Environment and Ecology 38 (4) : 872—883, October—December 2020
ISSN 0970-0420

Assessment of Tree Population Structureand Diversity Along Disturbance Gradientin Tropical Dry Deciduous Forests, Southern─Eastern Ghats, India.

C. Venkata Ramana, Dr. M. Sridhar Reddy

Received 8 August 2020, Accepted 10 September 2020, Published on 9 October 2020

ABSTRACT

The study aims to assess the tree population structure and species diversity in dry deciduous forest in Kadapa hill ranges of Southern Eastern Ghats. Eighteen forest sites were selected and based on anthropogenic and natural disturbances, these forests sites were categorized into three disturbance levels (low; LD, medium; MD and high; HD). Ten belt transects (10 ×100m) were laid each of the 18 sites. From the entire 18 ha area a total of 6483 stems (≥30 cm gbh) belonging to 110 species, 84 genera and 43 families were recorded. Across the study sites; stem density (ha^{-1}) and basal area ($m^2 ha^{-1}$) varied 193 to 471 and 2.83 to 12.64 respectively. on the Importance Value Index; *Pterocarpussantalinus, Anogeissuslatifolia, Chloroxylonswietenia* were the predominant tree species. The low, medium and high disturbance levels were dominated by Pterocarpussantalinus. Site-wise, a reverse J─ shape population structure (with increasing girth class) was noticed at all the sites. Low disturbance level had high stem density (471 stems ha^{-1}) and species richness (47 species ha^{-1}) and high disturbance level represented low stem density (193 stems ha^{-1}) and low species richness (19 species ha^{-1}). Species richness and stem density were negatively related with the disturbance scores as also the Shannon─wiener diversity index values. The present study revealed disturbance as an important factor that affects the distribution of tree species richness and tree density.

Key words: Dry deciduous forest, Disturbance scores, Tree diversity and population structure.

INTRODUCTION

Tropical dry deciduous forests constitute about 42% of Indian tropical forests (Baboo et al. 2017).They provide ecosystem services such as watershed protection, biodiversity, micro-climate regulation, soil fertility, flood control and provide resources like timber, fuel wood and fodder (Maass J.Metal 2005). It was noted that the structure, function and ecosystem services of tropical dry deciduous forests depend on species diversity, dominance and varied assemblages of dominant trees in the population overtime (Anitha et al. 2010). They represent one of the ecologically important as well as rich plant diversity regions of India with more than 3000 plant species and around 100 endemic species (Panda et al. 2013). Due to the presence of dense population in the surrounding plains of the hill ranges of Eastern Ghats the forests are under immense human pressure. The human activities include extraction of timber by logging, fuel wood collection, livestock grazing and minor forest products collection which has led to degradation of forests and conversion to scrub land (Reddy et al. 2015).Over the past few decades, Eastern Ghats have

C. Venkata Ramana[1], Dr. M. Sridhar Reddy[2*]
[1]Research Scholar (Ph.D.), [2]Assistant Professor
Dept. of Environmental Science, Yogi Vemana University, Vemanapuram, Kadapa, Andhra Pradesh 516005, India
Email: cvramana1986@gmail.com
Email: sridharmullangi@yahoo.com*
*Corresponding author

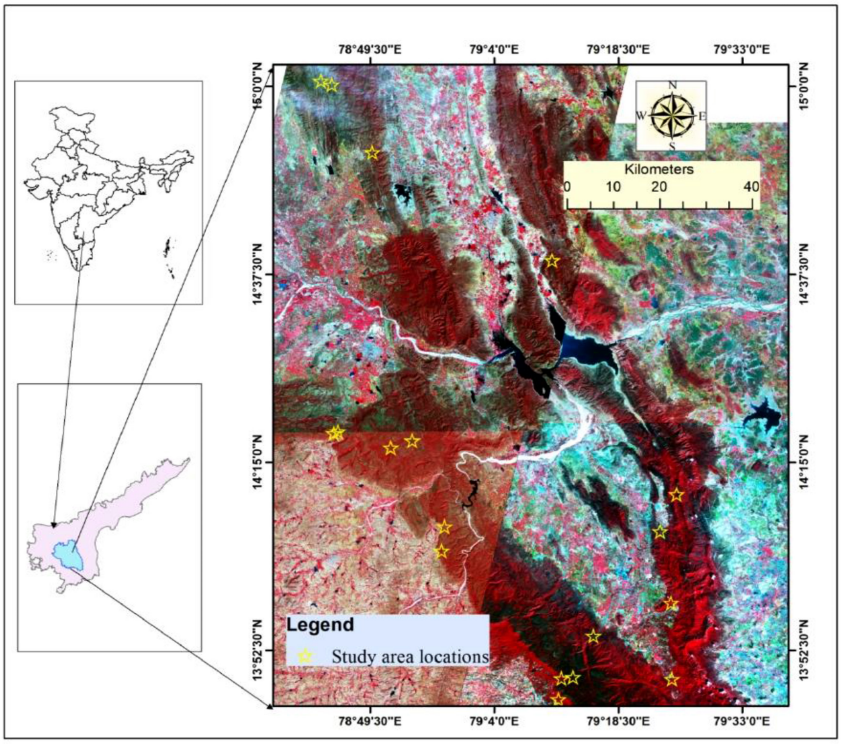

Fig 1. Population structure showing the total bumber of tree individuals with increase in gieth classes in LD forest Study sites.

lost nearly 40% of natural forest cover as they are cleared for agriculture, dam construction, settlements, rail, road network, mining and logging for timber (Ramachandran et al. 2020). collection which has led to degradation of forests and conversion to scrub land (Reddy et al. 2015).Over the past few decades, Eastern Ghats have lost nearly 40% of natural forest cover as they are cleared for agriculture, dam construction, settlements, rail, road network, mining and logging for timber (Ramachandran et al. 2020).

