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Diversity and Population Structure of Trees of Gundlabrahmeswaram Wildlife Sanctuary WLS, Andhra Pradesh, India

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Abstract: *The species diversity, density and stand structure of forests of Gundlabrahmeswaram Wildlife Sanctuary (GWLS), southern Eastern Ghats of Andhra Pradesh, was assessed throughout the terrain by laying 62 transects of 1000x5m in 37 grids of 6.25x6.25 km^2. A total of 14,262 stems with ≥30 cm girth at breast height (gbh) were enumerated. These represent 179 species belonging to 112 genera and 48 families. Tree species richness was as low as 28 species ha$^{-0.5}$ in Bollupalli and Gundlamotu reservoir areas to as high as 68 species in Gundlabrahmeswaram. Tree density ranges from 220 ha$^{-0.5}$ at Kanchuralla bodu to 748 stems ha$^{-0.5}$ at Mangloni bodu and basal area from 3.99 m^2/0.5ha at Kanchuralla bodu to 36.54 m^2/0.5ha at Rudrakod. Shannon-Wiener diversity values ranges from 2.78 to 3.92. Simpson index values range from 0.89 to 0.97. Family Importance Value index of the pooled data indicates that Combretaceae (36.19) was the most dominant family. The study site can be designated as Anogeissus latifolia-Lannea coromandelica-Terminalia alata series based on species importance value. A total of 3,160 regenerating individuals were registered in 124 regeneration plots of 5x5m size in the sampled grids across the study sites. The present paper reveals the current population structure of GWLS.*

Keywords: *Eastern Ghats, Gundlabrahmeswaram WLS, Trees*

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I. Introduction

Tropical forests, the most complex of all the terrestrial ecosystems and major repository of biodiversity, are undergoing rapid fragmentation and degradation all over the world [1]. They covers 7 % of the earth's land surface, but harbors more than half of the world's species and are currently disappearing at an overall rate of 0.8 to 2 % per year [2]. Species diversity in the tropics varies dramatically from place to place. Continuing species extinctions far above the historic rate, loss of habitats and changes in the distribution and abundance of species are projected throughout this century according to all scenarios analyzed in Global Biodiversity Outlook 3 [3]. Compared to other tropical forest types, dry deciduous forests are among the most exploited and endangered ecosystems of the biosphere [4,5]. Tropical trees are especially interesting subjects, as there is much species diversity [6,7]. Continued decline or loss of tree populations can have a major impact on the local forest structure. Around 7,800 tree species are currently recorded as threatened with extinction at the global scale [8]. Analysis of the quantitative relationship among the plant species growing around an area reflects structural property of the community and it not only to describe the vegetation, but also to predict its pattern and classify it in a meaningful way [9].

The Eastern Ghats, Western Ghats, Himalayas, north-eastern hills and Andaman constitute the important biodiversity areas of India. Present study area, GWLS fall in Southern Eastern Ghats of Andhra Pradesh State. Tree diversity and quantitative studies in the forests of Eastern Ghats are scanty[10,11,12] Inventory and quantitative studies of trees helps in understanding the structure of forests population study of trees will be of immense help in determining the regeneration of species which is crucial in their conservation. Hence the present study has been taken up. The data generated in the present study will be useful for a range of research, policy and intellectual property rights.

II. Materials & Methods

2.1. Study area

Gundlabrahmeswaram Wildlife Sanctuary (now on wards called as GWLS) encompasses with an area of 1,194 km^2 covering Kurnool, Prakasam districts in Andhra Pradesh and lies between N15° 22' 30" - 15° 53' &

E78° 37' 30" - 78° 55'. It falls in four forest divisions, Atmakur, Nandyal, Giddalur and Markapur. It is located between two important hill passes known as 'Mantralamma kanuma' and 'Nandi kanuma'. The Northern part of GWLS forms a major part of the Nagarjunasagar-Srisailam Tiger Reserve. The hilly terrain of the GWLS, decked with plateaus, ridges, gorges and deep valleys support a diverse flora and fauna. January, February and March months are usually pleasant with moderate winds from southeast with an average temperature varies from 24^o to 28^o C. April and May are the hottest months of the year with an average temperature of 32^oC-34^oC. The maximum temperature ranges during this season is 40^oC and minimum is 26^oC. The GWLS plateau receives about 127cm of rainfall. There is sacred grove in GWLS. Owing to the presence of the deity Gundlabrahmeswaram, the area got its name. These sacred forests were named as Pavithravanalu by Rao et al., [13]. [14] studied the plant biodiversity of sacred groves of Kurnool district covering Gundlabrahmeswaram and proposed this area for immediate conservation. The naturals springs, sacred groves and the perennial river 'Gundlakamma' that criss-crosses through the sanctuary add to the beauty of the sanctuary. There are many seasonal streams and natural perennial springs in GWLS.

