Assessment of tree diversity in tropical deciduous forests of Northcentral Eastern Ghats, India

M. Tarakeswara Naidu, D. Premavani, Sateesh Suthari and M. Venkaiah

ABSTRACT
The rapid inventory study provides information on the tree species diversity and stand structure in tropical deciduous forests of Northcentral Eastern Ghats, India. Tree diversity and its relation to habitat was explored using tree data-set of 12 belt transects (5 × 1000 m) totaling 6 ha in the study area. A total of 135 plant taxa (≥15 cm dbh) belonging to 105 genera of 45 families with 2959 individuals were recorded. Anogeissus latifolia, Xylia xylocarpa, Cleistanthus collinus and Lannea coromandelica were the predominant plant taxa where the members of Euphorbiaceae, Rubiaceae, Anacardiaceae and Mimosaceae contributed maximum stand density and species richness. The stand density ranged from 395 to 573 individuals ha⁻¹ while basal area varied from 13.05 to 28.42 m² ha⁻¹. Shannon-Weiner index (H') ranged from 3.59 to 4.05 while Simpson index from 0.97 to 0.98, evenness index from 0.66 to 0.78 and species richness Margalef index ranged from 7.29 to 12.99. The study provides a baseline data for the management of protected areas in developing countries like India and it shows the potential of in situ method in the conservation natural areas.

1. Introduction
Biodiversity assessment is one of the sub-divisions of conservation biology that has gained much attention due to the major impact it had on the practice of conservation. Tropical plant diversity assessment is a tool for the quantitative studies of regional scale biogeographical patterns (Gordon & Newton, 2006). International conservation organizations have conducted a variety of biodiversity assessment in global and regional scales for identifying priority areas where only limited resources available for conservation (Margules, Pressey, & Williams, 2002). These relied on a variety of primary and secondary information sources that vary in quality and quantity depending on the areas assessed (Phillips et al., 2003). The results of such assessments represent the best understanding of biodiversity priorities at any given time and are being used as a basis for targeting conservation resources (Redford et al., 2003).

Tropical forests are often referred to as the major carbon sink and have high standing biomass and greater productivity. Tropical forests are important because they provide many ecosystem services such as species conservation, prevention of soil erosion and preservation of habitat or plants and animals (Armenteras, Rodriguez, & Retana, 2009). Tropical forests occupy 7% of the earth’s land surface, but constitute more than half of the world’s species (Galley, 2014), but these forests are currently disappearing at an alarming rate of between 0.8 and 2% per year (Sagar, Raghubanshi, & Singh, 2003). Tropical forest destruction is likely to continue in the future, causing an extinction crisis. Fast paced conversion and destruction of tropical forests has led to an unprecedented decline in biodiversity and disruption of ecosystem services (Dierick & Hölscher, 2009).

Tropical deciduous forests occur under varied climatic conditions, but essentially with alternate wet and dry tropics (Naidu & Kumar, 2015). The structure and composition of deciduous forests can change the length of wet period, amount of rain fall, latitude, longitude and altitude. Phytosociological pattern of Indian deciduous forests are not-well known and these have diversified life-forms but are not considered species-rich (Panda, Mahapatra, Acharya, & Debata, 2013). Still these forests assume unusual significance for conservation since they are the most used and threatened ecosystems (Thakur & Khare, 2006), especially in India. The natural forest was narrated as irregular mixed forest and thus converted into a regular, normal and even-aged forest of valuable species in order to improve the quality and quantity of future yields.

Quantitative analysis on tree species diversity provides the floristic status and distribution pattern which
may help in biodiversity conservation. Quantitative data are often obtained through biodiversity inventories that are used to determine the nature and distribution of biotic resources of the area to be managed (Rennolls & Laumonier, 2000). Quantification of tree species distribution and abundance is an important aspect as they contribute to the structural characteristics of the forest and provides resources and habitat for many species (Huang et al., 2003). Tree species diversity varies significantly from location to location because of variations in biogeography habitat and disturbance (Majumdar, Shankar, & Datta, 2012). Central Eastern Ghats constitute rich tree species diversity and as well promote livelihood security to local communities. But these forests are also under immense anthropogenic pressures (Naidu & Kumar, 2015). Thus, the floristic inventories and qualitative studies of these dry deciduous forests claim more prominence. The information on tree composition and forest structure helps in protecting threatened and economic species, and to understand the forest ecosystem dynamics for nature conservation. The present study aims at assessing the tree diversity across different vegetation types in Northcentral Eastern Ghats, India.

2. Materials and methods

2.1. Study area

Eastern Ghats are located along the peninsular India extending over 1750 km with average width about 100 km and lies between latitudes 11°30' to 22°34'N and longitudes 72°22' to 87°29'E. The Eastern Ghats are delimited by Similipal hills of Odisha state on the North. The middle section from river Krishna (Andhra Pradesh) to near about Chennai city (Tamil Nadu) and includes the Nallamalais, Nigidi, Seshachalam and Veligonda hills and the last section runs in south–south west direction meeting the Western Ghats in the Nilgiris covering an area of 75,000 km². The wide range of topography and other physical features of the Eastern Ghats shaped the land to harbor rich and varied flora. The region is phyto-geographically interesting as considered to be a migratory route for plants of Himalayas to the southern peninsula and vice versa.

Our study was confined to the northcentral Eastern Ghats with particular to East Godavari district, Andhra Pradesh and plots are 245 km south-west of Visakhapatnam. The study area includes Gangampalem (GP), Sesharayi (SR), Kakarapadu (KP), Seetapalli (SP), Cherukumpalem (CP) and Vatangi (VT). East Godavari district is located between 16°18’ and 18°02’ N latitudes and 81°30’ to 82°36’E longitudes (Figure 1). Soil of Northcentral Eastern Ghats is loamy, black, lateritic and alluvial. Lateritic soils are the common type along the deciduous forests. The maximum temperature ranges from 28 to 46.2 °C and minimum from 12.9 to 27 °C. The maximum rainfall is 1300 mm per annum during south-west monsoon. The relative humidity varied between 70 and 88%. The forests of this area are classified as southern moist deciduous and dry deciduous forests (Premavani, Naidu, Kumar, & Venkaiah, 2017).

2.2. Field methods

For determination of biodiversity, methodology was adopted from National Bioresource Development Board, Department of Biotechnology, Government of India, to quantify plant resources of India. In all the six study sites, two belt transects of 5 × 1000 m size (totaling 1 ha) were laid in each site during 2009–2013 and all live trees with ≥15 cm girth at breast height (gbh) were enumerated. The height of trees was measured using Clinometer. The representative taxa were collected and identified with the help of floras (Pullaiah & Ramamurthy, 2002; Pullaiah, Ramamurthy, & Karuppasamy, 2007; Pullaiah & Rao, 2002) and made into herbarium. The voucher specimens were housed in the Botany Department Herbarium (BDH), Department of Botany, Andhra University, Visakhapatnam.