Eastern Ghats can be broadly divided into Northern and Southern Eastern Ghats and in Southern Eastern Ghats of Andhra Pradesh, floristic inventories were carried out to know the distribution of plant resources in Nallamalais (Basha 2009), (Sadasivaiah 2009) and Sheshachalam hill ranges (Babu and Rao 2010).In Southern Eastern Ghats, forests outside the protective area network and along the forest edges have considerable plant diversity and tree assemblages (Rawat 1997).It was reported that the availability of moisture during the dry period is crucial in dictating the plant richness and distribution in Eastern Ghats (Panda et al.2019).Quantitative tree inventories provide information about the effect of human disturbances on forest structure (Pragasan and Parthasarathy 2010) and the tree diversity is highly influenced by the prevailing disturbances in dry deciduous forests (Yadav and Gupta 2006) , (Sagar et al. 2003).

Plant diversity inventories in tropical forestshave mostly been concentrated on tree species than the other life forms,because tree species diversity forms an important aspectof forest ecosystem diversity(Pragasan and Parthasarathy 2010).The hypothesis of the study was to test whether tree diversity is influenced by the prevailing disturbance levels and the aim is to describe the forest structure of dry deciduous forests on Kadapa hill ranges.

Table 1. List of 18 (1─ha) forest study sites with their Geographical position and altitude ranges.

Sl. No.	Forest study area	GPS coordinates	Altitude (m)
1.	RF─ADKM Addodikanam Reserve Forest	N14˚52'17.7" E 78˚ 50^{l}'27.1"	251─335m
2.	RF─GPM Gopavaram Reserve Forest	N14˚41'52.3" E 79˚ 10' 39.6"	196─366m
3.	RF─GUV1 Guvvalacheruvu Reserve Forest	N14˚19'22.4" E 78˚ 46'14.7"	287─545m
4.	RF─GUV2 Guvvalacheruvu Reserve Forest	N14˚19'20.5" E 78˚ 46'09.4"	288─489m
5.	RF─BLP Balapalli Reserve Forest	N13˚48' 25.1" E 79 25.1' 13.9"	249─274m
6.	RF─CTVL1 Chitvel Reserve Forest	N14˚11' 10.5" E 79˚ 25' 18.5"	191─478m
7.	RF─SNP1 Sanipaya Reserve Forest	N14˚04' 24.3" E 78˚ 57' 44.2"	331─627m
8.	RF─SNP2 Sanipaya Reserve Forest	N14˚07'32.5" E 78˚ 59'10.3"	360─486m
9.	RF─RPM Ramapuram Reserve Forest	N14˚39'10.7" E 79˚ 10' 48.2"	161─344m
10.	RF─CTVL2 Chitvel Reserve Forest	N13˚58' 11.0" E 79˚ 24'43.8"	172─467m
11.	RF─VGM1 Vangimalla Reserve Forest	N14˚16' 28.3" E 78˚51'57.6"	541─604m
12.	RF─VGM2 Vangimalla Reserve Forest	N14˚17'24.1" E 78˚ 52' 49.2"	557─599m
13.	RF─Y&G Y.Kota and Gadala Reserve Forest	N13˚54'00.4" E 79˚ 15' 28.3"	249─333m
14.	RF─KKDP1 K DPalli Reserve Forest	N15˚00' 58.4" E 78˚ 43' 41.0"	350─443m
15.	RF─KKDP 2 K D Palli Reserve Forest	N15˚00' 35.9" E 78˚ 44'47.1"	369─481m
16.	BR─BLP1 Balapalli Reserve Forest	N13˚48' 21.8" E 79˚ 10' 54.8"	600─846m
17.	BR─BLP2 Balapalli Reserve Forest	N13˚48'39.7" E 079˚ 13' 10.4"	611─851m
18.	BR─BLP3 Balapalli Reserve Forest	N13˚48' 43.0" E 079˚ 11' 25.8"	599─779m

MATERIALS AND METHODS

Study area

The field inventory was conducted in dry deciduous forests of Kadapa hill ranges that occur in between the two important plant diversity centers like Nallamalais and Seshachalam hill ranges which are part of the Southern Eastern Ghats that lies in between 'N 13˚48'41.4"E 079˚13'04.5"and N15˚00'36.8"E 078˚45'00.0"in Andhra Pradesh (Fig.1). The study sites include Reserve forests of Guvvalacheruvu (N14˚19'22.4" E 78˚ 46'14.7") Vangimalla (N14˚16' 28.3" E 78˚51'57.6")Eddodikanam (N14˚52'17.7" E 78˚ 50^{l}'27.1")Y.Kota and Gadala (N13˚54'00.4" E 79˚ 15' 28.3") Kothakotadasarapalli (N15˚00' 58.4" E 78˚ 43' 41.0") Sanipaya (N14˚04' 24.3" E 78˚ 57' 44.2") Gopavaram (N14˚41'52.3" E 79˚ 10' 39.6") Ramapuram (N14˚39'10.7" E 79˚ 10' 48.2") and Chitvel (N13˚58' 11.0" E 79˚ 24'43.8") forest areas and Balapallireserve forest (N13˚48'39.7" E 079˚ 13' 10.4"). These sites mainly comprise of dry deciduous forests occurring in foothills, plateaus, valleys and hill ranges, they occur with an elevation range of (161─851m) (Table 1).

Southern tropical mixed dry deciduous forests which occur in Kadapa hill ranges are dominated by Pterocarpus santalinus tree species commonly referred as Red sanders (Dayanand and Lohidas 1988). Pterocarpus santalinus has a restricted area and larger proportion of its natural range area is confined to dry hill slopes of Kadapa hill ranges of Southern Eastern Ghats which lie as isolated hill ranges between Nallamalais and Sheshachalam hill ranges.(Champion and Seth 1968).Red sanders are found to be dominant on the slopes of these Kadapa hill ranges-Thurpukondas, Veligondas, Guvvalacheruvughat, Palakondas and Lankamallas hill ranges, but not in the tropical Thorn forests that occur in the adjoining plains and foot hills (Ankalaiah et al.2017).