2.2. Sampling Method

The present study aims at a first ever systematic attempt towards a fine scale assessment of the tree resources of GWLS based on field explorations. The plant resources were quantitatively assessed through 37 grids of size 6.25x 6.25 km, covering the whole terrain. The grids were stratified based on NDVI value 130 using remote sensed datasets. These 37 grids are distributed in two districts of Andhra Pradesh; Prakasam encompassing 20 grids and Kurnool, 17 grids.

A belt transect of 1000×5m was randomly laid in each grid. Based on heterogeneity of the terrain, these transects were split into 2-5 sub-transects of size 500x5m to 200x5m respectively were laid down in 37 grids of Nallamalais. In the belt transect all tree species with ≥30cm girth at breast height of 1.37m (gbh) from the ground were measured by using a measuring tape and their height was estimated by ocular estimates. For multiple stemmed trees, bole girths were measured separately; basal area was calculated for each stem. Within each transect/sub transect, two 5x5m quadrats were laid down for sampling the regeneration of tree taxa. The frequency distribution of the various girth classes of tree species was calculated. All the tree species were categorized with respect to the nine girth classes viz., 10-29, 30-59, 60-89, 90-119, 120-149, 150-179, 180-209, 210-239 and >240cm.

2.3. Data Analysis

Importance Value Index (IVI) for the tree species was calculated as the sum of relative values of three quantitative characters i.e. dominance, density and frequency following Curits & Cottam [15].

Relative Dominance = (Basal area of the individual speciesx100)/ Total basal area of all species

Relative Density = (Density value of a speciesx100)/Sum of density value of all species

Relative frequency = (Frequency value of a speciesx100)/ Sum of frequency value of all species

IVI: Relative dominance + Relative density + Relative frequency

Family Importance Value index (FIV) is calculated based on Mori et al., (1983). The family relative values were calculated as that of general relative values cited above replacing species with families.

FIV: Relative dominance (f) + Relative density (f) + Relative diversity (f)

Species diversity indices namely Shannon-Wiener index [16], and Evenness Index [17,18] Pielou, 1969, 1975) were calculated.

Shannon-Wiener index is a measure of the average degree of 'uncertainty' in predicting to what species an individual chosen at random from a collection of S species and N individuals will belong. It is estimated by using formula:

$$\mathbf{H' = -\sum (ni/N) \ln (ni/N)}$$

Where, ni = number of individuals belonging to the ith species

N = Total number of individuals in the sample.

Dominance Index[19] is a measure of dominance since it weighted towards the abundances of commonest species. It is estimated by using formula:

$$\mathbf{D = \sum (ni/N)^2 or\ Pi^2}$$

Evenness Index values range from 0-1, with 1 representing situation in which all species are equally abundant:

$$\mathbf{E = H'/H_{max}\ or\ H'/\ln S}$$

III. Results And Discussion

3.1. Tree species richness

A total of 179 tree species belonging to 112 genera and 48 families (71.8% of the tree species that are found in Nallamalais) **(TABLE 1)** were recorded in 18.5 ha (37 grids) area of GBM (**TABLE 2)**. Tree species richness varied across the grids and ranges from 28-68 species. The species richness is more in Gundlabrahmeswaram core area with 68 species where as low in Bollupalli and Gundlmotu reservoir areas with 28 species. Of these 37 grids, 54% are highly diversified with more than 40 species and 9 grids are low diversified with less than 35 species. In terms of species richness, GWLS has a lower number of species richness compared with similar dry afro-montane forests in Ethiopia, 113 species [20]. Comparatively, the lowest species richness was recorded in evergreen forests of Chandoli National Park, northern Western Ghats varied from 25-57/0.5 ha [21] and highest species richness: 31-66 species per 0.5ha in Southern Eastern Ghats [22] and 64-82 species/ha was recorded by Parthasarathy [23].

The present study area shows a species richness of 28-68, higher than that of semi-evergreen forest of Eastern Ghats and Western Ghats: Kolli hills 26-56 species [7], Kalrayan hill 42-47 species [11] and Peninsular India 42 species [24]. The species richness recorded in the present study is less when compared to that various sites of Western Ghats with about 82 species ha^{-1} in the medium elevation evergreen forests of Kalakad [23] and 87 species in Sal forests of Eastern Himalayas [25].

3.2. Tree density and Basal Area

A total of 14,262 individuals are reported from 62 transects of 37 grids which ranges from 220-748 individuals. The lowest density (220 individuals) was recorded in Kanchuralla Bodu, because of high grazing and people of this area are depended on forests mainly for fuel wood. The highest density was present in Mangaloni Bodu, because the soil of this area with rich nutrients and more fertile. Anogeissus latifolia occupies 1st position in density with 1217 individuals (8.54%) followed by Lannea coromandelica 719 (5%) and Chloroxylon swietenia (4.89%). Total basal area of the sampled grids in the study area is 499.298 m^2 (**TABLE 2).** The mean SD for basal area of the grids is 13.5±5.62 m^2/0.5ha and ranges from 3.99 to 36.54 m^2/0.5ha. The Rudrakod grid is with highest basal area of 36.54 m^2/0.5ha, because of the black soils with more humus and lowest 3.99 m^2/0.5ha in Kanchuralla bodu, due to heavy biotic interference.