2.3. Data analysis

Based on the individuals recorded in the discrete plot samples, vegetation data were quantitatively analyzed for basal area, relative density, relative frequency and relative dominance. The Importance Value Index (IVI) and Family Importance Value (FIV) of tree species were determined (Panda et al., 2013). The relative diversity of family was evaluated as the number of species with the family expressed as percentage of total number of species within all the families represented in the community (Pandey & Barik, 2006). The data were used to compute community indices like species diversity (H’), Species dominance (c), Evenness index (e) and Margalef index as suggested by Swamy, Sundarapandian, Chandrasekhar, and Chandrasekarakaran (2000).

The Shannon’s index was calculated as below:

\[ H' = -\sum (n_i/N) \ln(n_i/N) \]

where, \( H' \) is Shannon index of general diversity, \( n_i \) is importance of value index of species \( i \) and \( N \) is IVI of all species in that vegetation type.

Species dominance (c) was calculated using:

\[ c = \sum (n_i/N)^2 \]

where, \( c \) is index of dominance, \( n_i \) and \( N \) being the same as those for Shannon-Weiner information function.

Equitability of evenness refers to the degree of relative dominance of each species in that area and it was calculated as:

\[ e = H'/\log S \]
where, $H'$ is Shannon index, $S$ is number of species.
Species richness was determined by Margalef index as of below:

$$d = \frac{S}{\log N}$$

where, $S$ is number of species and $N$ is number of individuals.

Structural composition of trees was analyzed by comparing the tree height distribution and diameter classes. The number of individuals and richness of tree taxa were categorized into various groups of population as of predominant (>50), dominant (25 to <50), common (10 to <25), rare (2 to <10) and very rare (<2) (Majumdar et al., 2012).

3. Results

3.1. Species richness and diversity

A total of 135 angiospermous plant taxa of ≥15 cm gdbh that belong to 105 genera and 45 families were recorded. Plot-wise species richness was 60, 61, 46, 82, 68 and 57 in GP, SR, KP, SP, CP and VT, respectively, with a major difference between the plots (Table 1). Ten species (7.4%) were common to all the six plots, and 42 species (31.1%) occurred in any one of the plots. Out of these 42 species, 11 species were restricted to plot SP, and 10, 8, 7 were restricted to CP, SR, VT, respectively, and 3 species of each restricted to GP and KP plots. The families showing the most diversity in terms of the number of species were the Euphorbiaceae (11), Papilionaceae (9), Rubiaceae (8), Moraceae (7), Combretaceae and Caesalpiniaceae (6 species each), Anacardiaceae, Ebenaceae, Rutaceae, Sterculiaceae and Verbenaceae (5 species each), Apocynaceae and Sapotaceae (4 species each), Burseraceae, Annonaceae and Bignoniaceae (3 species each). Eleven families had two species each and 15 families were represented by single species. The high values of Shannon index in the range of 3.5–4.05 indicate high tree diversity. Among them, site SP is the most species rich plot with 82 species. Further, the species richness range of 46–82 species indicates the diverse nature of the forests and tree composition in this region. The high values of Shannon index indicate that in all the study sites few species have dominated the forest structure and many species comprised of fewer individuals. The Evenness index revealed KP as the most diverse plot and Margalef index had highest in plot SP (Table 1).
Table 1. Summary of tree inventory (≥15 cm) in the six plots of northcentral Eastern Ghats.

| Variable           | GP   | SR   | KP   | SP   | CP   | VT   |
|--------------------|------|------|------|------|------|------|
| Number of species  | 60   | 61   | 46   | 82   | 68   | 57   |
| Number of genera   | 51   | 52   | 42   | 66   | 57   | 50   |
| Number of families | 29   | 30   | 27   | 33   | 33   | 32   |
| Density            | 470  | 573  | 478  | 551  | 492  | 395  |
| Basal area (m² ha⁻¹)| 13.05| 28.42| 18.22| 21.59| 19.33| 15.79|
| Elevation (m)      | 131  | 712  | 310  | 335  | 216  | 636  |
| Latitude (N)       | 17°17′55.2″ | 17°43′35.3″ | 17°30′93.6″ | 17°23′03.8″ | 17°27′52.6″ | 17°27′85.0″ |
| Longitude (E)      | 81°44′29.6″ | 81°56′38.4″ | 81°55′99.4″ | 81°47′13.0″ | 82°08′81.8″ | 82°14′54.4″ |

3.2. Stand density and basal cover

The total stand density of trees for the six plots of study area was 2959 individuals. The mean stand density was 493 individuals ha⁻¹. The highest stand density observed in SR (573 individuals ha⁻¹), whereas the lowest stand density in VT (395 individuals ha⁻¹). The other four plots had moderate stand densities. The density of different tree species is differ within the six 1-ha plots. The distribution of the basal area across six plots, using gbh interval classes, revealed the dominance of smallest individuals in all the plots. Basal area in all the study plots ranges from 13.05 m² ha⁻¹ (plot GP) to 28.42 m² ha⁻¹ and the mean basal area for the six 1-ha plots was 19.4 m² ha⁻¹. The site SP has ranked first in tree species richness, a total of 82 species was exclusive to this area. The presence of low species remarkably in higher gbh class has led to greater basal area values.

3.3. Girth class distribution

Tree species richness as well as density decreased with increasing girth class in all the study plots, except in first girth class (15–30 class). The girth class distribution has revealed that majority of tree individuals represented in 31–60 cm class with 41% followed by 61–90 cm (21%), <30 (20%), 91–120 (11%) and less abundance in >120 cm girth class with 7%. A comparison was made of the relative distribution of the total number of individuals and their basal area in each diameter class. The basal area values ranged between 13.05 and 28.42 m² ha⁻¹. In all the six sites except VT the higher gbh class recorded higher basal values. 20.3% of tree individuals were present in lower gbh class and they registered 2.3% amount of basal area (Figure 2).

3.4. Tree dominance and rarity

The density of different species varied widely in the six study pots. Based on their density in 1-ha plots, the predominant group represented 18 species with 51% of total individuals. The most dominant species are Anogeissus latifolia, Xyla xylocarpa, Cleistanthus collinus and Lannea coromandelica. Twenty-one species are dominant with 24.1% individuals. Common species represented by 29 with 16% individuals. Rare species having 55 with 8.5% individuals and 12 species are very rare with 0.4% individuals such as Bischofia javanica, Drypetes roxburghii, Erythrina variegata, Euphorbia antiquorum, Glochidion velutinum, Gyrocarpus americanus, Hibiscus platanifolius, Hymenodictyon orixense, Kydia calycina, Litsea glutinosa, Salacia chinensis and Xantolis tomentosa. The total species rarity is the sum of rare and very rare are 49%.