Climate and soil

The climate is hot and dry with a maximum mean temperature 44^{o}C and the minimum mean temperature of 25^{o}C. The annual mean rainfall is 699.60 mm and the rainy days are in the range of 41─61days. The study sites comprise of shallow red ferruginous loam soil derived from Shale, Quartzite and Sandstone primary rocks. Soils are acidic in nature in the range of 5.8─6.5; soil organic carbon was in the range of 0.34─1.59% and soil bulk density was in the range of 1.13─1.67 mg/m^{3} (Ramana and Reddy 2019).

Field methods

A total of ten belt transects of (10 × 100 m; 1-ha)

Table 2. Details of Forest structure variables and cumulative disturbance scores for each of the 18 (1─ha) dry deciduous forest study sites of Kadapa hill ranges. LD = Least disturbance sites; MD = Moderate disturbance sites; HD = High disturbance sites.

Cate gory	Site name	Tree diversity (/ha)	Tree density (/ha)	Basal area (m^2/ha)	Shannon–winter index	Disturb ance scores
	LD1	42	411	11.8	2.96	9
	LD2	45	389	12.64	2.91	10
LD sites	LD3	47	429	9.3	3.03	9
	LD4	43	322	7.99	2.9	11
	LD5	39	309	6.26	2.83	12
	LD6	25	450	7.87	2.35	13
	LD7	32	471	7.87	2.55	13
MD sites	MD1	30	346	4.87	2.52	21
	MD2	25	342	5.79	2.06	20
	MD3	29	355	7.36	2.48	24
	MD4	19	376	6.01	2	19
	MD5	41	341	5.24	3	28
	MD6	38	329	5.8	2.89	23
	MD7	37	412	5.83	2.67	23
HD sites	HD1	19	229	3.2	2.07	38
	HD2	21	193	2.83	2.25	39
	HD3	34	408	5.72	2.4	32
	HD4	26	371	4.79	1.88	33

were randomly laid at each and every forest site in 18 dry deciduous forest sites of Kadapa hill ranges (Fig.1). The geographic location coordinates of each transect were recorded using Geographic Position System (Garmin GPS MAP 78S). At least 200─250m inter-distance between each transect were laid across the 18 (1-ha) forest study sites. A rope was used to delineate the transects during the inventory. In every belt transect (10x100m) was belongs to a rectangular shape. Kind of tree species and number of tree individuals (≥ 30cmgbh) at (1.37m)breast height based the entire tree species were recorded. As well as topographic details with GPS coordinates, soil type, rock type, dominant plant species and disturbance gradients were recorded in the assessment of tree diversity and population structure in Kadapa hill ranges.

The disturbance features like logging of trees, fuel wood collection, livestock grazing with varied degree of occurrence prevail in these forests. In addition features such as number of foot paths, near to road, near to habitation, near to agriculture fields, litter fall and rockiness that prevail in the forest sites were noted in the field and they were arranged on the 0─4 scale to calculate the disturbance score based on (Sagar et al. 2003).Among 18 (1-ha) forest study sites according to the cumulative disturbance score for each forest site they were categorized into three disturbance levels. Seven study sites represented least disturbed sites (LD), another seven sites were under moderately disturbance class (MD) and remaining four sites belonged to high disturbance category (HD) (Table 2).

Data analysis

Tree density, frequency and abundance of tree species were determined following by using the primary data; Importance Value Index (IVI) of each species was determined by summing the relative density, relative frequency and relative basal area for each study site (Curtis and McIntosh 1950). Diversity indices of Shannon─Wiener index, Simpson index, Pielou"s evenness index, Sorenson similarity index were computed based on (Magurran 2004).

Shannon – Wiener index: $H1 = -\Sigma\, pi \ln (pi)$

Pi = proportion of tree individuals present in the i^{th} species; *nni/Nni* is the total number of tree individuals of species (*i*)

N is the total number of individuals of all the tree species in the site.

Simpson s diversity index: $1- D = \Sigma\, ni\, (ni-1)/ N\, (N-1)$

1-D = Simpson dominant index,
ni = no of individuals of species (i),
N = total number of individuals of all species
Pielou's Evenness Index: E = H1/ln S
H = Shannon - Wiener diversity index,
S = Total number of species in the site
Margalef's species richness index: *SR = S-1/n(N),*
S = Total number of species,
N = Total number of individuals.
Sorenson Similarity *Index(S) = 2C/ A+B*
A = Number of species in study site
B = Number of species in study site
C = Number of species common in both study sites

Quantitative analysis

Importance value index (IVI)

Important value index (IVI), which indicates the relative ecological importance of a given tree species at a particular site, was determined from the summation of the relative values of density, frequency and basal area of each tree species (RD + RF + RBA) was calculated as
Density = Total number of individuals of a species in all quadrates
Total number of quadrates studied Frequency = Number of quadrates in which species (A) occurs
Total number of quadrates studied

The basal area was calculated for all trees (>30cm gbh) girth at breast height (1.37m) by using the formula

Basal area (BA) = $c^2 /4\pi$
BA= Basal area (m^2 /ha)
C=girth in centimeters at 1.37m at breast height,
Relative Frequency (RF) =
Frequency value for species A × 100
Total frequency value for all species
Relative density (RD) =
Number of individuals of species A×100
Total individuals of all species
Relative basal area (RBA) =
Basal area of species A X 100
Total basal area of all species
Index (IVI) = RD+RF+RBA

Table 3. Summary of tree species inventory (≥30cm gbh) for the whole study area 18 (1─ha) dry deciduous forest study sites of Kadapa hill ranges.

Sl No	Forest structural variable	Total	Mean ± Standard Range	Deviation (SD)
	Species richness	110	19—47	32±9
2	Number of tree individuals	6483	193—471	360±71
3	Families	43	14—26	20±4
4	Genera	84	17—39	29±7
5	Basal area (m^2/ha)	—	2.83—12.64	6.73±2.58
6	Shannon-Wiener	—	1.88—3.03	2.54±0.37
7	Simpson index	—	0.75—0.91	0.85±0.05
8	Pielous evenness index	—	0.57—0.81	0.73±0.059
9	Margalef index	—	3.03—7.58	5.42±1.49

Table 4. Consolidated details of tree species richness, families, genera, diversity indices, basal area and tree density across the sites differentiated into LD, MD and HD sites based on disturbance levels in the dry deciduous forest of Kadapa hill ranges.