3.3. Tree richness, Density and Basal area in different girth classes

Tree density and species richness consistently decreased with increasing girth class of tree species from 30 to > 240cm gbh (**Fig. 1**)**.** An obvious variation in representation of tree species and the proportion of dominant species in the study area can directly be attributed to rainfall distribution and favorable edaphic conditions. The girth class for rosettes of Bambusa arundinacea and Dendrocalamus strictus was not taken into account in the present study. The highest tree stand density and species richness of GWLS were found in the girth class of 30 to 59 cm gbh and 60 to 89 cm gbh.

The contribution of lower girth class size (30-59 cm gbh) tree density among the forest stands is 72.68% and basal area covers 30.5% where as the density of medium girth class size (120-149 cm gbh) covers 1.77% with an basal area of 7.06%. The high girth class size density (150-179, 180-209, 210-239 and > 240cm gbh) is 1.89% with a basal area of 27.32% was recorded. All the tree species of GWLS are distributed in various girth classes which represent the reverse J shaped structure which indicates a good regeneration of tree species with undisturbed nature of the forests **(Fig. 1)**, similarly Kanade et al. [21] reported the L shaped or reverse J shaped structure for girth class distribution of species in Chandoli National park.

3.4. Importance Value Index

The Importance Value Index calculated for the tree taxa encountered in the study area revealed that Anogeissus latifolia, is the most dominant (IVI=16.72; occupies 5.57% of the total IVI of tree species) followed by Lannea coromandelica (IVI=12.40; 4.13%) and Terminalia alata (IVI=10.79; 3.60%), Chloroxylon swietenia (IVI=10.12; 3.37%), Dalbergia lanceolaria (IVI=9.64; 3.21%), Pterocarpus marsupium (IVI=9.53; 3.18%) and Hardwickia binata (IVI= 9.53; 3.12%) **(TABLE 3)**. Anogeissus latifolia, Lannea coromandelica and Terminalia alata are the most dominant species with Chloroxylon swietenia, Dalbergia lanceolaria and Pterocarpus marsupium as co-dominants.

It is observed that the top ten dominant tree species have shared nearly 33% of the total IVI values of the study area as also observed in dry forest in Vindhyan hills [2] that few dominant tree species have evolved to these dry conditions and can utilize the resources in a better way. The higher value of IVI indicates that all the available resources are being utilized by that species and left over are being trapped by another species as the competitors and associates. The high IVI of a species indicated its dominance and ecological success, its good power of regeneration and greater ecological amplitude [26]. The present study site can be designated as Anogeissus latifolia-Lannea coromandelica-Terminalia alata series based on species importance value.

3.5. Family Importance Value index

The contribution of 48 plant families towards species diversity and density varied across the sampled sites of GWLS. Euphorbiaceae represented by 19 species (39.58%) was considered taxonomically diverse followed by Rubiaceae 18 species (37.5%), Moraceae 11 species (22.92%), Fabaceae-Faboideae 10 species (20.83%), Fabaceae-Mimosoideae and Verbenaceae with 8 species (16.67%) and Fabaceae-Caesalpinioideae 7 species (14.58%) in terms of species richness. Taking into consideration of FIV, Combretaceae appear more dominant than Euphorbiaceae. FIV is an independent of species richness but depends on high density of the species and its basal area. Although Combretaceae is represented by 5 species, but because of its large girth size and high density (2, 243 individuals) it ranked one with a high family importance value of 36.23 (12.08%), followed by Fabaceae-Faboideae 28.77 (9.59%), Euphorbiaceae 25.42 (8.47%), Rubiaceae 21.98 (7.33%) and Anacardiaceae 21.9 (7.3%) (**Fig. 2**). All these five families contributing ca. 44.77% of the forests stand. Melastomataceae (22%), Oleaceae (26%) and Lauraceae (28%) formed bulk of the tree population in Kolli hills, Shervarayan hills of Eastern Ghats and Kalakad forest respectively [23].

Euphorbiaceae and Rubiaceae (19 and 18 species respectively) in spite of their high species richness do not have high FIV value because of their lower density and lower basal areas. Similar studies were observed are Rubiaceae, Ebenaceae, and Sterculiaceae constituted the predominant plant families by density in the coastal forests [24]; Melastomataceae (22%), Oleaceae (26%) and Lauraceae (28%) formed bulk of the tree population in Kolli hills, Shevaroy hills of Eastern Ghats and Kalakad forest respectively [23]; Memecylon umbellatum (Melastomataceae) in Pudukottai, India [27] and Dipterocarpaceae is the dominant family in Malaysia [28,29]

