia floribunda</i>	38	0.472	0.250	0.851	1.574
46	<i>Soymida febrifuga</i>	25	1.181	0.165	0.224	1.569
47	<i>Olex scandens</i>	40	0.649	0.263	0.652	1.564
48	<i>Boswellia serrata</i>	37	0.826	0.244	0.474	1.544

Table 2 continued. Species abundance and plant community indices of tropical dry deciduous forests of northern Telangana.

	Species	No. of Stems	Relative Frequency	Relative Density	Relative Dominance	Importance Value Index
49	<i>Holoptelea integrifolia</i>	38	0.708	0.250	0.568	1.526
50	<i>Strychnos potatorum</i>	36	0.531	0.237	0.717	1.485
51	<i>Gardenia gummifera</i>	24	0.236	0.158	1.075	1.469
52	<i>Eucalyptus globulus*</i>	14	0.118	0.092	1.255	1.465
53	<i>Schleichera oleosa</i>	35	0.649	0.230	0.570	1.450
54	<i>Bombax ceiba</i>	26	0.945	0.171	0.291	1.407
55	<i>Ixora pavetta</i>	13	0.118	0.086	1.165	1.369
56	<i>Lantana x aculeata*</i>	22	0.236	0.145	0.986	1.367
57	<i>Oroxylum indicum</i>	28	0.767	0.184	0.386	1.338
58	<i>Annona squamosa*</i>	24	0.295	0.158	0.860	1.313
59	<i>Acacia leucoplea</i>	26	0.767	0.171	0.358	1.297
60	<i>Catunaregum spinosa</i>	22	0.295	0.145	0.789	1.229
61	<i>Mitragyna parviflora</i>	26	0.590	0.171	0.466	1.227
62	<i>Phyllanthus emblica</i>	24	0.708	0.158	0.358	1.225
63	<i>Bridelia retusa</i>	22	0.413	0.145	0.563	1.121
64	<i>Gmelina arborea</i>	21	0.472	0.138	0.470	1.081
65	<i>Firmiana simplex</i>	18	0.590	0.118	0.323	1.031
66	<i>Eriolaena hookeriana</i>	16	0.649	0.105	0.261	1.015
67	<i>Jatropha gossypifolia</i>	5	0.059	0.033	0.896	0.988
68	<i>Celastrus paniculatus</i>	9	0.118	0.059	0.807	0.984
69	<i>Aegle marmelos</i>	17	0.531	0.112	0.339	0.982
70	<i>Terminalia chebula</i>	11	0.177	0.072	0.657	0.907
71	<i>Ficus mollis</i>	4	0.059	0.026	0.717	0.802
72	<i>Semecarpus anacardium</i>	4	0.059	0.026	0.717	0.802
73	<i>Balanites roxburghii</i>	7	0.118	0.046	0.627	0.791
74	<i>Senna auriculata</i>	7	0.118	0.046	0.627	0.791
75	<i>Strychnos nux-vomica</i>	10	0.472	0.066	0.224	0.762
76	<i>Cochlospermum religiosum</i>	6	0.118	0.039	0.538	0.695
77	<i>Desmodium oojeinense</i>	6	0.118	0.039	0.538	0.695
78	<i>Erythrina suberosa</i>	6	0.118	0.039	0.538	0.695
79	<i>Terminalia arjuna</i>	8	0.236	0.053	0.358	0.647
80	<i>Ailanthus excelsa*</i>	3	0.059	0.020	0.538	0.616
81	<i>Albizia procera</i>	3	0.059	0.020	0.538	0.616
82	<i>Cassine glauca</i>	7	0.354	0.046	0.209	0.609
83	<i>Terminalia bellerica</i>	6	0.354	0.039	0.179	0.573
84	<i>Careya arborea</i>	6	0.236	0.039	0.269	0.544
85	<i>Alangium salvifolium</i>	5	0.177	0.033	0.299	0.509
86	<i>Diospyros montana</i>	5	0.177	0.033	0.299	0.509
87	<i>Haldina cordifolia</i>	5	0.177	0.033	0.299	0.509
88	<i>Albizia odoratissima</i>	4	0.118	0.026	0.358	0.503
89	<i>Cissus repanda</i>	4	0.118	0.026	0.358	0.503
90	<i>Ehretia laevis</i>	4	0.118	0.026	0.358	0.503
91	<i>Pongamia pinnata</i>	4	0.118	0.026	0.358	0.503
92	<i>Acacia nilotica*</i>	2	0.059	0.013	0.358	0.431
93	<i>Polyalthia cerasoides</i>	2	0.059	0.013	0.358	0.431
94	<i>Erythroxylum monogynum</i>	3	0.118	0.020	0.269	0.407
95	<i>Premna tomentosa</i>	3	0.118	0.020	0.269	0.407
96	<i>Manilkara hexandra</i>	3	0.177	0.020	0.179	0.376