Sl. No.	Forest structural variable	LD sites MEAN and SD RANGE (/ha)	MD sites MEAN and SD RANGE (/ha)	HD sites MEAN and SD RANGE (/ha)
1	Species richness	39±7.85 25—47	31±7.84 19—41	25±6.68 19—34
2	Number of tree individuals	397±61.82 309—471	357±28.21 329—412	300±105.18 193—408
3	Femilies	17—26	14—24	14—24
4	Genera	23—39	17—36	18—29
5	Basal area (m^2/ha)	6.26—12.64	4.87—7.36	2.83—5.72
6	Shannon—Wiener index	2.35—3.03	2—3	1.88—2.4
7	Simpson index	0.87—0.91	0.75—0.91	0.76—0.83
8	Pielous evenness index	0.73—0.79	0.64—0.81	0.57—0.74
9	Margalef index	3.92—7.58	3.03—6.85	3.31—5.48

RESULTS

Tree diversity

A total of 110 tree species belonging to 84 genera and 43 families were inventoried in 18 (1-ha) dry deciduous forest study sites (Appendix─I). The mean species richness was (32±9) and the range was (19─47) tree species/ha. The inventory has yielded 6483 tree individuals with a mean tree density 360±71

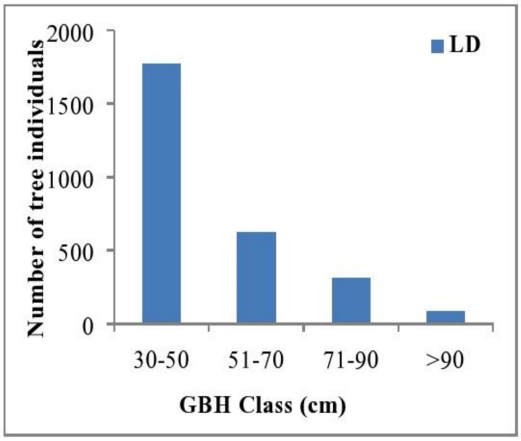

Fig. 2. Population structure showing the total number of tree individuals with increase in girth classes in MD forest study sites.

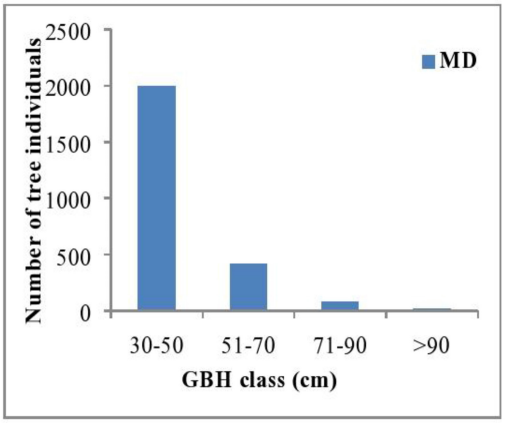

Fig. 3. Population structure showing the total number of tree individuals with increase in girth classes in HD forest study sites.

individuals/ha and range of 193─471 individuals/ha (Table 3). The mean and range of basal area values were 6.73±2.58 m^2/ha and 2.83─12.64 m^2/ha respectively. All diversity indices like Shannon─Wiener index (1.88─3.03), Pielous evenness index 0.57─0.81 and species richness Margalef index (3.03─7.58) were higher in LD sitesand lesser in HD sites (Table 4). Shannon─wiener diversity values revealed a significant negative relationship with disturbance scores (ρ (18) = -0.576 $p<0.05$. Simpson dominant index revealed that along with LD sites, MD sites also had higher values than HD sites (LD; 0.87─0.91), (MD; 0.75─0.91) and (HD; 0.76─0.83). Rubiaceae was the dominant family comprising of 12 species followed by Euphorbiaceae (10 species), Combretaceae (Seven species) and six families Fabaceae, Bignoniaceae, Rutaceae, Ebenaceae, Verbenaceae and Moraceae were recorded each with four species. Eighteen families were found to be with a single species. The top ten dominant tree species have accounted for 71.1% of the total tree density and 14 species were recorded with single individual and 16 species were found to be with two individuals only. Among 18 (1─ha) study sites *Pterocarpussantalinus* was ranked as the top most dominant tree species (25.69%) and co-dominant tree species namely *Anogeissuslatifolia* and *Chloroxylonswietenia* can be contributing 21.7% of total tree density in these forests.

Among the total, 110 tree species, 37 tree species were common to all the 18 (1─ha) sites and 29 tree species were exclusively recorded in LD sites, nine tree species were found only in MD sites and *Maeruaapetala* was restricted to HD sites. Higher species richness was recorded in LD sites (99 tree species) followed by MD sites with 70 tree species and lower species richness of 48 species was recorded in HD sites. Tree species richness was found to be significantly varied across the 18 (1─ha) sites across the disturbance gradient ($F_{(2, 15)}$ 4.5, $p<0.05$). Spearman rank correlation revealed a significant negative relationship between tree species richness and disturbance scores (ρ (18) = -0.616 $p<0.05$). Spearman rank correlation and all statistical analysis were carried out by using IBM SPSS20 statistical software.