3.6. Diversity Indices

The species dominance (Simpson index) represents the mean SD of 0.94 ± 0.014. The highest value 0.975 is observed in Gundlabrahmeswaram and the lowest value in 0.89 in Laddi Konda. The Simpson's index in the present study is towards the mixed values reported in various dry deciduous forest of India: 0.67 to 2.09 [22,30]; and evergreen forests of Western Ghats: 0.78 to 0.95[31]. The Evenness index was about 0.63 ± 0.08 and ranges from 0.42 to 0.87. The species diversity indices in GBM varied greatly across the grids as influenced by the disturbance level. Shannon-Wiener index for tree taxa in 37 grids is with mean SD of 3.27 ± 0.19, the highest value 3.92 is observed in Gundlabrahmeswaram, followed by 3.79 in Rudrakod temple. The lowest value is 2.78 in Kanchuralla Bodu. More comparable values were reported from in southern Eastern Ghats of Andhra Pradesh with diversity index values of 3.96 [22] and Kalakad Reserved Forests (3.69) in Western Ghats [32].

3.7. Regeneration Potential of trees

A total of 3,160 regenerating individuals were recorded in 124 regeneration plots of 5x5m size in the sampled grids across the study sites. These include 1,011 individuals in 0-40cm class; 637 individuals in 41-100cm class; 734 individuals in > 100cm class and with < 10cm gbh; 778 individuals in 10-30cm gbh class. These individuals belong to 102 species, comprising 57% of the total tree species on record in the sampled grids. Considering the IVI of the regenerating species, Chloroxylon swietenia is found with good regeneration potential with a maximum of 252 individuals in 22 regeneration plots (IVI 14.5). This is followed by Pterocarpus marsupium with 215 individuals in 25 plots (IVI 13.38); Anogeissus latifolia with 206 individuals in 25 plots (IVI 13.03); Terminalia alata with 168 individuals in 16 plots (IVI 45.7); Cleistanthus collinus with 157 individuals in 13 plots (IVI 9.84); Ziziphus xylopyrus with 111 individuals in 16 plots (IVI 8.82); Holarrhena pubescens with 123 individuals in 17 plots (IVI 8.63); Tectona grandis with 121 individuals in 16 plots (IVI 8.43); Grewia flavescens with 111 individuals in 46 plots (IVI 8) and Ochna obtusata with 106 individuals in 12 plots (IVI 7.41).

Few trees like Albizia thompsonii, Bombax ceiba, Bridelia airy-shawii, Butea monosperma, Ceiba pentandra, Flacourtia ramontchi, Gardenia resinifera, Haldinia cordifolia, Kydia calycina, Manilkara hexandra, Premna tomentosa, Terminalia chebula and Wendlandia tinctoria are registered with less than 3 individuals (IVI 0.58) followed by Boswellia ovalifoliolata, Ehretia aspera, Euphorbia nivulia, Firmiana colorata, Haldinia cordifolia, Morinda pubescens and Desmodium oojeinensis are with 2 individuals (IVI 0.59). These trees with low regenerating potential are likely to be vulnerable to any natural or anthropogenic disturbance. This is on par with the observations made by [33] that the species with only one individual are highly vulnerable, since a local population composed of few individuals can undergo catastrophic decline due to environmental change, genetic problems or simple random events when isolated in a limited geographic range. A total of 77 species (43% of the 179 recorded species) are found without any recruitment: of any seedlings or saplings. Hence they exhibited demographic instability and the declining trends of the species in future may gives wiped out indications. This calls for better conservation strategies for sustenance of these species, as the minimum population size is required for long-term viability of rare and endangered species as opined by [33].

IV. Conclusion

The inventory and quantitative studies in GWLS revealed a considerable variation in the composition of dominant species and stand density in various grids. The study site can be designated as Anogeissus latifolia-Lannea coromandelica-Terminalia alata series based on species importance value. From the present study, the sanctuary although found rich tree species diversity, observed biotic disturbances in natural habitats has alarming consequences on diversity. Hence an integrated and inter-disciplinary approach is needed to conserve the tree species in the study area.

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Table 1: Trees of Gundlabrahmeswaram Wildlife Sanctuary