Table 2 continued. Species abundance and plant community indices of tropical dry deciduous forests of northern Telangana.

	Species	No. of Stems	Relative Frequency	Relative Density	Relative Dominance	Importance Value Index
97	<i>Ficus racemosa</i>	2	0.118	0.013	0.179	0.310
98	<i>Ziziphus mauritiana</i> *	2	0.118	0.013	0.179	0.310
99	<i>Acacia torta</i>	1	0.059	0.007	0.179	0.245
100	<i>Anacardium occidentale</i> *	1	0.059	0.007	0.179	0.245
101	<i>Buchanania axillaris</i>	1	0.059	0.007	0.179	0.245
102	<i>Ceiba pentandra</i> *	1	0.059	0.007	0.179	0.245
103	<i>Dalbergia sissoo</i> *	1	0.059	0.007	0.179	0.245
104	<i>Dichrostachys cinerea</i>	1	0.059	0.007	0.179	0.245
105	<i>Ficus religiosa</i>	1	0.059	0.007	0.179	0.245
106	<i>Garuga pinnata</i>	1	0.059	0.007	0.179	0.245
107	<i>Givotia moluccana</i>	1	0.059	0.007	0.179	0.245
108	<i>Gyrocarpus americanus</i> *	1	0.059	0.007	0.179	0.245
109	<i>Streblus asper</i>	1	0.059	0.007	0.179	0.245
110	<i>Termianlia catappa</i> *	1	0.059	0.007	0.179	0.245
Total (N)		15192				

*Exotics to native forests, either planted or naturalized.

chanania axillaris, *Garuga pinnata*, *Givotia moluccana* and *Streblus asper* represented the least, being hardly getting included in the quadrats laid. In terms of species abundance, of the 37 families found, half of them are represented by single species only (Table 3).

3.2. Species Diversity and Stratification

There are 110 tree species, which have fallen under the quadrats, largely constitute the forests structure of northern Telangana, forming the (1) Canopy layer [30], (2a) Under storey [43], (2b) Under storey canopy ‘open’ category [14], (3a) Shrub layer [8], (3b) Shrub layer [under storey open category – 6] and (4) Liana/Climber [8] (Table 3). Amongst these, a few non-forest and exotic species are either naturalised (11 spp.) or planted (1

sp.). It is worth noting that these non-forest elements appeared either in canopy ‘open’ or shrub layer (under storey open) categories only. Furthermore, these species appeared in the ecotone areas.

The district-wise turnover of the forest species (Table 4) brings out the presence and performance of different floral elements in the landscape (beta diversity). Alpha diversity is expressed as the number of species (richness) in each ecosystem (e.g. 60 in Adilabad, 41 in Nizamabad, 70 in Karimnagar and 84 in Warangal). The beta diversity is notified as the forests in different districts are compared such as Adilabad vs. Nizamabad and the value is 48 between them. So, it is 40 for Nizamabad vs. Karimnagar, 38 for Karimnagar vs. Warangal and 51 for Warangal vs. Adilabad.

Accordingly, one finds greater species richness and diversity from Adilabad towards Warangal district. The tree species number increases from 60 in Adilabad to 84 in Warangal (Figure 3; Table 3). However, Nizamabad district has less than half the number of woody species of the eco-floristic zone.