Higher mean tree density (397 tree individuals/ha) was recorded in LD sites followed by MD sites with a mean tree density of 357 tree individuals/ha and lesser tree density (300 tree individuals/ha) was inventoried in HD sites. The distribution of tree density did not revealed a significant difference across the 18 sites ($F_{(2,15)}$3.51, $p>0.05$) and tree density also showed a negative but not significant relationship ($\rho_{18)}$ = -0.447, $p>0.05$) with disturbance scores. While higher basal area values in the range of 6.26─12.64 m^2/ha were recorded in LD sites followed by MD sites with a range of 4.87─7.36 m^2/ha and lower basal area in the range of 2.83─5.72 m^2/ha were recorded in HD sites (Table 3) and these values revealed a significant

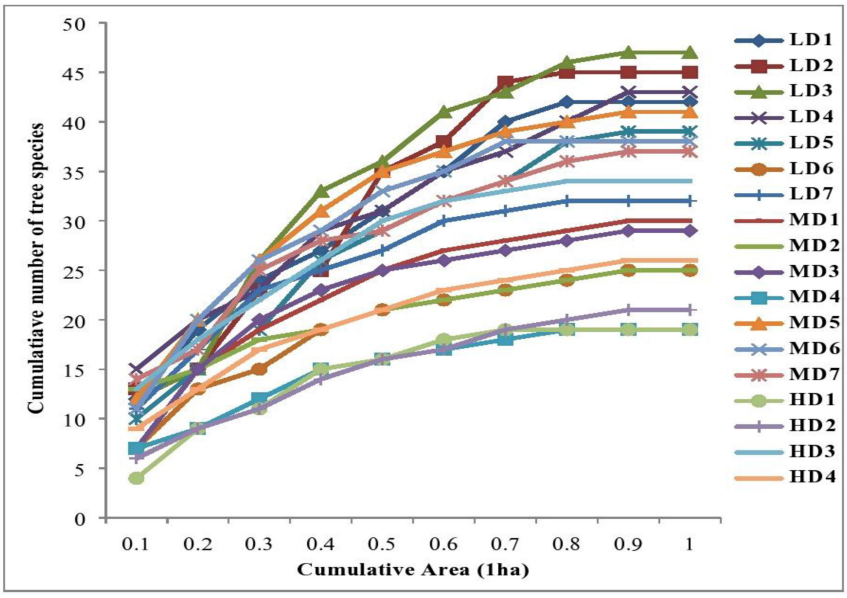

Fig. 4. Species are curve of the 18 (1-ha) day deciduous forest study sites.

negative relationship between disturbance scores and basal area ($\rho_{(18)} = -0.90$, $p<0.05$).

Population structure

The population structure of trees was studied by classifying the trees into different and increasing GBH classes i.e., 30─50cm, 51─70cm, 71─90cm and >90cm. The population structure of trees ≥30 cm gbh have showed reverse J shaped curve in all the 18 (1─ha) study sites with decrease in the number of tree individuals with increase in girth classes. All the number of tree individuals of LD sites cumulatively have featured reverse 'J' shape curve (Fig. 2) with 63.6% (1769 tree individuals) of trees in 30─50 cm gbh class followed by 22.4% of trees in 51─70 cm gbh class and 307 tree individuals in (11%) 71─90 cm gbh class and 81tree individuals in >90 cm gbh (3%). Similarly in MD sites the population structure revealed reverse 'J' shape curve (Fig. 3) with 1991 (79.6%) of tree individuals in lower gbh class, 418 tree individuals (16.71%) in 51─70 cm gbh class, 78 tree individuals (3.1%) in 71─90 cm gbh class and 14

Table 5. Details of the number of tree individuals and species richness in the varied gbh class among the three groups of forests study sites under three disturbance categories.

	LD site		MD site		HD site	
Tree gbh class (cm)	Tree individuals	Tree species richness	Tree individuals	Tree species richness	Tree individuals	Tree species richness
30─50	1769 (63.61%)	94	1991 (79.6%)	68	1096 (91.25%)	48
51─70	624 (22.43%)	54	418 (16.71%)	30	85 (7.07%)	17
71─90	307 (11.03%)	36	78 (3.11%)	13	16 (1.33%)	5
>90	81 (2.9%)	22	14 (0.55%)	5	4 (0.33%)	2

Table 6. List of tree species (≥30 cm gbh) and number of tree individuals in different disturbance levels of the dry deciduous forest sites in Kadapa hill ranges. TNI = Total Number of Individuals.

Sl. No.	Name of the tree species	LD sites	MD sites	HD sites	TNI
1	*Acacia chundra*	3	0	2	5
2	*Alangiumsalvifolium*	2	0	0	2
3	*Albiziaamara*	4	0	0	4
4	*Albiziaodoratissima*	12	14	0	26
5	*Anogeissuslatifolia*	366	403	94	863
6	*Atalantiaracemosa*	2	0	0	2
7	*Bauhinia racemosa*	7	10	1	18
8	*Boswelliaovalifoliolata*	0	6	13	19
9	*Boswelliaserrata*	27	15	16	58
10	*Bridelia airy-shawii*	1	0	0	1
11	*Brideliacinerascens*	29	19	2	50
12	*Buchananiaaxillaris*	83	82	7	172
13	*Buteamonosperma*	1	0	0	1
14	*Canthiumdicoccum*	15	4	0	19
15	*Capparisgrandis*	2	0	0	2
16	*Careyaarborea*	4	2	0	6
17	*Cassia fistula*	23	17	3	43
18	*Cassineglauca*	0	7	0	7
19	*Ceriscoidesturgida*	2	0	0	2
20	*Chloroxylonswietenia*	376	177	281	834
21	*Chukrasiatabularis*	1	0	0	1
22	*Cleistanthuscollinus*	87	9	0	96
23	*Cochlospermumreligiosum*	6	2	3	11
24	*Commiphoracaudata*	0	6	3	9
25	*Cordiamacleodii*	0	3	0	3
26	*Croton scabiosus*	3	31	2	36
27	*Dalbergiapaniculata*	60	18	13	91
28	*Deccaniapubescens*	10	31	8	49
29	*Dilleniapentagyna*	2	0	0	2
30	*Diospyroschloroxylon*	3	0	3	6
31	*Diospyrosebenum*	2	0	0	2
32	*Diospyrosmelanoxylon*	7	2	1	10
33	*Diospyrossylvatica*	1	0	0	1
34	*Dolichandroneatrovirens*	42	111	35	188
35	*Dolichandronefalcata*	0	2	0	2
36	*Ehretiaaspera*	1	0	0	1
37	*Ehretialaevis*	5	0	0	5
38	*Erythroxylummonogynum*	10	2	3	15
39	*Ficusbenghalensis*	4	0	0	4
40	*Ficusmicrocarpa*	2	0	0	2
41	*Ficusracemosa*	3	0	0	3
42	*Ficusvirens*	1	0	0	1
43	*Flacourtiaramontchi*	0	5	0	5
44	*Gardenia gummifera*	3	11	0	14
45	*Gardenia latifolia*	13	12	7	32
46	*Gardenia resinifera*	15	54	17	86
47	*Givotiamoluccana*	12	6	19	37
48	*Glochidionzeylanicum*	0	1	0	1
49	*Grewiaflavescens*	33	53	11	97
50	*Grewiatiliifolia*	6	11	3	20
51	*Gyrocarpusamericanus*	2	0	4	6
52	*Haldiniacordifolia*	1	6	0	7
53	*Hardwickiabinata*	126	72	106	304
54	*Hibiscus platanifolius*	1	0	1	2
55	*Holarrhena pubescens*	21	1	0	22