Name of the Taxon	Family	Nature
Acacia catechu (L.f.) Willd. (= A. chundra (L.f.) Willd.)	Fabaceae-Mimosoideae	D
Acacia leucophloea (Roxb.) Willd.	Fabaceae-Mimosoideae	D
Acacia nilotica (L.) Willd. ex Del. ssp. indica (Benth.) Brenan	Fabaceae-Mimosoideae	E
Aegle marmelos (L.) Correa	Rutaceae	D
Ailanthus excelsa Roxb.	Simaroubaceae	D
Alangium salvifolium (L.f.) Wangerin ssp. salvifolium	Alangiaceae	D
Albizia amara (Roxb.) Boivin	Fabaceae-Mimosoideae	D
Albizia lebbeck (L.) Willd.	Fabaceae-Mimosoideae	D
Albizia odoratissima (L. f.) Benth.	Fabaceae-Mimosoideae	E
Albizia thompsonii Brandis	Fabaceae-Mimosoideae	D
Anogeissus acuminata (Roxb. ex DC.) Guill. & Perr.	Combretaceae	D
Antidesma zeylanicum Lamk.	Euphorbiaceae	D
Azadirachta indica A. Juss.	Meliaceae	SE
Balanites aegyptiaca (L.) Del.	Balanitaceae	D
Bauhinia malabarica Roxb.	Fabaceae-Caesalpinioideae	D
Bauhinia racemosa Lam.	Fabaceae-Caesalpinioideae	D
Bombax ceiba L.	Bombacaeae	D
Boswellia serrata Roxb. ex Colebr.	Burseraceae	D
Bridelia airy-shawii P.J. Li (= B. retusa (L.) Spreng.)	Euphorbiaceae	D
Bridelia cinerascens Gehrm.	Euphorbiaceae	D
Bridelia crenulata Roxb.	Euphorbiaceae	D
Buchanania axillaris (Desr.) Ramam.	Anacardiaceae	D
Buchanania lanzan Sprengel	Anacardiaceae	E
Butea monosperma (Lam.) Taubert	Fabaceae-Faboideae	D
Canthium dicoccum (Gaertner) Teijsm. & Binn.	Rubiaceae	D
Capparis divaricata Lam.	Capparaceae	D
Capparis grandis L.f.	Capparaceae	D
Careya arborea Roxb.	Lecythidaceae	D
Caryota urens L.	Arecaceae	E
Casearia graveolens Dalz.	Flacoutiaceae	D
Casearia tomentosa Roxb. (= C. elliptica Willd.)	Flacoutiaceae	D
Cassia fistula L.	Fabaceae-Ceasalpinioideae	D
Cassine glauca (Rottb.) Kuntze	Celastraceae	E
Ceriscoides turgida (Roxb.) Tirveng.	Rubiaceae	D
Chionanthus macrophylla Blume (= C. ramiflora)	Oleaceae	E
Chloroxylon swietenia DC.	Flindersiaceae	D
Chukrasia tabularis A. Juss.	Meliaceae	D
Cipadessa baccifera (Roth) Miq.	Meliaceae	D
Cissus vitiginea L.	Vitaceae	D
Citrus sinensis (L.) Osbeck	Rutaceae	E
Cleistanthus collinus (Roxb.) Hook.f.	Euphorbiaceae	D
Cleistanthus patulus (Roxb.) Muell.-Arg.	Euphorbiaceae	E
Cochlospermum religiosum (L.) Alston	Cochlospermaceae	D
Commiphora caudata (Wight & Arn.) Engler	Burseraceae	D
Cordia dichotoma Forst. f.	Cordiaceae	D
Cordia macleodii Hook.f. & Thomson	Cordiaceae	D
Cordia wallichii G.Don.	Cordiaceae	D
Dalbergia lanceolaria L. f.	Fabaceae-Faboideae	D
Dalbergia latifolia Roxb.	Fabaceae-Fabaoideae	D
Dalbergia paniculata Roxb.	Fabaceae-Fabaoideae	D
Deccania pubescens (Roth) Tirveng. var. pubescens	Rubiaceae	D

Deccania pubescens (Roth) Tirveng. var. candolleana (Wight & Arn.) Tirveng.	Rubiaceae	D
Desmodium oojeinense (Roxb.) H. Ohashi (= Ougeinia oojeinensis (Roxb.) Hochr.)	Fabaceae-Faboideae	D
Dillenia pentagyna Roxb.	Dilleniaceae	D
Diospyros chloroxylon Roxb.	Ebenaceae	E
Diospyros melanoxylon Roxb.	Ebenaceae	D
Dolichandrone atrovirens (Roth) Sprague	Bignoniaceae	D
Dolichandrone falcata (Wall.ex DC.) Seem. var. falcata	Bignoniaceae	D
Drypetes sepiaria (Wight & Arn.) Pax & Hoffm.	Euphorbiaceae	E
Ehretia aspera Willd.	Cordiaceae	D
Ehretia laevis Roxb.	Cordiaceae	D
Ehretia pubescens Benth.	Cordiaceae	D
Eriolaena hookeriana Wight & Arn.	Sterculiaceae	D
Eriolaena lushingtonii Dunn	Sterculiaceae	D
Erythrina stricta Roxb.	Fabaceae-Faboideae	D
Erythrina suberosa Roxb.	Fabaceae-Faboideae	D
Erythroxylum monogynum Roxb.	Erythroxylaceae	E
Euphorbia antiquorum L.	Euphorbiaceae	E
Euphorbia nivulia Buch.-Ham.	Euphorbiaceae	D
Ficus arnottiana (Miq.) Miq.	Moraceae	D
Ficus benghalensis L.	Moraceae	E
Ficus hispida L.f.	Moraceae	D
Ficus microcarpa L.f. (= F. retusa)	Moraceae	D
Ficus mollis Vahl	Moraceae	E
Ficus racemosa L.	Moraceae	D
Ficus religiosa L.	Moraceae	D
Ficus rumphii Blume	Moraceae	E
Ficus virens Ait.	Moraceae	D
Flacourtia ramontchi L. (= F. indica (Burm.f.) Merr.)	Flacoutiaceae	D
Gardenia gummifera L.f.	Rubiaceae	D
Gardenia latifolia Ait.	Rubiaceae	D
Gardenia resinifera Roth	Rubiaceae	D
Garuga pinnata Roxb.	Burseraceae	D
Givotia moluccana (L.) Sreemadh.	Euphorbiaceae	D
Glochidion tomentosum Dalz.	Euphorbiaceae	E
Glochidion velutinum Wight	Euphorbiaceae	E
Gmelina arborea Roxb.	Verbnaceae	D
Grewia abutilifolia Vent. ex Juss.	Tiliaceae	D
Grewia damine Gaertner	Tiliaceae	D
Grewia flavescens Juss.	Tiliaceae	D
Grewia tiliaefolia Vahl	Tiliaceae	D
Gyrocarpus americanus Jacq.	Hernandiaceae	D
Haldinia cordifolia (Roxb.) Ridsd. (=Adina cordifolia (Roxb.) Hook.f. ex Brandis)	Rubiaceae	D
Hardwickia binata Roxb.	Fabaceae-Caesalpinioideae	D
Holarrhena pubescens (Buch.-Ham.) Wall. ex G.Don	Apocynaceae	D
Holoptelea integrifolia (Roxb.) Planchon	Ulmaceae	D