3.5. Importance value index (IVI)

Analyzing the IVI for the individuals in each site, a distinct pattern can be observed, which is present in all study plots. Top ten species accounted for 40.5% in GP, Anogeissus latifolia was the dominant species with 20.7 IVI. The co-dominant species were Dalbergia paniculata, Mangifera indica and Protium serratum. In SR, top ten species contributing 47% and Lannea coromandelica was dominant species with 25.4 IVI. The co-dominant species were Mangifera indica, Anogeissus latifolia and Garuga pinnata. Xyla xylocarpa has the dominant tree in plot KP with 18.6 IVI and top ten species accounted for 42.5% of the total IVI. The co-dominant species were Terminalia alata, Alangium salvifolium and Cleistanthus collinus. In plot SP, the dominant species is Anogeissus latifolia (22.9 IVI) with co-dominants are Dalbergia paniculata, Lannea coromandelica and Xyla xylopa. Top ten species contributed 35.5% IVI. In plot CP, Anogeissus latifolia was dominant species with 14.7 IVI and top ten species accounted for 32.4%, co-dominant species were Soymida febrifuga, Diospyros melanoxyylon and Xyla xylopa. The plot VT contributing the top ten species IVI is 43.2% with dominant tree species Anogeissus latifolia. The co-dominant species were Lannea coromandelica, Caanthium dicoccum and Xyla xylopa (Appendix 1).

3.6. Family composition

In terms of tree abundance, Combretaceae with 306 individuals (10.3%) also dominated the deciduous forests of northcentral Eastern Ghats, followed by Euphorbiaceae (253; 8.5%) Rubiaceae (224; 7.5%), Anacardiaceae (219; 7.4%) and, Mimosaceae and Ebenaceae (213 each; 7.2%).
gives a reliable instrument to indicate the diversity level of a study site (Premavani, Naidu, & Venkaiah, 2014). The present data can be compared with the large number of similar plots inventoried in India and elsewhere in the tropics. A total of 135 species belonging to 105 genera of 45 families were recorded in the study area. Species richness ranging from 46 to 82 ha⁻¹ with mean value of 62 ha⁻¹ recorded which is very distantly closed to 64–82 species ha⁻¹ in Sengaltheri-Kakachi (Parthasarathy, 2001), 25–61 species ha⁻¹ in Saddle peak of North Andaman Islands (Tripathi et al., 2004) and 18–84 ha⁻¹ in Little Andaman Island (Rasingam & Parathasarathy, 2009). The mean value in the present study is higher than that of 21 species ha⁻¹ in Kolli hills of India (Chittibabu & Parthasarathy, 2000), 31 species ha⁻¹ in dry deciduous forests of western India (Kumar, Kumar, Bhoi, & Sajish, 2010), 37 species ha⁻¹ in Kaan forest of Western Ghats (Gunaga, Rajeswari, & Vasudeva, 2013), 38 species ha⁻¹ in reserved forests of southern Eastern Ghats of

The top ten families with an abundance of 1951 individuals (66.9%) of total tree abundance contributed 64.4% of total importance value. Twelve families represented by single species with an abundance of 71 individuals accounted for 3.9% of total FIV. Combretaceae scored maximum FIV of 35.2, followed by Euphorbiaceae (FIV-28.4), Mimosaceae (22.1), Anacardiaceae (21.5), Rubiaceae (19.4), Papilionaceae (17.7) and Ebenaceae (17.2) (Appendix 2).

4. Discussion

Species richness is one of the characteristic features of the tropical forests. It is the simplest way to describe community and regional diversity and this variable number of species forms the basis of many ecological models of community structure (Sathish, Vishwanth, Kushalappa, Jagadish, & Ganeshaiah, 2013). Tree species richness at defined study sites and in minimum diameter classes gives a reliable instrument to indicate the diversity level of a study site (Premavani, Naidu, & Venkaiah, 2014). The present data can be compared with the large number of similar plots inventoried in India and elsewhere in the tropics. A total of 135 species belonging to 105 genera of 45 families were recorded in the study area. Species richness ranging from 46 to 82 ha⁻¹ with mean value of 62 ha⁻¹ recorded which is very distantly closed to 64–82 species ha⁻¹ in Sengaltheri-Kakachi (Parthasarathy, 2001), 25–61 species ha⁻¹ in Saddle peak of North Andaman Islands (Tripathi et al., 2004) and 18–84 ha⁻¹ in Little Andaman Island (Rasingam & Parathasarathy, 2009). The mean value in the present study is higher than that of 21 species ha⁻¹ in Kolli hills of India (Chittibabu & Parthasarathy, 2000), 31 species ha⁻¹ in dry deciduous forests of western India (Kumar, Kumar, Bhoi, & Sajish, 2010), 37 species ha⁻¹ in Kaan forest of Western Ghats (Gunaga, Rajeswari, & Vasudeva, 2013), 38 species ha⁻¹ in reserved forests of southern Eastern Ghats of

Figure 2. (a–f) Contribution of tree species stands density and basal area based on girth class distribution in northcentral Eastern Ghats.
Ghats (Pragasan & Parthasarathy, 2010), 832 trees ha\(^{-1}\) and also in Bannerghatta forests, the richness of woody species ranges from 9 to 41 per 0.1 ha (Varma, Anand, Gopalakrishna, Avinash, & Nishant, 2009), through a medium value of 99–121 species ha\(^{-1}\) for Ngoyavang's lowland forests, Cameron (Gomnadje et al., 2011) to a very high 137–168 species ha\(^{-1}\) in Amazon Terra Firme Forest (Cintra, Ximenes, Gondim, & Kropf, 2005).

The present inventory studies in tropical dry forests of Indian sub-continent reported 298 tree ha\(^{-1}\) at Madumalai forest reserve, 689 stems h\(^{-1}\) Sinharaj, Sri Lanka (Condit et al., 2000), 357 stems ha\(^{-1}\) in northern Eastern Ghats (Panda et al., 2013), 457 stems ha\(^{-1}\) in southern Eastern Ghats (Pragasan & Parthasarathy, 2010), 832 trees ha\(^{-1}\) (≥10 cm dbh) in tropical montane evergreen forest (shola) of the Nilgiri Mountains (Mohandass & Davidar, 2009) and 639–836 stems ha\(^{-1}\) in Eastern Ghats of northern Andhra Pradesh (Reddy, Babar, Amarnath, & Pattanaik, 2011). In comparison to these forests, the prevailing mean stand density of 493 stems ha\(^{-1}\) and tree density range of 395–573 stems ha\(^{-1}\) indicate that these forests constitute moderate tree density which depends on efficacy of seed dispersal, survival and establishment and also on the levels of resource extraction by humans.