Table 6 Continued.

Sl. No.	Name of the tree species	LD sites	MD sites	HD sites	TNI
56	*Holopteliaintegrifolia*	1	1	1	3
57	*Hymenodictyonorixense*	1	0	0	1
58	*Ixoraarborea*	10	15	2	27
59	*Lagerstroemia parviflora*	13	2	0	15
60	*Lanneacoromandelica*	110	49	8	167
61	*Limoniaacidissima*	6	0	0	6
62	*Litseaglutinosa*	2	0	0	2
63	*Madhucaindica*	14	10	8	32
64	*Maeruaapetala*	0	0	14	14
65	*Mallotusphilippensis*	2	0	0	2
66	*Manilkarahexandra*	6	4	3	13
67	*Memecylonumbellatum*	0	3	0	3
68	*Millusatomentosa*	2	2	0	4
69	*Mitragynaparvifolia*	7	2	0	9
70	*Morindapubescens*	34	39	15	88
71	*Naringialata*	3	2	3	8
72	*Naringi crenulata*	10	2	0	12
73	*Ochnaobtusata*	34	53	1	88
74	*Oroxylumindicum*	1	0	0	1
75	*Phyllanthusemblica*	4	13	1	18
76	*Polyalthiacerasoides*	10	53	8	71
77	*Premnatomentosa*	14	3	0	17
78	*Pterocarpusmarsupium*	52	0	1	53
79	*Pterocarpussantalinus*	542	741	383	1666
80	*Pterospermumxylocarpum*	2	1	0	3
81	*Santalum album*	2	2	0	4
82	*Sapindusemarginatus*	1	0	2	3
83	*Sapium insigne*	1	0	0	1
84	*Schleicheraoleosa*	2	0	0	2
85	*Schreberaswietenoides*	0	1	0	1
86	*Semecarpusanacardium*	9	5	0	14
87	*Shorearoxburghii*	2	0	0	2
88	*Shoreatumbuggaia*	23	2	0	25
89	*Soymidafebrifuga*	13	8	4	25
90	*Sterculiaurens*	1	0	7	8
91	*Stereospermumpersonatum*	2	0	0	2
92	*Strychnosnux-vomica*	15	34	10	59
93	*Strychnospotatorum*	17	27	50	94
94	*Suregadaanguistifolia*	1	0	0	1
95	*Syzygiumalternifolium*	92	37	0	129
96	*Tectonagrandis*	14	1	0	15
97	*Terminaliaalata*	70	52	0	122
98	*Terminaliaarjuna*	2	0	0	2
99	*Terminaliabellarica*	2	11	0	13
100	*Terminaliachebula*	104	62	3	169
101	*Terminaliapallida*	0	3	0	3
102	*Terminaliapaniculata*	4	0	0	4
103	*Tremaorientalis*	1	0	0	1
104	*Vitexaltissima*	22	4	4	30
105	*Vitexleucoxylon*	2	2	1	5
106	*Walsuratrifoliata*	0	2	0	2
107	*Wendlandiatinctoria*	5	0	0	5
108	*Wrightiaarborea*	1	0	0	1
109	*Wrightiatinctoria*	5	3	0	8
110	*Ziziphus xylopyrus*	46	45	14	105
	Total	2781	2501	1201	6483

individuals in the higher gbh class of >90 cm (Table 5). Similarly, the tree individuals present in HD sites cumulatively have featured reverse 'J' shape curve (Fig. 3) with higher proportion of 1096 tree individuals (91.25%) in the lower gbh class of (30─50 cm), 85 tree individuals (7%) in 51─70 cm gbh class, 16 individuals (1.33%) in (71─90 cm) gbh class and just four individuals (0.33%) in (>90 cm gbh, Table 5). Along the disturbance gradient, higher percent of lower girth trees were recorded in highly disturbed sites and higher proportion of large girth trees were present in LD sites (Table 5).Among 110 tree species 108 species were recorded in 30─50 cm gbh class, remaining two tree species such as *Dilleniapentagyna* and *Terminaliapaniculata* were found in (71─90cm gbh). Out of 110 tree species 15.45% of the species were found in all the gbh classes from lower gbh class to higher gbh class, 40.90% of the species were exclusive to 30─50 cm gbh class.61 species were featured in 51─70 cm gbh class, 40 species were present in 71─90 cm gbh class and 22 species were recorded in >90 cm gbh class.