Hymenodictyon orixense (Roxb.) Mabb.	Rubiaceae	D
Ixora pavetta Andrews (=I. arborea Roxb.ex Smith)	Rubiaceae	D
Kydia calycina Roxb.	Malvaceae	D
Lagerstroemia parviflora Roxb.	Lythraceae	D
Lannea coromandelica (Houtt.) Merr.	Anacardiaceae	D
Lepisanthes tetraphylla (Vahl) Radlk.	Sapindaceae	E
Limonia acidissima L.	Rutaceae	D
Madhuca indica J. Gmelin	Sapotaceae	D
Maerua apetala (Roth) Jocobs	Capparaceae	D
Mallotus philippensis (Lam.) Muell.-Arg.	Euphorbiaceae	E
Mallotus rhamnifolius Muell.-Arg.	Euphorbiaceae	D
Mangifera indica L.	Anacardiaceae	E
Manilkara hexandra (Roxb.) Dubard	Sapotaceae	E
Manilkara roxburghiana (Wight) Dubard	Sapotaceae	E
Melia azedarach L.	Meliaceae	D
Melia dubia Cav.	Meliaceae	D
Memecylon edule Roxb.	Melastomataceae	E
Memecylon umbellatum Burm.f.	Melastomataceae	D
Miliusa tomentosa (Roxb.) Sinclair	Annonaceae	D
Mitragyna parvifolia (Roxb.) Korth.	Rubiaceae	D
Morinda angustifolia Roxb.	Rubiaceae	D
Morinda pubescens J.E. Smith	Rubiaceae	D
Mundulea sericea (Willd.) A. Cheval	Fabaceae-Faboideae	D
Murraya koenigii (L.) Sprengel	Rutaceae	D
Naringi alata (Wall. ex Wight & Arn.) Ellis	Rutaceae	D
Naringi crenulata (Roxb.) Nicolson	Rutaceae	D
Nyctanthes arbor-tristis L.	Nyctaginaceae	D
Ochna obtusata DC. var. gamblei (King ex Brandis) Kanis (= O. gamblei King ex Brandis)	Ochnaceae	D
Ochna obtusata DC. var. obtusata Kanis	Ochnaceae	D
Oroxylum indicum (L.) Vent.	Bignoniaceae	D
Parkinsonia aculeata L.	Fabaceae-Caesalpinioideae	D
Pavetta indica L.	Rubiaceae	D
Phoenix sylvestris (L.) Roxb.	Arecaceae	E
Phyllanthus emblica L.	Euphorbiaceae	D
Phyllanthus indofischeri Bennet	Euphorbiaceae	D
Phyllanthus polyphyllus Willd.	Euphorbiaceae	D
Pittosporum napaulense (DC.) Rehder & Wilson	Pittosporaceae	E
Polyalthia cerasoides (Roxb.) Beddome	Annonaceae	SE
Polyalthia suberosa (Roxb.) Thwaites	Annonaceae	E
Pongamia pinnata (L.) Pierre	Fabaceae-Faboideae	E
Premna latifolia Roxb. var. mollissima (Roth) Hook.f.	Verbenaceae	D
Premna tomentosa Willd.	Verbenaceae	D
Prosopis chilensis (Molina) Stuntz.	Fabaceae-Mimosoideae	D
Pterocarpus marsupium Roxb.	Fabaceae-Faboideae	D
Pterospermum xylocarpum (Gaertner) Sant.& Wagh	Sterculiaceae	E
Radermachera xylocarpa (Roxb.) Schum.	Bignoniaceae	D