Basal area of a tree is the girth occupied at breast height (gbh) and it is an important attribute to quantify the vegetation structure and site quality (Suthari, 2013). In the present study, the basal area of tree species varied across the six plots (ranged from 13.05 in GP to 28.42 m\(^2\) ha\(^{-1}\) in SR), revealing that the stand structure is considerably poor in plot GP and healthy in plot SR. The mean basal area 19.4 m\(^2\) ha\(^{-1}\) was higher than the basal area of dry tropics of Eastern Ghats 11.46 m\(^2\) ha\(^{-1}\) (Reddy, Babar, Giriraj, Reddy, & Rao, 2008). Stand basal area was measured in the medium range compared to other Indian tropical forests as 25.32 m\(^2\) ha\(^{-1}\) in Singara Range of Western Ghats (Singh, Varma, & Jayakumar, 2016), 1.3 m\(^2\) ha\(^{-1}\) at Vindhyan hills (Sagar et al., 2003) to 98.6 m\(^2\) ha\(^{-1}\) at Namdapha National Park, northeast India (Nath, Arunachalam, Khan, Arunachalam, & Barbhuiya, 2005). Girth class frequency showed population structure of trees exhibited in the study sites are in conformity with other forest stands (Sahu, Dhal, & Mohanty, 2012). Tree density distribution across different girth classes indicates how well the growing forest is utilizing site resources. A few small to medium sized trees ha\(^{-1}\) may imply that land is not being fully utilized by the tree crop (Hitimana, Kiyiapi, & Njunge, 2004).

The species diversity depends upon adaptation of species and increases with stability of community the Shannon-Weiner (H') index for all the six plots varied from 3.59 to 4.05 which falls within the range of 0.67 to 4.86 reported in tropical forests Indian sub-continent (Kumar et al., 2010; Panda et al., 2013; Sundarapandian and Swamy, 2000). These values indicate that the present tropical deciduous forest is a species diverse system. The concentration of dominance (Simpson's index) in the present study is within the reported range of 0.64–1.34 in other forests (Lalikawma, Roy, Vanalhtripuria, & Vanalahluna, 2009; Sahu et al., 2012). The Margalef richness index is within the range 4.54–23.41 for other tropical forests (Kumar et al., 2010; Sathish, Viswanath, Kushalappa, Jagadish, & Ganeshiaiah, 2013). By this comparison, it shows how the current study plots have lost tree species through the influence of anthropogenic and ecological factors.

The most dominant tree species in the study area are Anogeissus latifolia, Xyila xylocarpa, Cleistanthus collinus and Lannea coromandelica. Pragasan and Parthasarathy (2010) reported dominant species in the southern Eastern Ghats are Albizia amara, Euphorbia antiquorum, Canthium dicoccum var. dicoccum, Memecylon edule and Chloroxylon swietenia whereas in northern Eastern Ghats, Shorea robusta, Lannea coromandelica, Madhuca indica and Diospyros melanoxylon (Panda et al., 2013). Rarity of species 49% obtained in the present study area is higher as compared to 43% in Kalrayan hills of Eastern Ghats whereas 41% tropical forests of Eastern Ghats of northern Andhra Pradesh, 40% rarity in Barro Colorado Island and 38% in Malaysia and lower than that of other tropical forests 59% rarity in Jenga Forest Reserve of Malaysia, 55.4% in New Guinea, 50% in West Java (Gandhi & Sundarapandian, 2014; Reddy et al., 2011).

When six plots were considered together, Combretaceae with 306 stems ranked first in terms of stem density followed by Euphorbiaceae, Rubiaceae, Anacardiaceae and Mimosaceae. The top 10 families comprised 66.9% of the total number of stems, similarly Panda et al. (2013) has also reported that Dipterocarpaceae, Euphorbiaceae, Anacardiaceae and Meliaceae were the dominant families reported from the northern Eastern Ghats while Mimosaceae, Euphorbiaceae, Rubiaceae and Anacardiaceae dominated the tropical forests of southern Eastern Ghats (Pragasan & Parthasarathy, 2010) and Combretaceae, Mimosaceae, Meliaceae, Rubiaceae and Celastraceae were the predominant families from Bannerghatta National Park in Eastern Ghats of southern India (Gopalakrishna, Kaonga, Somashekar, Suresh, & Suresh, 2015). The Euphorbiaceae (11 species), Papilionaceae (9), Rubiaceae (8) and Moraceae (7) were most speciose families in the present study. Interestingly, similar findings were reported by Padalia et al. (2004) where Euphorbiaceae and Rubiaceae were the most dominant family in all forest types, except mangrove. Sandhyarani, Murth, and Pulilah (2007) resulted that Euphorbiaceae is the dominant family followed by Moraceae and Lauraceae in the Eastern Ghats, while Suthari and Raju (2018) reported that Fabaceae constitute the predominant family with 26 species which is distinctly
followed by Rubiaceae (9 species) and Combretaceae (7 species) along the gradients in the dry deciduous forests of Godavari valley, Telangana State. Reddy et al. (2011) also indicated that, Rubiaceae and Papilionaceae were the most dominant families in the Eastern Ghats of northern Andhra Pradesh. But in tropics, Leguminosae was a most speciose family in neotropical deciduous forests (Stehee et al., 2000). This trend indicates that across various tropical forests a greater similarity is evident at the family level.

5. Conclusion

Measures of biodiversity provide baseline information on the distribution richness and relative abundance of taxa required for conservation decisions.

- The present study inferred the presence of more species richness and mean stand density, and the study plots indicate the uniqueness and potentiality for conservation of ecosystem in its totality.
- The forests in the study region are subjected to over exploitation to meet the growing demands for the cultivation practices, firewood, fencing and fodder for livestock and wood exploitation for domestic and commercial utilization.
- Forest fires, grazing, cut stumps and medicinal plant collection are observed in peripheral areas of some study sites, which results in diminishment of forests at an alarming pace. The immediate attention on people participation is most essential for the effective conservation.
- The present study will serve as a primary input towards maintaining and sustaining the phytodiversity and also would help in understanding the threats that are faced by the tropical forests and would help in driving conservation policies.

Disclosure statement

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References

Armenteras, D., Rodriguez, N., & Retana, J. (2009). Are conservation strategies effective in avoiding the deforestation of the Colombian Guyana Shield? Biological Conservation, 142, 1411–1419.

Chittibabu, C.V., & Parthasarathy, N. (2000). Attenuated tree species diversity in human-impacted tropical evergreen forest sites at Kolli hills, Eastern Ghats, India. Biodiversity and Conservation, 9, 1493–1519.