Species area curve

A total of 18 (1-ha) study sites of the species accumulation curves of in each site at least 50% of the species got accumulated at 0.3 hectare itself and after 0.7 hectare, the increment is in the range of only 1─3 species for every 0.1 hectare. In all of the forest study sites species area curves have increased steadily and reached plateau and asymptote condition (Fig. 4)

DISCUSSION

The presence of 110 tree species with a relatively lower range of 19─47 tree species/ha reiterates the importance of tree inventory at different areas at a larger area in-order to achieve the representative tree species in dry deciduous forests (Pragasan and Parthasarathy 2010). The tree inventory (110 tree species) in Kadapa hill ranges indicate that the tree species richness is lower than tree species that occurred in Seshachalam dry deciduous forests of Southern Eastern Ghats 222 tree species (Babu and Rao 2010). Deciduous forests of Northern Eastern Ghats 153 tree species (Reddy et al. 2011). Dry deciduous forests of North Central Eastern Ghats 135 tree species (Naidu et al. 2018) and tropical hill forests of Southern Eastern Ghats 272 tree species (Pragasan and Parthasarathy 2010). Rubiaceae and Euphorbiaceae families were the species rich families as also recorded in Seshachalam hill ranges (Babu and Rao 2010). While in hill forests of Southern Eastern Ghats where Mimosaceae and Euphorbaiceae were the dominant families (Pragasan and Parthasarathy 2010).The presence of negative relationship between disturbance and tree species richness indicate the influence of tree species richness on the intensity of disturbance levels in these forests. Only 19 species was recorded in a highly disturbed site which indicates that higher disturbance levels may lead to loss of late succession species and may favor only the disturbance tolerant species as observed in deciduous forests (Sapkota et al. 2009). Along the disturbance gradient species density was maximum on lightly disturbed site and minimum on heavily disturbed site, as well as Shannon-wiener index value was 0.71, 1.19 and 1.28 for heavily, moderately and lightly disturbed sites (Oraon et al. 2015). Higher level of Sorenson similarity index (S = 0.72) values was noticed between LD and MD sites followed by similarity index (S = 0.69) between MD and HD sites and lower similarity index (S = 0.61) was observed between LD and HD sites. This condition was due to the presence unique tree species like *Dilleniapentagyna, Terminaliapaniculata, Shoreathumbuggaia, Diospyrossylvatica, Mallotusphilippines, Oroxylumindicum, Sapium insigne, Semecarpusanacardium, Suregadaanguistifolia, Ficusracemosa* and *Ficusvirensin* LD sites. *Terminaliapallida, Cordiamacleodii* and *Glochidionzeylanicum* were in MD sites, only and only *Maeruaapetala* in HD sites. Among 42 least frequent tree species (≤5 tree individuals/ha); 36 tree species were exclusively recorded in LD sites and remaining six species were restricted to MD sites. The presence of higher number of species with only one or 1─10 individuals among the forest sites indicate the mixed nature of the forest and patchy distribution of species which will increase the species richness in the dry forests (Sagar et al. 2003). The occurrence of significant difference in tree species richness but not in tree density across the study sites suggest that tree density in these forests is influenced by few dominant tree species as also observed in Vindhyan dry forests (Sagar et al. 2003). The record of Pterocarpussanta-

linus, *Anogeissuslatifolia* and *Chloroxylonswietenia* as dominant and co-dominant tree species across the study sites indicate that these species have high regeneration potential (Ankalaiah et al. 2017). These tree species would have occupied the ecological niches created by the disturbance factors leading to lesser difference in tree density. But the presence of significant difference in basal area values across the study sites suggest that the induced disturbance levels have increased the number of stems but the higher girth trees are restricted to least disturbed sites. This situation has arisen because dry deciduous forest trees usually took longer periods for their girth increment(Kennard et al. 2002)and the presence of logging in the highly disturbed sites. The relative density of predominant tree *Pterocarpussantalinus* has increased significantly with increase in disturbance levels ($r = 0.564$ $p<0.05$) but the relative basal area got decreased with increase in disturbance. Similarly *Anogeissuslatifolia* showed increase in tree individuals with increase in disturbance scores. Thus the increase in share of dominant tree species in the total tree density but not in the total basal area has a prominent negative effect in the tree species distribution among these dry deciduous forests. Further, the relative density of *Pterocarpussantalinus* have revealed a significant negative relationship with tree species richness ($\rho = -0.730$, $p<0.0$) indicating that the increase in share of predominant tree has led to reduction of tree species richness and thus the prevailing disturbance levels had acted as a gradient factor in the distribution of tree species in these dry deciduous as was also noticed in dry forests of Vindhyan hill ranges (Sagar et al. 2003).

A typical negative exponential curve representing reverse 'J' shape curve was recorded in all 18 (1-ha) study sites. It indicates that a continuous regeneration is possible and younger tree individuals will replace the mature tree individuals as also observed in study sites of dry deciduous forests of Southern Eastern Ghats (Pragasan and Parthasarathy 2010).But in HD sites, higher percent of tree individuals (91.3%) was recorded in lower gbh class itself and maximum contribution to basal area was by lower gbh class only. While in MD sites 20.37% and LD sites 36.4% were present in the higher gbh class and their contribution to basal area was 40.3% and 64.9% in MD sites and LD sites respectively. In the context of no significant difference in tree density across the 18 sites under three disturbance levels, but in the occurrence of basal area suggests that the disturbance conditions had play a role in the occurrence of mature stands in these Kadapa hill ranges as maximum share of basal area being contributed by higher gbh class in MD and LD sites and lower gbh class in HD sites.

The dry forests of Kadapa hill ranges were characterized by the dominance of three tree species namely *Pterocarpussantalinus, Anogeissuslatifolia,* and *Chloroxylonswietenia* as they accounted for 51.30% of the total basal area suggesting them as the indicator tree species of the forest. The set of 38 tree species except *Maeruaapetala* recorded in the HD sites were also encountered in MD and LD sites as well as in the tree inventory in Southern Eastern Ghats (Babu and Rao 2010).Thus, these set of tree species and *Pterocarpussantalinus* ─ *Anogeissuslatifolia* ─ *Chloroxylonswietenia* can be considered as typical tree assemblage of dry deciduous forests of Kadapa hill ranges. If these tree species are lacking in any dry deciduous forests, then they can be considered as those forests which are slowly changing into scrub or Savanna type of forests as also inferred by the study carried out at larger scale in peninsular India (Ratnam et al. 2019).