Sapindus emarginatus Vahl	Sapindaceae	D
Schleichera oleosa (Lour.) Oken	Sapindaceae	D
Schrebera swietenioides Roxb.	Oleaceae	D
Semecarpus anacardium L. f.	Anacardiaceae	E
Senna siamea (Lam.) Irwin & Barneby (=Cassia siamea Lam.)	Fabaceae-Caesalpinioideae	D
Soymida febrifuga (Roxb.) A. Juss.	Meliaceae	D
Sterculia urens Roxb.	Sterculiaceae	D
Sterculia villosa Roxb. ex DC.	Sterculiaceae	D
Stereospermum personatum (Hassk.) Chatterjee	Bignoniaceae	D
Stereospermum suaveolens (Roxb.) DC.	Bignoniaceae	D
Streblus asper Lour.	Moraceae	E
Streblus taxoides (Roth) Kurz.	Moraceae	E
Strychnos nux-vomica L.	Loganiaceae	D
Strychnos potatorum L.f.	Loganiaceae	D
Suregada angustifolia (Baillon ex Muell.-Arg.) Airy Shaw	Euphorbiaceae	E
Suregada multiflora (Juss.) Baillon	Euphorbiaceae	E
Syzygium alternifolium (Wight) Walp.	Myrtaceae	D
Syzygium cumini (L.) Skeels	Myrtaceae	E
Tamarindus indica L.	Fabaceae-Caesalpinioideae	E
Tamilnadia uliginosa (Retz.) Tirveng. & Sastre	Rubiaceae	D
Tectona grandis L. f.	Verbenaceae	D
Terminalia alata Heyne ex Roth	Combretaceae	D
Terminalia arjuna (Roxb.ex DC.) Wight & Arn.	Combretaceae	E
Terminalia bellirica (Gaertner) Roxb.	Combretaceae	D
Terminalia chebula Retz.	Combretaceae	D
Vitex altissima L. f.	Verbenaceae	D
Vitex leucoxylon L. f.	Verbenaceae	D
Vitex peduncularis Wall. ex Schauer	Verbenaceae	D
Vitex pinnata L.	Verbenaceae	D
Wendlandia bicuspidata Wight & Arn.	Rubiaceae	D
Wendlandia heynei (Roemer & Schultes) Santapau & Merchant	Rubiaceae	D
Wendlandia tinctoria (Roxb.) DC.	Rubiaceae	E
Wrightia arborea (Dennst.) Mabb.	Apocynaceae	D
Wrightia tinctoria R. Br.	Apocynaceae	D
Ximenia americana L.	Olacaceae	D
Ziziphus mauritiana Lam. var. mauritiana	Rhamnaceae	D
Ziziphus xylopyrus (Retz.) Willd.	Rhamnaceae	D

D-Deciduous; E-Evergreen; SE-Semi-evergreen

Table 2. Basal Area, Density and Richness among the Grids

S. No	District	Toposheet	Veg. Type	Representative Location	Basal Area	Species Density	Species Richness
1	KNL	57 I/10 NE1	DD	Pangidi vagu	28.016	416	65
2	KNL	57 I/10 NE2	DD	Velgodu- GBM route	4.723	229	31
3	KNL	57 I/10 NE3	DD	Yogananda konda	12.670	254	39
4	KNL	57 I/10 NE4	MD	GBM	23.843	639	68
5	KNL	57 I/10 SE1	DD	Omkaram temple 3 km	12.445	295	40
6	KNL	57 I/10 SE2	DD	Omkaram temple	12.077	316	45
7	KNL	57 I/10 SE3	DD	Near Maddimanukonda	13.899	598	33
8	KNL	57 I/10 SE4	DD	Near Baireni	27.368	558	53
9	KNL	57 I/11 NE1	DD	Mahanandi	14.693	451	50