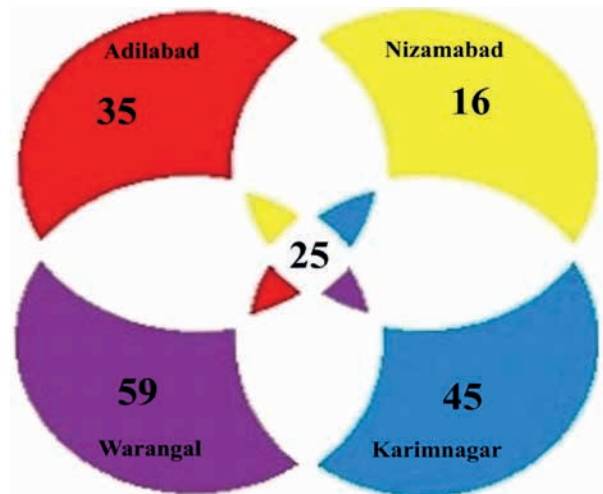


Figure 3. Exclusive and common tree species in four districts of northern Telangana.

4. DISCUSSION

In tropical forests, the plant diversity inventory largely concentrated on tree species diversity than the other life forms because tree species diversity is fundamental and important aspect for forest ecosystem. The tree diversity greatly varies from location to location mainly due to the factors such as geographical variation in the habitat, anthropogenic pressure, disturbances and climate. The floristic composition is one of the major characters of the plant community where the number of species and their individuals in a community reflect its gene pool and adaptation potential. Moreover, the floristic composition and diversity patterns of plant community are a prerequisite to understand the

Table 3. Abundance (stems number) and strata-wise composition of tree species in northern Telangana in the districts of study.

Forest Strata/Species		District***	Adilabad (A)	Nizamabad (B)	Karimnagar (C)	Warangal (D)
1. Canopy Layer						
01	<i>Aegle marmelos</i>	Rutaceae	5	0	1	11
02	<i>Albizia amara</i>	Leguminosae	39	0	63	09
03	<i>Albizia odoratissima</i>	Leguminosae	0	0	0	4
04	<i>Albizia procera</i>	Leguminosae	3	0	0	0
05	<i>Anogeissus latifolia</i>	Combretaceae	176	101	274	178
06	<i>Bombax ceiba</i>	Malvaceae	1	6	11	8
07	<i>Boswellia serrata</i>	Burseraceae	18	1	1	17
08	<i>Careya arborea</i>	Lecythidaceae	0	0	6	0
09	<i>Dalbergia paniculata</i>	Leguminosae	54	167	59	113
10	<i>Diospyros melanoxylon</i>	Ebenaceae	133	36	272	268
11	<i>Ficus mollis</i>	Moraceae	0	3	0	1
12	<i>Ficus religiosa</i>	Moraceae	1	0	0	0
13	<i>Gmelina arborea</i>	Lamiaceae	0	0	5	16
14	<i>Haldina cordifolia</i>	Rubiaceae	0	0	2	3
15	<i>Hardwickia binata</i>	Leguminosae	0	0	141	31
16	<i>Holoptelea integrifolia</i>	Ulmaceae	30	0	0	8
17	<i>Lagerstroemia parviflora</i>	Lythraceae	230	114	131	401
18	<i>Lannea coromandelica</i>	Anacardiaceae	64	27	150	182
19	<i>Madhuca longifolia</i> var. <i>latifolia</i>	Sapotaceae	18	65	27	87
20	<i>Manilkara hexandra</i>	Sapotaceae	0	0	1	2
21	<i>Mitragyna parviflora</i>	Rubiaceae	15	0	10	1
22	<i>Pterocarpus marsupium</i>	Leguminosae	17	0	20	11
23	<i>Schleichera oleosa</i>	Sapindaceae	0	0	25	10
24	<i>Soymida febrifuga</i>	Meliaceae	3	0	17	0
25	<i>Tectona grandis</i>	Lamiaceae	1777	618	464	307
26	<i>Terminalia alata</i>	Combretaceae	165	0	453	890
27	<i>Terminalia arjuna</i>	Combretaceae	0	0	7	1
28	<i>Terminalia bellerica</i>	Combretaceae	3	0	2	1
29	<i>Terminalia catappa</i>	Combretaceae	0	0	0	1
30	<i>Terminalia chebula</i>	Combretaceae	6	0	0	5
2a. Under Storey						
31	<i>Acacia eburnea</i>	Leguminosae	0	0	0	0
32	<i>Alangium salviifolium</i>	Alangiaceae	2	0	0	3
33	<i>Bauhinia racemosa</i>	Leguminosae	47	40	15	15
34	<i>Bauhinia vahlii</i>	Leguminosae	0	3	27	9
35	<i>Bridelia montana</i>	Phyllanthaceae	4	6	27	197
36	<i>Bridelia retusa</i>	Phyllanthaceae	12	0	5	5
37	<i>Buchanania axillaris</i>	Anacardiaceae	0	0	0	1
38	<i>Buchanania cochinchinensis</i>	Anacardiaceae	29	9	22	49
39	<i>Cassia fistula</i>	Leguminosae	38	16	14	13