CONCLUSION

The present study in Kadapa hill ranges indicated that disturbance factor has influenced negatively towards the tree species composition as well as the tree density. A typical negative relationship between site disturbance scores and variables like species richness, tree density and basal area was observed. The increase in share of predominant tree has led to reduction in tree species richness. Least disturbed sites comprised of higher tree species and tree density and 29 tree species were exclusively recorded in LD sites and nine tree species were restricted to MD sites and Maeruaapetala was recorded only in HD sites. Thus stricter protection measures are needed to conserve the tree species and forest structure typical of dry deciduous forests of Kadapa hill ranges.

ACKNOWLEDGEMENT

We thank the Andhra Pradesh Forest Department

(APFD) for providing the permission to conduct the tree inventory field work in Kadapa hill ranges.

REFERENCES

Anitha K., Joseph S., Chandran R.J., Ramaswamy E.V. and Prasad S.N. (2010) Tree species diversity and community composition in a human dominated tropical forest of Western Ghats.Biodiver.Hotspot Ind. Ecol.7: 217─224.

Ankalaiah C., Mastan T. and Reddy M.S. (2017) A study on the density, population structure and regeneration of Red sanders (Pterocarpussantalinus) Fabales – Fabaceae in a protected natural habitat – Sri Lankamalleswara Wildlife Sanctuary, Andhra Pradesh, India. J.Thr.Tax.9 (9): 10669─10674.

Baboo B., Sagar R., Bargali S.S. and Verma H. (2017) Tree species composition, regeneration and diversity of an Indi an dry tropical forest protected area. Trop. Ecol.58 : 409─423.

Babu S.M.V. and Rao B.R.P. (2010) Diversity and Quantification of trees in Seshachalam hill ranges, Eastern Ghats, India. Ind. J. Trop. Biol.Diver.18: 143─161.

Basha S.K. (2009) Diversity, Quantification and Conservation of tree resources of Nallamalais, AndhraPradesh. Ph.D. thesis. Sri Krishnadevaraya University, Anantapuramu, India.

Champion H. G. and Seth S.K.(1968)A revised survey of the forests types of India, Government of India Publications, New Delhi.

Curtis J.T. and McIntosh R.P. (1950) An Upland Forest Contin uum in the Prairie-Forest Border Region of Wisconsin. Ecol.31: 476─496.

Dayanand T. and Lohidas T. (1988) Effect of different treat ments on pod germination of Red sanders (Pterocarpus santalinus Linn. f). Ind. J. For. 11 : 87─88.

Kennard K.R., Gould K., Putz F.E., Fredericksen T.S. and Morales F. (2002) Effect of disturbance intensity on regeneration mechanisms in a Tropical dry forest.For.Ecol. and Manag.162: 197─208.

MaassJ.Metal (2005) Ecosystem services of tropical dry forests: Insights from long-term ecological and social research on the pacific coast of Mexico Ecological society1017 (www. Ecology and society.org/vol10/iss1/art17/)

Magurran A.E. (2004)Measuring Biological Diversity Blackwell Publishing Oxford, UK.

Naidu M.T., Premavani D., Suthari S. and Venkaiah M. (2018) Assessment of tree diversity in tropical deciduous forests of North central Eastern Ghats India. Geo. Ecol.and Land2: 216─227.

Oraon P.R., Singh L., JhariyaM.K. (2015) Shrub species diversity in relation to anthropogenic disturbance of Bhoramdeo wildlife sanctuary, Chattisgarh. Environ. Ecol.33(2A): 996─1002.

Panda P.C., Mahapatra A.K., Acharya P.K. and Debata A.K. (2013) Plant Diversity in Tropical Deciduous Forests of Eastern Ghats India: A Landscape Level Assessment. Int. J. Biol. and Con.5: 625─639.

Panda R.M., Behera M.D. and Roy P.S. (2019) On the relation ships between plant species richness and the environment: A case study in Eastern Ghats, India. Envmon ass191:784 https://doi.org/10.1007/s10661-019-7686-7.

Pragasan A.L. and Parthasarathy N. (2010) Landscape-level tree diversity assessment in tropical forests of Southern Eastern Ghats, India.Flo.205: 728─737.

Ramachandran R.M., Roy P.S., Chakravarthi V. (2020) Land use and climate change impacts on distribution of plant species of conservation value in Eastern Ghats, India: Simulation study. Environ. Monit. Assess. 192: 86.

Ramana C.V. and Reddy M.S. (2019) Soil organic carbon and soil respiration in dry deciduous forest and grass land of Kadapa hill ranges, Andhra Pradesh, India. Ind. J. Ecol. 46 (3) : 668─671.

Ratnam J., Chengappa S.K., Machado S.J., Nataraj N., Osuri A.M. and Sankaran M. (2019) Functional traits of trees from dry deciduous forests of Southern India suggest seasonal drought and fire are important drivers.Front in Ecol. and Evol. 7:8.

Rawat S.G. (1997) Conservation status of forest and Wildlife in the Eastern Ghats India.Environ. Con.24: 307─315.

Reddy C.S., Babar S., Amarnath G. and Pattanaik C. (2011) Structure and floristic composition of tree stand in tropical forest in the Eastern Ghats of Northern Andhra Pradesh, India. J. For. Res.22 (4) : 491─500.

Reddy C.S., Jha C.S., Diwakar P.G. and Dadhwal V.K. (2015) Nationwide classification of forest types of India using remote sensing and GIS.Environ. Mon. Assess.187: 1─30.

Sadasivaiah B. (2009) Diversity, quantification and conservation of herbaceous plant resources of Nallamalais, Andhra Pradesh. Ph.D. thesis. Sri Krishnadevaraya University, Anantapuramu, India.

Sagar R., Raghubanshi A.S. and Singh J.S. (2003) Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. For. Ecol. and Manag.186: 61─71.

Sapkota I.P., Tigabu M. and Oden P.C. (2009)Spatial distribution, advanced regeneration and stand structure of Nepalese Sal (Shorearobusta) forests subject to disturbances of different intensities. For. Ecol. and Manag. 257: 1966─1975.

Yadav A.S. and Gupta S.K. (2006) Effect of micro-environment and human disturbance on the diversity of woody species in the Sariska Tiger Project in India. For. Ecol.and Manag.225: 178─189.