Cintra, R., Ximenes, A.C., Gondim, F.R., & Kropf, M.S. (2005). Forest spatial heterogeneity and palm richness, abundance and community composition in Terra Firme Forest, Central Amazon. Revista Brazilian Botany, 28(1), 75–84.

Condit, R., Ashton, P.S., Baker, P., Bunyavejchewin, S., Gunatilleke, S., Gunatilleke, N., … Yamakura, T. (2000). Spatial patterns in the distribution of tropical tree species. Science, 288, 1414–1418.

Dierick, D., & Hölscher, D. (2009). Species-specific tree water use characteristics in reforestation stands in the Philippines. Agricultural and Forest Meteorology, 149, 1317–1326.

Galley, R.E. (2014). Ecology of tropical rain forests. In R.K. Monson (Ed.), Ecology and the environment (pp. 247–272). New York, NY: The Plant Sciences, Springer.

Gandhi, D.S., & Sundarapandian, S. (2014). Inventory of trees in tropical dry deciduous forests of Tiruvannamalai district, Tamil Nadu, India. Biodiversitas, Journal of Biological Diversity, 15(2), 169–179.

Gonmadje, C.F., Doumenge, C., McKey, D., Tchouto, G.P.M., Sunderland, T.C.H., Malinga, M.P.B., & Sonke, B. (2011). Tree diversity and conservation value of Ngoyang’s lowland forests, Cameroon. Biodiversity Conservation, 20, 2627–2648.

Gopalakrishna, S.P., Kaonga, M.L., Somashekar, R.K., Suresh, H.S., & Suresh, R. (2015). Tree diversity in the tropical dry forest of Bannerghatta National Park in Eastern Ghats, southern India. European Journal of Ecology, 1(2), 12–27.

Gordon, J.E., & Newton, A.C. (2006). The potential misapplication of rapid plant diversity assessment in tropical conservation. Journal for Nature Conservation, 14, 117–126.

Gunaga, S., Rajeswari, N., & Vasudeva, R. (2013). Tree diversity and disturbance of Kaan forests: Relics of a community protected climax vegetation in the central Western Ghats. Tropical Ecology, 54, 117–131.

Hitimana, J., Kiyiapi, J.L., & Njunge, J.T. (2004). Forest structure characteristics in disturbed and undisturbed sites of Mt. Elgon moist lower montane forest, Western Kenya. Forest Ecology and Management, 194, 269–291.

Huang, W., Pohjonen, V., Johansson, V., Nashanda, M., Katigula, M.I.L., & Luukkanen, O. (2003). Species diversity, forest structure and species composition in Tanzanian tropical forests. Forest Ecology and Management, 173, 111–124.

Kumar, J.I.N., Kumar, R.N., Bhoi, R.K., & Saijish, P.R. (2010). Tree species diversity and soil nutrient status in three sites of tropical dry deciduous forest of western India. Tropical Ecology, 51, 273–279.

Lalakawma, S.U.K., Roy, S., Vanjalhritpua, K., & Vanjalhluina, P.C. (2009). Community composition and tree population structure in undisturbed and disturbed tropical semi-evergreen forest stands of North-East India. Applied Ecology and Environmental Research, 7, 303–318.

Majumdar, K., Shankar, U., & Datta, B.K. (2012). Tree species diversity and stand structure along major community types in lowland primary and secondary moist deciduous forests in Tripura, Northeast India. Journal of Forestry Research, 23(4), 553–568.

Mani, S., & Parthasarathy, N. (2006). Tree diversity and stand structure in inland and coastal tropical dry evergreen forests of peninsular India. Current Science, 90, 1238–1246.

Margules, C.R., Pressey, R.L., & Williams, P.H. (2002). Representing biodiversity: Data and procedures for
identifying priority areas for conservation. *Journal of Biosciences*, 27(4), 309–326.

Mohandass, D., & Davidar, P. (2009). Floristic structure and diversity of a tropical montane evergreen forest (shola) of the Nilgiri Mountains, southern India. *Tropical Ecology*, 50(2), 219–229.

Naidu, M.T., & Kumar, O.A. (2015). Tree species diversity in the Eastern Ghats of northern Andhra Pradesh, India. *Journal of Threatened Taxa*, 7(8), 7443–7459.

Nath, P.C., Arunachalam, S., Khan, M.L., Arunachalam, K., & Barbhuiya, A.N. (2005). Vegetation analysis and tree population structure of tropical wet evergreen forests in and around Namdapha National Park, northeast India. *Biodiversity Conservation*, 14, 2109–2135.

Padalia, H., Chauhan, N., Porwal, M.C., & Roy, P.S. (2004). Phytosociological observations on tree species density of Andaman Islands, India. *Current Science*, 87(6), 799–806.

Panda, P.C., Mahapatra, A.K., Acharya, P.K., & Debata, A.K. (2013). Plant diversity in tropical deciduous forests of Eastern Ghats, India: A landscape level assessment. *International Journal of Biodiversity Conservation*, 5, 625–639.

Pandey, H.N., & Barik, S.K. (2006). *Ecology, Diversity and conservation of plants and ecosystems in India*. New Delhi: Regency Publications.

Parthasarathy, N. (2001). Changes in forest composition and floristic structure in three sites of tropical evergreen forests around Sengaltheri, Western Ghats. *Current Science*, 80, 389–393.

Phillips, O., Martinez, R.V., Vargas, P.N., Monteagudo, A.L., Zans, M.E.C., & Sanchez, W.G. (2003). Efficient plot-based floristic assessment of tropical forests. *Journal of Tropical Ecology*, 19, 629–645.

Pragasan, L.A., & Parthasarathy, N. (2010). Landscape-level tree diversity assessment in tropical forests of southern Eastern Ghats, India. *Flora - Morphology, Distribution, Functional Ecology of Plants*, 205, 728–737.

Premavani, D. (2009). Phytosociological analysis on tree diversity of Eastern Ghats of East and West Godavari Districts, Andhra Pradesh, India. (PhD Thesis). Department of Botany, Andhra University, Visakhapatnam.

Premavani, D., Naidu, M.T., Kumar, O.A., & Venkaiah, M. (2017). Diversity and distribution of tree species in tropical forests of Northcentral Eastern Ghats, India. *Asian Journal of Forestry*, 1(1), 27–32.

Premavani, D., Naidu, M.T., & Venkaiah, M. (2014). Tree species diversity and population structure in the tropical forests of north central Eastern Ghats, India. *Notulae Scientia Biologicae*, 6(4), 448–453.

Pullaiah, T., & Ramamurthy, K.S. (2002). *Flora of Eastern Ghats: Hill ranges of East South India* (Vol. 2). New Delhi: Regency Publications.