Table 3 continued. Abundance (stems number) and strata-wise composition of tree species in northern Telangana in the districts of study.

District***		Family	Adilabad (A)	Nizamabad (B)	Karimnagar (C)	Warangal (D)
Forest Strata/Species						
40	<i>Cleistanthus collinus</i>	Phyllanthaceae	50	0	94	198
41	<i>Cochlospermum religiosum</i>	Bixaceae	0	0	0	6
42	<i>Dalbergia latifolia</i>	Leguminosae	15	0	46	67
43	<i>Desmodium oojeinense</i>	Leguminosae	0	0	0	6
44	<i>Diospyros chloroxylon</i>	Ebenaceae	11	4	14	60
45	<i>Diospyros montana</i>	Ebenaceae	0	0	0	5
46	<i>Ehretia laevis</i>	Boraginaceae	0	0	4	0
47	<i>Eriolaena hookeriana</i>	Malvaceae	0	7	2	7
48	<i>Erythrina suberosa</i>	Leguminosae	6	0	0	0
49	<i>Erythroxylum monogynum</i>	Erythroxylaceae	0	0	3	0
50	<i>Ficus racemosa</i>	Moraceae	0	2	0	0
51	<i>Firmiana simplex</i>	Malvaceae	1	3	2	12
52	<i>Gardenia gummifera</i>	Rubiaceae	0	24	0	0
53	<i>Gardenia latifolia</i>	Rubiaceae	4	0	22	74
54	<i>Gardenia resinifera</i>	Rubiaceae	0	0	104	73
55	<i>Garuga pinnata</i>	Burseraceae	1	0	0	0
56	<i>Givotia moluccana</i>	Euphorbiaceae	1	0	0	0
57	<i>Grewia tiliifolia</i>	Malvaceae	1	0	0	50
58	<i>Helicteres isora</i>	Malvaceae	6	22	11	21
59	<i>Holarrhena pubescens</i>	Apocynaceae	206	0	486	236
60	<i>Milusa tomentosa</i>	Annonaceae	5	108	148	139
61	<i>Morinda pubescens</i>	Rubiaceae	0	0	233	8
62	<i>Nyctanthes arbor-tristis</i>	Nyctanthaceae	0	16	0	44
63	<i>Oroxylum indicum</i>	Bignoniaceae	19	0	9	0
64	<i>Phyllanthus emblica</i>	Phyllanthaceae	0	0	2	22
65	<i>Pongamia pinnata</i>	Leguminosae	4	0	0	0
66	<i>Semecarpus anacardium</i>	Anacardiaceae	4	0	0	0
67	<i>Strychnos nux-vomica</i>	Loganiaceae	2	0	1	7
68	<i>Strychnos potatorum</i>	Loganiaceae	0	0	35	1
69	<i>Wrightia arborea</i>	Apocynaceae	0	44	0	0
70	<i>Wrightia tinctoria</i>	Apocynaceae	73	219	29	0
71	<i>Xylocarpus xylocarpa</i>	Leguminosae	8	0	48	514
72	<i>Ziziphus mauritiana</i>	Rhamnaceae	0	0	0	2
73	<i>Ziziphus xylopyrus</i>	Rhamnaceae	39	09	126	62
	2b. Under Storey (Canopy Open Category)					
74	<i>Acacia chundra</i>	Leguminosae	22	26	102	66
75	<i>Acacia leucopsea</i>	Leguminosae	22	0	2	2
76	<i>Acacia nilotica*</i>	Leguminosae	2	0	0	0
77	<i>Ailanthus excelsa*</i>	Simaroubaceae	0	0	0	3
78	<i>Anacardium occidentale*</i>	Anacardiaceae	0	0	0	1
79	<i>Annona squamosa*</i>	Annonaceae	0	18	0	6