10	KNL	57 I/11 NE2	DD	SaravaNarasimhatemple	11.732	463	43
11	KNL	57 I/11 NE3	DD	Chelama	18.558	319	38
12	KNL	57 I/11 NE4	DD	Chelama old	14.349	314	49
13	PKSM	57 I/13 SE1	DD	Peddamantala	9.996	314	43
14	PKSM	57 I/13 SE2	DD	Kulukula selava	9.022	314	29
15	KNL	57 I/13 SW1	DD	Bairlooty	20.894	414	57
16	KNL	57 I/13 SW2	DD	Mogilutla	6.011	300	33
17	PKSM	57 I/13 SW3	DD	Near Rollatpenta	11.274	231	42
18	PKSM	57 I/13 SW4	DD	Mogilutla	5.825	369	43
19	PKSM	57 I/14 NE1	Scrub	Bollupalli	4.061	272	28
20	PKSM	57 I/14 NE2	DD	Vallapurayani Temple	10.400	395	33
21	PKSM	57 I/14 NW1	DD	Betludatha Konda	8.982	346	46
22	PKSM	57 I/14 NW2	DD	Betludatha narava	5.121	236	38
23	PKSM	57 I/14 NW3	DD	Mangaloni Bodu	14.586	748	49
24	PKSM	57 I/14 NW4	DD	Peraya Kunta	12.685	408	38
25	PKSM	57 I/14 SE1	DD	Gunikonda	8.205	393	36
26	PKSM	57 I/14 SE2	DD	Rangaswami Temple	15.177	431	32
27	PKSM	57 I/14 SW1	DD	Isuka Gundam	12.241	428	39
28	PKSM	57 I/14 SW2	DD	Pulichedu	6.464	267	37
29	PKSM	57 I/14 SW3	DD	Peddinayana Penta	9.613	373	37
30	PKSM	57 I/14 SW4	DD	Lokki Vaagu	9.164	452	43
31	PKSM	57 I/15 NW1	DD	Kanchuralla Bodu	3.999	220	30
32	PKSM	57 I/15 NW2	DD	Dona bavi	15.562	593	62
33	PKSM	57 I/15 NW3	DD	Isukagundam Road	35.472	502	63
34	PKSM	57 I/15 NW4	DD	Gundlamotu Reservoir	6.585	267	28
35	KNL	57 I/9 SE2	DD	Rudrakod temple	36.544	420	66
36	KNL	57 I/9 SE3	DD	Rudrakod	15.245	367	61
37	KNL	57 I/9 SE4	DD	Rudrakod temple 2km	11.796	350	50
					499.298	14262.000	

Table 3. Occurence, Basal Area and IVI of species in Gundlabrahmeswaram WLS **Error! Not a valid link.**

Fig. 1. Girth Class Distribution of General Stand in Gundlbrahmeswaram WLS

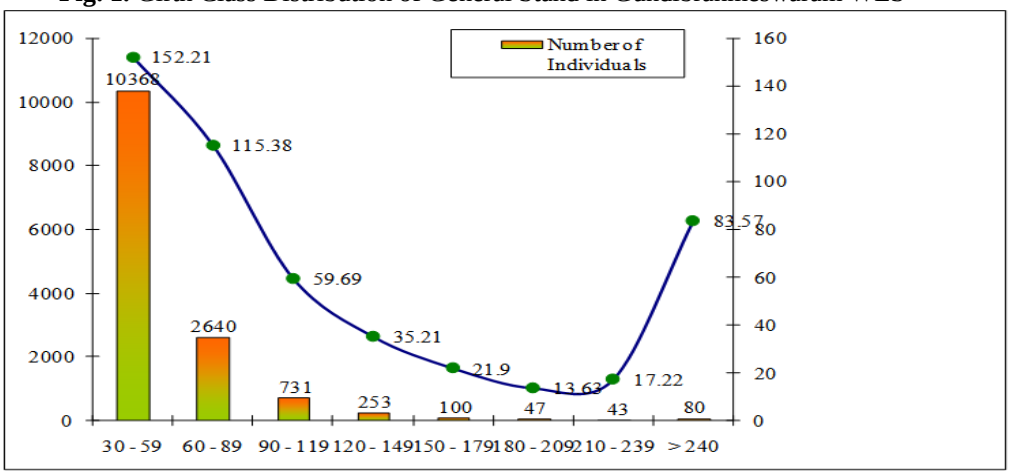
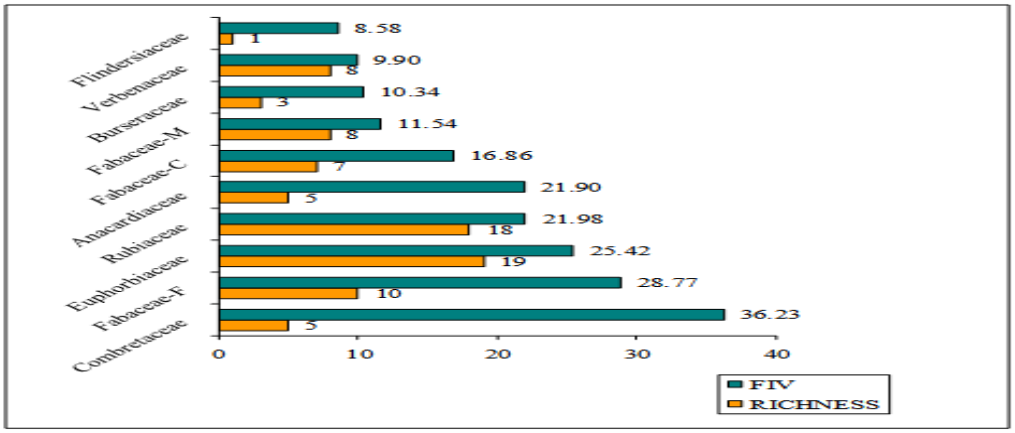


Fig. 2. Family-level dominance based on species richness and FIV



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