Pullaiah, T., Ramamurthy, K.S., & Karuppusamy, S. (2007). *Flora of Eastern Ghats: Hill ranges of South East India* (Vol. 3). New Delhi: Regency Publications.

Pullaiah, T., & Rao, D.M. (2002). *Flora of Eastern Ghats: Hill ranges of South East India* (Vol. 1). New Delhi: Regency Publications.

Rao, B.R.P., Babu, M.V.S., Reddy, M.S., Reddy, A.M., Rao, V.S., Sunitha, S., & Ganeshiah, K.N. (2011). Sacred groves in southern Eastern Ghats, India: Are they better managed than forest reserves? *Tropical Ecology*, 52, 79–90.

Rasingam, L., & Parathasarathy, N. (2009). Tree species diversity and population structure across major forest formations and disturbance categories in Little Andaman Island, India. *Tropical Ecology*, 50(1), 89–102.

Reddy, C.S., Babar, S., Amarnath, G., & Pattanaik, C. (2011). Structure and floristic composition of tree stand in tropical forest in the Eastern Ghats of Andhra Pradesh, India. *Journal of Forestry Research*, 22, 491–500.

Reddy, C.S., Babar, S., Giriraj, A., Reddy, K.N., & Rao, K.T. (2008). Structure and floristic composition of tree diversity in tropical dry deciduous forest of Eastern Ghats, Southern Andhra Pradesh, India. *Asian Journal of Scientific Research*, 1, 57–64.

Redford, K.H., Coppolillo, P., Sanderson, E.W., Da Fonseca, G.A.B., Dinerstein, E., & Groves, C. (2003). Mapping and conservation landscape. *Conservation Biology*, 17, 116–131.

Rennolls, K., & Laumonier, Y. (2000). Species diversity structure analysis at two sites in the tropical rain forest of Sumatra. *Journal of Tropical Ecology*, 16, 253–270.

Sagar, R., Raghubanshi, A.S., & Singh, J.S. (2003). Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. *Forest Ecology and Management*, 186, 61–71.

Sahu, S.C., Dhal, N.K., & Mohanty, R.C. (2012). Tree species diversity and soil nutrient status in a tropical sacred forest ecosystem on Niyangiri hill range, Eastern Ghats, India. *Tropical Ecology*, 53, 163–168.

Sandelharyani, S., Murth, K.S.R., & Pullaiah, T. (2007). Tree flora in Eastern Ghats of southern peninsular India. *Research Journal of Botany*, 2(4), 176–185.

Sathish, B.N., Viswanath, S., Kushalappa, C.G., Jagadish, M.R., & Ganeshiaiah, K.N. (2013). Comparative assessment of floristic structure, diversity and regeneration status of tropical rain forests of Western Ghats of Karnataka, India. *Journal of Applied & Natural Science*, 5, 157–164.

Singh, D., Varma, S., & Jayakumar, S. (2016). Tree inventory along the altitudinal gradients in Singara Range, Western Ghats, India. *Proceedings of the International Academy of Ecology and Environmental Sciences*, 6(4), 97–109.

Stege, H.T., Sabatier, D., Castellanos, H., Andel, T.V., Duivenvoorden, J., de Oliveira, A.A., & Mori, S. (2000). An analysis of the floristic composition and diversity of Amazonian forests including those of the Guiana Shield. *Journal of Tropical Ecology*, 16, 801–828.

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

Suthari, S. (2013). Biodiversity characterization and aboveground vegetation carbon pool assessment in Northern Telangana at landscape level using geospatial technique (PhD Thesis). Department of Botany, Kakatiya University, Warangal.

Suthari, S., & Raju, V.S. (2018). Tree species composition and forest stratification along the gradients in the dry deciduous forests of Godavari valley, Telangana, India. *Indian Forester*.

Swamy, P.S., Sundarapandian, S.M., Chandrasekar, P., & Chandrasekaran, S. (2000). Plant species diversity and tree population structure of a humid tropical forest in Tamil Nadu, India. *Biodiversity and Conservation*, 9, 1643–1669.

Thakur, A.S., & Khare, P.K. (2006). Species diversity and dominance in tropical dry deciduous forest ecosystem. *Journal of Environmental Research and Development*, 1(1), 26–31.

Tripathi, K.P., Tripathi, S., Selvan, T., Kumar, K., Singh, K.K., Mehrotra, S., & Push pangadan, P. (2004). Community structure and species diversity of Saddle Peak forest in Andaman Island. *Tropical Ecology*, 45, 241–250.

Varma, S., Anand, V.D., Gopalakrishna, S.P., Arinash, K.G., & Nishant, M.S. (Eds.). (2009). *Ecology, conservation and management of the Asian Elephant in Banangeredha National Park, southern India* (p. 301). Bangalore: A Rocha India/ANCF: Asian Ecology and Conservation Reference Series No. 1. A Rocha India and Asian Nature Conservation Foundation.
### Appendix 1. Density, basal area and importance value index (IVI) of the tree species in six 1-ha sites