Table 3 continued. Abundance (stems number) and strata-wise composition of tree species in northern Telangana in the districts of study.

Forest Strata/Species		District***	Family	Adilabad (A)	Nizamabad (B)	Karimnagar (C)	Warangal (D)
80	<i>Azadirachta indica*</i>		Meliaceae	40	7	17	33
81	<i>Balanites roxburghii</i>		Zygophyllaceae	0	4	3	0
82	<i>Butea monosperma</i>		Leguminosae	49	57	12	15
83	<i>Ceiba pentandra*</i>		Malvaceae	0	0	0	1
84	<i>Chloroxylon swietenia</i>		Rutaceae	150	47	135	216
85	<i>Dalbergia sissoo</i>		Leguminosae	0	0	0	1
86	<i>Gyrocarpus americanus*</i>		Hernandiaceae	0	0	0	1
87	<i>Ixora pavetta</i>		Rubiaceae	0	0	11	2
3a. Shrub Layer							
88	<i>Benkara malabarica</i>		Rubiaceae	0	24	8	32
89	<i>Cassine glauca</i>		Celastraceae	2	0	0	4
90	<i>Catunaregam spinosa</i>		Rubiaceae	2	0	9	11
91	<i>Gymnosporia emarginata</i>		Celastraceae	31	30	31	7
92	<i>Polyalthia cerosoides</i>		Annonaceae	0	0	0	2
93	<i>Premna tomentosa</i>		Lamiaceae	0	0	2	1
94	<i>Streblus asper</i>		Moraceae	1	0	0	0
95	<i>Woodfordia floribunda</i>		Lythraceae	0	0	1	37
3b. Shrub Layer (Under Storey Open Category)							
96	<i>Carissa spinarum</i>		Apocynaceae	0	0	44	0
97	<i>Dichrostachys cinerea</i>		Leguminosae	0	0	0	1
98	<i>Gitonia floribunda</i>		Combretaceae	3	0	188	0
99	<i>Jatropha gossypifolia#</i>		Euphorbiaceae	0	5	0	0
100	<i>Lantana x aculeata*</i>		Verbenaceae	0	22	0	0
101	<i>Senna auriculata*</i>		Leguminosae	0	7	0	0
4. Liana/Climber							
102	<i>Acacia sinuata</i>		Leguminosae	5	22	26	3
103	<i>Acacia torta</i>		Leguminosae	0	0	0	1
104	<i>Butea superba</i>		Leguminosae	136	34	9	13
105	<i>Celastrus paniculatus</i>		Celastraceae	0	0	9	0
106	<i>Cissus repanda</i>		Vitaceae	0	0	4	0
107	<i>Dalbergia volubilis</i>		Leguminosae	6	0	9	29
108	<i>Olax scandens</i>		Olacaceae	0	32	5	3
109	<i>Ziziphus oenopolia</i>		Rhamnaceae	03	04	13	35
5. Plantation							
110	<i>Eucalyptus globulus**</i>		Myrtaceae	0	0	0	14
<i>Total</i>			3815	2000	4308	5069	
<i>Number of species</i>			60	41	70	84	

*Naturalized; **Planted; #Exotic, naturalized. *Contiguous with forest and fallen under the quadrats, indicating the proximity of plantations to forests. Note: Under Storey (Canopy Open category and Shrub Layer (Under Storey Open category) are due to removal of canopies of original strata.