| Species name | GP | SR | KP | SP | CP | VT |
|--------------|----|----|----|----|----|----|
| Acacia chundra | – | – | – | – | – | – |
| Acacia leucophloea | 1.5 | 0.16 | 3.12 | – | – | – |
| Acacia nilotica | – | – | – | – | – | – |
| Aegle marmelos | 5.5 | 0.1 | 5.68 | 2.5 | 0.01 | 1.44 |
| Alangium salviifolium | 4.5 | 0.06 | 3.64 | 2.5 | 0.03 | 2.15 |
| Albizia chinensis | 1.5 | 0.4 | 5.0 | 1 | 0.02 | 1.6 |
| Albizia odoratissima | 2.5 | 0.03 | 2.58 | 5.5 | 0.28 | 4.11 |
| Alstonia venenata | – | – | – | 1 | 0.06 | 1.74 |
| Annona squamosa | – | – | – | – | – | – |
| Anogeissus acuminata | 4.5 | 0.14 | 4.28 | – | – | – |
| Anogeissus latifolia | 17.5 | 1.41 | 20.8 | 25.5 | 0.76 | 14 |
| Antidesma bunius | – | – | – | 1 | 0.02 | 1.6 |
| Antidesma ghaesembilla | 1 | 1.73 | 1.5 | 0.04 | 1.84 | – |
| Atlantia monophylla | 4.5 | 0.08 | 3.77 | – | – | – |
| Azadirachta indica | 1.5 | 0.03 | 2.15 | 1 | 0.02 | 1.6 |
| Barringtonia acutangula | – | – | – | – | – | – |
| Bauhinia malabarica | 3.5 | 0.05 | 4.4 | – | – | – |
| Bauhinia purpurea | – | – | – | – | – | – |
| Bauhinia racemosa | 2 | 0.02 | 2.29 | 4.5 | 0.08 | 3.04 |
| Bischofia javanica | – | – | – | 0.5 | 0.02 | 1.43 |
| Bombax ceiba | – | – | – | – | – | – |
| Boswellia serrata | – | – | – | – | – | – |
| Bucida burkei | 3.5 | 0.34 | 5.34 | 9.5 | 0.59 | 7.76 |
| Buchanania axillaris | – | – | – | – | – | – |
| Buchanania cochinchinensis | – | – | – | – | – | – |
| Canthium dicoccum | 2 | 0.02 | 2.26 | – | – | – |
| Capparis grandis | – | – | – | – | – | – |
| Careya arborea | – | – | – | – | – | – |
| Caryota urens | – | – | – | 4.5 | 0.47 | 3.93 |
| Casearia elliptica | – | – | – | – | – | – |
| Cassia fistula | 3.5 | 0.07 | 3.54 | 9.5 | 0.59 | 7.76 |
| Ceiba pentandra | 1.5 | 0.27 | 4.1 | – | – | – |
| Chloroxylon swietenia | 9.5 | 0.19 | 7.33 | 7 | 0.22 | 5.23 |
| Cleistanthus collinus | 12 | 0.23 | 9.36 | 14 | 0.28 | 8.26 |
| Cleistanthus patulus | – | – | – | 1 | 0.01 | 1.58 |
| Cordia dichotoma | – | – | – | – | – | – |
| Cochlospermum religiosum | 2.5 | 0.11 | 2.6 | – | – | – |
| Dalbergia lanceolaria | – | – | – | – | – | – |
| Dalbergia latifolia | – | – | – | 2 | 0.06 | 4.33 |
| Dalbergia paniculata | 14.5 | 1.51 | 20.3 | 9 | 0.75 | 6.98 |
| Dalbergia sissoides | 1 | 0.12 | 2.63 | – | – | – |
| Diospyros chloroxylon | 10 | 0.28 | 8.5 | 4.5 | 0.07 | 3.52 |
| Diospyros melanoxylon | 5.5 | 0.09 | 5.55 | 4.5 | 0.07 | 3.52 |
| Diospyros montana | 0.5 | 0.01 | 1.54 | – | – | – |
| Diospyros syriaca | – | – | – | 4.5 | 0.15 | 3.92 |

(Continued)
| Species name          | GP | BA | M | D | BA | IV | D | BA | IV | SP | BA | IV | D | BA | IV | SP | BA | IV | VT |
|-----------------------|----|----|---|---|----|----|---|----|----|----|----|----|---|----|----|----|----|----|----|
| Dolichandrone falcata |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Drypetes roxburghii   |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Eriolaena hookeriacea |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Erythrina suberosa    | 5.5| 0.19| 6.29|1.5| 0.03| 1.83|   |    |    |    |    |    |   |    |    |    |    |    |    |
| Erythrina variegata   |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Erythroxylum monogynum|    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Ficus benghalensis    |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Ficus microcarpa      |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Ficus religiosa       |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Ficus tinctoria       |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Ficus tomentosa       | 0.5| 0.19| 2.94|   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Flacourtia indica     |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Gardenia latifolia    | 4  | 0.15| 5.41|4.5| 0.07| 4.18|   |    |    |    |    |    |   |    |    |    |    |    |    |
| Geruga annata         | 6  | 0.58| 9.54|14 | 1.87| 13.9|6.5|0.504|7.04|6   | 0.41|5.75|2   |    |    |    |    |    |    |    |
| Glischion velutinum   |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Glischion zeylanicum  |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Gmelina arborea       |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Grewia tiliafollia    | 1  | 0.03| 1.89|5.5|0.19| 4.98|4.5|0.203|4.55|6.5 |0.27| 3.3|1   |    |    |    |    |    |    |    |
| Gymnocalycium americanus| 2 | 0.36| 4.89|   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |    |
| Haladnia cordifolia   |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Helicteres isora      |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Hibiscus platanifolius|    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Holarrhena pubescens  | 7.5| 0.1 | 6.45|   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |    |
| Holoptelea integrifolia| 2 | 0.36| 4.89|   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |    |
| Hymenodictyon orizense|    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Ipomoea pescifera     |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Jacaranda curcas      |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Kydia cajalcura       | 0.5| 0.11| 2.29|   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |    |
| Lagerstroemia parviflora| 1.5| 0.08| 2.53|5.5|0.49| 6.03|5.5|0.44|7.84|3   |0.08| 3.14|1.5|0.31| 3.39|2   |0.06| 3.09|    |
| Lannea coromandelica  | 7  | 0.51| 9.43|14.5|5.13| 25.5|8.5|0.751|10.81|11  |0.95|10.1|9.5|0.65| 9.55|10  |1.55|18.2|    |
| Lea indica            |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Limonia acidissima    |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Litsea decarnesia     |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Litsea glutinosa      |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Moba buxifolia        |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Macaranga peltata     |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Madhuca longiflora    |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Malpighia pinnata     |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Mangifera indica      | 3  | 1.26| 13.5|6  |4.45|20.1 |1  |0.036|2.17|4   |1.61|9.77|   |    |    |    |    |    |    |
| Manilkara hexandra    |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Memecylon edule       |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Milicia tomentosa     |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Mimosa elengi         |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Mitragyna parviflora  | 2.5| 0.09| 2.99|3.5|0.06| 2.61|2   |0.021|2.51|1.5 |0.06| 1.66|   |    |    |    |    |    |    |    |
| Morinda pubescens     | 3.5| 0.04| 3.07|6  |0.03| 1.98|6   |0.399|7.82|2.5 |0.12| 2.31|   |    |    |    |    |    |    |    |
| Morura paniculata     |    |    |   |   |    |    |   |    |    |    |    |    |   |    |    |    |    |    |    |
| Naringi crenulata     | 3  | 0.06| 2.98|4  |0.06| 2.81|4   |0.055|3.53|1.5 |0.07| 1.72|1  |0.04| 1.75|   |    |    |    |

(Continued)
| Species name                  | GP | sR | Kp | sp | cp | VT | d | Ba | IVI | d | Ba | IVI | d | Ba | IVI | d | Ba | IVI | d | Ba | IVI | d | Ba | IVI | d | Ba | IVI | d | Ba | IVI | d | Ba | IVI | d | Ba | IVI | d | Ba | IVI | d | Ba | IVI | d | Ba | IVI |
|------------------------------|----|----|----|----|----|----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|----|-----|---|726

*value < 0.001; GP = Gangampalem; sR = Sesharavi; Kp = Kakarapadu; sp = Seetapalli; cp = Cherukumpalem; VT = Vatangi; D = Density; BA = Basal Area; IVI = Importance Value Index
### Appendix 2. Family-wise tree species richness, genera, basal area and family index value (FIV) in six 1-ha sites

| Sl. No. | Family          | Genera | Species | Abundance | BA      | R.D.  | R.Dom | R.Div | FIV  |
|---------|-----------------|--------|---------|-----------|---------|-------|-------|-------|------|
| 1       | Combretaceae    | 2      | 6       | 306       | 0.294   | 10.3  | 20.45 | 4.44  | 35.2 |
| 2       | Euphorbiaceae   | 9      | 11      | 253       | 0.168   | 8.55  | 11.67 | 8.14  | 28.4 |
| 3       | Mimosaceae      | 3      | 6       | 213       | 0.15    | 7.2   | 10.47 | 4.44  | 22.1 |
| 4       | Anacardiaceae   | 4      | 5       | 219       | 0.149   | 7.4   | 10.38 | 3.70  | 21.5 |
| 5       | Rubiaceae       | 8      | 9       | 224       | 0.085   | 5.27  | 5.73  | 6.66  | 17.7 |
| 6       | Fabaceae        | 5      | 9       | 156       | 0.082   | 5.27  | 5.73  | 6.66  | 17.7 |
| 7       | Ebenaceae       | 2      | 5       | 213       | 0.091   | 7.2   | 6.31  | 3.70  | 17.2 |
| 8       | Bursaceae       | 3      | 3       | 131       | 0.066   | 4.43  | 4.62  | 2.22  | 11.3 |
| 9       | Apocynaceae     | 4      | 4       | 133       | 0.051   | 4.49  | 3.52  | 2.96  | 11.1 |
| 10      | Caesalpinioideae| 4      | 6       | 103       | 0.024   | 3.48  | 1.68  | 4.44  | 9.61 |
| 11      | Flindersiaceae  | 1      | 1       | 99        | 0.078   | 3.35  | 5.41  | 0.74  | 9.51 |
| 12      | Rutaceae        | 5      | 5       | 102       | 0.02    | 3.45  | 1.39  | 3.70  | 8.55 |
| 13      | Sterculiaceae   | 4      | 5       | 75        | 0.015   | 2.53  | 1.05  | 3.70  | 7.29 |
| 14      | Moraceae        | 2      | 7       | 42        | 0.003   | 1.42  | 0.20  | 5.185 | 6.81 |
| 15      | Sapindaceae     | 2      | 2       | 76        | 0.029   | 2.57  | 1.99  | 1.481 | 6.05 |
| 16      | Verbenaceae     | 4      | 5       | 48        | 0.009   | 1.62  | 0.6   | 3.70  | 5.93 |
| 17      | Alangiaae       | 1      | 1       | 65        | 0.034   | 2.2   | 2.33  | 0.74  | 5.27 |
| 18      | Meliaceae       | 2      | 2       | 70        | 0.02    | 2.37  | 1.39  | 1.48  | 5.24 |
| 19      | Sapotaceae      | 4      | 4       | 49        | 0.008   | 1.66  | 0.56  | 2.96  | 5.19 |
| 20      | Annonaceae      | 3      | 3       | 53        | 0.009   | 1.79  | 0.59  | 2.22  | 4.61 |
| 21      | Loganiaceae     | 1      | 2       | 60        | 0.014   | 2.03  | 1     | 1.481 | 4.51 |
| 22      | Lythraceae      | 1      | 1       | 38        | 0.011   | 1.28  | 0.79  | 0.74  | 2.82 |
| 23      | Tillaceae       | 1      | 1       | 37        | 0.011   | 1.25  | 0.75  | 0.74  | 2.75 |
| 24      | Bignonioideae   | 3      | 3       | 10        | *       | 0.34  | 0.02  | 2.22  | 2.58 |
| 25      | Areceae         | 2      | 2       | 24        | 0.003   | 0.81  | 0.19  | 1.48  | 2.49 |
| 26      | Rhamnaceae      | 1      | 2       | 19        | 0.002   | 0.64  | 0.11  | 1.48  | 2.24 |
| 27      | Ulmaceae        | 2      | 2       | 18        | 0.002   | 0.61  | 0.14  | 1.48  | 2.23 |
| 28      | Bombacaceae     | 2      | 2       | 19        | 0.001   | 0.64  | 0.1   | 1.48  | 2.23 |
| 29      | Flacourtiaae    | 2      | 2       | 11        | *       | 0.37  | 0.04  | 1.48  | 1.89 |
| 30      | Stilaginae      | 1      | 2       | 8         | *       | 0.27  | 0.02  | 1.48  | 1.77 |
| 31      | Barringtonioideae| 2      | 2       | 8         | *       | 0.27  | 0.01  | 1.48  | 1.77 |
| 32      | Lauraceae       | 1      | 2       | 4         | *       | 0.14  | 0.006 | 1.48  | 1.62 |
| 33      | Malvaceae       | 2      | 2       | 2         | *       | 0.07  | 0.001 | 1.48  | 1.55 |
| 34      | Myrtaceae       | 1      | 1       | 16        | 0.002   | 0.54  | 0.14  | 0.74  | 1.42 |
| 35      | Cochlospermaceae| 1      | 1       | 14        | 0.002   | 0.47  | 0.108 | 0.741 | 1.32 |
| 36      | Oleaceae        | 1      | 1       | 14        | 0.002   | 0.47  | 0.108 | 0.74  | 1.32 |
| 37      | Erythroxylaceae | 1      | 1       | 9         | *       | 0.3   | 0.045 | 0.741 | 1.09 |
| 38      | Melastomataceae | 1      | 1       | 4         | *       | 0.14  | 0.009 | 0.741 | 0.88 |
| 39      | Capparaceae     | 1      | 1       | 3         | *       | 0.1   | 0.005 | 0.74  | 0.85 |
| 40      | Dilleniaceae    | 1      | 1       | 3         | *       | 0.1   | 0.005 | 0.74  | 0.85 |
| 41      | Leaceae         | 1      | 1       | 3         | *       | 0.1   | 0.005 | 0.74  | 0.85 |
| 42      | Cordiaceae      | 1      | 1       | 2         | *       | 0.07  | 0.002 | 0.74  | 0.81 |
| 43      | Bischofiaceae   | 1      | 1       | 1         | *       | 0.03  | *     | 0.74  | 0.78 |
| 44      | Hernandiaceae   | 1      | 1       | 1         | *       | 0.03  | *     | 0.74  | 0.78 |
| 45      | Hippocrastaceae | 1      | 1       | 1         | *       | 0.03  | *     | 0.74  | 0.78 |
| Total   |                 | 105    | 135     | 2959      | 1.437   | 100   | 100   | 100   | 300  |

*value < 0.001; BA = Basal Area; R.D. = Relative Density; R.Dom = Relative Dominance; R.Div = Relative Diversity; FIV = Family Index Value.