Table 4. District-wise tree species composition in northern Telangana

District	Canopy layer	Under Storey	Under Storey (Canopy Open category)	Shrub layer	Shrub layer (Under Storey Open category)	Liana/ Climber	Planted*	Total Species
Adilabad	20	25	6	4	1	4	0	60
Nizamabad	10	16	6	2	3	4	0	41
Karimnagar	23	26	7	5	2	7	0	70
Warangal	26	31	12	7	1	6	1	84
Average	19	24	7.75	4.75	1.75	5.25	0.25	63.75

overall structure and function of an ecosystem (Singh et al. 2016).

Northern Telangana has a landscape characterised on the abiotic factors such as temperature, rainfall, physico-chemical parameters of soil and fire and biotic factors such as dominance of teak, overgrazing, collection of fuel wood, timber and non-timber forest products (Table 1). The soils are basic, alluvial and ferruginous black on tops. The soils are laterite and well-drained under teak. The teak flourishes well in the north of the river Godavari, as an extended distribution from central India. The forest landscape gradually changes from *Tectona* zone to *Terminalia* zone in Adilabad to Warangal, in the northeasterly direction (Gopalkrishna et al. 2017). The forest in Mancherial Division (Khanapur range) was classified as 'Dry teak' with the associates of *A. latifolia*, *T. alata*, *D. melanoxylon*, *Hardwickia binata* and *Dendrocalamus strictus* (Puri et al. 1989).

The importance value index (IVI) indicated that *T. grandis* is the most predominant tree species followed by *T. alata*, *L. parviflora*, *H. pubescens* and *D. melanoxylon* in the study area, whereas *Pterocarpus marsupium*, *Schleichera oleosa*, *Mangifera indica*, *Syzygium cumini*, *Bauhinia vahlii*, *Mallostus philippensis* and *Grewia tiliifolia* are the most common species in the tropical forests of R.V. Nagar Range of Eastern Ghats, India (Reddy & Ugle 2008). *T. grandis* is the predominant taxon with highest IVI value (32.6) and the co-dominant species are *T. alata*, *L. parviflora*, *H. pubescens* and *D. melanoxylon* with an IVI of 17.958, 12.557, 12.422 and 11.392, respectively.

It is observed that the top 10 dominant taxa have shared 41% of the total density of the study area that resulted in less diversified forest ecosystem. In tropical forest ecosystem, it is very common for one or two species to grow and spread all over. In northern Telangana region, 30 tree species, especially from genera such as *Tectona*, *Terminalia*, *Madhuca* and *Anageissus*, occupy the top canopy and share more than half of the density. The under storey accounts for 35%, and liana and plantation category are negligible in the forest strands. *Butea superba* is the important liana and indicator species of undisturbed forests present, whereas *Gitonia floribunda* is the successional species occupying the fringes of forest patches,

which are secondary and formed because of deforestation or removal of select woody species (Suthari 2013).

T. grandis, *T. alata*, *L. parviflora*, *H. pubescens*, *D. melanoxylon*, *A. latifolia*, *X. xylocarpa*, *C. swietenia*, *L. coromandelica* and *M. tomentosa* are the most common tree species in the natural vegetation of the Godavari Valley in northern Telangana. *T. grandis* was the most common, abundant and dominant taxon, and with its ecological function, it is the fundamental element of the ecosystem (cf. Ellison et al. 2005). The plausible anthropogenic reason for the decline of teak further southeast is the increased non-tribal population and their great demand for teak timber that has led to its cutting and smuggling despite some protective measure by the State Forest Department. The baseline data, which provide the tree species composition, diversity and stratification in the forests, served to characterise the tropical dry deciduous forest ecosystem will be of certain use in the future change detection studies. The data further help to formulate new policies for the conservation of these native forests as natural resource utilisation base for the ethnic inhabitants and the local climate protection.

DISCLOSURE STATEMENT

The authors declare that there is no conflict of interest.

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